NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

- - - - - - - - - - - - - - - - - X

In the Matter of: :
:
THE INVESTIGATION OF THE :
USAIR INC., FLIGHT 427, :
A BOEING 737-300, N513AU, :
:
ALIQUIPPA, PENNSYLVANIA, : Docket No.: SA-510
SEPTEMBER 8, 1994 :
:
- - - - - - - - - - - - - - - - - X

Pittsburgh Hilton and Towers Hotel
Pittsburgh, Pennsylvania

Monday, January 23, 1995

The above-entitled matter came on for hearing pursuant to notice, before JIM HALL, Chairman, at the Pittsburgh Hilton and Towers Hotel, 600 Commonwealth Place, Pittsburgh, Pennsylvania, on Monday, January 23, 1995, at 12:00 p.m., before:

Board of Inquiry

JIM HALL, Member, NTSB
Chairman

Bud Laynor, Deputy Director of
the Office of Aviation Safety

Ronald Schleede, Chief,
Major Investigations Division, Hearing Officer

John Clark, Chief, Vehicle Performance Division
Office of Research and Engineering

Technical Panel

Thomas E. Haueter, Investigator-in-Charge,
Hearing Officer

Gregory Phillips, Senior Systems Investigator

Charles Leonard, Operations Investigator

Thomas Jacky, Vehicle Performance Investigator

Cynthia Keegan, Structures Investigator

Roff Sasser, Systems Investigator

Nora Marshall, Senior Survival Factors
Investigator

Staff:

Mike Benson, Office of Public Affairs

Jamie Finch, Special Assistant

Robert Francis, Board Member

Kenneth Jordan, Managing Director

Peter Goelz, Director of Congressional
and Intergovernmental Relations

Julie Beal, Director of Public Affairs Office

Shelly Hazle, Confidential Assistant

Carolyn Dargan, Administrative Assistant

Shirley Wright, Administrative Assistant

National Transportation Safety Board
National Safety Transportation Board
490 L'Enfant Plaza, SW
Washington, D.C. 20594

Parties to the Hearing

Department of Transportation,
Federal Aviation Administration
Harold Donner
AAI-100
800 Independence Avenue, SW
Washington, D.C. 20591

USAir, Inc.
Captain Gene Sharp
115 Commerce Drive
RIDC Parkridge 2
Pittsburgh, Pennsylvania 15275

Airline Pilots Association
Captain Herb LeGrow
535 Herndon Parkway
Herndon, Virginia 22070

Boeing Commercial Airplane Group
John Parvis
7342 East Marginal Way, South
Building 3-800.3, Bay A2
Seattle, Washington 98108

Monsanto Company
Frank Jakse
800 N. Lindbergh Boulevard

St. Louis, Missouri 63167

Parker Hannifin Corporation
Steve Weik
14300 Alton Parkway
Irvine, California 92718-1814

International Association of
Machinists and Aerospace Workers
73 Auburn Street
Saugus, Massachusetts 01906

C O N T E N T S

I N D E X

P R O C E E D I N G S

(Time Noted: 12:01 p.m.)

CHAIRMAN HALL: Ladies and gentlemen, this public hearing will come to order. Good morning and welcome. My name is Jim Hall. I am Chairman of the National Transportation Safety Board and Chairman of this Board of Inquiry. At this hearing we are considering an accident that occurred on September 8, 1994 at Aliquippa, Pennsylvania involving U.S. Air Flight 427.

The hearing is being held for the purpose of supplementing the facts, conditions and circumstances discovered during the on-scene investigation. This process will assist the Safety Board in determining the probable cause and in making any recommendation to prevent similar accidents.

The American public has been shocked in recent months by a series of catastrophic airline accidents, four of which since July 2nd of last year claimed the lives of 252 persons. The accident that occurred here in September is the worst aviation tragedy in this country in more than seven years.

As I have said in the past, airline accidents are extremely rare events. That is why they make such big news. But, when they occur, it is the job of the National Transportation Safety Board with the assistance of the Federal Aviation Administration and other parties from government, industry and labor, to find out what happened, why it happened and how we can make sure it doesn't happen again. This hearing is an important part of that process.

It is no secret that the aviation community is concerned about this accident, not just because of the great human tragedy it represents, but because this is the second accident in nearly four years involving a Boeing 737 for which as yet no cause has been readily identified. Issues at this hearing will cover not only operational aspects of the aircraft, but data recording capabilities, as well.

I want to assure the traveling public that investigators from many organizations are working diligently to find the cause of this accident. As an example, it is estimated that approximately 25,000 man hours have been expended so far in the course of this investigation.

I understand that there are some of the victims' families in the audience today. I want to assure them that as the National Transportation Safety Board does in every investigation, the Safety Board will pursue every lead toward an ultimate solution.

Certainly, your presence at this hearing is a clear reminder to each of us of the importance of this proceeding. We at the National Transportation Safety Board never forget that the Board is funded by the

American taxpayers and is dedicated to the pursuit of independent accident investigations.

Public hearings such as this are an exercise 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 representing 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 working force, pilots and machinists that they are performing up to the standards of professionalism expected of them.

These proceedings tend to become highly technical affairs, but they are essential in seeking to reassure the public that everything is being done to insure the safety of the airline industry.

This inquiry is not being held 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 collect information that will assist this Safety Board in its examination of safety issues arising from this accident.

Specifically, we will concentrate on the following issues: (1) wake vortex encounters and possible effects on performance and stability of USAir flight 427; (2) aircraft performance studies of various systems and structural failures and malfunctions that could lead to in-flight upsets and loss of control of USAir flight 427 with attention given to Boeing 737 lateral and directional control systems design, certification and service history; (3) airframe and aircraft component manufacturer's service difficulty programs and continuing airworthiness standards and practices. Airline programs for aircraft flight control hydraulic fluid quality assurance; (4) flight crew training for recovery from in-flight upsets and unusual attitudes; (5) management and Federal Aviation Administration oversight of USAir flight operations, maintenance and safety; (6) standards for enhanced recording of airline flight operations, to include expanded flight data recorder parameters and cockpit video cameras.

I would like to introduce the other members of the Board of Inquiry at this point. They are, to my right, Mr. William G. Laynor, Deputy Director of the Office of Aviation Safety. To his right, Mr. John Clark, Chief of the Vehicle Performance Division.

To my left, Mr. Ronald L. Schleede, Chief of the Major Investigations Division, and to his left, Mr. Michael Marx, Chief of the Material Laboratory Division. The Board of Inquiry will be assisted by a

Technical Panel.

These persons are seated at the table to my right and they are Mr. Thomas E. Haueter, the Investigator-in-Charge and Hearing Officer, Mr. Gregory Phillips, the Senior Systems Investigator, Mr. Charles Leonard, the Operations Investigator, Mr. Thomas Jacky, the Vehicle Performance Investigator, Ms. Cynthia Keegan, the Structures Investigator and Mr. Roff Sasser, the Systems Investigator.

Mr. Mike Benson from the Safety Board's Public Affairs Office is here to assist in matters dealing with the news media. Mr. Jamie Finch, my Special Assistant, Mr. Robert Francis, Board Member, Mr. Kenneth Jordan, Managing Director, Mr. Peter Goelz, Director of Congressional and Intergovernmental Relations and Ms. Julie Beal, Director of the Safety Board's Public Affairs Office are also here to assist with this hearing, as well as Ms. Shelly Hazle, my

Confidential Assistant.

Mrs. Carolyn Dargan and Ms. Shirley Wright have handled the administrative matters dealing with the hearing up to this point. They will also be present at the hearing to provide administrative support, as needed. You may contact any of these -- you may contact any of them for assistance regarding copies of exhibits and other items.

Neither I nor any 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 this accident.

Such analysis and cause determinations will be made by the full Safety Board after consideration of all the evidence gathered during our investigation. The report on the aircraft accident involving flight 427 reflecting the Safety Board's analyses and probable cause determinations will be considered for adoption by the full Board at a later public meeting which will be held at the Safety Board's headquarters in Washington, D.C. and will be open to the public.

The Safety Board's rules provide for the designation of parties to public hearings. 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 the party, I would appreciate it if the designated spokesperson would give his, or her name, title and affiliation for the record. The parties are seated at tables in front of me. The Department of Transportation, Federal Aviation

Administration.

MR. DONNER: Mr. Chairman, My name is Harold Donner, the Manager of the Accident Investigation Division, Federal Aviation Administration.

CHAIRMAN HALL: Thank you, Mr. Donner. The Airline Pilots' Association.

CAPTAIN LEGROW: Thank you, Mr. Chairman. My name is Captain Herb LeGrow, and I was the Coordinator for the accident at 427.

CHAIRMAN HALL: Thank you, Captain. USAir, Inc.

CAPTAIN SHARP: Thank you, Mr. Chairman. My name is Gene Sharp. I am the Vice President of Flight Operations for USAir.

CHAIRMAN HALL: Thank you, Captain. The Boeing Commercial Airplane Group.

MR. PURVIS: Thank you, Mr. Chairman. My name is John Purvis. I am the Director of Air Safety

Investigation for the Boeing Commercial Airplane Group. Thank you.

CHAIRMAN HALL: The Monsanto Company.

MR. JAKSE: Mr. Chairman, my name is Frank Jakse. I am Senior Research Specialist for Monsanto Company, manufacturer of skydraul (sic) hydraulic fluid.

CHAIRMAN HALL: Thank you. Parker Hannifin, Inc.

MR. WEIK: Thank you, Mr. Chairman. My name is Steve Weik. I am Technical Support with the Parker Hannifin Corporation.

CHAIRMAN HALL: The Association of Machinists and Aerospace Workers.

MR. WURZEL: Thank you, Mr. Chairman. My name is Jack Wurzel and I am with the Flight Safety Committee of the International Association of Machinists, District 141.

CHAIRMAN HALL: I want to publicly thank all of the parties for the assistance and cooperation they have displayed during the course of this investigation. On January 23rd 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 witnesses to testify to those issues was finalized.

Copies of the witness list developed at the pre-hearing conference are available at the press table. There are numerous exhibits to be used in this proceeding. Copies of the exhibits are available at the press table for review.

The Safety Board has provided a complete set of exhibits to Kinko's Copy Center located at 600

Liberty Avenue, Pittsburgh, Pennsylvania. Copies of the exhibits can be obtained on request and at the individual's own expense at Kinko's.

The witnesses testifying at this hearing have been selected because of their ability to provide the best information available on the issues of aviation safety. The first witness will be the Investigator-in-Charge of the accident investigation who will summarize certain facts about the accident and the investigative activities that have taken place since then.

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 this 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 of this accident and will be available for inspection at the Board's Washington Office. Anyone wanting to purchase a transcript should contact the Court Reporter directly.

At this time, I would like to acknowledge other officials who are here observing this hearing. They are seated to my left. Representing CFM International, the engine manufacturer, Mr. Paul Mingler; AVIALL, the engine overhaul company, Mr. Paul M. Rehder; the National Air Traffic Controllers Association is represented by Mr. William West; the Transportation Workers Union #545 is represented by Mr. Juergen-Peter Schuetz; the Association of Flight Attendants is represented by Ms. Nancy L. Gilmer; PATS, Incorporated, who was a manufacturer of the auxiliary fuel tank, is represented by Mr. Harvey Patrick; the Federal Bureau of Investigation is represented by Mr. William Perry; Hopewell Township by Mr. Jim Eichenlaub; the Pennsylvania State Police by Lieutenant James R. Neville; the Pennsylvania Emergency Management Agency, Mr. Joseph L. LaFleur; the Beaver County Coroner, Mr. Wayne N. Tatalovich.

We have representatives here from the Transportation Safety Board of Canada, Board Members Mr. Hugh MacNeil and Ms. Zita Brunet; from the United Kingdom Civil Aviation Authority, Mr. Michael Benoy; from the French Bureau of Accident Investigations Bureau, Yves Lemercier; from the French Civil Aviation Authority, Mr. Maxime Brugel and Mr. Eric Dormoy.

As I stated earlier, this will be a lengthy hearing. We have it planned for the full week. There will be a number of witnesses that will be called. A lot of the testimony will be very technical in nature.

We will attempt to be sure to the extent possible that the testimony is as understandable to the general public as it can be made.

We will now proceed with this hearing, and I would like Mr. Schleede to call the first witness.

MR. SCHLEEDE: Mr. Haueter, please come forward.

THE WITNESS: Witness complies.

(Witness testimony continues on next page.)

THOMAS HAUETER, TECHNICAL PANEL, UNITED STATES OF AMERICA NATIONAL TRANSPORTATION SAFETY BOARD

Whereupon,

THOMAS HAUETER,

was called as a witness by and on behalf of NTSB, and, after having been duly sworn, was examined and testified on his oath as follows:

MR. SCHLEEDE: Mr. Haueter, please state your full name and business address for the record.

THE WITNESS: My name is Thomas E. Haueter. I am employed by the National Transportation Safety Board at 490 L'Enfant Plaza, Washington, D.C.

MR. SCHLEEDE: What is your position with the NTSB?

THE WITNESS: I am the Deputy Chief of Major Investigations and the Investigator-in-Charge for this accident.

MR. SCHLEEDE: Could you give us a brief description of your aeronautical experience and training that qualifies you for your present position?

THE WITNESS: I hold a commercial pilot's license with an instrument rating. I started flying when I was 16. I currently fly and operate my own airplane.

(Pause.)

CHAIRMAN HALL: Can Mr. Haueter be heard in the back of the room?

All: No.

THE WITNESS: No?

MR. SCHLEEDE: Let me start again.

CHAIRMAN HALL: Let's see, Mr. Haueter, if you could -- as usual with most public events, it seems that the microphones are always a problem, so if you could please try to get as close to the microphone -- so everyone can hear. I would appreciate it.

THE WITNESS: My aviation background, I started flying when I was 16. I hold a commercial license with an instrument rating. I currently own and operate my own airplane for sport and nothing else. I have a degree in aeronautical and astronautical engineering from Perdue University. I have a degree on operations research from George Mason University.

I was employed by -- in the aviation industry first for United Technologies and then I was a consultant for several years in aircraft structures before joining the Safety Board.

MR. SCHLEEDE: How long have you worked with the Safety Board?

THE WITNESS: I have been with the Safety Board for 11 years, seven years as an Investigator-in-Charge.

MR. SCHLEEDE: Thank you, and you have a prepared statement to read?

THE WITNESS: Yes, I do. Thank you, Mr. Chairman. On September 8th, 1984 -- can I be heard?

ALL: Yes.

THE WITNESS: Okay, I will start again. On September 8th, 1994 at about 7:03 Eastern Daylight Time, USAir flight 427, a Boeing 737-300, registration November 513 alpha uniform crashed while descending to land at the Pittsburgh International Airport, Pittsburgh, Pennsylvania.

The airplane was being operated as a scheduled passenger flight under instrument flight rules from Chicago-O'Hare International Airport, Chicago, Illinois to the Pittsburgh International Airport.

During the approach to landing, control of the airplane was lost and the airplane crashed near Aliquippa, Pennsylvania. The airplane was destroyed by impact forces and fire. All 132 persons on board were fatally injured.

I was on duty as the Investigator-in-Charge for that week and was notified of the accident at about 7:20 in the evening. A Safety Board investigative go team was assembled that evening, but because of the lack of availability of an FAA airplane or commercial flights, the team did not depart Washington until the next morning on an FAA airplane. The team arrived at the accident site at about 7:30.

Accompanying the team were Board Member Carl Vogt, his special assistant, Cody Miller, the acting managing director, Ron Battocchi and Mike Benson from the public affairs office.

The investigative team comprised specialists in the areas of operations, human performance, aircraft structures, aircraft systems, power plants, maintenance records, air traffic control, survival factors, aircraft performance, meteorology and witnesses.

Specialists were also assigned to stand by in the Safety Board's laboratories for the cockpit voice recorder and the flight data recorder groups. Because of the magnitude of the accident, in most cases two Safety Board investigators were assigned to each group on scene.

Parties that provided technical assistance to the investigation were the Federal Aviation Administration, Boeing Commercial Airplane Group, Airline Pilots Association, CFM International, AVIALL, National Air Traffic Controllers Association, USAir Transportation Workers Union #545, International Association of Machinists and Aerospace Workers, Association of Flight Attendants, Parker Berta Aerospace, Monsanto Company, PATS, Incorporated, the Federal Bureau of Investigation, Hopewell Township, Pennsylvania State Police, Pennsylvania Emergency Management Agency, the Beaver County Coroner's Office and emergency response personnel from Beaver and Allegheny Counties.

Additionally, air safety investigators from the aircraft accident authorities from the United Kingdom, France, Denmark, Australia and Canada participated in the investigation as technical observers in accordance with prior arrangements for such participation.

The investigation of this accident has been one of the most complex and extensive aircraft accident investigations conducted by the Safety Board. To date, over 25,000 investigative man-hours have been expended in direct support of the Safety Board's investigation.

Additionally, the parties to the investigation have allocated considerably more man-hours in providing indirect support to the investigation in response to questions raised by the Safety Board's investigators.

The Safety Board's investigation included the on-site wreckage examination and removal, the tear-down and examination of numerous flight control system components, aircraft performance simulation studies, partial reconstruction of various portions of the airplane, detailed structural analyses, metallurgical analyses, chemical analyses, cockpit voice recorder, flight data recorder studies, including sound spectrum analyses, the examination of several incidents involving control difficulties with the Boeing 737 series airplanes and seemingly countless meetings and planning sessions.

I would like to digress for a moment and publicly thank all of those that participated in the on-scene investigation; the Safety Board staff, investigators from the parties and those that helped in identification of the remains and removal of the wreckage.

The on-site work was beyond description and there are too many "heroes" to list in the time that I have available. However, all of the people who assisted, from those who participated during the work at the scene to those who provided refreshments to the investigation team, can be justifiably proud of their accomplishments. It was an honor to have worked with them all.

The general facts of the investigation are as follows: The accident occurred near the end of the third day of a three-day flight sequence for this flight crew. The flight crew had started the three-day trip in Philadelphia on September 6th. They spent that night in Toronto, Canada. On September 7th they flew four flight segments, ending in Jacksonville, Florida.

On the third day, they arrived in the Jacksonville airport at about 12:15 in the afternoon crew Flight 1181. The airplane for this flight and the remainder of their duty day was the airplane involved in the accident, once again, registration N513AU.

The airplane had spent the night of September 7th in Windsor Locks, Connecticut, where a maintenance transit check was accomplished. Only routine service was performed and there were no outstanding or deferred maintenance items.

The flight crews who flew the airplane on the day before the accident reported that nothing out of the ordinary occurred on the flights and that there were no problems with the airplane.

The airplane was flown from Jacksonville at about 12:20 in the afternoon to Charlotte, North Carolina and then on to Chicago's O'Hare International Airport where it landed shortly after 5:00. Those flights were reported to have been normal with no significant events. There was a jump seat rider, a USAir pilot, on these flights who will testify at this hearing as to the events of those flights.

At O'Hare the airplane was assigned as flight 427 to Pittsburgh, once again with the same flight crew. There were no items noted in the maintenance log for this flight, including in the minimum equipment list, the configuration deviation list, or any ground security items.

Prior to departure, the airplane was fueled with an additional 2,320 pounds of fuel for a total departure fuel load of 15,400 pounds. The scheduled fuel use would have provided about 8,400 pounds of fuel remaining upon arrival at Pittsburgh.

Flight 427 departed Chicago-O'Hare at about 6:10 p.m. The en route time was planned for 55 minutes, all en route air traffic control communications with the flight were routine. Examination of the cockpit voice recorder and the air traffic control tapes identified the first officer as flying the airplane on this leg and the captain as handling the radio transmissions.

Conversation within the cockpit was routine and included all appropriate checklist items. The in-range check to the USAir facility at the Pittsburgh airport was performed by the flight crew using the Automated Communications Addressing & Reporting System

(ACARS) at about 7:00 p.m.

The initial arrival of the flight into the Pittsburgh area was uneventful. The airplane was vectored by Approach Control for a landing on runway 28 right, which the crew acknowledged. In accordance with standard arrival procedures, flight 427 was assigned an altitude of 6,000 feet. Flight 427 was inbound to the airport following a Delta Airlines Boeing B-727, which was 4.2 miles ahead at the time of the accident.

Numerous interviews were conducted with flight crews of aircraft either arriving at or departing the airport about the time that flight 427 was on arrival vectors. None of the flight crews described any unusual weather, including turbulence, or the presence of birds.

The captain of the Delta Boeing 727 did not recall hearing flight 427 during the approach. However, he described the flight conditions as "good weather, with no turbulence or bird activity."

The cockpit voice recorder and the flight data recorder indicate that the flight crew was using the Auto-Flight System, or autopilot during the flight and during the approach to the airport. This is standard procedure for the Boeing 737-300.

Shortly after 7:00, the Air Traffic Controller issued instructions for flight 427 to turn left to 1-4-0 degrees and to reduce airspeed to 1-9-0 nauts. The flight crew acknowledged this transmission and asked for confirmation of the landing runway.

At 7:02:22, the controller requested flight 427 to turn to a heading of 1-0-0 degrees and advised the flight crew about another airplane (a Jetstream) at their two o'clock position and climbing out of 3,300 feet to 5,000 feet. At this time, flight 427 was still at an altitude of 6,000 feet.

The captain of flight 427 reported to ATC that they were looking for the Jetstream traffic. Shortly after 7:03, a transmission was made by the captain of "4-2-7 emergency." The controller noted that flight 427 had departed its assigned altitude and instructed the flight to maintain 6,000 feet.

Shortly thereafter, the tower controllers saw dense smoke rising to the northwest of the airport. Numerous ground witnesses observed the airplane in its descent, which was described by most observers as "nearly vertical," just before impact. There were no reports of witnesses to the initial upset.

Mr. Chairman, at this time I would like to present a video reconstruction of the last moments of the accident flight based on the flight data recorder. I must point out that the flight recorder contained only eleven parameters, none of which measured the positions of the control surfaces.

If you could run the video, please? As the video plays --

VOICE: (Inaudible.)

MR. HAUETER: No, it should be fine.

(Visual aid shown.)

You will see along the side are the aircraft instruments, as recorded, and also along the bottom of the aircraft to the upper left-hand corner. In the top right corner the first instrument will be -- we will wait for it to come up.

(Pause.)

Once again, this is based on the flight data recorder information.

(Pause.)

The instrument in the upper right is the air speed indicator in nauts. The next instrument down is the altimeter. The third one down is the magnetic heading in degrees. The one at the bottom right is the attitude indicator. To the left of it is the vertical airspeed indicator. To the center is the vertical acceleration in G's.

Then you will see the control column indication. This column position is measured in the cockpit; however, it does not rotate. We only have back and forth motion in the control column. Above it is the longitudinal acceleration measured in G's, and to the far left-hand side at the bottom are the engine instruments recorded.

At this time the aircraft was on its approach and descending into the Pittsburgh area. You will be able to see the altimeter coming down toward 6,000 feet and the air speed is being reduced to 190 nauts.

(Pause.)

The flight crew is now getting vectors to turn to a heading of 1-0-0 and being advised of the Jetstream traffic.

(Pause.)

As the aircraft starts to roll out they report seeing the Jetstream. The co-pilot states that over his microphone, then the upset occurs. There is no --

(Pause.)

The vertical bars, or timing marks are five seconds apart.

(Pause.)

Thank you.

CHAIRMAN HALL: Does that complete your testimony?

MR. HAUETER: No, I have got a little bit more. Mr. Chairman, I would like to provide a brief synopsis of the investigation to date.

Upon arrival at the accident site, Safety Board investigators conducted a preliminary investigation of the scene, and in cooperation with public safety officials for Hopewell Township, Beaver

County, the Pennsylvania State Police and the Beaver County Coroner's Officer, determined that the accident site was a potential biological hazard area and, as such, the use of protective personal equipment and safety procedures were required by the Occupational Safety and Health Administration regulations.

Fortunately, Beaver and Allegheny Counties had specially trained emergency response personnel who had expertise in hazardous material protection measures, including biological hazards, which made the accomplishment of the tasks of rescue and recovery workers, as well as the accident investigators, much more efficient.

All personnel on-site were requested to comply with these important health and safety requirements to ensure their safety, as well as that of the general public. The use of personal protective equipment and decontamination of personnel and specific wreckage were precautionary measures.

I wish to stress that any wreckage that required decontamination was thoroughly examined by Safety Board personnel and bomb experts prior to its being decontaminated.

The cockpit voice recorder and the flight data recorder were recovered by FAA personnel the night of the accident. The recorders were secured and taken to the Safety Board's laboratory on the morning of September 9.

The depiction of the FDR data has previously been shown on the videotape. The CVR was one of the clearest recordings ever processed by the Safety Board. The CVR provided no evidence of any problems before impact that precipitated the accident.

Additionally, examination of the background sounds on the CVR found no evidence of noises that could be associated with a failure of the airplane's structure of systems, or any evidence of criminal intent, such as an explosion.

I would like to point out that explosions or gun shots provide distinctive sound spectrums, and there were no such spectrums found in the recording of the flight 427 CVR.

The on-scene phase of the investigation lasted until the 20th of September. During that time, the wreckage was thoroughly examined in place at the scene and then was moved to a hangar at the Pittsburgh airport for additional examination and disassembly.

The on-scene investigation determined the following: The airplane struck the ground at an angle of descent of about 80 degrees in a slight roll to the left, and the airspeed was about 260 nauts at impact. The airplane was severely fragmented by impact and there was an intense post-crash fire.

Both engines were producing power at impact and were running symmetrically. The thrust reversers were stowed at impact. The flaps were at a "Flap 1" setting. At this setting, the leading edge slats and Kreuger flaps are extended. The spoilers were retracted and the landing gear were retracted. These are the expected positions for the airplane during the initial approach.

The horizontal stabilizer was in an intermediate position, consistent with an air speed of 190 nauts. The elevator control unit was at 14 degrees, nose up. The rudder was determined to be 2 degrees right (airplane nose right) at impact.

The captain had a total of about 12,000 flight hours, of which 4,000 were in the Boeing 737. The first officer had a total flight time of about 9,100 hours and about 3,700 hours in the Boeing 737. Nothing unusual was noted in the pilot's records. Both were described by other pilots as being very professional and competent pilots.

The maintenance records examination found that all applicable airworthiness directives had been complied with and there were no maintenance items being deferred, or outstanding. The airplane's daily flight log was recovered and there were no maintenance write-ups for the last three flights, including the accident flight.

Witnesses reported they did not see anything fall from the airplane during its descent. A ground and helicopter search did not disclose any items from the airplane outside of the major impact area, although some light items were found some distance away. These items were all found downwind from the accident site and had been blown there by wind after the impact.

The following items were removed from the wreckage for examination under the Safety Board's control: The rudder Power Control Unit (PCU), the standby rudder actuator, the rudder trim actuator, the rudder centering unit, the aileron power control unit (PCU), the spoiler actuators, the slat actuators, the autopilot servos, various autopilot electrical relays, the pilot's rudder pedal system and control yoke systems and most of the control cables.

Hydraulic fluid samples were obtained from the various systems. Additionally, a survey was made of computer systems on the airplane that might have contained non-volatile memory chips. All of the electronic boxes were severely damaged and most of the chips were destroyed.

Besides the work accomplished in the Safety Board's laboratory, the Systems Group traveled to manufacturer's facilities in Irvine, California and Seattle, Washington on seven separate occasions to examine and test all of the components removed from the airplane.

Additionally, during the investigation four incidents involving a sudden yawing moment and one accident involving an overseas-operated Boeing 737 resulted in the Safety Board conducting special examinations of the control system components and the flight data recorder information from those airplanes.

Hydraulic fluid samples removed from the accident airplane and samples taken from 24 other Boeing 737's were taken to facilities in St. Louis, Missouri and Oklahoma City, Oklahoma for analysis. The results of these examinations are provided in the reports entered into the public docket released today.

The aircraft performance group completed over 200 flight simulations of various failure modes using an engineering simulator. These simulations considered various single point failures and how they may -- how they would affect the airplane. Additional simulator work was accomplished using the flight data recorder information from flight 427 to "back-drive" the simulator.

Radar data indicated that no other airplanes were in proximity to flight 427 before the accident. However, a Delta Boeing 727 had passed the same location of flight 427 about 70 seconds before and 300 feet higher.

Analysis of the radar data indicates that flight 427 passed through the wake of the Delta 727. Therefore, the engineering simulator was modified to portray an encounter with the wake vortices of a Boeing 727.

Numerous simulator flights were conducted in which the airplane flew through the wake vortex at various angles and vortex intensities. The docket contains the results of these tests and experts will testify as to the results of those tests.

One of the most labor-intensive efforts was the two-dimensional reconstruction of the major structure of the airplane, concentrating on the floor beams and bulkheads of the airplane.

This work was accomplished in the hangar at the Pittsburgh International Airport. This effort required two investigative teams of about 20 persons each working two shifts per day for almost 3 weeks. Assistance was provided by two investigators from the Air Accidents Investigation Branch of the Department of Transport, United Kingdom.

Due to the severe fragmentation of the airplane, it was not practical to complete a three-dimensional reconstruction. The reconstruction was accomplished to examine the possibilities of a control cable failure, bird strikes, floor beam failures, or an explosion of the auxiliary fuel tank.

Additionally, the wreckage was examined by the FBI for any evidence of sabotage. During the reconstruction, the wreckage was further examined for any evidence of an in-flight structural failure or tire burst in the wheel well.

During the investigation, weekly telephone conferences took place with the parties to the investigation. These tele-conferences were necessary to provide for an open exchange of information and ideas and to keep all of the parties informed as to the progress of the investigative teams.

Additionally, on October 19th and 20th in Pittsburgh and December 7th in Seattle, meetings were held with all of the parties to the investigation to further discuss the activities of the investigation and to define additional areas for research.

During these meetings, the parties were asked to provide their comments on the scope of the investigation. I would like to state that throughout the investigation all of the parties have been very cooperative and supportive of the Safety Board's investigation.

Additionally, the Safety Board has received several hundred unsolicited letters and phone calls from persons offering their opinions and thoughts on the accident.

Mr. Chairman, at this time, I am not aware that any party to the investigation, or any other persons, or organizations have raised avenues of investigation that we have not pursued fully, or are currently examining.

Mr. Chairman, this concludes my statement. The record of the investigation is contained in the documents in our public docket. The Court Reporter has a copy. Thank you, sir.

CHAIRMAN HALL: Thank you, Mr. Haueter, you may step down.

(Witness excused.)

Before I call the next witness, I would like to make an addition and a clarification to my opening remarks. First of all, I failed to introduce Mr. Dan Campbell, the Board's General Counsel who is seated to my rear along with my personal staff.

Also, in referencing -- in my opening remarks I referenced that approximately 25,000 man-hours had been expended so far in this investigation. That figure represents the work of Safety Board employees.

When you consider the fact that one of the parties to this investigation has, by their estimate, invested 42,000 man-hours in this investigation, I would guess that probably in excess of 100,000 man-hours have been expended in this investigation by the Safety Board and by the parties to the investigation.

I would like to now call Captain William Jackson, our next witness. Captain Jackson? Mr. Schleede, if you would swear the witness in, please?

(Witness testimony continues on the next page.)

CAPTAIN WILLIAM JACKSON, JUMP SEAT RIDER ON USAIR FLIGHT 1181, USAIR, INC., PITTSBURGH, PENNSYLVANIA

Whereupon,

CAPTAIN WILLIAM JACKSON,

was called as a witness by and on behalf of NTSB, and, after having been duly sworn, was examined and testified on his oath as follows:

CHAIRMAN HALL: Thank you for your appearance here today, Captain. Your question -- you will be questioned initially by Mr. Charles Leonard of the Safety Board. Mr. Leonard, please proceed.

MR. LEONARD: Good afternoon, Captain Jackson. Can you hear me okay, sir?

THE WITNESS: Yes, sir.

MR. LEONARD: Captain Jackson, I would like to ask you a few questions today regarding -- relating to USAir flight 1181 which, as earlier stated, operated on September 8th, 1994 from Jacksonville, Florida, it thence went to Charlotte, North Carolina and its destination, final destination, was Chicago, Illinois, the O'Hare International Airport.

Would you please tell us your role as a passenger on that flight that day?

THE WITNESS: Yes, sir. I had the occasion to travel from Jacksonville to Charlotte and on to Chicago that day on flight 1181. I rode in the cabin of the aircraft from Jacksonville to Charlotte and I rode in the cockpit jump seat, or observer's seat from Charlotte to O'Hare.

MR. LEONARD: What was your purpose for that flight that day, sir?

THE WITNESS: The next day I was scheduled to pick up a split trip in Chicago and I was just pre-positioning myself in Chicago the next morning.

MR. LEONARD: Have you flown the B-737-300 as a crew member?

THE WITNESS: Yes, sir, both as a Captain and as a First Officer.

MR. LEONARD: So, you have a -- what you call an ATP rating in the 737?

THE WITNESS: Yes, sir.

MR. LEONARD: You have also flown it as a passenger?

THE WITNESS: Yes, sir, that is correct.

MR. LEONARD: Did you know the pilots on board flight 1181 that day?

THE WITNESS: Not until that day, not until I introduced myself in the cockpit.

MR. LEONARD: Were you aware -- or, when were you aware that the flight crew and the aircraft 513 on

1181 also turned to flight 427 from Chicago to Pittsburgh?

THE WITNESS: I was aware that the crew was returning to Philadelphia that day via Pittsburgh, and after I saw the news reports of the accident I assumed it was that crew of that aircraft.

MR. LEONARD: I see. You stated a moment ago that on the flight from Jacksonville to Charlotte you sat in the passenger compartment. Do you remember where you sat, specifically?

THE WITNESS: I sat in the cabin, coach section, about mid-coach and on the left-hand aisle.

MR. LEONARD: Do you have any recollections of unusual noises that occurred during that flight?

THE WITNESS: No, sir. During that segment I heard no noises that were unusual, or felt any aircraft movement that would have been unusual.

MR. LEONARD: On the flight from Charlotte to

Chicago you stated that you flew in the cockpit jump seat, and why was that, sir?

THE WITNESS: The aircraft filled up in both the first class and coach section. I had previously signed up for the aircraft jump seat and rode that jump seat on that leg.

MR. LEONARD: Would you briefly describe the arrangement of the cockpit jump seat in a 737-300?

THE WITNESS: The jump seat is located immediately inside the cockpit door and just aft of the pilot's center console that is located between the two pilot's seats, and just after their seats.

It is a rigid and very erect seating arrangement. It is a small cockpit, and once you are seated in the seat your back is only a couple, three inches from the cockpit door and your knees would only be several inches from the aft portion of the center console.

MR. LEONARD: Would you describe, or comment of the demeanor of the flight crew during that flight from Charlotte to Chicago?

THE WITNESS: They were a very good crew. They seemed to get along well, they had a good rapport amongst themselves both professionally and personally, they seemed to have a good working relationship with the flight attendants in the cabin and they were more than willing to have me along as a jump seat rider.

MR. LEONARD: Were there any unusual noises that you are aware of during the flight from Charlotte to Chicago?

THE WITNESS: Not from the cockpit. I did not hear any unusual noises.

MR. LEONARD: Was there any contact from the flight attendants to the cockpit regarding any noises in the cabin?

THE WITNESS: There was a situation probably half way during the flight, certainly at cruise altitude. The Captain took a call from a flight attendant that had related a passenger had complained about a noise in the cabin, and the Captain immediately after that call turned to me and told me that my knee was on the PA mike, which it was.

I had crossed my legs, and I moved my leg and had no further complaints about the noise in the cabin, or any discussion after that about the noise.

MR. LEONARD: So, would you describe it as an inadvertent actuation of the public address mike, itself?

THE WITNESS: Yes, sir. As I said before, it is a fairly small cabin and it becomes a little cramped at times riding the jump seat, and when I crossed my legs I inadvertently keyed the microphone.

MR. LEONARD: Were you aware of any mechanical problems, airworthiness issues in that air -- operation of that aircraft during that flight?

THE WITNESS: None, at all. I didn't feel anything, or hear anything in the cabin. I didn't feel anything, or hear anything in the cockpit when I was riding up there. I did not see any MEL stickers in the cockpit.

I wasn't aware of any maintenance write-ups that the crew had, or any problems that they had intended to write up. As far as I know, it was a perfectly fine aircraft.

MR. LEONARD: Thank you very much, Captain Jackson. That concludes my questions at this time.

THE WITNESS: Thank you.

(Witness excused.)

CHAIRMAN HALL: Okay, we will move, then, to the parties. Mr. Jakse, does Monsanto have any questions for this witness?

MR. JAKSE: Mr. Chairman, we have no

questions.

CHAIRMAN HALL: Okay. Mr. Wurzel, does the International Association of Machinists have any questions for this witness?

MR. WURZEL: Mr. Chairman, we have no questions.

CHAIRMAN HALL: Mr. Weik, does Parker Hannifin have any questions for this witness?

MR. WEIK: Mr. Chairman, no, we don't.

CHAIRMAN HALL: Mr. Purvis, does Boeing have any questions for this witness?

MR. PURVIS: Mr. Chairman, we have no questions.

CHAIRMAN HALL: Okay. Mr. Donner, does FAA have any questions for this witness? We could get the --

MR. DONNER: No questions, Mr. Chairman, thank you.

CHAIRMAN HALL: Captain Sharp, does USAir have any questions for this witness?

CAPTAIN SHARP: Just a couple, Mr. Chairman. Captain Jackson, while you were riding in the cockpit on the jump seat you had a chance to observe both pilots flying the airplane. How would you characterize their performance in those situations of both the Captain and the First Officer?

THE WITNESS: I thought they were a well-qualified and very able crew. They, as I said before, had a very good rapport between themselves, they seemed to have a good working relationship in the cockpit, everything that needed to get done had a timely sequence to it.

They utilized the aircraft checklist, made all the standard and required call-outs, and all in all I thought it was a very capable and very professional crew.

CAPTAIN SHARP: Would you say that the activities of the two pilots and their exercise of CRM was professional and adequate?

THE WITNESS: Yes, sir. They had a good working relationship between themselves and they, in fact, included me in discussions of watching for air traffic control as a jump seat rider being a second set of -- or, third set of eyes on the flight up, and discussions about arrival into Chicago.

CAPTAIN SHARP: Thank you, Captain Jackson. Mr. Chairman, I have no further questions.

CHAIRMAN HALL: All right, Captain LeGrow, does the Airline Pilots' Association have any questions?

CAPTAIN LEGROW: Mr. Chairman, just a couple. Good afternoon, Captain Jackson.

THE WITNESS: Hi.

CAPTAIN LEGROW: On your flight between

Jacksonville and Charlotte you rode in the cabin of the airplane, is that correct?

THE WITNESS: Yes.

CAPTAIN LEGROW: And then you rode in the jump seat, and you said you didn't identify any noises. How much experience do you have in the Boeing 737?

THE WITNESS: I have flown the aircraft both as the Captain and First Officer, and I have approximately 2,800 hours in that aircraft.

CAPTAIN LEGROW: Have you ridden frequently in the cabin of the airplane?

THE WITNESS: Yes.

CAPTAIN LEGROW: Thank you. You stated that sometime during cruise the flight attendant called the Captain and identified a noise, and he said that you must have inadvertently hit the PA mike switch. Would you just describe briefly where that is located?

THE WITNESS: Certainly. It is located on the aft wall of the center pilot console. Sitting in the jump seat that mike would only be several inches from my knees. It is on a clip that hangs on that podium, so it is exposed externally on the outside of the podium -- the console -- and the mike key itself is located on the top portion of that microphone.

CAPTAIN LEGROW: Thank you. I have no further questions, Mr. Chairman.

CHAIRMAN HALL: Mr. Marx, do you have any questions for this witness?

(Pause.)

MR. MARX: During your flight when you were jump seat rider, did you notice the position of the feet of the pilot, or the co-pilot?

THE WITNESS: No, sir, I didn't. I can't recall exactly. I assume they were on the floor near the rudder pedals.

MR. MARX: In your experience as a First

Officer, or a Captain where do you normally keep your feet during that phase of flight?

THE WITNESS: On the floor.

MR. MARX: On the floor. Thank you.

CHAIRMAN HALL: Mr. Clark, do you have any questions for this witness?

MR. CLARK: No, sir, I don't.

CHAIRMAN HALL: Mr. Schleede?

MR. SCHLEEDE: No questions.

CHAIRMAN HALL: Mr. Laynor?

MR. LAYNOR: Captain, do you have anything else that you would add to this record, or would care to add at this time?

THE WITNESS: Not really. I think we have pretty much covered everything that I can attest to.

MR. LAYNOR: Okay.

CHAIRMAN HALL: I believe, then, unless there are -- I hear any other questions of any of the parties, the Technical Panel, or the people at the table have, that concludes our testimony. We appreciate your presence here today. Yes, sir, you had one additional question?

VOICE: (Inaudible.)

CHAIRMAN HALL: The microphone. We --

(Pause.)

CAPTAIN LEGROW: Mr. Chairman, is the Captain now excused? He wants to go back to work. I just wondered if he was excused for the day?

CHAIRMAN HALL: Yes, Captain Jackson, you are excused. Thank you, sir.

(Witness excused.)

I would like to call the next witness, Mr. William Perry, Supervisory Special Agent with the Federal Bureau of Investigations, Pittsburgh, Pennsylvania.

VOICE: (Inaudible.)

CHAIRMAN HALL: All right, Mr. Perry?

(Pause.)

CHAIRMAN HALL: Mr. Perry, thank you for your presence here today, and Mr. Schleede has some initial questions.

(Witness testimony continues on the next page.)

WILLIAM PERRY, SUPERVISORY SPECIAL AGENT, FEDERAL BUREAU OF INVESTIGATION, PITTSBURGH, PENNSYLVANIA

Whereupon,

WILLIAM PERRY,

was called as a witness by and on behalf of NTSB, and, after having been duly sworn, was examined and testified on his oath as follows:

MR. SCHLEEDE: Mr. Perry, could you give us your full name and business address for the record, please?

THE WITNESS: Yes, William Perry, Federal Bureau of Investigations, 700 Grant Street, Pittsburgh, Pennsylvania.

MR. SCHLEEDE: What is your position with the FBI?

THE WITNESS: My position is a Special Agent in Charge of the FBI Field Office in Pittsburgh.

MR. SCHLEEDE: How long have you held that position?

THE WITNESS: I have held that position for three years.

MR. SCHLEEDE: How long have you worked for the FBI?

THE WITNESS: I have worked for the FBI approximately 24 years as a Special Agent.

MR. SCHLEEDE: Could you give us a brief

description of your education and background which qualifies you for your position?

THE WITNESS: Yes. I have a -- graduated college in 1965, subsequent to college entered the United States Navy as a Naval Officer in Submarine Service for approximately six years and thereafter entered the FBI in 1971 and served with the FBI in the Detroit, Philadelphia and Miami field offices and at FBI Headquarters in Washington, D.C.

MR. SCHLEEDE: Thank you. Mr. Haueter will proceed with questioning.

(Pause.)

MR. HAUETER: Okay. Mr. Perry, can you hear me?

THE WITNESS: Yes, sir.

MR. HAUETER: Thank you for coming this afternoon. Just a few questions. There was a lot of speculation early on in the investigation of possible foul play. To your knowledge, were there any protected witnesses on board flight 427?

THE WITNESS: To my knowledge, there were no protected witnesses on board USAir flight 427.

MR. HAUETER: Were there any persons on 427 that the FBI would be suspect for possible criminal intent, or --

THE WITNESS: Well, initially we heard speculation that there was a protected witness aboard that, so I made -- and representatives of my office made inquiry as to that, and an individual named Paul Olsen who was aboard that aircraft had gone to Chicago on September 7th at the request of the United States Attorneys Office in Chicago to be debriefed concerning possible information that he might have concerning a defendant who was coming up for trial in the Chicago office.

MR. HAUETER: Was this gentleman ever

considered for the witness protection program, or --

THE WITNESS: He was not in the witness protection program and never had been in the witness protection program. I don't know if he was ever considered for it.

MR. HAUETER: During the investigation several samples, or parts of the aircraft were sent to the FBI's laboratory in Washington. Were there any residue that would indicate an explosion, or chemical debris?

THE WITNESS: On two occasions specimens were sent by NTSB to the Federal Bureau of Investigation for examination of residue that would be consistent with an explosive device on the plane.

No residue consistent with an explosive device was determined in examination of those specimens. Those specimens were provided on September 14th and September 19th.

MR. HAUETER: Also, the Safety Board made a request for the FBI to assemble a team of bomb specialists to look at the wreckage in the hangar. Could you describe those activities for us, please?

THE WITNESS: That is correct. On December 19th and 20th four bomb experts from the FBI examined wreckage from flight 427 in the USAir hangar in Pittsburgh, Pennsylvania.

The examiners considered the possibility that, one, an explosive device was placed, or carried on board and was inside the aircraft when it detonated and that, two, an explosive device such as an air-to-air or surface-to-air missile may have detonated outside the aircraft.

Thousands of aircraft fragments were examined by the forensic examination team for indications of explosive damage, explosive related phenomena and components of various explosive devices.

Based on the forensic examinations of the investigative team, no evidence was found on or among the items examined which would indicate that an explosion occurred internally or externally to the Boeing 737 which was USAir flight 427 prior to its crash.

MR. HAUETER: How many members of the FBI's team were there?

THE WITNESS: There were four bomb experts that examined the wreckage in the hangar.

MR. HAUETER: I guess my last question -- and this has been a nagging question in the event of a bomb. In the FBI's estimation, is there any reason to consider that foul play was a part of this accident?

THE WITNESS: No. When I responded to the crash scene, I did for two purposes -- and representatives from my office. One was for any request by the Coroner's Office to have our disaster team proceed to the location in helping to identify the remains, and number two was the FBI would be the federal law enforcement agency that would respond to any indication of a criminal act that caused that crash.

Attending to those responsibilities, I remained with the Investigative Team from NTSB and attended at least all of the briefings looking for any indication that would suggest a criminal act.

Particularly, during that time, I was in -- I was in communication with FAA bomb search -- bomb experts which examined the wreckage at the scene regarding any indication by them that there was a criminal act of any sort involved with the accident, and none was forthcoming and no indication has come to our attention that would support that there was criminal act involved in that crash.

MR. HAUETER: Thank you. That's all the

questions I have, Mr. Chairman.

CHAIRMAN HALL: All right. Mr. Weik with Parker Hannifin, does Parker -- do you have any questions for this witness?

MR. WEIK: Mr. Chairman, not at this time.

CHAIRMAN HALL: Mr. Jakse with Monsanto, do you have any questions for this witness?

MR. JAKSE: No questions, Mr. Chairman.

CHAIRMAN HALL: Mr. Wurzel with the Machinists?

MR. WURZEL: Yes, Mr. Chairman, one question. Good afternoon, Mr. Perry.

THE WITNESS: Good afternoon, sir.

MR. WURZEL: To your knowledge, are there any explosives that you know of in existence that when detonated do not leave a residue?

THE WITNESS: Sir, I do not know. I would qualify that in terms of the fact that I am not a bomb expert, but was requested to testify as to the results of our examinations.

MR. WURZEL: One more question. What are the possibilities of such a device being placed on board USAir flight 427?

THE WITNESS: I could not speculate to the possibility of such a device being placed on flight 427.

MR. WURZEL: Thank you. That concludes my questions.

CHAIRMAN HALL: Thank you. Mr. Purvis, do you have any questions?

MR. PURVIS: I have a couple of questions for Mr. Perry, thank you.

CHAIRMAN HALL: Please proceed.

MR. PURVIS: When you examined the wreckage in the hangar on December 19th and 20th, had it already been decontaminated with chlorine, with a chlorine solution?

THE WITNESS: I don't know the answer to -- I don't know if it had, or had not. That would be more properly directed to other people that were involved prior to their arrival at the scene.

MR. PURVIS: Are you aware of explosive devices that are made, like RDX or PETN, that have a very small, light-weight -- can be put in a very small, light-weight package and when they do detonate, or if they are detonated that they create almost no explosion, or fire -- or, smoke or fire?

THE WITNESS: No. I personally am not familiar with those -- with those devices; however, I can speak in terms of the results of the examination in terms of what they looked for and what they did not find.

MR. PURVIS: Okay, I would like to have you describe that.

THE WITNESS: In my discussion with the Chief Examiner, they looked for a phenomena that would be consistent with an explosive -- a high explosive device being set off on that flight. For example, pitting, or cratering, or feathering, gas-washing also, and found none of that phenomena that would be indicative of a high explosive on that flight.

MR. PURVIS: Okay. Are you aware that only maybe 20 percent of the forward area of the fuselage and the floor beams -- less than 20 percent was examined?

THE WITNESS: It was bound for examination. I can only speak to what was in the hangar that the NTSB requested that we examine. In terms of that examination, they examined thousands of fragments that were in that hangar, and no determination was found, or residue that would indicate any explosive device.

MR. PURVIS: There was about -- there were about 13 bags and maybe 2,000 pounds of magazines in the forward compartment. Was that examined?

THE WITNESS: The -- whether that was part of the debris that was forwarded in terms of -- when I spoke of the prior examinations at FBI Headquarters, the NTSB sent numerous debris and items to the FBI for examination. Where those debris and specimens came from was not described.

So, whether -- in answer to your question, whether that was part of that debris sent for examination of residue, I do not know. What was sent did not contain residue indicative of an explosive device.

MR. PURVIS: Okay, so you are not -- you are not aware of whether that forward cargo material was examined, or what -- you are not aware that it was not examined?

THE WITNESS: That is correct.

MR. PURVIS: Okay. Thank you very much, Mr. Chairman.

CHAIRMAN HALL: Captain LeGrow, Airline Pilots' Association?

CAPTAIN LEGROW: Thank you, Mr. Chairman. I have just a couple questions. Good afternoon, Mr. Perry.

THE WITNESS: Good afternoon, Captain.

CAPTAIN LEGROW: You stated -- you testified that there was a passenger on USAir 427 by the name of Paul Olsen that had been called to Chicago by the U.S. Attorney, I believe you said, to be interviewed in a case. Could you tell us what kind of case it was?

THE WITNESS: Yes, it was a representative of the United States Attorneys Office that requested his appearance there. It was a narcotics investigation, a drug investigation conducted by the United States Attorneys' Office, and also with the IRS and DA.

Mr. Olsen was asked to go to Chicago. They -- the United States Attorneys' Office had information that they had just recently received that he might be able to provide information regarding a defendant.

The defendant had been indicted in 1988 and had not been located until recently. So, what they were looking to talk to Mr. Olsen about was any association he had had with that defendant in terms of drug activity prior to 1988.

The individual -- in my discussion with representatives of the United States Attorneys Office is they debriefed Mr. Olsen and determined that his information was of little -- limited value to them. They had not made a determination at the time of the crash whether they intended to use him in trial, or not to use him in trial.

Subsequently, they felt that they would not have used him in terms of that trial. Subsequently, the defendant in question pled guilty to those drug charges.

CAPTAIN LEGROW: Okay, thank you. Did Mr. Olsen appear of his own volition, or was he subpoenaed to (inaudible).

THE WITNESS: He appeared on his own volition.

CAPTAIN LEGROW: Thank you. During the course of the investigation, it was some two months after the accident that the FBI conducted their examination in Pittsburgh wreckage, is that correct?

THE WITNESS: That is correct, sir.

CAPTAIN LEGROW: Could you tell us why it took two months for the FBI to examine the wreckage?

THE WITNESS: The FBI examined the wreckage at the request of the National Transportation Safety Board. The individual agency that had been the on-scene investigation investigators relative to any bomb that might have been on board was the Federal Aviation Administration which we consulted with on a regular basis as to any evidence that they might have found of an explosive device.

CAPTAIN LEGROW: So, that request was not made by the FAA, but was made by the Safety Board?

THE WITNESS: That is correct.

CAPTAIN LEGROW: Thank you. I have no further questions.

CHAIRMAN HALL: USAir, Captain Sharp, do you have any questions for this witness?

CAPTAIN SHARP: We have no questions, Mr. Chairman.

CHAIRMAN HALL: Mr. Donner, does the Federal Aviation Administration have any questions for this witness?

(Pause.)

If we could get Mr. Donner's microphone?

MR. DONNER: We have no questions.

CHAIRMAN HALL: Mr. Marx, do you have any questions for this witness?

MR. MARX: (Inaudible.)

CHAIRMAN HALL: Mr. Clark, do you have questions for this witness?

MR. CLARK: No, sir.

CHAIRMAN HALL: Mr. Schleede?

MR. SCHLEEDE: Yes. Are you aware of any claims by individuals, or organizations that they sabotaged flight 427? Are you aware of any claims?

THE WITNESS: No, sir, I am not aware of any -- any -- we have not received any evidence that would suggest a criminal act, other than speculation on somebody, and in each instance where we had speculation we went out and asked those persons, and they had no personal knowledge of any, or could provide no information of a sabotage, or a criminal act.

MR. SCHLEEDE: Well, I am aware that in several cases in the past organizations have made a claim following a disaster officially through some channel, through an embassy, or through official channels, and I am aware that your organization would receive classified message traffic.

Are you aware of any claims of that nature, individuals or organizations, against flight 427?

THE WITNESS: We received no such claim, sir.

MR. SCHLEEDE: Thank you.

CHAIRMAN HALL: Mr. Laynor?

MR. LAYNOR: No questions.

CHAIRMAN HALL: Mr. Perry, as you know, there has been a great deal of press attention to this accident and this investigation. I would appreciate if you could walk us through exactly what you did and what the FBI routinely does when it is called to an accident of this nature and, again, just briefly outline for us, if you would, your work on that particular day of the accident.

MR. ERCK: The night that the accident occurred I received information and proceeded to the scene of the accident and asked representatives from my office to also proceed to the scene of that accident.

My responsibility, as I had mentioned previously, was twofold. One, I was -- I was interested in determining if assistance was needed in terms of the disaster team that would respond to assist the Coroner in the identification of the remains. That request was forthcoming from the Coroner, and the disaster scene proceeded to Pittsburgh, D.C. -- from Washington, D.C. and was assisted by my office in terms of the identification.

Also, the FBI would be responsible to investigate any federal laws that if there was a criminal act regarding the crash of flight 427, the FBI would be responsible for the investigation of that criminal act and, as a result, I and representatives of my office attended the daily debriefings held by the National Transportation Safety Board with the intent of learning any information that came to anyone's attention that would suggest a criminal act occurred in regard to that crash.

It was also to stay close with the FAA who was a part of that on-scene investigative team to be alert to any indication that there was any criminal act that was responsible for that crash.

CHAIRMAN HALL: Since the date of that accident, again let me ask the question that Mr. Schleede asked. Has the FBI received any information that -- or, any claim from any party that would lead you to believe that an investigation of a criminal act causing this accident is warranted?

THE WITNESS: No, sir.

CHAIRMAN HALL: In addition, did you look at the -- and was there discussion at the time of the wreckage pattern of this aircraft, and if a bomb had been aboard whether there would have been an in-flight break-up of the plane?

THE WITNESS: I --

CHAIRMAN HALL: -- and resulting in scattered wreckage, or do you know whether that was part of -- part of your investigation?

THE WITNESS: I can only recall from the debriefings that occurred during the NTSB investigation, and I think it was mentioned earlier by Mr. Haueter that there was some -- some specimens that were later sent to the FBI laboratory that were found downwind from the crash site.

Those -- some of those I think were forwarded to the FBI laboratory in Washington, D.C. concerning any -- the identification of any residue that would expect an explosive device, and no residue -- no such residue was found on those items.

CHAIRMAN HALL: There is an exhibit -- I believe it is Exhibit 7(i) in the docket -- that is a report in addition, from a Special Agent Edward Kittel who is with the Aviation Explosive Security Unit of the FAA, and in addition we have evidence, a report from the FBI laboratory that is in the file.

Is there anything else, sir, that you would like to add at this time that would assist us with this hearing?

THE WITNESS: No, sir, other than to say that in addition to that FBI report that you had mentioned dated December 27th, there is also an FBI report dated September 20th and October 3rd that covers the specimens that NTSB sent to the FBI laboratory for examination.

CHAIRMAN HALL: I believe that concludes at this point our questions, Mr. Perry. Would you be available this week if there were additional questions for you?

THE WITNESS: Yes, sir.

CHAIRMAN HALL: Okay, thank you very much. You are excused.

(Witness excused.)

I think as we are approaching a little after 1:20, I think it would be appropriate at this time to take a 15 minute break. We have a number of additional witnesses to cover today, so I would ask those who are interested in this proceeding to be back in their seats in 15 minutes. Off the record.

(Whereupon, a brief recess was taken.)

CHAIRMAN HALL: On the record. The next witness is Mr. George Green, a Vortex Project Engineer for NASA-Langley. Mr. Green, if you would please approach.

(Witness complies.)

Mr. Schleede, if you would begin the questioning? Mr. Schleede, excuse me. Let me -- I meant to mention before -- I apologize, Mr. Green. In an attempt to facilitate this minor difficulty we are having with the microphones -- and I appreciate the two gentlemen to my left who are assisting up here in this endeavor. I would ask that the parties at the table would please keep their microphones on, or be sure before you are called upon that your microphone is on.

Secondly, they have told me that the Board has the microphones identified by the party's name, so I will call the party's name when I call on each person.

To save some time, unless you have a question on some of these witnesses -- I will ask you at the conclusion to hold your hand up. If you all have questions, fine. If not, I will not call on you if you do not have questions for a particular witness, and that may save us some time. Will you please proceed, Mr. Schleede?

(Witness testimony continues on the next page.)

GEORGE GREEN, WAKE VORTEX PROJECT ENGINEER, NASA-LANGLEY, HAMPTON ROADS, VIRGINIA

Whereupon,

GEORGE GREEN,

was called as a witness by and on behalf of NTSB, and, after having been duly sworn, was examined and testified on his oath as follows:

MR. SCHLEEDE: Mr. Green, would you please state your full name and business address for our record?

THE WITNESS: My name is George C. Green. My address is Langley Research Center, Hampton, Virginia.

MR. SCHLEEDE: What position do you hold at Langley?

THE WITNESS: I am a Senior Research Engineer on the Vortex Project Engineer. I have responsibility for Wake Vortex Research at NASA-Langley.

MR. SCHLEEDE: Could you give us a brief description of your education and background that qualifies you for your present position?

THE WITNESS: I have a Bachelor and Masters Degree in Engineering. I have worked at NASA-Langley for 30 years. The first 15 years was in developing measurement techniques for atmospheric research.

I was in charge of a weather station which we flew to the planet Mars in the late 70's. For the last 15 years I have been in wake vortex research in one capacity or another, leading that research at NASA-Langley.

MR. SCHLEEDE: Do you hold any FAA ratings or certificates?

THE WITNESS: No, I fly some for fun, but I have no official rating.

MR. SCHLEEDE: Thank you. Mr. Jacky will proceed.

(Pause.)

MR. JACKY: Thank you, Mr. Schleede.

CHAIRMAN HALL: Mr. Jacky is on the Technical Panel.

MR. JACKY: Is this better?

CHAIRMAN HALL: Maybe you want to get closer to the microphone, Mr. Jacky, if you would, please, and maybe raise it up a little to make sure everybody can hear.

MR. JACKY: My apologies. Good afternoon, Mr. Green. You have been called to testify to the phenomena of wake vortices. Could you please briefly describe some of the research that you have accomplished while at NASA on this phenomena?

(Pause.)

THE WITNESS: As I said, I have been involved in this research for about 15 years doing both theoretical and experimental research. During that period of time we have worked with a number of agencies in the U.S. Government and other governments abroad.

Wake vortex issues are important not only in the U.S., but most other countries, as well. In addition to theoretical research, we do wind tunnel experiments, what we call towing tank experiments. We assist the FAA and any other organization that is trying to run experiments in this area.

We do that in a cooperative nature, because we like to get whatever data we can get from whatever sources we can get it, since it is important. They are important military applications of wake technology.

We cooperate with military organizations. Usually when there is a Vortex problem almost anywhere, either in an airport, or military accident, or whatever, we get involved. We have been involved in other NTSB investigations, as you are probably aware.

MR. JACKY: Could you explain or answer if any of this research has been involved with the Boeing 727 aircraft?

THE WITNESS: There was a few years ago a rather extensive test series at Idaho Falls that we assisted the FAA in setting up a measurement program for, and the primary purpose of that program was to measure the wake characteristics of some of the newer aircrafts, specifically a Boeing 757 and 67.

As a control, a Boeing 727 was also included in that test matrix so that the data could be compared with data taken years earlier to see if there was any change in the test technique that might cause the 727 data to be different from test to test, and therefore give us a clue as to whether the test technique was suitable for looking at the other aircraft.

CHAIRMAN HALL: Now, Mr. Jacky, I believe it would assist the general public and any observers if you could ask Mr. Green to begin with an explanation for us as simply as he can put it of what a wake vortex is.

MR. JACKY: Yes, sir, that was my next question, as a matter of fact.

(Laughter.)

THE WITNESS: I have some transparencies, if I might use them, that I don't think would be controversial that might help with that.

(Visual aid shown.)

When an airplane generates lift, in the process of generating lift you end up with a higher pressure underneath the wing than you do above and, as you can see rather vividly in this photograph -- well, first of all, wake vortices are invisible.

It is a swirling mass of air that you can't see, and in this particular test there is a source of red smoke which you can see along the ground, and this smoke is caught up in a swirling air mass and it makes the vortex visible.

It illustrates the way the swirling begins, with high pressure air flowing outboard underneath a lifting surface toward the lower pressure on top of the wing, ending up in a spiral that is sometimes referred to as a horizontal tornado.

In your personal experience, if you have ever paddled a canoe, as you dip the paddle in the water you will see a pair of whirlpools on the surface of the water. It is a similar phenomena anytime you create lift, or impart a force into a fluid.

(Next visual aid shown.)

The next transparency shows the 727 in particular. The first aircraft was a small agricultural aircraft. This is typical of many transport aircraft where you have -- you may be in different configurations.

For example, if you have flaps deployed you will end up with more than one vortex from each side of the wing. In this transparency, the aircraft had smoke generators mounted on the outboard portion of the wing, and that smoke is entrained in the vortex coming off the tip of the wing.

Just downstream of the wing you see what appears to be a kink in that smoke trail, and at that point the vortex of the flap system which you can't see at that point, since it is invisible, it is wrapping around and merging with the vortex from the tip of the wing which then ultimately ends up as a pair of vortices which are rotating in opposite directions downstream of the airplane.

These may extend, you know, quite some distance. Their strength is predictable. How long they last is a very strong function of the ambient weather conditions.

(Next visual aid shown.)

The next chart summarizes how strong vortices are. We use the term "circulation" to describe that. Basically, they are proportional to the lift that you are generating, or the weight of the airplane divided by the air density, the forward speed of the aircraft and the span of the generating aircraft, and that factor K is a variable depending on how the wing is loaded, or the aircraft configuration, whether or not the flaps are down and so forth, and the --

When you use relatively simple formulas like this to predict the initial strength, you get excellent agreement with the measurements for the initial strength of these vortices. The key question then becomes how strong are vortices when they are perhaps several miles behind an airplane, and that is addressed on the next chart.

I am sorry, may we go back to the second chart just to lead into this? I forgot to mention the tower.

(Pause.)

The test series here that I described that was conducted a few years ago, the aircraft were flown upwind of a tower which had smoke plumes, as you can see on the right.

The wind will transport vortices and, as you fly further and further upwind of this tower, it takes longer and longer for the smoke-marked vortices to drift over to the tower, and the tower not only has smoke, but it was equipped with quite extensive instrumentation for measuring weather conditions and the speeds in the vortex to measure the strength of the vortex.

So, by varying the position the airplane was flown upwind of the tower, you can progressively measure strength of vortex with age by making different passes by the tower. Now, the chart that --

CHAIRMAN HALL: Do the colors mean anything, Mr. Green?

THE WITNESS: No, the colors have no meaning. They were just intended to be dramatic.

CHAIRMAN HALL: Okay.

(Next visual aid shown.)

THE WITNESS: On this chart the colors do have a meaning, and this is a chart taken from the Noah publication which summarized the results of the test. The tower was a NOAH facility in Idaho Falls.

There are three colors on this chart; red, purple and green. On the vertical axis is a term which is proportional to the strength, "the average circulation." It is a technical term, and along the bottom of the chart is vortex age in time.

Now, all of the red symbols are for a Boeing 727, and if you look at the scatter in those which were taken at various times during the day it will be very apparent that the weather has a very strong influence on vortex strength, and there are only a very small fraction of the symbols which are close to that red line, and that is a curve that was drawn to bound the -- this -- be an indication of the longest lasting data from these tests for the 727.

Now, the factors that effect the K, primarily things like atmospheric turbulence, tend to be stronger near the ground than away from the ground, primarily because the vertical change in the horizontal wind is greater near the ground than at altitude, and also because when the sun shines on the ground you get an effect that is very similar to water boiling. You get convective turbulence that is created by the heating of the ground.

At certain times during the day near the ground you can get the few points that have that long-lasting characteristic where the ground is actually radiating heat, beginning to give heat back, and the ground becomes cooler and begins to cool the bottom part of the atmosphere.

It is a little bit like putting oil on water. It begins to stabilize the turbulence, so you end up with some short periods during the day where vortices may last longer than others.

We compare our theoretical results with data like this to make estimates of what would happen to vortices for conditions away from the ground where it is very difficult to make these kinds of measurements, and that is what we have done.

MR. JACKY: Could you relate what happens to a vortex as it is generated by an aircraft?

THE WITNESS: When a vortex is generated it immediately begins to descend. The fundamental aspect of generating lift is that you are pushing air downward and the reaction of that holds the airplane up so that these vortices descend.

How fast they descend depends on -- it is directly proportional to how strong the vortices are, and it is inversely proportional to how far apart they are, and this is reasonably predictable. We have, you know, a fair amount of data on that.

As the vortices begin to descend it is some initial velocity, and that as the vortices decay that descent velocity begins to slow down, and finally at some point the vortices cease to descend anymore and they are moved laterally with the wind, or they move with the general wind field.

MR. JACKY: What was your participation in this accident?

THE WITNESS: For this accident, we took the measurements of atmospheric conditions from the weather team and we made an estimate of the turbulence levels and other characteristics that we then put into a theoretical calculation of how far the vortices from flight 1427 would have descended and how much they would have decayed so that we could have an estimate that could be used in a simulation of a vortex encounter to see if that would agree with the motions that were observed.

MR. JACKY: If I could ask you to please refer to Exhibit 13(i), please? Specifically, pages 15 through 18.

THE WITNESS: Is that here, or --

MR. JACKY: You should have the exhibit in front of you, and we have also made some transparencies of the pertinent pages.

(Pause.)

THE WITNESS: Okay, I have it in front of me.

MR. JACKY: Are these pages the plots that you prepared in participation with this accident?

(Pause.)

THE WITNESS: Yes, these are curves that I prepared.

MR. JACKY: Okay, could you briefly describe them for us, please?

(Visual aid shown.)

THE WITNESS: Page 15, which is shown on the overhead, shows how far a vortex from a 727 would descend as a function of time given two different assumptions about how the wing was loaded under conditions of light turbulence and very light stratification, similar to a standard atmosphere for the speed of 205 nauts true with an airplane weight of 126,400 pounds with the air density there, and it shows that the curve marked "elliptic" is sort of a classical version of the way -- sort of a starting point, I guess, in the design of airplanes.

The symbols, that "b" over "s", refers to how far apart the vortices would be relative to the semi-span -- I am sorry, to the span of the aircraft and for an elliptic wing loading that is pi over 4, or about .78 of the wing span, so that when the vortices are fully rolled up in the wake the separation distance between the vortices would be about .78, and what we believe to be more representative for this airplane in this configuration where the "b" over "s" is .7, in this case, you can see with a "b" over "s" of about .7, the vortices descend about 300 feet in approximately 70 seconds which is about the separation and altitude from the preceding 727.

MR. JACKY: Could you proceed with --

CHAIRMAN HALL: This information is basically as much as we could simulate from the aircraft that was in front of the accident aircraft, is that correct, the 727?

THE WITNESS: I believe that is correct, yes. This is the information that we were given on the characteristics of the aircraft, plus our own research data as to what kind of spacing and other considerations that we have had from a number of previous tests from this aircraft.

CHAIRMAN HALL: I just want to be sure everybody is clear what you are talking about.

THE WITNESS: Because we use available data to the maximum extent possible, but this is an extrapolation to altitude where vortices do last longer than they do near the ground, but it is also from a theoretical standpoint the easiest to model, and we have had much greater success in this case than we normally do near the ground, so, in some sense, this is a much easier problem than the tower fly-by case.

MR. JACKY: In terms of your calculations, the weather conditions that you used for your plots here, could you describe the atmospheric conditions that went into these calculations?

THE WITNESS: Yes. The weather was -- the winds were light. The winds were about 15 nauts and there was almost no variation in wind with altitude, which is conducive for producing very little turbulence, and I guess it also agrees qualitatively with the comments that we have heard, that it was a smooth flight.

The wind direction was along the flight path, nearly, so there would be very little lateral drift and it would -- the vortices would be coming almost straight down.

MR. JACKY: What would the weather conditions indicate toward the life span and decay rate of the wake vortex?

THE WITNESS: Well, that is shown on the next transparency, I think, for this.

MR. JACKY: Page 16?

(Next visual aid shown.)

THE WITNESS: Well, this is actually what we call a worst case here. These may be out of order, but we can do this one. This is slightly different conditions where there was -- we postulated there was absolutely no turbulence, or stratification. It is a condition that you can create in a laboratory, but it hardly ever, if ever, occurs in the real world.

This gives you the worst case. The K

characteristics for a vortex. This allows you to set an upper bound on the vortex strength, as it could not be any higher than this. It would decay at least this much.

CHAIRMAN HALL: For the record, Mr. Jacky, if you could be sure that we know exactly the page number and the exhibit that is presently on the screen and the witness is testifying concerning. I believe it is page 16, is that --

MR. JACKY: Yes, that is correct.

CHAIRMAN HALL: Okay.

MR. JACKY: Exhibit 13, page 16.

CHAIRMAN HALL: Okay.

THE WITNESS: Actually, page 16 and 17 go together, and 15 and 18 go together.

(Pause.)

Page 17 shows how the wake is predicted to descend for those worst case conditions, which are probably not even possible that it is that bad. In that case, in 70 seconds the wake would be predicted to descend nearly 350 feet, and in the more reasonable conditions about 300 feet.

But, they are -- you know -- isn't, you know, a great deal of difference in those, but do not think it could have been any stronger than that worst case, because that is already descending further than what would be observed.

MR. JACKY: Okay, thank you. I would like to now ask if you could refer to Exhibit 13(h), please?

(Witness complies.)

Specifically, page number 42.

(Pause.)

THE WITNESS: Okay, I have it.

MR. JACKY: This is a plot of the radar data abstracted for both the USAir 427 and also the preceding aircraft which is Delta 1083 which was identified as a Boeing 727.

If I could, I would like to refer you to the center of the plot and ask you to comment on the flight tracks of the two airplanes in terms of the potential for a wake vortex encounter.

THE WITNESS: Well, it is almost a classic scenario when you could have a wake encounter when at a point where the X range is minus three.

CHAIRMAN HALL: Again, Mr. Green, just to help us, what is an encounter?

THE WITNESS: I am sorry.

CHAIRMAN HALL: In this situation.

THE WITNESS: When an airplane flies into this rotating mass of air it tends to experience forces that a pilot might not expect, the one that is usually thought of as a rolling motion, but there also can be yawing and pitching effects, as well.

In extreme situations, if you ingest a vortex in an engine you can get a flame-out, so an encounter could encompass a number of things.

CHAIRMAN HALL: There are a lot of different encounters, but you are going to describe the one that we best attempted to model here, correct?

THE WITNESS: That is correct. The point of this chart is that an X range of minus three, the flight tracks were vertically coinciding at a time differential of about 70 seconds and they were separated in altitude by 300 feet.

This is the classic example that if you were near the ground the Airman's Information Manual warns against. You don't want to be below and behind another airplane.

MR. JACKY: In terms of the predicted wake model by the 727, do you believe that there would be the potential for 427 to have intercepted the vortices from Delta 1083?

THE WITNESS: Yes, I do. The sky is a big place and it is impossible to prove whether or not, you know, any airplane went through a very small region, but there was certainly a vortex in the general region that flight 427 went through, and we predict with some confidence roughly what its strength is and how far it would have descended, and it would have been there to be hit.

It is -- you know, it is impossible given the general character of the atmosphere and the way things change to say, "Yes, for sure it exactly hit it," but it was certainly in the right place to be hit.

MR. JACKY: If we make the assumption that 427 did, indeed, encounter the 727's wake, given that, could you make some sort of statement as to the strength of the vortex that 427 would have encountered?

THE WITNESS: Well, our best prediction was page 18 of the previous exhibit.

MR. JACKY: Would you like to go back to that exhibit?

THE WITNESS: Yes.

MR. JACKY: Okay.

CHAIRMAN HALL: Page 18 from the previous exhibit that we had up there on the screen a minute ago.

MR. JACKY: Exhibit 13(i).

(Previous visual aid shown.)

THE WITNESS: The best estimate that I can make is that the vortex strength would be just under 1,500 feet squared per second, which is simply a technical unit, and you may recall that in the worst case, which was the other chart that we showed, the worst case it could be no higher than about 2,000, so that we bounded the problem so if it were any stronger it would have descended so far below the flight path that it couldn't be hit and if it were significantly weaker it wouldn't have got down to where it could be hit.

So, with some certainty we can give you a range of somewhere of about 1,500 feet squared per second, which is the input that we gave that went in to go into the Boeing simulation.

MR. JACKY: Okay, you are jumping ahead of me, but that is my next question. Could you relate to us your experiences regarding the Boeing simulator work and the wake vortex integration?

THE WITNESS: Yes. When we participated in that simulation we made these calculations and made them available, I think, in parallel. Boeing had made some similar estimates of strength and they were reasonably similar, except perhaps for the what I will call the core size. That is a technical parameter for how large the center portion of a vortex is where you have the extremely high velocities.

With the exception of a difference in the core size of the vortices, the numbers were in pretty good agreement and, in fact, in the simulator we used both sets of numbers, and the pilots who were flying the simulator while I was in the simulator as a witness could not tell any significant difference between the two.

MR. JACKY: So, could you then make an estimate as to if when the circulation values that you believe would be most likely to have been present at the time, assuming a 427 encounter with the vortex, could you describe what you thought was the result of the interaction -- the simulator's interaction with that wake?

THE WITNESS: It was about what I expected. When an airplane flies into a vortex, the encounter depends very much on the direction that it enters the vortex. If you fly into a vortex and approach it from the side, the almost immediate reaction is for the vortex to toss you right out.

Typical encounters with vortices for jet aircraft that are reported are usually pretty small, ten degrees or so, and it -- at this altitude, you know, that would not be any greater than you might experience in turbulence, I guess, and occasionally you get larger bank angles as a result of an encounter.

In the simulator, the motions that we were going through, although we didn't have a direct read-out of the bank angle, were consistent from, you know, previous experience,

MR. JACKY: Would you believe that using a vortex circulation value of approximately 1,500 feet squared per second and assuming a 737 interaction or encounter with that vortex, do you believe that the resulting encounter matches, or can be related at all, or characterized similarly to the results that were shown from the -- from the accident aircraft?

THE WITNESS: The general character of the flight data recorder traces -- for example, when you get inside a vortex you have a lower pressure. It often causes an error in the static pressure measurement from the aircraft, giving you perhaps a bump in air speed which you saw.

The general motions were of the right order, you know, that you would expect. Again, when you -- in terms of an exact replication of the motion at the time we were in the simulator, it was not possible because there is no such -- I mean, any path you take --

I mean, any pilot response is different, so that anytime you fly into the same vortex you are going to get a slightly different geometry of the encounter, and the path the aircraft takes as it passes through is going to be slightly different depending on control inputs so that the traces may vary and will vary, you know, with pilot technique and so forth, but, as a general statement, there was -- there was a reasonable match between what I expected and what we saw in the simulator.

CHAIRMAN HALL: The bank angle in the simulator was what? What did you use for the bank angle?

THE WITNESS: The bank angle is whether the wings are level, or not.

CHAIRMAN HALL: Right, okay.

THE WITNESS: And that's -- would be -- when we were in the simulator, that is a visual determination as you look out at the -- through the projected cockpit windows.

CHAIRMAN HALL: Okay.

MR. JACKY: Would you believe that a vortex with a circulation value of approximately 1,500 feet squared per second would be enough to upset, or cause severe roll to a 737?

THE WITNESS: I don't know what the word "severe roll" means, but if it could be, you know, 10, 20, 30 -- you know, depending on exactly how you hit it, it could vary either way. At the altitude it was flying, that, in my experience, wouldn't be considered a serious encounter.

I mean, we have had encounters with about that much bank angle within a few hundred feet of the ground where the pilot flies away.

MR. JACKY: I have no further questions.

CHAIRMAN HALL: Which of the parties desire to question the witness? If you would, just hold your hands up so I can see. ALPA? Anyone else? If not, Captain LeGrow with the Airline Pilots Association, please proceed with your questions.

CAPTAIN LEGROW: Thank you, Mr. Chairman. Good afternoon, Mr. Green. On your chart on page 18 of

Exhibit 13(i) you are talking about a 15 -- and please excuse my ignorance here, but it is 15 feet per second, or 15 -- 15 feet squared per second? Is that --

THE WITNESS: 1,500 feet squared.

CAPTAIN LEGROW: 1,500, I am sorry. I believe Mr. Jacky asked you, you know, if that would be a substantial upset. In your experience at NASA, have you ever known where an upset of -- or, a force of between 1,500 and 2,000 would render a transport airport -- airplane uncontrollable?

THE WITNESS: I am not an expert in controllability of aircraft. We usually have to boil down, you know, very subjective kinds of data into something like bank angle, or something like that and, you know, that strength vortex can give you 10, 20, 30 degrees of roll depending on how you get in it, and whether or not that is -- and we usually make some assessment of whether that is hazardous.

In our experience, that has not been a hazardous bank angle when you have, you know, plenty of altitude to recover in. When vortices are encountered intentionally in a flight test program, you often use altitudes about the same as flight 427 was, because that is viewed as an altitude from which you have plenty of time to recover.

With some of the smaller airplanes, sometimes, you know, the -- the very smallest airplanes behind the very largest you may have 360 degree rolls, or 700 degree rolls at this altitude, with test pilots, and have no problems whatsoever.

CAPTAIN LEGROW: But, in this encounter you wouldn't expect more than a 30 degree bank, is that --

THE WITNESS: Ball park.

CAPTAIN LEGROW: That would be maximum in your view?

THE WITNESS: It is typical of the kinds --

vortex encounters are not uncommon in the 20, perhaps up to even the 30 degree range.

CAPTAIN LEGROW: Thank you. I have no further questions, Mr. Chairman.

CHAIRMAN HALL: All right, if there are no other questions from the parties, Mr. Marx, do you have any questions?

MR. MARX: (Inaudible.)

CHAIRMAN HALL: Please proceed.

MR. MARX: In your testimony, you indicated that the -- when you approach the vortex that the airplane can get into a roll, pitch and/or a yaw condition. That is what I heard you say. Could you explain to me -- I can understand the roll, but I have a hard time understanding how an airplane gets into the yaw.

THE WITNESS: If you are approaching a vortex, a pair of vortices, or a single vortex from below, or if you are flying level and a vortex is descending upon you, one of the first parts of the airplane that feels the vortex is the vertical tail, because it is sticking up and, as that vortex swirling flow field impinges on the tail, then you will get motion such as yawl and --

MR. MARX: That is only because it is above -- it has to be -- in other words, it has to be -- in other words, you have to be approaching this vortex from below? If it is coming from above, you won't have that?

THE WITNESS: Well, as you encounter a vortex, this low pressure may exist over part of the fuselage, and it is an extremely complex flow field when you have a pair of vortices -- I hate to do this with my hands, but you have got flow swirling in both directions (demonstrating) and when you stick, you know, almost any part of the airplane in there and the airplane tends to disrupt that flow field a bit, you get very complex flow patterns over the entire aircraft.

MR. MARX: Okay, let's see if I understand that. What is actually happening here is that the rolling motion of the vortex is going against the side of the tail and causing the yawl in the airplane? Is that the way I understand it?

THE WITNESS: That is one of the causes and, of course, airplanes are dynamic beings. Whenever you -- the motions are coupled so that when you --

CHAIRMAN HALL: Mr. Green, would you mind showing us with your hands, because you do do a good job, the difference between a roll and a yawl?

THE WITNESS: A roll is with the wings moving, as I am doing with my hands (demonstrating). A yawl is if the airplane -- if the airplane turns side to side. That is, the tail in the back wants to weather cock the airplane into the local wind, or into the local flow field, and when you change that flow field with a vortex the airplane tries to align itself with the new wind field.

CHAIRMAN HALL: Thank you. I think that is very helpful for the people that aren't familiar with those terms.

MR. MARX: Do you have any data on the amount of yawl that you would expect to have if you approached a vortex from below and have a high circulation number? For instance, the 1,500 to 2,000, or 2,500 that we are talking about?

THE WITNESS: Every time you encounter a vortex, you get a different answer and --

MR. MARX: Well, you were mentioning something about 10 to 20 degrees roll. Do you have anything that would be an indicator for yawl?

THE WITNESS: You could get the same amount roughly. I mean, you could get --

MR. MARX: Okay.

THE WITNESS: You could easily get five degrees of yawl. It depends on the -- it depends a lot on what the pilot is doing and how you encounter the vortex.

MR. MARX: Well, in the worst case scenario. Let's say that the -- you encounter the vortex from below and the vertical fin is in the vortex and none of the other part of the airplane is in there. What -- how much yawl can we maximumly get out of there?

THE WITNESS: Well --

MR. MARX: Just pure yawl.

THE WITNESS: That is really beyond my expertise. You really need -- I mean, that is really the reason that the simulation was done, and I think there is someone who is going to testify as to what the simulator would show you would get.

MR. MARX: I have one other question. It deals with the circulation numbers that you feel is the 1,500 to 2,000 is insufficient to flip a 737 upside down, and I am quoting from Exhibit Number 13(h) on page 14. What circulation numbers would you need to have to flip a 737 upside down?

THE WITNESS: I don't think there is anything out there that can generate a strong enough vortex to flip a 737 upside down.

MR. MARX: So, it would be -- you mean the worst case scenario such as a heavy jet, a 747 --

THE WITNESS: It wouldn't flip it upside down.

MR. MARX: And that is mainly in the -- oh, I am sorry, that was 13(i). Instead of 13(h), it was 13(i). Well, I am confused as to why we are worried about 737's flying behind 727's, then. Why do we have a four-mile, 70-second, or whatever, rules for it if the vortices won't cause an airplane to be upset?

But, what I am really looking for here is if you have any numbers that would tell you what the circulation data would be to cause an upset of the airplane. If you don't have any, just say so.

THE WITNESS: I -- there aren't any hard numbers, because it is very difficult to reach a consensus as to what constitutes a hazardous upset, because it is -- near the ground, I think you would not want to have even a 10, or 20 degree upset when you are very close to the ground, and if you are further from the ground, you know, you have the safety margin of altitude, and the separation standards and the way you -- and the operational procedures, I mean, these are procedures that have been developed over many, many years of establishing separation so that by the time the planes are near the ground, as they are being sequenced in and spaced and such, that they will not get into a hazardous situation.

MR. MARX: I have no further questions.

CHAIRMAN HALL: Mr. Clark?

MR. CLARK: Yes, I have several. Mr. Green, in -- I believe in a general sense that you described that the airplane was in the region of the vortex. Can you put a number on that, the size of that region plus or minus altitude, or --

THE WITNESS: If the flow field is disturbed somewhat in a region that is on the order of two wing spans, or a couple of hundred feet wide and maybe a 150 feet high, the largest part of the disturbance by far is concentrated in a very small region that, you know, may be as small as a few feet, but this flow field extends, you know -- as you get into this flow field and begin to feel it, it is large enough that its effects extend over the entire aircraft once you begin to get into it.

MR. CLARK: Okay. If we assume that the center of the vortex is at the core, can you give me a plus or minus range on the position you may find that core? I think you indicated normally at 300 feet. Do you have an estimate of a plus or minus range that that core may be in?

THE WITNESS: Between 250 and 350 feet is the range that I think would be possible, given the atmospheric conditions.

MR. CLARK: Plus or minus 50 feet is what you are comfortable with?

THE WITNESS: Um-hum.

MR. CLARK: If we assume that an airplane was entering the vortex and there is a large flow field, what will the effect of the nose have on -- or, the front end of the airplane have on disturbing the vortex, or busting the vortex, in your experience?

THE WITNESS: Well, that is something where we have changed our mind in the past year as a result of some tests. We have a wind tunnel technique where we can actually fly an airplane inside a wind tunnel and mount another aircraft wing upstream to generate a vortex and, so, inside a wind tunnel simulate the motions that one might experience.

We had always assumed that when you put an airplane in the middle of a vortex that it would tend to break the vortex up and somewhat reduce the hazard potential.

What was observed in those tests was that the vortex, instead of breaking up, would simply wrap around the fuselage and -- which was a surprise and, of course, the low pressure in there contributes to some of the pitching and yawing moments that would be observed when an airplane did encounter a vortex.

MR. CLARK: Okay, one final question. You referred, or mentioned that at 6,000 feet an airplane should have plenty of altitude for recovery from a vortex upset. Were you referring to the type of upset that we saw with the extreme attitudes in this case, or were you referring -- at one point you mentioned a typical upset of about a 30 degree bank angle.

THE WITNESS: I was referring to a typical upset.

MR. CLARK: The 30 degree bank angle?

THE WITNESS: Yes, when -- with vortices of this strength.

MR. CLARK: Okay, I have no further questions.

CHAIRMAN HALL: Mr. Schleede?

MR. SCHLEEDE: Thank you. I misunderstood your last statement here. I had a question about this. The 30 degrees of bank that you mentioned in your earlier testimony, was that what you said just recently for a typical upset, or did you equate that to the actual 427 event? Would you have expected this vortex to cause a 30 degree bank?

THE WITNESS: No, this was what you would expect -- what I would expect from an encounter with the strength vortex, depending how you entered it. You know, you -- anywhere from a few degrees up to something like 30 degrees, depending on exactly how you hit it.

MR. SCHLEEDE: So, that would be the largest value you would estimate in worst case encounter?

THE WITNESS: The problem with that, we have done a lot of testing and you never know if you have hit exactly the worst case, but in my opinion that is the ball park.

MR. SCHLEEDE: Okay, and you also mentioned the typical or classical scenario you get rolling and pitching and yawing. I know Mr. Marx pursued this area. Can you quantify for us the yawing, as you mentioned, the rolling up to 30 degrees. Can you quantify in any way the potential yawing you would get from the same value vortex?

THE WITNESS: I really can't. That is why you go to a simulator, because, you know, these motions are coupled. They depend on pilot inputs, they depend on not only the forces, but the rates that things are going on.

I think that probably discussion of simulation will clarify some of this coupling when you -- later in the testimony.

MR. SCHLEEDE: Okay, well, at one point you -- I heard you say you could easily get five degrees of yaw, and I thought that is what we could -- what was that based on? Was that --

THE WITNESS: There are a lot of traces published in the literature of, "Look what happens to airplanes when they encounter," and they are just, you know, data traces of changes in the aircraft parameters when they encounter vortices.

MR. SCHLEEDE: Those data, are those from measured flight test data?

THE WITNESS: Yes.

MR. SCHLEEDE: At altitude, or from the ground towers?

THE WITNESS: Most -- oh, typically at altitude. It is very difficult to do flight testing near the ground and be comfortable about the safety impacts.

MR. SCHLEEDE: Are you aware in your experience of any encounters in which a sustained steady state yaw rate was caused by wake vortex?

THE WITNESS: Now, that is one of the areas that is a little hard to understand about the trace here. When you hit a vortex, most of the encounters last, oh, less than a half second, or less than a second. You are thrown out of it pretty quickly.

The exception to that is if you fly into a vortex on one side and hit it just right so that it sort of throws you over to the other vortex and you get, maybe, bubble back the other way, or if you are entering a vortex from the side and the vortex is attempting to throw you out and you put in enough roll control to stay in it, and then you drift through so that you have both a vortex force and aircraft control in the same direction that maybe takes you a little longer to correct, and you roll through the other vortex. Even there you don't get long, sustained, steady kinds of forces.

MR. SCHLEEDE: I know you testified about your contribution to the development of the model that we are going to hear testimony about from Boeing. How accurate do you believe that the model that was used in this case is to the real world?

THE WITNESS: It is -- if I had to put a number on it, I would say it is sort of a 20 percent kind of accuracy. Anytime you are predicting what is going on in the atmosphere, it is really hard.

It depends on the accuracy of your inputs. When you have laboratory controlled conditions, it is extremely accurate. When you have uncertainties in the input conditions, it is going to -- it is going to give you uncertainties in what you predict.

MR. SCHLEEDE: Well, help me with that 20 percent. 20 percent of possibility that it is correct, or --

THE WITNESS: That is a fair question.

MR. SCHLEEDE: Thank you.

THE WITNESS: No, I think there is a -- this is the easiest case to predict. We do this sort of prediction routinely for a lot of different things. There is actually a lot more interest in predictions of this sort for military vehicles that have signatures than there is even, you know, in the civil world, and there has been quite a bit more energy expended in trying to develop these kinds of methods for applications for some of the military applications and, so, there is data available that we can compare with that gives us pretty good confidence for this kind of condition.

MR. SCHLEEDE: So, can you put a value on the confidence? I think we may have had the record confused here with your 20 percent number you used.

THE WITNESS: Oh, I -- you know, I would say that there is a very high confidence level that the strength numbers are sort of within plus or minus 20 percent.

MR. SCHLEEDE: Okay, so that's worth 20 percent.

THE WITNESS: You know, you are not going to be significantly over 2,000 feet squared per second, and if there were a lot more turbulence than we think there was you could be lower, but if it were much weaker it would not have descended to the point where an airplane could have encountered it. So, it pretty much has to be in this range to even have been involved in an encounter.

MR. SCHLEEDE: I know we have Mr. Kerrigan coming on to testify. Do you feel the modeling and the information that was used during the Boeing simulation is representative of what you believe this vortex strength was?

THE WITNESS: Yes, and I think that was Mr. Jacky's intent in having NASA involved in that Boeing effort and was to make sure that there was a consensus that we were using reasonable inputs into the simulation.

MR. SCHLEEDE: Thank you very much, Mr.

Green.

CHAIRMAN HALL: Mr. Laynor?

MR. LAYNOR: Just a couple. Mr. Green, are there any active programs to -- leading to the measurement of freer characteristics of vortices?

CHAIRMAN HALL: Yes, there are. Would you like for me to tell you what is happening?

MR. LAYNOR: Yes, sir.

THE WITNESS: As a matter of fact, I am currently heading up a tiger team effort in a joint program with NASA and the FAA to look at the possibility of changing, or seeing if there is any reason to change some of the airplane separations near the ground, and part of this is the result of the NTSB's recommendations to the FAA, and they tend to use us as their technical arm to help them accomplish that.

As part of that we just completed our initial shake-down testing. We went to Memphis with a fairly sophisticated set of instrumentation, probably the most intense set of measurements that has ever been made.

When we -- the shake-down was successful. We plan to be back at Memphis this summer where when the weather conditions are more conducive to having long-lasting vortices -- and make measurements for at least a month at Memphis with the fleet mix that flies in and out of Memphis.

One of the interesting things about the Memphis site is that Fed Ex has a terminal there. They use a lot of 727's and as that -- as weather conditions change and we have a string of 727's, or quite a few of them coming in, we have the opportunity not only to see wakes of different airplanes, but we can look at wakes of similar airplanes as the weather conditions change.

This is part of a longer-range program, but which will -- I mean, we will go from there to another airport since the weather conditions at one airport may be totally unlike weather conditions at another airport. But, it's a -- it's a multi-million dollar per year program, because it is viewed within NASA as a very important problem in this country.

MR. LAYNOR: What time frame do you think information will start becoming available that will allow you to confirm the extrapolation that is now done from the tower tests?

THE WITNESS: Well, there is a wide range of testing going on from using wind tunnel tests where we mount models statically behind other models. We have just completed testing behind 747 and DC-10 models.

We are going back into the free-flight wind tunnel phase this summer with a 737 model as the model that will encounter the vortex from the upstream wing, so we will be doing this with a 737 model.

Not so much because of flight 427, but because at NASA-Langley we have a very good static wind tunnel model of a 737 and we have a 737 aircraft which was the number one 737, and it is also an aircraft that Boeing used 25 years ago in wake turbulence studies. So, we will have eventually flight tests, the free-flight wind tunnel and static tests all of the same aircraft.

MR. LAYNOR: Within the next couple of years, perhaps?

THE WITNESS: Um-hum.

MR. LAYNOR: What characteristics of the airplane determine the velocity distribution, core size and the maximum tangential velocity?

THE WITNESS: To the best of my knowledge, there is no -- the answer is, no one really knows. We separate airplanes now. We call them airplane separation. Some of us believe they should be more appropriately called weather separations.

Most of the pilots I talk to sort of know that when they get one of those nice, calm days they are a little more alert, and if they are being bounced around in turbulence they don't really worry too much about vortices. Separating out those effects is something people have attempted for the past 20 years, but without total success.

MR. LAYNOR: I think what I was trying to find out, because you can have two aircraft that have the same weight, wing span, fly approach speeds about the same, so they would theoretically have about the same circulation, I assume, but they could have different vortex characteristics in terms of velocity distribution, is that true?

THE WITNESS: That is correct, and things like the relative import -- how much profile drag you have, how clean the airplane is and where it is distributed.

It is very difficult to quantify that, but there was a lot of research done where people intentionally added drag to airplanes in an attempt to break up the vortices, and they were able to make them decay, you know, somewhat more quickly.

So, in a qualitative sense we understand some of these things, but I think it is safe to say that the technology to design an airplane and accurately predict exactly what its weight characteristics are going to be in terms of a velocity distribution, you know, it is not there, and it may not even be important. It may be that it is only the total strength.

I know this is awfully technical, but there -- you know, there is a term that we call vorticity, which is sort of how fast a particle of fluid is rotating, and then a term which we call vortex strength, or circulation, which when you add all the fluid particles up what do you get, and it is not clear to what extent the distribution effects the total when you have large airplanes.

When you have -- the problem we had many years ago was one where you -- and it is still today. The crashes tend to occur to the very smallest aircraft which would just about span the vortex core, or, you know, the inner part of a vortex, but when you have encounters involving aircraft that have a 100-foot wing span and extend far beyond the region where you have the very high velocities, then it is the velocities in this outer part of the flow which is determined by the strength of the vortex which contributes most to the torque that would tend to roll the aircraft.

MR. LAYNOR: Excuse me. Has NASA conducted any simulations of vortex entries?

THE WITNESS: I beg your pardon?

MR. LAYNOR: Has NASA actually conducted any simulations of vortex entries, vortex encounters?

THE WITNESS: Yes, they have.

MR. LAYNOR: But, you are not aware of those?

THE WITNESS: There is a long history of simulations by at least a half a dozen organizations over the past 20, or 30 years of vortex encounters.

MR. LAYNOR: I was curious how much data exists that would allow you to look at different angular entries, from perpendicular where you would get a pitching moment to nearly parallel where it would be nearly a pure roll. Is there much date around?

THE WITNESS: There is some, and we are getting ready to add quite a bit to that database. I mean, as part of this program I described earlier, you know, there will be a considerable amount of simulation.

It will -- as the models to that predict how strong a vortex will be two, three, four miles behind an airplane, have confidence levels raised to a sufficient point and those can get plugged into simulations, then to see what sort of response you get.

MR. LAYNOR: Okay, thank you, Mr. Green.

CHAIRMAN HALL: Mr. Green, just generally speaking, how long has there been knowledge of wake vortex in the aviation area and how long has NASA been involved in looking at it?

THE WITNESS: Well, let's see. I guess the first published description of a wake vortex was probably back about 1907, or so. It goes back to the classical foundations of aerodynamics.

CHAIRMAN HALL: I understand that the separation distances with aircraft which obviously impact on traffic which impact on how many planes can fly in and out of an airport at a given period of time, do you know how long we have had separation distances established by the FAA, roughly?

THE WITNESS: 25 years.

CHAIRMAN HALL: I am very pleased to see and appreciate your -- the knowledge that -- you all are proceeding full speed ahead on some of the recommendations that we have earlier made. You mentioned ambient weather that -- I believe you said that the vortex, the length of it lasts as a result of the weather conditions.

Now, weather conditions the day of that flight, have you had a chance to look at those?

THE WITNESS: Yes, I have.

CHAIRMAN HALL: Just, you know, in my terminology, would they have lasted longer or shorter that day?

THE WITNESS: That was a relatively long-lasting weather condition conducive for long-lasting vortices. You had low winds, you had very small gradients in the wind, and the gradients in the wind can generate atmospheric turbulence which chops them up.

CHAIRMAN HALL: You described the encounter that you put together as a result from what you could obtain as a serious encounter? Is that fair to say?

THE WITNESS: I don't think I said serious. I mean, I -- you have to define what serious is before you can -- I mean, serious -- for example, we are working currently with the British CAA to -- you know, they want our inputs basically in what is serious.

They have an incident reporting system when they have categorized encounters as either an A, B, or C depending on whether it was at the 10, or 20, or 30 degree kind of a roll upset, and now they are going back and they are interested in seeing if there can be an international consensus developed that when you report an encounter it is a -- the seriousness would be not only a function of the roll angle, but a function of the altitude and the roll angle.

They have basically proposed that if you are more than a few thousand feet, I think the encounter needs to be -- I don't know, 40, or 50 degrees before it is serious from a hazard standpoint, and most of the encounters that they have experienced where they have had roll upsets exceeding 30 degrees have been at altitudes greater than 2,000 feet, and most of the upsets that they have down near the ground are, you know -- are the 10 degree variety.

CHAIRMAN HALL: Okay. Just one last question. You said that there was the possibility in terms of the yaw that that would be where the vortex is coming down and would encounter the tail first, possibly, or the tail would come up?

THE WITNESS: That is a simplification, but, I mean, clearly you can get -- I mean, airplane motions are coupled and you can get --

CHAIRMAN HALL: So, you could get a yaw and a roll, both?

THE WITNESS: Yes.

CHAIRMAN HALL: In a wake encounter?

THE WITNESS: And, I mean --

CHAIRMAN HALL: Okay.

THE WITNESS: -- one can cause the other without a vortex, even. When you get -- I mean --

CHAIRMAN HALL: Mr. Green, I understand, I believe, that NASA is funded the same way the NTSB is, primarily through taxpayers' dollars, is that correct?

THE WITNESS: That is correct.

CHAIRMAN HALL: Well, I appreciate your attempt today to make a technical area understandable to the people that are paying our bills, and I appreciate your time.

THE WITNESS: Thank you very much.

CHAIRMAN HALL: Thank you very much. You are excused.

(Witness excused.)

The next witness is a very significant witness to this hearing and is going to focus a substantial amount of time in his testimony and in the questioning, so although we have just recently taken a break, rather than start the next witness I would suggest that we take -- it is now close to three o'clock -- that we take a 15 minute break and come back and begin at 3:15 so we can -- will not have to have an interruption during the next witness' presentation. Off the record.

(Whereupon, a brief recess was taken.)

CHAIRMAN HALL: On the record. Please take our seats.

(Pause.)

Thank you. I call the next witness, Mr. James Kerrigan, Principal Engineer 737 Aerodynamics Stability and Control with the Boeing Commercial Airplane Group, Seattle, Washington.

I will mention at this point that Mr. Kerrigan will testify, or present his testimony here as witness number four and then will be re-called later in the hearing. Mr. Schleede, if you would please proceed.

(Witness testimony continues on next page.)

JAMES KERRIGAN, PRINCIPAL ENGINEER 737 AERODYNAMICS
STABILITY AND CONTROL WITH THE BOEING COMMERCIAL
AIRPLANE GROUP, SEATTLE, WASHINGTON

Whereupon,

JAMES KERRIGAN,

was called as a witness by and on behalf of NTSB, and, after having been duly sworn, was examined and testified on his oath as follows:

MR. SCHLEEDE: Mr. Kerrigan, would you please state your full name and business address for the record?

THE WITNESS: James William Kerrigan. Business address, P.O. Box 3707, Seattle, Washington. I am employed by the Boeing Company.

MR. SCHLEEDE: What is your position at Boeing?

THE WITNESS: I am a lead engineer in the Aerodynamics Stability and Control Group at Boeing, and my group supports the 707, 727 and 737 airplanes.

MR. SCHLEEDE: Could you briefly describe your education and background that qualifies you for your current position?

THE WITNESS: I graduated from the University of Minnesota with a degree in aeronautical engineering in 1964. I have been with Boeing for the last 29 years and have worked almost the entire time in Stability and Control, and basically started on the 737 during its original certification in 1966.

MR. SCHLEEDE: Do you hold any FAA ratings, or certificates?

THE WITNESS: No, sir.

MR. SCHLEEDE: All right, thank you. Mr.

Jacky will proceed.

MR. JACKY: Thank you. Good afternoon, Mr. Kerrigan. I would like to first ask you if in your experience with Boeing Aircraft Group, have you ever participated in any NTSB accident investigations?

THE WITNESS: Yes, I have participated in several.

MR. JACKY: Okay. Could you perhaps list a couple of those, please?

THE WITNESS: The ones that have occurred -- the major ones would include 727 TWA spiral dive some years ago, several recent accidents on the 737, including Colorado Springs. That may be the more -- the ones that involved the NTSB, that is probably -- probably it.

MR. JACKY: During your participation of the investigation of these accidents, what have been your -- what has been the result of your participation, or what have you participated in, or what aspects of the investigation?

THE WITNESS: Well, my group is primarily aerodynamics, stability and control. We look at the flight data recorder traces that come out, cockpit voice recorder, put together a simulation of the particular airplane characteristics, whether it is a 737 200, or 300.

We take the simulation and try to recreate on the simulator the accident scenario. We have pilots involved sometimes. Some of it we do in a background mode on the simulator.

MR. JACKY: How do you simulate the 737, or 727 aircraft?

THE WITNESS: Well, we have -- as part of our flight crew training groups, we create a simulator document in my group that actively portrays the various models. We build -- starting with the wind tunnel database we will build a predicted simulator.

We later then, when we have flight test data available, we will use that data to try and recreate, or to check the simulation model and adjust it wherever it needs to be adjusted so that we end up with a very close match to the flight test data, and that data, then, is put into a simulator.

We have a cab that we use associated with the simulator. It is called the M-cab, multi-purpose cab. The cab is capable of being made into a 727, or 37, or 47, whatever model and whatever instruments we want to put on it, and that is a motion-based cab.

MR. JACKY: During the course of this investigation did you use the M-cab as part of the reconstruction, or simulation?

THE WITNESS: Yeah. Yes, we used the M-cab whenever we wanted to bring a pilot into the loop and get his reaction to the occurrences.

MR. JACKY: Did you use the M-cab simulator to investigate a possible wake vortex encounter?

THE WITNESS: Yes, we did, we had to establish a wake vortex model as part of this exercise. We did not have one readily available. We had created one for Colorado Springs, and this was an offshoot of that, a much tighter wake, of course, from a 727.

MR. JACKY: Well, just for information sake, is the investigation that you participated in in regards to the Colorado Springs accident, was that not a rotor which is just one large --

THE WITNESS: Yes, that is correct. We -- in that accident, there was known rotor activity in the area, and the model that we put together was for a rotor which was anywhere from several hundred feet to maybe a thousand feet across, whereas these are more on the order of 4 to 16, 17 feet in diameter.

MR. JACKY: So, in terms of the rotor, we are talking about a one large solid mass of rotating air as opposed to in the wake vortex we are looking at more -- two smaller rotating bodies of air?

THE WITNESS: That is correct, two smaller wakes, and they -- also, there is an interaction between the two. They are rotating, one clockwise and one counter-clockwise, so they tend to react one with the other.

MR. JACKY: Could you please describe how Boeing was able to model the wake vortex into the M-cab, please?

THE WITNESS: Well, we got together with the NASA people and came up with a set of parameters that we used. There is a foil, if we could look at the exhibit. I believe it is page 3 of Exhibit 13(j).

(Visual aid shown.)

This shows in general what the vortex model looked like. You see two tight circles that represent the actual core, and that, as I said, is anywhere from two to about 16 feet in diameter.

As you can see, the influence of the vortex goes far beyond the core and it just -- it dissipates pretty rapidly, but it still is present for at least a couple diameters away from the core.

You can see between the core -- the two cores, that there is a down-flow and in the span of the wake model that we used it is about 85 feet, as Mr. Green pointed out.

CHAIRMAN HALL: Mr. Jacky, I think it might be just put on the record at this point, if we could, just -- Mr. Kerrigan, could you explain, then, to us just briefly the difference between an engineering simulator and a regular simulator?

THE WITNESS: Well, in terms of the aerodynamic data set that is in the two, they are generally identical. In a case of an accident where we may get out of the normal flight envelope where the -- into an area where our simulator has ever been programmed, we may have to re-program it slightly.

The major difference between the two in terms of the model is that we have the ability to look at all the bits and pieces within the aerodynamic model. All the parameters that deal with airplanes are available to us. We can dump them out and record them as a function of time and look at them off-line.

But, the simulator database is identical, generally, to the training simulators, and we have -- the motion system that we have on ours may not be exactly the same, and this, as I said, is multi-purpose, so the interior is not a perfect 737 model. In fact, it is a -- it can be varied to simulate any of the different models.

CHAIRMAN HALL: Now, are there many engineering simulators around, or do you all have the majority of them?

THE WITNESS: Well, in terms of what we have at Boeing, we have -- we have -- several of the other airplanes have their own specific engineering simulators, but outside of the Boeing Company, I don't know.

CHAIRMAN HALL: All right, thank you.

(Pause.)

MR. JACKY: Could you describe what inputs you used in modeling the wake vortex specifically for the preceding 727 aircraft?

THE WITNESS: Okay. We had -- through the NASA gentleman and through our own experts, have come up with some parameters that we believe that the 727 wake would exhibit.

As he mentioned, the maximum theoretical circulation is about 2,400 feet squared per second and the predicted dissipation for the atmospheric conditions of the day were about 30 percent. On the simulator, the dissipation was varied anywhere from 13 to 55 percent just to make sure that we bounded the possibilities for the day.

The diameter of the core was about 4 to 16 feet and, as I said, the centers to the wake are about 85 feet apart, which is the theoretical distance that they would be apart for the 727. The wake, again, was generated consistent with the energy that a 727 -- the rate and speed and flap of the Delta airplane would generate.

The wakes vary -- rotate in opposite directions to one another. The left wake from the rear rotates clockwise, the right wake counter-clockwise. For the simulation, we actually put some color to the wake, as he showed with the airplanes flying through with colored smoke. We on the simulator created wakes and put a color to it so that we could find it when we had piloted simulations.

The velocity distribution through the core is linear and maximum at the outside radius of the core and then dissipates fairly rapidly outside the core. The velocity of the wakes tend to move down due to the down-wash behind the wing and expect that for this -- about the time that the two airplanes would have -- the wake of the 727 and the 737 would have come together, that it would have moved down about 300 feet.

MR. JACKY: How are you able to put this model -- or, to model this energy in the M-cab simulator?

THE WITNESS: Well, the wake model is simply a mathematical model and it is generated in the model. In this simulation it is just external to the airplane as a series of winds with the characteristics that we have just described.

The -- it is totally independent of the

aircraft, and when the airplane flies into the wake we have a -- we had to revise our model somewhat to include a distributed lift model on the 737. If you could put up page 4, page 4 of Exhibit 13(j)?

(Next visual aid shown.)

This -- typically when we simulate a model, it is done as a point mass. We look at the center of gravity of the airplane, and all the things that affect that airplane are generated at that point, so that if you flew into a wake you wouldn't see any effect of it until the center of gravity of the airplane got to the wake.

In order to make this happen as a wing got into the wake, we went to a distributed lift model and the wing basically was divided into 23 two-foot segments and the vertical tail into six two-foot segments. That way, each segment could be evaluated individually as the wake encountered it. We also modelled the horizontal tail, as you see in the (inaudible).

As we evaluated that on the simulator, we found that it tended to produce some rather unrealistic tendencies, motions of the airplane. We believe that is primarily because on the airplane when you hit a wake, typically it will hit the wing first and that will cause an interaction, or a slight change in the wake before it gets back to the horizontal tail.

The pilots felt that what they were getting out of the simulation was very reasonable in roll and in yaw, but didn't feel that the pitch was correct. So, subsequently we disabled that part of the model and just used the roll and yaw.

Then the effect of the wake on each segment of the wing and in the vertical tail was determined by averaging the flow angle change due to the wake's flow field, and then, using this change and flow angle, the lift and side force could be calculated from the known local lift characteristics of the wing and tail.

The rolling moment and yawing moment, then, could be due to the wake to then be determined by integrating the lift and side force along the surfaces. The validity of the model was confirmed mainly at -- during this stage by comparing the new model to maneuvers that had been flown on the previous model to make sure that the distributed lift model gave the same results and, also, the pilots flew it with and without a wake involved to make sure that the characteristics of the 737 were still correct.

MR. JACKY: Who did the verification of both the distributed lift modelling and also of the vortex, itself?

THE WITNESS: The simulator studies that we did included a number of pilots; FAA pilots, and I believe there were some NASA pilots, or NTSB people that flew it, and then also some USAir pilots that participated in the performance group, and Boeing flight test pilots. That was the primary verification at the time we flew it on the simulator.

MR. JACKY: What was the feeling of the pilots in regard to the modelling?

THE WITNESS: Basically, they felt that it was very significant, or very close to what they had experienced in flight, that collectively they had -- all had had encounters with wakes at one time, or another and felt that what they were seeing in the simulator was very much like what they had experienced in flight.

MR. JACKY: Now, when you were actually doing the simulations of the airplane encountering the wake, how did you go about setting that up and what sort of primaries did you use to bound the problem?

THE WITNESS: Well, we -- in terms of what we did on the simulator, with the pilots that were there we flew well over a hundred runs on the simulator and we did vary the wake size, the strength, the location relative to the aircraft, and the movement of the whole wake was also evaluated.

The pilots felt that a wake vortex with a 1,500 feet squared per second was probably the most typical of what they had encountered in flight. In that -- you know, that is about it.

MR. JACKY: What did the pilots feel as far as -- or, what was their belief as far as the results of the aircraft encountering a 1,500 wake?

THE WITNESS: Well, I think, again, they felt that it was not an unusual wake to encounter in flight. It is very difficult to get it tied directly to this flight data recorder information. Every time -- as Mr. Green pointed out, every time you fly through a wake you get a slightly different outcome.

The angle at which you enter the wake is very important and whether you come from above, or below, and all the parameters that a wake -- can vary dramatically the result that you get.

I think that our bottom line was that the piloted simulations and some preliminary un-piloted results show that a wake vortex of the size and strength that we calculated for Delta 727 could cause an upset of the magnitude shown on the flight data recorder of USAir 427 during the initial part of the upset, but could not cause a continuation of the maneuver beyond the initial upset.

We do have a chart that shows roughly how long we think the 727 was -- or, the 737 was in the wake of the 727. We could show -- I believe it is Exhibit 13(m).

(Visual aid shown.)

As was earlier stated, the 727 was

approximately 4 miles and 70 seconds ahead of USAir 427, and at the point where the radar paths come together the 27 was about 300 feet above the 737 and descending.

The top of this chart shows the actual radar hits with symbols for the east, south and -- or, east-west and north-south movements of the two aircraft as recorded on the radar. It is similar to the chart you have seen before. The same data charts are on both charts.

The lines represent a kind of a probable smooth path of the two aircraft through the data. The chart shows that the 727 is turning onto the same heading that USAir 737 will have about 70 seconds later.

The bottom of the chart gives the estimated evalu -- elevation of the wake at two different times in the accident sequence based on the known elevation of the 727 from the radar data and the known elevation of the 737 from radar data.

As you can see from the -- at the elapsed time of the 134 seconds, USAir 427 was at about 6,000 feet and the wake would have been at about 6,050 feet. Five seconds later, 139 seconds, the 737 was at 5,950 and the wake would have been at about 5,900 feet.

So, they have crossed over at -- somewhere in between there, and within the accuracy of the radar data and as Mr. Green mentioned, all the many variables in terms of the wake descending, we believe that this analysis would be fairly close in that these two airplanes would be in fairly close -- or, well, the wake and the 737 would be in fairly close proximity for about five seconds, perhaps a little bit more, and that is consistent with the flight data recorder, as far as the initiation of the event is concerned.

I do have a video of a wake encounter if --

MR. JACKY: Could I ask you one question --

THE WITNESS: Sure.

MR. JACKY: -- before we go to that? In looking at that -- the chart, do you believe, then, that the two ground tracks, as shown, would represent a potential vortex encounter for USAir 427?

THE WITNESS: Yes, I think that is -- I think that is the case. The radar, as Mr. Green pointed out, is not proof positive that these two things would have occurred, or would have been in the same air space at the same time, but the flight data recorder traces, which we will get into here in a few minutes, I think definitely indicate that there is -- potentially, at least -- a wake encounter at the beginning of the upset.

MR. JACKY: Okay, and you said that you have a video to show?

THE WITNESS: Yes, that is one of the -- part of Exhibit 13(l).

CHAIRMAN HALL: Mr. Kerrigan, before we begin with the video, would you please, if you will, describe to us what -- what we are about to see and how this was put together?

THE WITNESS: Okay, yes, I will. The video depicts an arbitrary wake encounter and it doesn't necessarily try to recreate the accident wake encounter. However, the wake is consistent with the wake expected from the Delta 727, assuming a nominal 30 percent dissipation of the wake.

In this case, the wake is level and it is fixed in space. The 737 aircraft is approaching the wake from the left with the autopilot on and starting to turn onto the heading of the wake. The autopilot in this case and the auto-throttles are both on during the entire event and there is no pilot input.

You will see that in this case the bank angle that it results is a bit more than what Mr. Green indicated, but, again, there is no attempt by the pilot in this case to hold the wings level.

CHAIRMAN HALL: If you could dim the lights now and walk us through the video, we are ready.

THE WITNESS: As we -- as we go through this, it all happens pretty fast.

CHAIRMAN HALL: Mr. Haueter, they need a copy of the video at the desk over here.

(Pause.)

Mr. Kerrigan, I think it is important at this point -- well, since we have got a moment -- to point out that you participated in the performance group, and this work that you are representing to us all of the performance group participated in, and Exhibit 13(a) of the many exhibits outlines the participants of the performance group that is included.

Mr. Jacky who doing the questioning, Mr.

Steve O'Neill with the FAA, Mr. Bob McCullough with USAir, Mr. Keakini Kaulia, I guess, with the Airline Pilots Association. Is that -- I apologize, sir.

MR. KAULIA: It is Keakini Kaulia.

CHAIRMAN HALL: Okay, sir, I apologize to you. That is the first time I have seen that, and that is -- along with Mr. Kerrigan. So, although you are a representative of Boeing, this represents work that all of the performance group has participated in.

(Video presentation shown.)

THE WITNESS: Yes, that is correct. On this video, the first thing that occurs is the right wing encounters the left wake which causes a slight roll left. The aircraft then moves fully into the left wake causing a right roll.

It moves between the wakes, it moves down rolling left, then moves into the right wake increasing the left roll and moves to the left because of the left roll, but passes below both wakes.

CHAIRMAN HALL: We need to get rid of these lights if we are going to be able to see it, I think.

(Pause.)

THE WITNESS: Now, the maximum bank angle for that particular case was about 50 degrees. Can anybody see that, or should we try to run it again with less lights? Is that possible?

CHAIRMAN HALL: Can it be seen out there all right?

VOICES: (Inaudible.)

CHAIRMAN HALL: Okay, well, never mind, we can look at it later.

THE WITNESS: Again, this wasn't an attempt to try and show what would happen specifically during the USAir 427 wake encounter, but it does show that a wake encounter can result in a pretty significant upset to the aircraft, especially with only the autopilot trying to correct it.

However, if you notice, the autopilot was able to correct it, and after leaving the influence of the wake it just attempted to get the airplane back on the originally selected heading.

MR. JACKY: Just for clarification, was the data represented in the video, was that produced during the aircraft performance group work simulations?

THE WITNESS: No, that particular one was run after -- after we met last in -- it was -- just represented some background work. There was no pilot involved in that simulation.

MR. JACKY: Okay, thank you.

(Pause.)

If you would, I would like to talk about the FDR data that was extracted from the flight data recorder.

THE WITNESS: Okay, we have -- if we could put up page 7 of Exhibit 13(j)?

(Visual aid shown.)

Turn it 90 degrees.

(Pause.)

Okay, this data is all from the flight data recorder and it is plotted versus time. This first chart shows the last 70 seconds of the flight. It includes the descent to 6,000 feet in the turn from the heading of 140 to about 100 degrees.

The parameters shown include the air speed on top, the altitude, heading angle, roll angle, the longitudinal acceleration, normal load factor, pitch angle, N-1 which is engine revolutions per minute, and control column position. There are several other engine parameters that were available, but not plotted and some weren't particularly significant to the investigation.

The second chart, if you could put up the page 6 of that same exhibit?

(Next visual aid shown.)

The second chart shows basically the same information, but concentrates on the final 30 seconds of the flight. As we move through this, the first indication of anything out of the ordinary was an oscillation of the air speed indicator concurrent with several bumps and normal load factor.

I have an electronic pointer here, which may, or may not work. The bumps in load factor are right in that area (indicating). Oh, I am sorry, the air speed, and load factor down in that area, you can see that is moving around, and those parameters start to move prior to the roll angle changing very much.

The roll angle is heading back towards zero as he flies the maneuver and trying to get back on the heading of 100 degrees. So, the first upset to roll is actually as it rolls back toward the -- toward the left.

This was -- the initial bumps in load factor and the air speed indicator was followed shortly by the roll oscillation, first back to the left and then to the right and then back to the left again. The aircraft continued to roll to the left.

It stabilized momentarily at about 70 degrees of roll and then continued to roll sharply to the left. During this time, the control column which was the only control position recorded on the flight data recorder was pulled back, reaching about a full nose up position and about the same time that the bank angle reached 70 degrees, or slightly later than that.

Air speed and altitude were maintained fairly constant until the roll angle exceeded 70 degrees. You saw a video earlier of the accident sequence, and this is a better way of visualizing that for a lot of people, instead of a graph.

So, Boeing has also produced a video at the request of the NTSB to better visualize the data. If we could see that at this point, the external view?

(Video presentation shown.)

This video depicts the flight path of USAir 427 obtained from the flight data recorder. The instruments are driven by the flight data recorder information directly where it is available, and from derived data in the case of a decline which is not directly measured in the flight data recorder.

The attitude of the airplane follows the pitch, roll and heading recorded on the flight data recorder, but air speed and altitude follow a kinematically derived data set which basically takes the position error out of the data set.

The instruments shown which are fairly hard to see are, from left, N-1 for both engines, on the first gauge air speed, then altitude, attitude director indicator, the ADI above, the compass below and on the far right, the altimeter above, the rate of climb below it.

At this point, he is in the turn to the left trying to return to a 100 degree heading.

(Pause.)

There is a bobble in air speed and altitude at that point, then the aircraft rolls off to the left.

(Pause.)

If we could just go ahead and show the -- there is a second video with the forward view from the cockpit during the maneuver. The flight crew would actually have a slightly broader field of view than what we are showing, because they would have side windows and be able to look out the other pilot's window.

(Next video presentation shown.)

This shows the same instruments as we had before.

(Pause.)

One further thing that we did do with the flight data recorder information was to conduct a correlation test using the cockpit voice recorder and the flight data recorder together in the Boeing 737-300 flight simulator.

During the correlation tests, participating pilots were provided with sound-blocking headsets and were placed in the 737-300 motion-based simulator. The pilots were from the various parties.

I think every party had any pilots that were a part of the Operations Group, or the CVR Group plus two or three more that participated directly at the parties' selection.

What occurred was that a short segment of the cockpit voice recorder was played through the headsets while the motion-based simulator was driven through the corresponding time history of the flight from the flight data recorder.

During the test, the flight instruments and the column and throttles were driven from the values known from the flight data recorder and the visual scene through the cockpit's front window corresponded through the view that we have just seen from the aircraft cockpit.

The wheel and rudder pedals were not driven during the test, since their motion is not recorded on the flight data recorder and we don't know for sure what was happening there.

The throttle handle position is also not known, but what we did -- we do know what the N-1 of the airplane did, so we calculated -- back-calculated a throttle position to go with that N-1, and those of you who fly will understand that that isn't necessarily the actual throttle position, but it was close. You can move the throttles quickly and the engines can't quite keep up with it, so that was not totally accurate.

In addition, the external view of the aircraft, again, similar to what we just saw, was available outside the simulator and crews waiting to enter the simulator could listen through headsets to the cockpit voice recording while viewing the aircraft motion from an external view.

The response of the pilots experiencing the correlation test was, in general, very positive and they did feel it was an excellent tool and I think came away with a very much better appreciation for the rapidity of the upset experience of flight 427.

MR. JACKY: Mr. Kerrigan, what was the objective of that test, or that effort?

THE WITNESS: I think the -- well, the objective of the test was primarily to see if the pilots could pick up anything, any sounds that they might recognize.

There were a number of sounds that were heard on the cockpit voice recorder which still haven't been identified. There are some clicks and thumps which didn't make sense as to what they might have come from. There is no way of knowing that.

I think the thought here was if you put the pilots in the environment that the USAir pilots were in that they might possibly be able to say, "Oh, yeah, I recognize that, that was . . ." -- whatever.

I believe that that was not the case. I don't think they identified any additional sounds. One of the pilots that participated in it will be available as a witness later on and can address, you know, what they did find.

MR. JACKY: Did you participate in the effort?

THE WITNESS: No, the performance group did not participate directly in the correlation tests and, in fact, I personally have not yet heard the cockpit voice recording, even though I have spent about 120 percent of my working time on this accident since it happened.

I saw the transcript of the recorded comments for the first time this morning when they were released by the NTSB. In fact, while I understand that this is the current NTSB policy, I believe it is vital that those conducting an accident investigation have all the information available to them as soon as possible in the investigation to insure that all the avenues can be thoroughly explored.

I hope that this NTSB policy can be changed to allow those directly involved in the investigation to have the benefit of all the information available.

MR. JACKY: Thank you. If you would, please, I would like to direct your attention back to the plot of the FDR data, which is Exhibit 13(j), page number 6, please.

(Witness complies.)

Just for the record, although the exhibit shown here is a Boeing plot, was the data produced from this done as part of the NTSB's flight data recorder group effort?

THE WITNESS: That is correct. We received from the NTSB a tape of the flight data recorder information and then processed that and produced this plot directly from that. There is -- nothing has been done to this data, at all. This is just the raw data.

MR. JACKY: Okay, thank you. In your estimation, where do you believe, in terms of time, did the upset first occur? What was the beginning of the upset?

THE WITNESS: Well, the airspeed and load factor traces show at about 132 and a half seconds, the first movement from what we would call normal flight. So, I would say at 132 and a half seconds is roughly where the first effects of the wake were encountered.

MR. JACKY: You may have already answered this question, but is there anything, or any data that you see in these traces that would believe, or make you believe that there was a wake vortex encounter?

THE WITNESS: Well, certainly the air speed anomaly that is shown there is something that has been visible in other wake encounters where airplanes have not been as seriously upset, and also the oscillation that occurs in roll where the oscillation is -- has a period that is roughly the same as the Dutch roll period of the airplane. You know, it would indicate that something of that order has contacted the airplane, impacted the airplane.

MR. JACKY: Could you please explain what the Dutch roll oscillation is?

THE WITNESS: Well, the large jet transports have -- with the swept wings -- have a mode that is called Dutch roll, and it is basically named after the Dutch ice skaters of years ago because it is a motion that goes back and forth.

Not rapidly, it can have a period of four to seven seconds, so it would make one oscillation every four, or five seconds, and that mode is something that is present on all airplanes, and yaw dampers are installed on most large jet transports to damp out that oscillation.

But, if the airplane is disturbed, that -- in the directional sense, that will typically be the, you know, more or less the mode that it will seek out. The frequency will quite often be similar to that if you have a lateral directional upset.

MR. PURVIS: Mr. Chairman?

CHAIRMAN HALL: Yes, John?

MR. PURVIS: Would it be useful for us to use the laser pointer from the table to point to what he is referring to on the chart while he speaks so he can kind of face the panel and we could point for him? Is that allowed?

CHAIRMAN HALL: That would be fine.

MR. PURVIS: All right.

MR. JACKY: Are there any other indications in the FDR traces that would lead you to believe that 427 experienced the wake vortex of the preceding 727?

THE WITNESS: In terms of the flight data recorder, itself, I think the main indications are load factor, air speed and the lateral upset shown in the roll maneuver.

As we developed and tried to extract from this data the aerodynamic characteristics that caused the upset, we have come up with a set of moments that would be, I think, similar to what you would expect to get from a wake encounter.

We can go on, if you like, to the -- our match of this data using our back-drive simulation.

MR. JACKY: Well, before you do that, I have a couple more questions to ask you. Now, in looking through the FDR data, one of the first concerns or thoughts in terms of the causation of the upset in the accident was a deployment, or partial deployment of the 737's engines' thrust reversers.

Is there any indications in these traces in your belief that would give indication that there was a thrust reverser deployment, or a partial thrust reverser deployment?

THE WITNESS: It is difficult to tell exactly what is going on with the thrust reversers, but we do have several parameters that aren't shown on this plot for the engines. We have -- in addition to N-1 which is shown here, engine RPM N-2 is also recorded, fuel flow and temperatures.

I don't know if that is enough to really tell whether that thrust reverser deployed, or not. The system, the thrust reverser system, if one engine had deployed, thrust reversers should be pulling one engine back to idle fairly quickly as soon as it occurs.

As you can see here, if the -- if it -- if the incident started way back at 132 and a half, and really I think the -- an upsetting moment in addition to that had to occur somewhere at about 137 seconds. Up to that point, the engines are still pretty continuous.

The N-1 is fairly -- very solid up to that point, so it is obvious that at least the initiation of the event -- well, it couldn't have been associated with the thrust reverser.

MR. JACKY: The N-1 traces on that plot, do they indicate that both engines would be running in parallel, that one would not be divergent from the other?

THE WITNESS: Right, both N-1 traces are fairly solid up to about 138 seconds, and then they advance slightly and then come back. There is a slight difference between engines one and two, but it is only on the order of less than half a second, and that is typical of the difference between thrust as the throttles are brought back. So, yes, it would indicate that they are operating together.

MR. JACKY: Okay. If I could ask for you to refer to Exhibit Number 10(a), please.

(Witness complies.)

In particular, page number 73.

(Pause.)

I believe there should be a view foil for that.

(Visual aid shown.)

As a matter of explanation, this is a plot produced by the NTSB of the FDR data taken from USAir 427 and includes the other engine parameters that were not included on the Boeing plot.

The question I have for you is, in looking at those traces do you see any sort of divergence in any of the other traces -- and before I do that, let me explain the traces.

From the top, we have normal or vertical acceleration; directly below that is longitudinal acceleration; below that we have a control column position; and next is EGT which is exhaust gas temperature; and then below that is engine fuel flow; and then we have N-2 and N-1 which are measurements of engine fan speeds; and below that altitude; and, finally, indicated air speed.

Now, the plot is somewhat expanded. It goes back further in time than the actual -- the accident --

start of the accident sequence, but the time of the accident sequence is approximately 1:32, and the time should be similar as to the plot that we are looking at just before.

So, having said all that, do you see in any of the EGT, or fuel flow, or any of the engine traces here that would give you an indication that either of the engines went divergent from the other?

THE WITNESS: Well, I -- again, am not an engine expert, but the two engines appear to be working very closely together in this plot and everything appears to be happening simultaneously for both engines.

MR. JACKY: Okay, thank you. I am going to ask you to flip back to your previous exhibit, if I may, please, which is exhibit 13(i), page 6, please.

(Witness complies.)

CHAIRMAN HALL: 13(j), or (i)?

MR. JACKY: 13(i).

CHAIRMAN HALL: 13(i)

MR. JACKY: Page 6, and there should be a view foil if I could have it. It was the view foil that was put up previous to the last.

(Discussion off the record.)

I am sorry, I had 13(j) before, I am sorry.

(Visual aid shown.)

I would like to refer you to the longitudinal acceleration trace. At the beginning of what we -- or, what you believed to be the time of the upset, or the -- of the incident, do you see any indication in the longitudinal acceleration trace that would lead you to indicate that a thrust reverser on this airplane had deployed, or partially deployed?

THE WITNESS: I really have a difficult time answering that, because longitudinal acceleration is something that is taken out of -- along the center line of the airplane, as opposed to strictly a slowing down, or speeding up, and I am not sure exactly what that would look like if you were to deploy a thrust reverser.

MR. JACKY: Would you expect some sort of reaction in the longitudinal acceleration trace?

THE WITNESS: I would think there would be some, yes. There should be an increased drag and therefore a fairly substantial change in that parameter.

MR. JACKY: How would that be represented on the trace?

THE WITNESS: Well, again, the overall acceleration would need to be slowed down, and that would be showing up somehow in both the normal load factor and the longitudinal acceleration, but, again, I don't know exactly how to characterize that, I haven't tried that on the simulator to see what the result would be.

MR. JACKY: Okay, thank you. Now I would like to discuss -- as part of the aircraft performance group's work, there was a -- what we call the back-drive of the FDR data produced, is that correct?

THE WITNESS: That is correct.

MR. JACKY: Okay, could you briefly -- or, could you please describe the back-drive process and what data went into this study?

THE WITNESS: Okay. To help determine the sequence of events, during the flight of USAir 427 a simulation of the 737-300 was used to try to recreate the flight path.

This was accomplished using a mathematical pilot to fly the simulator over the same flight path and attitudes of USAir 427. The mathematical pilot in this case used aerodynamic coefficients to recreate the flight path, and results in the match that is shown in -- on page 10 of Exhibit 13(j)?

(Next visual aid shown.)

The dash line in this case is the simulator data, the solid line is the flight data recorder information and the long dashes with several small ones interspersed is the -- some initially derived data for air speed and altitude which, again, takes care of the position errors, or the indicators on the airplane.

The aerodynamic coefficients, the lift, the drag, the rolling moment, yawing moment and pitching moments which produced this match are shown in another chart. It should be page 12 of Exhibit 13(i).

(Pause.)

MR. JACKY: Did you mean page 12 of 13(j)?

THE WITNESS: I believe it was (i), wasn't it?

VOICE: (Inaudible.)

THE WITNESS: Yeah, okay, that's it.

(Visual aid shown.)

This shows the -- it shows the aerodynamic coefficients along that that it takes to create the match that you just saw. The angle of attack and side slip angles that result are also shown.

You notice that there is a fair amount of scatter in some of these coefficients, particularly in the moment coefficients, and this is -- this is caused by the tight gains that we put into our mathematical pilot to try and match the flight path of the accident airplane.

They will not significantly effect the match. We could fare through those and do quite well in matching that time history. These coefficients represent the amount of aerodynamic input required to produce the match, and they could come from any of several sources.

They could be from the flight controls other than the elevator which we do know from the column and the flight data recorder, they could be from outside sources such as the wake of a 727, or any other atmospheric disturbances, or they might possibly be from any structural deformation that might have been present on the airplane if something actually had failed.

The first coefficient to move substantially is the rolling moment, and we believe that that was probably caused by the 727 wake. Are we hitting that with the --

About a second later the yawing moment changes substantially which, again, may be caused by the 727 wake. Knowing that there is a wake in the area, it is not easy to break out the -- what is wake and what is flight controls.

So, this -- that part of it could have been caused by the vertical fin of the airplane impacting the wake and, of course, the wake -- the radar data does show that the 737 was in the vicinity of that wake for about five seconds, and that first oscillation and roll and yaw lasts for about that long, five or six seconds.

The coefficients which persist beyond that time are most likely not caused by the wake, because the airplane would have departed the area where the wake was likely to have been. That would leave the flight controls as potential causes, structural deformation, or by atmospheric disturbances other than the wake.

To better understand the magnitude of these aerodynamic coefficients which I am sure don't mean too much to most of you, we have converted them into equivalent wheel and rudder angles. I believe that is chart page 12 in 13(i).

(Next visual aid shown.)

These data show that once the 737 exited what we believe was the 727 wake, that a rolling moment equivalent to about 50 to 60 of wheel to the right was being applied to the 737 and that a yawing moment roughly equivalent to full rudder was being applied in a direction to roll the aircraft to the left.

Since the aircraft was rolling to the left during this period of time the yawing moment was clearly the cause of the left roll. That -- what occurs there is that when the yaw -- yawing moment acts on the airplane it creates a side-slip, and the side-slip would be to the -- cause the airplane nose to go left which causes the right wing of the airplane to sort of lead the airplane, and that causes more lift on the right wing than on the left wing and that would cause a left roll.

The source of the yawing moment is not available from the flight data recorder. We have done a fair amount of thinking about this, of course, and -- of course -- and the weather in the area was such that it is not reasonable to believe that any turbulence was the cause of the yawing moment.

We can tell from the magnitude, the large magnitude of the yawing moment, that it would require that any aerodynamic cause would have had to have a large moment arm. That means it would have either had to been way at the back of the airplane, or out on the wing tip in order to create a force that would yaw the airplane that amount.

That could, of course, be caused by the rudder itself, or by structural deformation on the outboard portion of the wing, and originally we did look at a large thrust of symmetry. These three scenarios have been looked at in some detail.

The thrust of symmetry caused by an inadvertent thrust reverser was one thing we looked at, that the yawing moment was caused by deformation of the number one leading edge slat is something that we have looked at, and that it was caused by rudder input.

The engines were targeted early in the investigation because of some of the apparent structural anomalies which were found in the wreckage which could have indicated a thrust reverser deployment.

However, the engines were pretty thoroughly instrumented, as we have already discussed, and we really don't believe that the thrust reversers were a part of this accident. So, we are basically, I think, ready to eliminate the thrust reverser as potentially having caused the accident.

The number one slat had also some structural damage in the form of a fractured main track, which could possibly be consistent with a deformed slat in in-flight. The slat could have been damaged by a bird strike in the air, or it could have been damaged by contact with the ground.

We are still trying to determine what the deformation of the slat would have been had the damage occurred in flight, and once that deformation has been determined we will try to determine the aerodynamic affects of the configuration.

MR. JACKY: Could I interrupt you for just one second?

THE WITNESS: Sure.

MR. JACKY: When you are talking about the slat, could you please define where on the airplane that could be found?

THE WITNESS: Okay, the number one leading edge slat is the most outboard slat on the left wing of the airplane. The slat -- I don't have a slide, or anything, but the left -- the slats are the little airfoil shapes that come out on the leading edge of the wing during take-off and landing.

They are out -- they generally form a slight gap with the wing, and it is the most outboard one of these that have a main track that was found to be fractured, and we do know that --

CHAIRMAN HALL: Mr. Kerrigan, also, for clarification, when you are saying "we" in these conclusions, is this your opinion? Is this what we are getting?

THE WITNESS: Well, it is, I think, the opinion generally of the performance group. Again, I am here myself. Mr. Jacky can correct me if I say something he doesn't agree with.

Again, this fracture on the slat could very well have been caused during the impact with the ground, but there was some speculation that it could have occurred in flight, although I don't believe there were any bird remains found. There was a section of the slat just ahead of the broken part which I believe has not been recovered.

Once we have determined what the deformation of that would have been -- and that is not an easy task because the loads that would act on that wing on the slat are pretty well known when it is in its normal position. When it gets out of its normal position, we don't know what the loads are.

If it had that failure, it would be -- it is a fairly difficult task to define what the final position of that slat would be. We did have an early cut at a change to the shape and we took that in to the University of Washington wind tunnel and tested it, and that itself did not cause enough of a yawing moment to be a factor in the accident, but we are still -- that still is an open item in our minds.

The other possible cause of the yawing moment is the rudder.

MR. JACKY: Wait, before you go too far on that, could I ask you a couple of follow up questions on that, please?

THE WITNESS: Sure.

MR. JACKY: You are describing the leading edge slat that may have -- in your mind have become partially deployed, or fractured. If that were the case, what do you believe would be the result of the -- or, the aerodynamic result of that occurrence?

THE WITNESS: Well, again, we haven't -- we can't specifically say, until we can define where that slat would have departed to, if it -- if it had -- if that main track had become disconnected in flight.

The slat is held on by two main tracks, one on -- basically on either end, not out all the way to the end, but fairly far out on the slat. There are several auxiliary tracks that position it and an actuator that holds onto the slat.

Once you disconnect one of the main tracks, which is one of the main structural members that holds the slat on, the slat tends to -- will twist in some way and may well leave the airplane if it were to get twisted too much.

As it moves up in the air flow, the air loads on it get to be very large and eventually it might depart the airplane. In this case we know that the slat didn't depart the airplane, but how far up into the flow the slat goes we can't determine and, not knowing that, it is very difficult to determine what the aerodynamic effects of that would be.

We would expect that if it significantly got into the flow -- these are fairly big pieces. I would say 18 inches in cord and probably 10 feet long. If that gets out in the flow in some unusual attitude, it could give you a fairly big yawing moment.

It quite often gives a -- would give a fairly big lift along with it, and drag and rolling moment, but until we can define that configuration, we really can't evaluate it.

MR. JACKY: You said that you performed these tests in a wind tunnel at the University of Washington?

THE WITNESS: That's correct.

MR. JACKY: Can you characterize at all the results of that wind tunnel testing?

THE WITNESS: Well, the test that we ran was on a slat that had only lifted about six inches full scale, and that resulted in a fairly small yawing moment and small lift loss to the slat.

MR. JACKY: Just for definition -- excuse me -- to which direction did the roll and did the yaw --

THE WITNESS: The rolling moment, if it would have been to the left, and the yawing moment also to the -- pulled the nose to the left, in the right direction to cause an upset.

MR. JACKY: Okay, and if the flight crew were to try and correct that, how would they go about doing that, in your estimation?

THE WITNESS: Well, the -- the proper movement if that were to occur would be primarily a roll upset, perhaps. Again, it depends on whether it is a roll upset, or a yawing moment upset.

But, if it were a roll upset the pilot would certainly put in wheel in the opposite direction to try to keep the wings level, and if it is a yaw upset that, also, would eventually result -- fairly quickly result in a roll and, again, the common -- or, the best approach would be to put wheel in to try to stop that from occurring, to stop the roll.

MR. JACKY: Would it be correct to say that that type of wheel and rudder input would be to the right?

THE WITNESS: Yes.

MR. JACKY: Right. Now, I believe we may have testimony tomorrow or later on regarding this, but are you aware of any instance in which a slat of this type had become disconnected from a 737?

THE WITNESS: I don't personally know of any occasions where this has occurred directly. I have not worked on any incidents where a slat has come disconnected on one end.

MR. JACKY: Thank you.

THE WITNESS: As we were saying, the third possible cause of this yawing moment is the rudder. The rudder is capable of causing the yawing moment required to sustain the maneuver. The match that we showed indicates that.

If the yawing -- if the rudder is the cause of the moment, the yawing moment, there is nothing in the flight data recorder that would tell us whether that rudder resulted from an un-command -- or, a commanded input from the pilot, or an un-commanded input from the rudder system.

MR. JACKY: The maximum amount of that rudder input would be?

THE WITNESS: Our analysis showed -- and in that chart you can see that it takes nearly full rudder to sustain the maneuver and, in fact, we will also be hearing of a kinematic study that was also done which indicates a slightly larger rudder than did the simulator exercise.

MR. JACKY: Okay, and on the trace there is some words that say "projected blow-down angle." Could you please explain that for us?

THE WITNESS: Okay, yeah, the blow-down angle on the rudder is determined by the amount of hydraulic pressure that is available to the rudder control system. The 737 has 3,000 pounds per square inch of pressure available and it works through a piston which is -- that provides a certain amount of force to the rudder system.

The aerodynamics of the situation are such that the hinge moments of the rudder will tend to produce an aerodynamic force, and the blow-down angle is basically the aerodynamics working against the hydraulic forces.

The rudders that are shown here, the rudder angles for blow-down, is showing that match in hydraulic pressure forces with the aerodynamic forces. It changes as a function of side-slip angle and air speed. That is why it is moving around as much as it is.

MR. JACKY: Can you characterize, please, the equivalent wheel position?

THE WITNESS: The equivalent wheel position, as you can see, the initial part of the maneuver, the wheel goes actually -- if you ignore the one sharp spike, the wheel goes to about -- is it 50 degrees, or a little more?

The next peak goes up to about 60 degrees of wheel in the opposite direction, then back down to minus 40 degrees of wheel, and that is not inconsistent with encountering a wake with a wake that would be equivalent to that kind of a wheel input.

Then, as the wheel -- after the maneuver is fairly well entered, it goes up to about 60 -- 50 to 60 degrees of wheel. A 737 wheel will go all the way to 107 degrees, and in most power-on flights it reaches all of its lateral control capability of about 87 degrees. So, that is about three quarters of the wheel, three quarters of the lateral control that is being used there.

Then, later in the maneuver, obviously the wheel goes very erratic and at that point we are getting into some of the computational problems that I alluded to earlier.

MR. JACKY: Could the data that is indicated here, could that be characterized as saying that the flight path could be produced by actions inside the cockpit by the pilots?

THE WITNESS: Well, certainly the -- you know, if you look at everything that is there, the maneuver could be set up on the airplane by the controls. I mean, we have shown that in the simulator. The airplanes' control inputs are sufficient to run you through this kind of a maneuver, that is true. That is not necessarily, you know, what happened.

We believe the early part of this is wake, and it is difficult to know what part of that is wake and which part is flight controls.

MR. JACKY: In the back-drive of this data you came up with an equivalent rudder to compensate for the yaw moment coefficient, is that correct?

THE WITNESS: Yes.

MR. JACKY: To your knowledge, is there any other system, or control surface on the aircraft that could produce the type of yaw that is seen through this back-drive?

THE WITNESS: Certainly not in its normal mode of operation. The slats and wheel and everything else don't normally produce much yawing moment, and the only -- the only situation that might is if, again, the slat or something on the outboard end of the wing got up into the flow. That is a possibility.

MR. JACKY: For the type of yawing moment that is indicated here, do you believe that the yaw moment could have been compensated by a wheel in the opposite direction?

THE WITNESS: The wheel that has been calculated here shows that it is about three-quarters of what is available on the airplane and, again, we don't know specifically where all these parameters, or where all the rolling moment and the yawing moment is coming from.

There should have been more lateral control available during the early portions of the encounter. We have done some flying of the airplane in the past where we have flown what we call steady side-slips with full rudder, and at this flight condition the capability -- the lateral -- capability of the lateral control system on the airplane should be able to just balance full rudder, but it takes nearly full wheel to do it.

MR. JACKY: Are there any limitations to this process as far as in the firm -- I guess in the firmness of the data if we look -- or, if we hold back the moments a certain amount of time? Does that effect the bottom line answer as far as the equivalent control surface positions?

THE WITNESS: I am not sure I understand your question.

MR. JACKY: Let me approach it this way. The timing of the FDR data is exact enough that it would definitively indicate the control surfaces. There is no gray areas in terms of the air range on the output of the control surfaces, or the results of the back-drive?

THE WITNESS: Oh, certainly I don't mean to indicate that this is a precise science. The flight data recorder parameters that are measured are measured fairly infrequently on the airplane. A heading, for example, is only recorded once every second.

In trying to back-drive through this kind of a time history, there certainly are -- you know, there is room for some error. I think in testimony tomorrow you will hear from our -- of a kinematic study that was also done, and it does show slightly different results than what we see here. So, yeah, there is -- you certainly can't call this a precise science. There is -- there are a lot of unknowns in this scenario.

MR. JACKY: What would help you define the model to a better degree? Do you feel there is more -- if more effort was put into this effort, or the back-drive that you could further refine the data?

THE WITNESS: Well, we are still pursuing it vigorously. We have -- we are working in a background mode in the simulator at this point in time. We are trying to work with the model of the wake to get a better feel of what portion of this might have been caused by the wake, as opposed to by control inputs.

We are working with the simulator match that we have, which is, you know, a fairly good match of the flight data recorder, trying to figure out what the autopilot would have done, because we believe the autopilot was connected early on in the flight, and also whether the auto-throttles could have caused the throttle movement that we are seeing here, or whether that is a manual input.

So, we are trying -- we are still working very hard on trying to come up with a better story as to what is occurring, what is causing the various parameters that we see.

(Pause.)

MR. JACKY: I have no further questions at this time.

CHAIRMAN HALL: Are you going to discuss flight data recorders, or are we going to get into that, at all?

MR. JACKY: We are hoping to save that for Mr. Kerrigan the next time that he -- when he is re-called for his testimony.

CHAIRMAN HALL: But, we will get into that the next time he is up here, the expanded parameters and what it would --

MR. JACKY: Yes, sir, definitely.

CHAIRMAN HALL: All right, which of the parties have questions? If you would, signify by raising your hand.

(Show of hands.)

I see three, and I will start with Mr. Donner with the Federal Aviation Administration.

MR. DONNER: Thank you, sir. Mr. Kerrigan, just one small question, probably a nit-picking detail, but earlier in your testimony you mentioned that as the airplane entered the maneuver, the departure from control flight, that the flight data recorder indicated that the control column was pulled back.

Does the flight data recorder indicate pressures on the control column, or merely position of the control column?

THE WITNESS: It -- just strictly the position, that is correct.

MR. DONNER: Okay, thank you. That is all I have, sir.

CHAIRMAN HALL: Thank you, Mr. Donner. Captain LeGrow with the Airline Pilots Association?

MR. LEGROW: Thank you, Mr. Chairman. Good afternoon, Mr. Kerrigan. I have just a couple of questions. First of all, the -- this graph here, this Exhibit 13(i), page 12, the equivalent wheel position that is plotted here, is this a derived value, or is this a --

THE WITNESS: No, it is a derived value. The wheel position and the lateral control system is not recorded on the flight data recorder.

MR. LEGROW: So, is it a precise indication of the wheel position?

THE WITNESS: No, not at all. It is an

estimate based on the simulator match that we managed to put together.

MR. LEGROW: Therefore, it is possible that full deflection of the wheel was used?

THE WITNESS: That is possible. I don't know that we can determine precisely whether that was the case, or not.

MR. LEGROW: On the wake vortex video that you showed us early in your presentation, I believe that you testified in a question from Mr. Jacky that the performance group did not participate in the making of that video, is that correct?

THE WITNESS: That is correct.

MR. LEGROW: Did the performance group -- was the performance group involved in assembling the data? Did they all agree on the data that was used for the assemblance of that video?

THE WITNESS: Well, the wake that was used and the data that was used to set up the 737 was all part -- it was the same as what we had used in the performance group.

MR. LEGROW: I am referring to the specific data that was used for that particular video.

THE WITNESS: No, the video --

MR. LEGROW: Was that -- I am sorry.

THE WITNESS: The video was not done. It was out -- the NTSB requested that we put together a video of a wake encounter and we did so, but we did not use any -- the performance group did not specifically participate in that.

MR. LEGROW: Thank you, Mr. Chairman. I have no further questions.

CHAIRMAN HALL: Thank you, Captain. Mr. McGrew with Boeing?

MR. MCGREW: Mr. Kerrigan -- are we on?

CHAIRMAN HALL: Is Boeing's microphone on, please?

MR. MCGREW: Yes, we have it. Mr. Kerrigan, I wonder if we might go into a little more detail on the simulator and how it is used in the design process and the accident investigation process.

Would you spend a minute on the parameter changes that are capable beyond just the data set?

THE WITNESS: The simulator is, again, developed very early in the process.

CHAIRMAN HALL: And if you could give us in that how many hours it takes to recreate one of these.

THE WITNESS: To recreate --

CHAIRMAN HALL: Basically, generally, you know, what -- I assume you don't do it alone, right?

THE WITNESS: That is correct. I have, including myself, seven people in my group in Stability and Control, and since the accident we basically have been working, all seven of us, 100 percent plus overtime on this exercise, so we have somewhere around 6,000 hours just in my group pursuing this accident investigation.

As far as the simulator is concerned, in the development, once it is developed, before -- it is developed before the airplane ever flies. It would be based on wind tunnel data, and in the case of the 737-300, based on our 737-200 experience in simulator development.

It is used for the certification to some extent and used by Boeing pilots in the design of the airplane. It is used to ferret out any problems that might exist in the flight control systems.

In the accident investigation, the simulator is used -- the piloted simulation is used primarily when we want to bring a Boeing pilot, or a USAir pilot, or anybody else in to evaluate any parameters that occur in flight. We can try to recreate with the pilot in the loop the accident scenario.

It is often difficult to do because of the many variables that are involved in an accident. We also use it in a background sense that we can with a math pilot drive the simulator through any number of runs to try to recreate what we see in a flight data recorder.

We can make, then, small variations on top of that to try to determine exactly what might have caused the upset, or accident that we are investigating.

MR. MCGREW: Thank you, Mr. Kerrigan. Would it also be correct to say that since this is a motion-based simulator that the occupants feel the motion actually as though they were in a real, moving aircraft?

THE WITNESS: Well, the simulator is definitely motion-based and it -- like all simulators, it has a fairly limited motion system, but there is an indication of bank angle and heading and pitch, heave. You can feel the load factor when it occurs. If it is a small step, it can't sustain load factor for any length of time.

MR. MCGREW: Thank you, Mr. Kerrigan. We have no further questions, Mr. Chairman.

CHAIRMAN HALL: Thank you very much. Mr. Marx?

(No response.)

No questions. Mr. Clark?

MR. CLARK: Mr. Kerrigan, referring to Exhibit 3(i), page 12 that is up there now, can you point out --

CHAIRMAN HALL: What is the exhibit?

MR. CLARK: I said 3, I meant 13.

CHAIRMAN HALL: 3 -- 13(i).

MR. CLARK: I am sorry. Page 12. Can you point out on that graph where the match of the wake vortex modeling ends?

THE WITNESS: Where the match of the --

MR. CLARK: You indicated that for the initial portion you felt that you could be modeling the wake vortex encounter, and then at some point indicated that you were no longer modeling that.

Can you point out on that chart at what point, or length of time at the bottom where you think the transition may have occurred?

THE WITNESS: Okay. Let's see if this is working. Our feeling is that the wake vortex is significant in this loop here. It is difficult to tell exactly where the wake vortex would be stopping and a control input, or some other input would take over.

I think in everything that we have seen in the simulator in the middle of this wake vortex encounter it would -- the control input would have to come in right in the middle of the encounter.

If you look at the yawing moment, which is the lower part of the chart, there is a fairly sharp bump right there (indicating) which I would characterize as the vertical tail getting into the wake.

There is also, then, a fairly steep rise in this region (indicating). It is difficult to know exactly where -- what is wake and what would be whatever else is upsetting the airplane. The wake could be causing part of that, as well.

But, there is, you know -- the amount of time that we are in the vicinity of the wake is on the order of five, or six seconds. So, it would be from the initiation of the -- that rolling moment to five, or six seconds later.

MR. CLARK: Would that be in the 138-second to 140-second time range?

THE WITNESS: Yes, that looks to be about right.

MR. CLARK: Would you describe the equivalent rudder motion that produced the best match of the FDR data? Give us a brief description of the events going on.

THE WITNESS: Well, I guess the -- again, not knowing exactly what is causing the movement, whether it is rudder, or some other structural deformation, the rate of the change there is on the order of about five degrees a second.

Again, there is a lot of smaller motions superimposed on top of it, but in terms of equivalent rudder, it is on the order of four to six degrees per second of rate, rudder rate, equivalent rudder rate that would be involved and, again, it goes to very near full -- equivalent to full rudder deflection.

MR. CLARK: Basically, if we had a rudder moving at about five degrees per second, we could expect a reasonable match of the heading data?

THE WITNESS: That is correct, assuming, again, that the lateral input is equivalent to what we have shown.

MR. CLARK: In your modeling up there, how long did that rudder deflection, or the equivalent rudder deflection remain in place?

THE WITNESS: In this case with the simulator, it is fairly difficult to tell. It -- if you look late in the maneuver it appears that the rudder goes well beyond its bear-down capability. However, when we get to the kinematic solution to the flight data recorder, that trace comes down considerably.

The simulator -- I should have mentioned this -- the simulator in the high side-slip angle, high angle of attack area, is -- has not ever been tested in flight, nor did we have any appreciable amount of data in that area.

When we went to the University of Washington wind tunnel we did some additional testing which attained data in that high angle of attack, high side-slip angle data area, and we read the -- are revising our simulator to include that data set.

Now, that doesn't happen until -- the high side-slip doesn't happen until the rudder gets fully in, and the high angle of attack doesn't occur until the column is nearly fully in, and the stick shaker goes off somewhere in the middle of that exercise.

MR. CLARK: Would you be fairly comfortable with your data up to the time of about 148 seconds? That seems to where we are at, the blow-down limit. Is that where you would start questioning the fidelity of the simulator?

THE WITNESS: Right. I think -- I don't remember the time in which the stick shaker went off.

Yeah, actually the stick shaker went off, I think, at 145 seconds, so we are starting to get into the high angle of attack area there that -- where the data will have some -- loses some of its validity until we implement our additional data.

Again, the kinematic study that we will see tomorrow is not dependent on the database of the simulator, so that will be more to the point.

CHAIRMAN HALL: Well, the question, I believe, is how long did the rudder deflection remain in place, and you are saying -- can you either answer that, or not answer that? That is what I am --

THE WITNESS: Well, I think we can answer that. Again, the kinematic study will show that rudder -- probably, if it was rudder -- remained in place until -- almost until impact.

CHAIRMAN HALL: Okay, and how long was that, roughly?

THE WITNESS: Impact was 160 seconds.

CHAIRMAN HALL: Okay.

THE WITNESS: Yes, so it started at 140, or thereabouts, about 20 seconds.

MR. CLARK: So, the simulation to this point, whatever started causing this, whether it were rudder, or pilot input, or some external factor, or slats, essentially lasted the duration of the upset?

THE WITNESS: That is correct.

MR. CLARK: For what you simulated so far?

THE WITNESS: Yes, that is correct.

MR. CLARK: In the modelling that you have completed, did you get any match of the heading data with the vortex encounter?

THE WITNESS: The vortex encounter data that we have run so far really hasn't had any -- there haven't been many results that we feel are very final. I certainly don't have anything with me that would support that.

I think that if the rudder -- if the fin actually gets into the wake, I think there is a possibility that that sharp break in yawing moment could be caused by that impact with the vertical.

The sharp in this particular plot when you look at the sharp equivalent rudder input that occurs early, that appears to be very necessary to the head -- rate of change of heading that occurred on the airplane.

You see the heading make a very rapid movement, and that sudden sharp little input to the rudder is what causes that to occur and, yes, that may very well be a function of the wake.

MR. CLARK: Have you found any other failure modes that could produce a match of the heading data?

THE WITNESS: Structural failure modes of other systems than the rudder?

MR. CLARK: Systems, or structure.

THE WITNESS: Well, again, we haven't found anything at this point that would cause that directly. The only item that I think is still open at all is the leading edge slat.

MR. CLARK: Okay. You indicated with the leading edge slat that there is not enough data available as of yet to completely rule that out, enough aerodynamic data to show that you can, or cannot get a match of the FDR data.

THE WITNESS: That is correct. We haven't looked at that in the wind tunnel at this point.

MR. CLARK: Would it be reasonable to assume a worst case condition and put the slat in the worst possible condition and test that in the wind tunnel and then see if that is possible?

THE WITNESS: Well, the slat, as I mentioned, is a fairly large piece of metal, and if you put it in its absolute worst position and made it like a big door out in front of the wing it would cause some pretty large yawing moments, I think yawing moments big enough to cause this.

It may have -- may well have other characteristics like a lift loss and increased drag which would not fit, but that -- there is some wind tunnel data available on other configurations that made us interested in this to begin with that showed fairly large moments, but we need a pretty specific set of data. We need a yawing moment without too much rolling moment, et cetera.

MR. CLARK: If you had a slat in that position creating those large moments, or large lift losses, would you describe the forces that would be on the slat, the structural forces that it would have to withstand?

THE WITNESS: The structural forces that it could withstand?

MR. CLARK: That it would have to to produce those large yawing moments.

THE WITNESS: Well, obviously the -- as it gets out in front of the wing it will undergo some fairly large -- large forces, and from a structural standpoint, you know, our structures people have looked at it and they agree that at some point it is going to leave the airplane.

But, the actual loads that exist with the slat extended in some odd position are really not known. It is not something we have tested, obviously. There are safeguards on the airplane that prevent the slat from getting into some of those positions.

MR. CLARK: But, if we were to estimate those loads that it would take for the slat to leave the airplane, those would be the maximum loads that could effect the yawing moment. Is that a fair statement?

THE WITNESS: That is possible, yeah.

MR. CLARK: Earlier you were talking about background simulation. Would you define what that is?

THE WITNESS: Well, basically, when we run a simulation we could either have it -- what we call foreground that would be with a pilot in the loop. We would have a cab and actually fly pilots through some maneuver.

Background, we could just sit down at a computer console and input any kind of a pilot -- any kind of an input that a pilot can make, we can make mathematically. So, we refer to that as a background simulation.

MR. CLARK: Would those simulations be more repeatable than a pilot in the loop?

THE WITNESS: Yes. Obviously when you put a pilot in the loop you never know what he is going to do, precisely, and he won't do it the same twice. He is going to react to whatever upsets the airplane.

In background we can fly into the same wake, or the same set of circumstances a number of times making slight variations and do a better evaluation in that manner.

MR. CLARK: At the start of the hearing we heard Mr. Haueter describe a -- that there had been over 200 simulator runs. Were those background, or foreground?

THE WITNESS: No, that would be simply the foreground runs with pilots in the loop. We probably have run maybe ten times that many in background.

MR. CLARK: 2,000?

THE WITNESS: Perhaps. I haven't tried to keep track of them.

MR. CLARK: When you have made those large number of background runs, have you explored -- how much have you explored in the area of impingement angle, or encounter angles, both laterally and vertically?

THE WITNESS: With the wake?

MR. CLARK: Yes.

THE WITNESS: That has occurred to some extent and, again, it is not a study that we are -- we have completed. We have done some work along those lines and have re -- you know, have gotten some fairly good results with getting the roll to match fairly well with the flight data recorder.

Again, in the middle of that encounter you do have to put in an equivalent rudder yawing moment to sustain the maneuver beyond the first few seconds.

MR. CLARK: Okay. Has Boeing conducted any flight tests related to a yaw damper, or rudder (inaudible)?

THE WITNESS: We have not done any real formal testing. We have done a test where we have flown the airplane up to some fairly large bank angles and basically put in some rudder in a flight condition where we had about 45 degrees of bank, and put in rudder in addition to that. The airplane rolled over to something a little beyond 90 degrees of bank and then quickly recovered back to wings level flight.

MR. CLARK: How many of those tests have you done?

THE WITNESS: Basically, I think on two different occasions it has been -- been tried on -- in -- several times. In each case, the maneuver was conducted.

MR. CLARK: Did you record any data on those?

THE WITNESS: There is some data available, yes.

MR. CLARK: From where? From what source?

THE WITNESS: Just from the flight data recorder. We have not done this on any instrumented airplanes.

MR. CLARK: How many parameters are on those flight data recorders?

THE WITNESS: I don't know precisely, but it was -- you know, it is a recent delivered -- recently delivered airplane, so it has got at least the minimum required by the FAA. So, it is probably a -- I think the current -- it is on the order of 60 parameters.

MR. CLARK: Has any of that data matched the data that we see from the Pittsburgh accident?

THE WITNESS: Well, again, this was a very controlled flight test. The angle of attack was held very constant. I mean, it wasn't -- there was no attempt to pull the nose up to try and match to get stick shaker and what not. So, there is really -- it is really not comparable with the flight data recorder from USAir.

(Pause.)

MR. CLARK: If you would refer to Exhibit 13(j), page 8, please?

(Witness complies.)

THE WITNESS: Okay.

MR. CLARK: Let's see.

(Visual aid shown.)

On this chart there is a tag, "define predicted stall warning." Would you describe the source of that information?

THE WITNESS: Well, this, again, is a chart that comes from a kinematically produced data set which will be addressed fully tomorrow, but the predicted leading edge slat, or leading edge auto slat extension and the predicted stall warning come from that kinematically derived data set.

MR. CLARK: Does that agree with the point we correlate the stick shaker --

THE WITNESS: From the CVR?

MR. CLARK: -- from the CVR to our FDR data?

THE WITNESS: It is within a half a second, or so, I believe.

MR. CLARK: Um-hum. Have you analyzed the data for the controllability in the area that the stick shaker sounded, or the stall warning? Those are one in the same, I assume.

THE WITNESS: Well, during some of the simulator testing that was done with pilots in the loop, full rudder was put into the simulator and the amount of control wheel required to maintain wings level flight was evaluated.

Basically, when the airplane is slowed down significantly and approaching stick shaker, the rudder is able to overpower the lateral control system in the airplane. If the speed is made -- is high relative to normal -- or, normal or higher, then lateral control is able to overpower the rudder.

This is, I think, fairly typical of all aircraft in that the lateral control comes from devices on the wing, ailerons and spoilers, and as the airplane gets to higher and higher angles of attack, especially in the stall region, those devices become pretty ineffective because the wing in the area of the device is already stalled.

So, the lateral control capability of the airplane deteriorates very much as you get up close to stall angles of attack, whereas the rudder is affected somewhat, but not nearly as much.

MR. CLARK: It is not unusual to lose roll control in a stall condition?

THE WITNESS: Correct.

MR. CLARK: In a swept wing airplane.

THE WITNESS: Right.

MR. CLARK: Then, if you would look at the dotted line -- or, the dashed line that runs through the roll angle data, if you move up the line about a third of the way up the graph it appears that the roll angle quit changing for a small period of time at about the time the stick shaker activated, right in that area (indicating), and then the roll took off.

Is that consistent with a high angle of attack, flow separation, loss of roll control?

THE WITNESS: I would guess that that is probably what happened there.

MR. CLARK: If we were to go back on this chart and from the modelling you have done -- I assume the timing is consistent throughout your charts and graphs. The time you described as being out of the effect of the wake is between 138 and 140 seconds?

THE WITNESS: Right, yes.

MR. CLARK: Earlier, and then we see a marked increase in roll rate at about 145 seconds. That gives us roughly a five, or six second time frame that --

from being out of the wake until we have a change in the state of control?

THE WITNESS: Yes.

(Pause.)

MR. CLARK: Earlier, Mr. Jacky asked you about the effects of a thrust reverser deployment, and are you familiar with the data, the circumstances of the 767 thrust reverser deployment with the Louda (sic) airplane?

THE WITNESS: To a limited extent.

MR. CLARK: Are you familiar with the various signatures that were present on longitudinal acceleration, vertical?

THE WITNESS: No, not --

MR. CLARK: All right, let me back up there, that's not fair. There were no -- the flight data recorder was destroyed on that. In the simulations that went with that investigation, are you familiar with the data from those?

THE WITNESS: No, I have not been involved in that directly.

MR. CLARK: A little bit earlier we talked about two -- well, I don't want to mischaracterize the word you used. I think it was something on the order of informal flight tests, the two flight tests, or flight demonstrations of large bank angles and rudder input. Whose airplanes were those?

THE WITNESS: I don't remember the specific airline, but it was -- it was done on a B-1 -- a Boeing flight test, pre-delivery to a customer.

MR. CLARK: Okay. I have no further questions.

CHAIRMAN HALL: You mentioned that testing is continuing?

THE WITNESS: Well, certainly on the simulator we are continuing to do a lot of background work to try and further improve the match and determine what characteristics the autopilot and what not would have had.

CHAIRMAN HALL: Well, you had mentioned there were some specific things you all were trying to do. What time line do you think it will take you to accomplish those things, generally?

THE WITNESS: We are, I think, to the point where we will within the next couple of months have many of those things pulled together much more so than we do right now.

CHAIRMAN HALL: Okay, thank you. Mr. Schleede?

MR. SCHLEEDE: Thank you, Mr. Chairman. I would like to ask one more question in the area of the thrust reverser. I want to make sure I understand.

From your expertise in aerodynamics and flight dynamics, do the data that we have, the aeronautical data that we have, support, or refute a thrust reverser deployment on the left side?

THE WITNESS: It is difficult to really pin that down, I think. The aerodynamics -- one thing that is missing in the signature of the load factor is buffet.

I understand from looking at past data that we have seen on test airplanes that the load factor when a thrust reverser is extended has a lot of buffet associated with it, and we don't see that signature in here.

Aerodynamically what we get out of that is a very large yawing moment. That is what we would expect. We are not in particularly high speed flight here, we are not at high mock numbers.

We are at fairly low speed, so the characteristic is not nearly as dramatic as it was in the case of the 767 where he was at cruise when that occurred, I understand. So, you wouldn't expect to see as violent an upset as they might have experienced.

MR. SCHLEEDE: Okay, well, I just want to go back, because I know the Chairman asked you at one point when you said -- you used the phrase "we have eliminated" the thrust reverser, and he had you clarify that, who the we was, whether that was you, or Boeing, or the aircraft performance crew.

THE WITNESS: Well, I think overall, you know, it has been a collection of information that has led us to not believe that the thrust reverser is involved, and I guess the "we" is maybe Boeing, but I think the performance group also believes that. We haven't spent a lot of time on that.

MR. SCHLEEDE: I just want to narrow that down to your particular area of expertise in what we have called you here for. Do you see data that lets you refute it, or is it inconclusive from your --

THE WITNESS: Well, again, I think from a load factor standpoint I don't believe that the thrust reverser was involved.

MR. SCHLEEDE: Okay, thank you. One other area, and I know we are going to see you again during the hearing, so maybe I will have to come back to it, but understanding these documents like 13(i), we have been referring to several charts and graphs.

I want to talk particularly about what you said the equivalent rudder angle and equivalent rate of rudder travel that would be derived from this chart. I think I wrote down that you thought it was five -- averaged five degrees per second?

THE WITNESS: Approximately. It is moving around a fair amount. We had a lot of noise.

MR. SCHLEEDE: A lot of noise?

THE WITNESS: Well, a lot of computational things. It is not a nice, smooth trace that you can put a straight edge on, and if you have ten people do it you will get ten slightly different answers, I am sure.

MR. SCHLEEDE: Well, that is kind of what I was driving at. What kind of confidence level can we put in looking at a chart like this? How confident can we be that we are within some reasonable tolerance of, you know, five --

I have heard three and a half degrees per second maybe two weeks ago, and I have heard two and a half degrees per second, depending on where I look at it. Here, I can get it down to two degrees per second.

THE WITNESS: Yes, it is difficult to pin down exactly and, again, we don't know for certain what is coming from rudder and what would be coming from wake, so it is very difficult to pin down a rate specifically out of that data.

MR. SCHLEEDE: Is one of the values -- I

think you mentioned this, that the critical value that we do have available here is heading? The sample, once per second?

THE WITNESS: That is correct.

MR. SCHLEEDE: Is that a major player in driving these?

THE WITNESS: Yes, it certainly is the major indication of yawing moment on the airplane. The yaw acceleration would be derived from heading rate.

MR. SCHLEEDE: Since it is sample once per second, is there a possibility that we are missing some step inputs, some instantaneous inputs here, or are we --

THE WITNESS: Well --

MR. SCHLEEDE: -- smoothing this too much?

THE WITNESS: I think if you get a step input you see a very rapid change in heading, and you would pick it up even in one second, particularly if it went in and stayed in. You would pick that up pretty quickly.

Again, we don't know exactly what the wake is doing to this thing, if the vertical tail is getting into the wake just one time, or if it is passing through the wake twice. That is something that we would hope to be able to narrow down a little bit in our further studies, but at this point I really can't say precisely what the situation is.

MR. SCHLEEDE: I don't know if you covered this, or if it is going to be in your next phase of testimony; rate of rudder trim, what is its -- has it been considered as one of the possible inputs to this?

THE WITNESS: We evaluated that early on in the -- in the simulator, and I think we will probably talk about it tomorrow, but the rudder rate is -- trim rate is about a half a degree per second on the airplane. It would take a substantial amount of time for that to drive the rudder over to its 14-degree limit.

MR. SCHLEEDE: Okay, thank you very much, Mr. Kerrigan.

CHAIRMAN HALL: Mr. Laynor?

MR. LAYNOR: Just a couple, Mr. Kerrigan. Early on in your answers to Mr. Jacky you described the distributed lift modelling that he used and, as I understood it, that was used to simulate the effects of a wake vortex, or a vortex on the body of the aircraft.

THE WITNESS: Yes, it was designed so that we could evaluate the effects of the wake, or -- even if it only hit a small portion of the wing.

MR. LAYNOR: I was wondering if any consideration was given to the difference in the pressure distribution over the fuselage for different angular increase?

THE WITNESS: No, at this point the model that we put together did not include any body effects.

MR. LAYNOR: Do you think that they might be significant?

THE WITNESS: I don't believe that they would be of the same order of magnitude as the -- either the wing, or the vertical tail. So, I would think they would not be -- they would be a second order affect.

MR. LAYNOR: I kind of would like to sometime later in the investigation pursue that a little further, perhaps. Mr. Clark asked you what range of impingement or entries were examined, and I don't know whether you answered that with any indication --

THE WITNESS: Yeah, I didn't necessarily answer it specifically. We did look at various penetrations, but it was generally in conjunction with piloted simulations, so we may have set him up with a -- like a 20-degree intercept angle, but then had him roll out onto the heading of the wake as he approached it. So, I don't have a specific parameter set that I can refer to.

I think we felt that the primary upset was lateral and that we were going to maximize that if he approached it almost tangentially, and that is pretty much what the radar data was indicating, so that was the primary thrust of things.

MR. LAYNOR: Well, I think we both recognize that radar data leaves some tolerances, and I believe we could perhaps go further than that. I think you might have mentioned this already, but in the autopilot encounters, was the autopilot programmed to logically be following a course intersect as the accident airplane was?

THE WITNESS: For the video that we showed where we were looking at the autopilot only acting in that case, the autopilot was about to roll the airplane out onto the heading of the wake as it impacted the wake.

MR. LAYNOR: So, you believe we reproduced a case where an aircraft on autopilot enters a vortex encounter with the autopilot attempting to roll it out, or if the vortex results in an overshoot of the course, bring it back?

THE WITNESS: That was the case that we simulated, yes. Again, that wasn't part of any parametric study that we were doing. It was merely trying to get a representative encounter.

MR. LAYNOR: How much engineering data were recorded during those 200 -- or, 2,000 autopilot runs?

THE WITNESS: Well, we have -- it can vary from case to case, but we typically would have perhaps a hundred parameters recorded during the simulator runs, on that order. We can actually, you know, record many more than that, but that -- those are the ones that are typically of interest.

MR. LAYNOR: Have they been examined to the extent necessary to determine which ones most closely represent the first four or five seconds of this encounter?

THE WITNESS: Again, we haven't parametrically studied the wake encounters to that extent. We are in the process of doing that and we will, but right now we haven't -- just -- we are not there yet.

MR. LAYNOR: Okay, one final question, and you might get to this tomorrow, but in a wake vortex encounter what effect would you -- how active do you think the yaw damper would be?

THE WITNESS: I am sorry, I didn't hear the last part.

MR. LAYNOR: I am wondering how you think the yaw damper on the aircraft would react during a wake vortex encounter.

THE WITNESS: Well, again, the -- it depends on the encounter. If the airplane simply is roll upset, then the yaw damper would not probably have a large input. If it -- if the vertical tail impinges into the wake and it gives you a fairly large and significant yaw upset, then I would say the yaw damper might well go to its authority limit and it -- you know, it can be anywhere in between those two.

If they airplane is rolled significantly and then as it kicks out it has a fairly rapid rate of change of yaw heading, the yaw damper would certainly be trying to encounter that initially.

MR. LAYNOR: Okay. All right, thank you, Mr. Kerrigan.

CHAIRMAN HALL: Mr. Kerrigan, first let me say I think you have been up here for about two hours and 15 minutes, if the Chairman's watch is correct, and we appreciate the time that you have spent and look forward to your return.

I will just try to ask you when we get back in -- when you do return and we talk about kinetic modelling -- is that correct?

THE WITNESS: Actually --

CHAIRMAN HALL: Kinematic.

THE WITNESS: Yeah, Mr. Dellicker will be discussing the kinematic --

CHAIRMAN HALL: Okay, well, he will give us a description of that. I would appreciate it. I assume you are saying -- it is my understanding that what we are seeing on these charts and graphs could have basically most likely happened from some type of rudder input, or maybe some structural deformation of the wing -- of the slat, maybe?

THE WITNESS: That is correct.

CHAIRMAN HALL: And that the rudder moved and we are not sure whether it was a commanded or an un-commanded input?

THE WITNESS: That is correct.

CHAIRMAN HALL: Because we don't have information on the flight data recorder that would reflect that?

THE WITNESS: That is correct.

CHAIRMAN HALL: And you are going to come back, or someone is going to come back and we are going to talk about the flight data recorders that are currently available on these aircraft and what might be available?

THE WITNESS: Right.

CHAIRMAN HALL: All right. Well, thank you very, very much. You have been very helpful and very patient, and I thank you and also thank the six, or seven people you have identified that you worked with that have assisted us, and we appreciate your continued assistance in the work that you are going to continue to do in this effort in the next couple of months.

(Witness excused.)

We are going to go on to call one more witness today. However, before we do that we will take a 20 minute break and we will reconvene here at 5:50, or ten of 6:00. Off the record.

(Whereupon, a brief recess was taken.)

CHAIRMAN HALL: On the record. We will reconvene this proceeding. I have an announcement that I would like to make for the benefit of those -- the parties and the individuals who are interested in following these proceedings.

The second day of this hearing will begin in this room tomorrow morning promptly at 8:30 a.m., 8:30 a.m. A number of people have inquired as to the time that this proceeding will begin tomorrow. This proceeding will begin tomorrow at 8:30 a.m. So, if you would please assist me in being sure that everyone gets that information that would be greatly appreciated.

The next witness that we will call for this hearing is Mr. Brian Johnson. He is a Boeing 737 structure specialist with the Boeing Commercial Airplane Group in Seattle, Washington. If Mr. Johnson could come forward, please?

(Witness complies.)

Mr. Schleede, if you could begin the questioning?

(Witness testimony continues on next page.)

BRIAN JOHNSON, BOEING 737 STRUCTURE SPECIALIST, BOEING COMMERCIAL AIRPLANE GROUP, SEATTLE, WASHINGTON

Whereupon,

BRIAN JOHNSON,

was called as a witness by and on behalf of NTSB, and, after having been duly sworn, was examined and testified on his oath as follows:

MR. SCHLEEDE: Mr. Johnson, could I have your full name and business address for our record, please?

THE WITNESS: My name is Brian E. Johnson. Business address, Boeing Commercial Airplane Group, P.O. Box 3707, Seattle, Washington 98124.

MR. SCHLEEDE: In what position are you employed at Boeing?

THE WITNESS: Lead structural engineer.

MR. SCHLEEDE: How long have you worked for Boeing?

THE WITNESS: I have been employed in that capacity as structural engineer for 11 years. For the last nine years I have worked on this model, 737.

MR. SCHLEEDE: Give us a brief description of your education and background that qualifies you for your present job.

THE WITNESS: I have a degree in engineering with major and structural engineering from the

University of Washington. As I stated, I have got 11 years practical experience on air frame structural analysis.

I am also an FAA designated engineering rep, more commonly referred to as DER, and I am a licensed professional engineer in the State of Washington.

MR. SCHLEEDE: Thank you. Ms. Keegan will proceed.

MS. KEEGAN: Good afternoon, Mr. Johnson.

THE WITNESS: Ms. Keegan.

MS. KEEGAN: What was your position on this investigation?

THE WITNESS: My position was as a member of the NTSB Structures Group. I was sent at the request of the Air Safety Group at Boeing to assist the NTSB.

MS. KEEGAN: What other aircraft accident investigations have you participated in?

THE WITNESS: One other. I was involved in

KOPA flight 201 in Panama in June, 1992.

MS. KEEGAN: What aircraft was that?

THE WITNESS: That was also a Boeing 737.

MS. KEEGAN: What was your position in that investigation?

THE WITNESS: On that investigation I was sent as a Boeing representative, again at the request of the Air Safety Group, to assist the NTSB in their investigation.

MS. KEEGAN: Have you ever been involved in another wreckage reconstruction?

THE WITNESS: At KOPA there was a limited reconstruction that I was involved in. Yes, I have been.

MS. KEEGAN: Can you describe any parallels of that reconstruction investigation with this reconstruction investigation?

THE WITNESS: I feel the direction and flavor of each investigation is somewhat unique. I can't really describe any parallels between KOPA and flight 427.

MS. KEEGAN: When you say "unique", can you give us a little more detail?

THE WITNESS: Well, KOPA was very challenging. On the contrary, we had a lot of assistance here on flight 427 by USAir, their facilities, the presence of a hangar, engineering drawings, things like that.

All of these conveniences that made my job as a structures member much easier here on 427 were not present on KOPA, so it did handicap the process a bit.

MS. KEEGAN: How was flight 427 wreckage reconstruction reconstructed and oriented?

THE WITNESS: Well, the concept of reconstruction, I will clarify. When I say reconstruction -- and I will say this over and over.

It simply refers to positioning the wreckage pieces in their correct airplane location.

By doing that, you serve to document the structure, you serve to organize the structure, so it is really a fundamental starting point. The orientation -- to answer your question, Ms. Keegan, the orientation that was selected was essentially a conventional layout, a standard engineering convention.

The forward portion of the airplane, or nose portion of the airplane, was positioned to the left as you entered the hangar. The tail section, or referred to as the empennage area, was positioned to the right.

On the far side of the wreckage was the right wing, on the near side the left wing. So, you have got essentially the same perspective as an engineering drawing.

MS. KEEGAN: What was the purpose of the reconstruction?

THE WITNESS: Well, as I have stated, it serves to document the structure, it serves to organize the structure and it really gives you a good beginning point to commence other detailed inspections of the structure.

MS. KEEGAN: More specifically, what was the purpose of the reconstruction of areas such as the forward pressure bulkhead, the slats, the floor beams?

THE WITNESS: Well, let me answer that question in order. We can look at areas like the forward pressure bulkhead. That reconstruction effort came on after the initial full scale reconstruction effort of the major air frame.

The forward pressure bulkhead, we did a two-dimensional reconstruction of that. The direction of the investigation, or reason for doing that reconstruction was to investigate possibility of bird strike to that bulkhead.

MS. KEEGAN: Then, the reason for the reconstruction of the floor beams?

THE WITNESS: Again, floor beam reconstruction was another specific effort that we undertook after the major air frame had been laid out and two-dimensionally reconstructed. The purpose of the floor beam reconstruction really centered over the systems group.

The floor beams, the web of the floor beams, have cut-outs in them for the control cables. You have a floor beam approximately ever 20 inches on the fuselage. So, we have a fair amount of structure that is, so to speak, surrounding, or housing the control cables, and there was, again, another direction in the investigation to fully understand that structure around the control cables, and that would mean a floor beam reconstruction.

MS. KEEGAN: Mr. Johnson, did you observe any evidence of structural fatigue, or failure prior to impact during the wreckage reconstruction and examination?

THE WITNESS: Evidence of structural fatigue, no, I did not observe any evidence of structural fatigue.

MS. KEEGAN: Did you observe any evidence of a failure prior to impact of the structure, or any areas of the structure?

THE WITNESS: No, I did not observe any evidence of an in-flight type of failure, catastrophic failure, no, I did not.

MS. KEEGAN: I would like to refer you to Exhibit 7(d), page 1, specifically.

(Witness complies.)

What were the results of the examination of the slats and, specifically, the number one outboard slat track?

THE WITNESS: Well, as -- as the exhibit states, the slat was submitted for a metallurgical examination, an NTSB metallurgical examination, and using visual means the NTSB metallurgist could determine that that slat outboard main track had failed due to an overload condition. This was in contrast to a fatigue-type failure.

MS. KEEGAN: Are you aware of why the structures group was specifically interested in examining the slats?

THE WITNESS: Well, the slats -- and this gets back to one of the earlier questions -- there was a reconstruction effort undertaken on the slats, the concern being that there may have been a bird strike to a slat, and the reconstruction was really centered on that direction again in the investigation.

MS. KEEGAN: How was the examination of the slat -- how were the slats examined for any evidence of bird debris?

THE WITNESS: Well, let me start off by saying I am not an expert in the technique that was employed for looking for bird debris, or bird fluids. The method is called black light inspection.

Simply, it entails a light, an ultraviolet light of a given wave length that makes it invisible to the human eye. Hence, the name black light. When this ultraviolet light is shown on bird debris, or some fluids, the debris or fluid will absorb and react to the light and give an indication, a visible indication, which is termed fluorescing. So, that was the method that was employed.

MS. KEEGAN: I would like to refer you to Exhibit 7(g).

(Witness complies.)

The Armed Forces of Pathology examination of the debris that was removed from the number one slat, could you describe what the examination revealed?

THE WITNESS: Well, I will back up one step and say the reason for the Exhibit 7(g), there was a mild indication of bird strike using the aforementioned black light method. As a follow-up procedure, the Armed Forces Institute of Pathology in Exhibit 7(g) performed three additional inspections for evidence of bird strike.

Exhibit 7(g) goes into detail on each of those three methods and concludes by saying that in each of the three methods there was no evidence of bird strike.

MS. KEEGAN: I am sorry, can you say that again? Did you say that -- what was the --

THE WITNESS: Yeah, let me back up.

MS. KEEGAN: What was the conclusion of the examination of the debris from the slat?

THE WITNESS: The conclusion from Exhibit

7(g) was that there was no evidence of bird strike, and they utilized three different inspection methods to try and find evidence of bird strike.

MS. KEEGAN: Are you aware of the history of the Boeing 737 -- any history of an outboard slat failure in flight?

THE WITNESS: To the best of my knowledge, I am -- well, before I answer the question, let me see if I understand the question. When you say "failure of a slat," slat separation from the wing?

MS. KEEGAN: That is correct, the slat separation, or --

THE WITNESS: No, to my knowledge there has not been a case of a slat separating from a wing in flight.

MS. KEEGAN: Mr. Kerrigan previously mentioned that there was a section of the slat missing. Are you aware of any such section, and has that concern been brought to the attention of the investigation?

THE WITNESS: On slat one there is a portion of slat that is gouged and severely dented. It is adjacent to a slat rib. Oftentimes it is not uncommon to see structure adjacent to a stiffening member such as a rib exhibit more deformation.

There are small pieces of the slat that are not attached to the slat, but it is essentially a v-shaped gouge, a very deep gouge, and most of the slat structure is there, it is just that it has been deformed quite a bit.

MS. KEEGAN: What were the difficulties, or obstacles in accomplishing 100 percent reconstruction?

THE WITNESS: Well, as stated in Exhibit 7(a), the major obstacle was the fragmentation of the structure. We found that we were looking at pieces that were more simply too destroyed to try and locate their correct airplane location. So, really the fragmentation of the air frame was the major obstacle.

I would like to mention that in some areas there was relatively high percentage of reconstruction. Overall, we probably ranged around the 50 percent level.

MS. KEEGAN: When you say "high percentage of reconstruction," what area are you referring to and how high?

THE WITNESS: Okay, what I am referring to is just the percentage of structure that comprises the un-deformed structure that we are able to identify and place.

In general, as you went aft along the airplane we found more structure, more identifiable structure, and the actual percent of reconstruction in some of those local areas were well in excess of 50 percent.

On the contrary, as you go forward, we found it difficult in some places to reconstruct pieces because of the fragmentation, and the percent of reconstruction was much, much less than 50 percent.

MS. KEEGAN: Are you aware of any evidence of pre-impact fire, or explosion during the -- found during the examination of the wreckage?

THE WITNESS: Well, again, I will qualify my answer by stating I am not a flammability, or an explosion expert. However, I will go on to say that I did not see any evidence that would suggest that.

MS. KEEGAN: What do you base your --

THE WITNESS: Well, let me clarify. With regards to a fire, what we found as we progressed through this reconstruction process is that we would -- we would find a fire-damaged piece of structure and we would identify and place the matching adjacent structure to that fire-damaged piece, and oftentimes there would be no transitioning of fire damage. It was apparent that this fire-damaged piece had occurred at a separate location, presumably from impact.

MS. KEEGAN: Did you observe any evidence of depressurization?

THE WITNESS: Well, the idea of depressurization is -- really infers that there was a penetration, or some type of a failure of the pressured shell. You know, the fuselage is pressurized.

So, to answer that question, I will refer to the issues of penetration of the pressured shell, or structural failure. I found no indication of either one of those events.

MS. KEEGAN: What were the results of the examination and reconstruction of the cargo doors?

THE WITNESS: The cargo door reconstruction showed a couple of things. First of all, we found pieces of both cargo doors, the forward cargo door and the aft cargo door.

CHAIRMAN HALL: Could you describe for us how many cargo doors there are and the approximate size of the cargo doors?

THE WITNESS: The cargo doors are in two positions. There are two cargo doors. We are talking about lower load cargo doors. There is one in the forward position around body station 400 which is, you know, a few feet aft of the forward service door.

There is an aft cargo door which is, again, some feet forward of the aft service door, roughly body station 800. The dimensions of the cargo door, again, roughly we are talking a three-foot type dimension, 30-inch, 40-inch type rectangular dimension.

As I was saying, the reconstruction of the cargo doors yielded a couple of points. We found pieces of both cargo doors, forward and aft, and we also found evidence that suggested these cargo doors were closed on impact. In fact, I can say these cargo doors were, indeed, closed on impact.

MS. KEEGAN: Where do you base your conclusion? What evidence do you base your conclusion on for that?

THE WITNESS: Okay, let me explain. I will start off with the forward cargo door. We located a couple of key components at the door. The first one was a device called a snubber. It is similar to a shock, or a damper is probably the best way to describe it. It controls the door and gives it some controllability.

That piece was found in the extended position. The extended position is the normal door closed position. On the forward cargo door we also found a latch fitting on the door, and we found the mating latch fitting on the fuselage frame.

On these two fittings you could see a consistent set of marks, or gouging where the door latch fitting had gouged and then loaded the fuselage fitting, and vice versa. Again, this indicates that there was an engagement on impact -- excuse me -- on impact, which would imply door closed position.

With regards to the aft cargo door, we found some of that same evidence; the snubber in the extended position, the -- we found a fuselage door fitting that had imprints from the actual door fitting, so we have two parts that mate together and we could see where one had actually imprinted on the other one on impact.

Also, on the aft cargo door we found the handle for the door in the recessed closed position and, not only that, but it did exhibit some consistent deformation with the surrounding structure indicating the door closed position.

MS. KEEGAN: I think you have covered it all pretty thoroughly, but let me just ask this question.

THE WITNESS: Yeah.

MS. KEEGAN: Did you observe any evidence that the cargo door, or other airplane structure had failed prior to impact?

THE WITNESS: No, no, I did not observe any evidence of that.

MS. KEEGAN: Are you aware of the ground and aerial searches conducted during the on-site investigation?

THE WITNESS: I am aware they were carried out. I did not participate in either the ground, or the aerial search, but I was on-site during that time and am aware of the activity.

MS. KEEGAN: I would like to refer you to exhibit 7(c), the accident site and search location. Can you describe, or explain why the ground search aerial search was conducted and what were the results of the ground search?

THE WITNESS: The ground search was performed mainly because early in the reconstruction there was some -- some notable missings from the reconstruction effort. Early on, after about two days of in the hangar doing the work, I realized we weren't finding much of the forward cargo door, and there was some other structure that was missing, as well.

So, that was really the reason behind doing this search, was to find any structure that might have fallen off the aircraft prior to impact, and I would like to point out that later in the reconstruction as it progressed we found pieces of all the doors, including that forward cargo door.

The search, both the ground search and aerial search, did not find any structure from flight 427.

MS. KEEGAN: What is the history of in-flight complications, or failures of the same type cargo door, or the cargo doors on the Boeing 737?

THE WITNESS: Well, let me begin by saying a bit about the design of the door. These are inward opening cargo doors. They are commonly referred to as a plug-type door. We have no in-flight service of a failure of this type of door.

It is a reliable design, simply stated. The door is larger than the opening. It is held in place by internal pressure.

MS. KEEGAN: So, are you aware of any prior history of in-flight failures of the cargo doors where they opened, or --

THE WITNESS: No, I am not.

MS. KEEGAN: -- separated in flight?

THE WITNESS: I am not aware of any in-flight failure to cargo doors.

MS. KEEGAN: Okay. I would like to go back to when I was speaking about the reconstruction of the forward pressure bulkhead. Can you please describe the historical basis for the concerns of a bird strike to the forward pressure bulkhead?

THE WITNESS: Historically, if we go back and look at service data, on rare occasions there have been birds that have struck that bulkhead. Let me clarify where this bulkhead is. It is located just behind the radome, which is the nose section of the airplane.

There have been cases where a bird has penetrated the radome and struck the bulkhead, and there have been even rarer cases where a bird has penetrated the forward pressure bulkhead.

MS. KEEGAN: What were the results of the black light examination of the forward -- reconstructed forward pressure bulkhead?

THE WITNESS: The results were negative for evidence of bird strike on that bulkhead.

MS. KEEGAN: What is the history of in-flight complications, or failures regarding a bird strike to the forward pressure bulkhead on a Boeing 737?

THE WITNESS: There have been some rare cases where a bird has struck that bulkhead. In all cases the airplane has been able to land safely. There have, to my knowledge, been no accidents, or incidents resulting from that.

MS. KEEGAN: Do you recall what the approximate percentage of the forward pressure bulkhead was reconstructed?

THE WITNESS: We completed the effort with about 40 percent of the bulkhead reconstructed. That was based on a percentage of the surface area of the bulkhead.

MS. KEEGAN: Do you recall what other airplane structure was examined for bird debris and what the results were?

THE WITNESS: In addition to the forward pressure bulkhead and the slat structure that I mentioned previously, we also looked at the radome which is essentially the nose in front of the pressure bulkhead.

In addition, some of the cockpit components were inspected, the left-hand wing was inspected, the leading edge. They also inspected the left-hand wing spoilers. The leading edge of the horizontal stabilizer was inspected, as well as the leading edge of the vertical stabilizer.

MS. KEEGAN: What were the results of those examinations?

THE WITNESS: In all cases the results were negative for bird strike.

(Pause.)

MS. KEEGAN: Were there any structural -- other structural concerns regarding flight 427?

THE WITNESS: I don't have any other structural concerns with flight 427. I feel the team kept an open mind. We looked at everything and I don't feel I have any other concerns about flight 427's structural investigation.

MS. KEEGAN: What are your feelings regarding the reconstruction of the floor beams and the potential for an in-flight failure of the floor beams?

THE WITNESS: My feeling with regard to that is that if we go back and look at our service experience, we will find that we have never had that failure scenario where a floor beam had suddenly collapsed and put an input into a control cable. It simply isn't a failure mechanism that we have ever seen.

MS. KEEGAN: So, are you saying there is no history of any in-flight failure of the floor beams?

THE WITNESS: I am saying, to my knowledge there is no history of a catastrophic failure of a floor beam that would involve several inches of deflection and input to a control cable.

MS. KEEGAN: Are you satisfied that the areas that the Structures Group covered in the re-examination and reconstruction of flight 427 were adequately reconstructed and investigated?

THE WITNESS: I feel the reconstruction effort was adequately inspected, yes. We spent a very long time reconstructing the airplane, and I think we have looked into all possible leads. I cannot think of any other piece of structure on the airplane that I would recommend a reconstruction on at this phase.

MS. KEEGAN: Are you aware that these same views were expressed during the reconstruction by the members of the structures team?

THE WITNESS: Yeah, I -- I can speak on their behalf that we openly expressed our views and our opinions towards the direction of the investigation and we, especially the Boeing representatives, feel that we did a very thorough job on the reconstruction, and I can't -- I can't really foresee any other structure to further reconstruct.

MS. KEEGAN: Are you aware of a history, or an event of a partial failure of a slat on the Boeing 737?

THE WITNESS: Getting back to the issue of a bird striking slats, the typical damage resulting from such an event would be a denting of the slat structure leading edge structure. In rare cases you might get some tearing of the leading edge structure, but that is in general the extent of the damage, at least to my knowledge, from bird strike on slats.

MS. KEEGAN: Thank you very much, Mr. Johnson. I have no further questions at this time.

CHAIRMAN HALL: Thank you, Ms. Keegan. Do any of the parties have questions for this witness?

(No response.)

Seeing no questions from the parties, I will go to Mr. Marx.

MR. MARX: No questions.

CHAIRMAN HALL: Mr. Clark?

(Pause.)

MR. CLARK: Mr. Johnson, do you know what the pressurization would be on the airplane at 6,000 foot, just prior to the upset, or the pressure differential?

THE WITNESS: I don't know the exact value. I would estimate it at probably around one PSI.

MR. CLARK: Okay. Earlier today there were questions about the possible presence of a bomb on board the airplane. Have you identified any type of mechanism in which a bomb could produce this type of event, this type of departure?

THE WITNESS: Have I identified any type of a mechanism? Do you mean have I seen any structural failure scenario consistent with a bomb explosion, or -- I am not sure --

MR. CLARK: Well, not only -- I think you testified earlier that you saw no evidence, direct evidence, of the presence of a bomb, but, within that, have you identified any potential mechanisms in which a bomb could produce a slow-moving rudder?

THE WITNESS: Again, I am not sure if I fully understand your question. From a structural inspection of the debris, there is no evidence of an explosion. However, as I stated to Ms. Keegan, I am not an explosives expert and, really, I think the other exhibits and witnesses can attest to the presence or mechanism of an explosive device.

MR. CLARK: Okay, thank you. I have no further questions.

CHAIRMAN HALL: Mr. Schleede?

MR. SCHLEEDE: Yes, clarification in two or three areas here. I believe Ms. Keegan asked you about your knowledge of any history of floor beam failures in flight, and your answer was you were not aware of any catastrophic failures in flight. Are you aware of floor beam failures in 737 in flight that --

THE WITNESS: No, I am not. No, I was simply trying to delineate between what you might consider routine maintenance on a floor beam where you may find a bit of corrosion, or something requiring a repair and some approval process, but, no, I know of no floor beam failure in the classical sense.

MR. SCHLEEDE: Right, okay, and another clarification. You were asked if you were aware of any partial failure of a slat in flight. In your answer you put it in the context of a bird strike, but I think the question was are you aware of any partial structural failures of a slat in flight on a 737, regardless of the reason.

THE WITNESS: No, not to my knowledge.

MR. SCHLEEDE: As part of your examination, and I may have missed it, the aux fuel tank? Was that your responsibility in part of this investigation?

THE WITNESS: I identified several pieces of that tank. However, later in that investigation we had a PATS engineer come and do a thorough investigation of the tank, and he submitted an exhibit on his findings of the tank.

MR. SCHLEEDE: Did you participate in that examination?

THE WITNESS: No, I did not.

MR. SCHLEEDE: And the last area. Regarding the forward pressure bulkhead, you spoke about 40 -- roughly 40 percent of the material surface area was recovered.

Could you characterize how random that was, or was it like it was one side missing and you had part of the other side, or was it sort of totally random? Could you characterize where those pieces were from?

THE WITNESS: It wasn't all that random. It tended to -- and based on memory, we found a fairly substantial portion of the lower right quadrant, and then in the upper left quadrant we found another fairly substantial portion of it.

There were some areas of that bulkhead that we simply could not find any structure to try and reconstruct.

MR. SCHLEEDE: Okay, thank you very much.

THE WITNESS: Yes, sir.

CHAIRMAN HALL: The forward cargo door, could you tell me one more time what you found on the forward cargo door?

THE WITNESS: Well, we found -- what we found on the forward cargo door was the handle, we found a torque tube which was just part of the latching mechanism, we found some of the structural framing, we found a latch, we found a snubber.

As a percentage, it was well under 50 percent of the door that we found on the forward, whereas the aft door we probably found just about 50 percent.

CHAIRMAN HALL: All right. I don't believe that I have any other questions, Mr. Johnson. Are we sure none of the parties have any questions of this witness?

(No response.)

If not, you are dismissed. Thank you very much for your time.

THE WITNESS: Thank you.

(Witness excused.)

CHAIRMAN HALL: Mr. Haueter, do we want to call one more witness, or do we want to conclude for the day? The Chairman does not like to be unpopular.

MR. HAUETER: (Inaudible.)

CHAIRMAN HALL: One more?

MR. HAUETER: (Inaudible.) I'm sorry. We

have one more witness, and it would take about 45 minutes to an hour to get through him, we believe.

CHAIRMAN HALL: Well, with that information, the Chairman believes we will begin at 8:30 in the morning, and we are in recess.

MR. HAUETER: Okay.

CHAIRMAN HALL: Off the record.

(Whereupon, at 6:35 p.m. the hearing was adjourned, to reconvene the following day in the same location.)

- - -