UNITED STATES OF AMERICA
NATIONAL TRANSPORTATION SAFETY BOARD

PUBLIC HEARING
AMERICAN AIRLINES FLIGHT 587
BELLE HARBOR, NEW YORK

Tuesday, October 29, 2002

APPEARANCES:

Members of the Board:

CAROL CARMODY, Acting Chairman
JOHN J. GOGLIA
JOHN HAMMERSCHMIDT
GEORGE W. BLACK

National Transportation Safety Board Technical Panel:

STEVE MAGLADRY
JOHN CLARK
JOHN O'CALLAGHAN
CAPT. DAVE IVEY
DR. MALCOLM BRENNER
ROBERT BENZON
LORENDA WARD, Hearing Officer

On behalf of American Airlines, Inc.:

CAPT. ROBERT AHEARN

On behalf of the Allied Pilots Association:

CAPT. DONALD W. PITTS

On behalf of Airbus:

DR. JOHN LAUBER

On behalf of the Federal Aviation Administration:

HAROLD DONNER

APPEARANCES: (Continued)

On behalf of the Bureau D'Enquetes et D'Analyses pour la Securite de L'Aviation Civile (BEA):

PIERRE JOUNIAUX

I N D E X

WITNESSES:

PROCEEDINGS

9:39 a.m.

CHAIRMAN CARMODY: Good morning. Some of you may wonder why there are so many empty seats. We're holding those vacant for a while because we're expecting some family members arriving later this morning, and we wanted to be sure they had a seat. So they may be released later, but right now we're trying to hold them free.

Good morning, ladies and gentlemen, and welcome to the NTSB. My name is Carol Carmody. I'm the acting chairman of the National -- Transportation Safety Board and the chairman of this board of inquiry.

Today we're opening a public hearing concerning the accident that occurred on November the 12th, 2001, at Belle Harbor, New York, involving American Airlines Flight 587. There were 265 fatalities from that crash, the second deadliest in U.S. history.

I'd like to acknowledge today in the -- in the audience are family members of those who lost their lives. I want to express my profound condolences for your loss, and I am joined in that by the entire Safety Board and by all the parties to this hearing.

We can't change the tragedy that occurred on

November the 12th, but what we can do is assure the families of the passengers and the crew that the Safety Board will pursue every lead in search of answers for the cause.

Our nation was still stunned by the events of September the 11th when this crash occurred on November the 12th, 2001. Although there were no indications of terrorist activity associated with it, that possibility could not be discounted. Therefore, in addition to the NTSB Go Team which was dispatched immediately, the FBI also sent a team to the site. And that agency has been in regular touch with the Board ever since.

There is no indication to date of any criminal activity associated with the crash.

Information from this hearing will supplement the facts, conditions, and circumstances discovered the on-scene and continuing investigation. This process will assist the Board in determining the probable cause of the accident and in making any recommendations to prevent similar accidents in the future. We will not render a determination of cause during these proceedings.

This investigation has taken investigators not just to New York but to France, Germany, Oklahoma, Virginia, Arizona, Washington state, and California.

The volumes of pages of information we've released this morning are the work of scores of investigators representing government and private industry.

The purpose of this hearing is twofold. First, the issues that will be discussed at this hearing will assist the Safety Board in developing additional factual information to analyze to determine the cause of the accident. Second, this hearing gives the aviation community and the traveling public a chance to see a portion of the investigative process and a view of the dedicated efforts of the many investigators from different organizations in their effort to find answers.

I might also add, the hearing is available as a live Web cast through the Safety Board's Web site, which is www.ntsb.gov.

Public hearings such as this one are exercises in accountability: accountability on the part of the Safety Board that it is conducting a thorough and fair investigation; accountability on the part of the FAA that it is adequately regulating the industry; accountability on the part of the airline that it is operating safely; accountability on the part of the manufacturers for the design and performance of their products; and accountability on the part of the work force, including pilots and mechanics, that they are performing up to the high standards expected of them.

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

This board of inquiry is not intended to determine the rights or liability of private matters, and matters dealing with such rights or liability will be excluded from these proceedings. Our purpose is to collect information that will assist the Board in examination of safety issues arriving from this -- arising from this accident.

Specifically, we'll concentrate on the following issues.

Number one, the design and certification of the vertical stabilizer and the rudder.

Number two, the rudder system design, certification, and operation.

Number three, wake turbulence.

And number four, -- operations and training.

At this point, I'd like to introduce my colleagues and the other members of the Board.

To my left, Member John Hammerschmidt. To my right, Member John Goglia. And on the end, Member George Black. George Black was on scene at the accident of 587.

The Board will be assisted by a Technical Panel consisting of the following Safety Board staff: Mr. Robert Benzon, investigator in charge; Ms. Lorenda Ward, hearing officer; Mr. John Clark, director of aviation safety; Mr. Tom Haueter, deputy director of aviation safety; Dr. Vern Ellingstad, director of research and engineer; Dr. Alan Kushner, deputy director of research and engineering; Mr. Steve Magladry, systems group chairman; Capt. David Ivey, operations group chairman; Dr. Malcolm Brenner, human performance group chairman; Mr. John O'Callaghan, aircraft performance group chairman; and Dr. Matt Fox, materials group chairman.

Since this accident involved a foreign-manufactured aircraft, in accordance with Annex 13 of the Chicago Convention, the Technical Panel will also include members from the BEA, which is the French equivalent of the NTSB. Mr. Pierre Jouniaux, Mr. Bernard Bourdon, and Mr. Thierry Loo.

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

Ms. Brenda Yager and Sharon Bryson from the Office of Transportation Disaster Assistance are here to assist any family members in the audience.

Ms. Carolyn Dargan and Christine Carey are here to -- are present to provide administrative support as needed. They will also be providing copies of exhibits to witnesses.

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

The final report on the accident reflecting the Safety Board's analyses and probable cause determinations will be considered for adoption by the full Board at a public meeting here at the Safety Board's headquarters at a future date.

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

As I call the name of each party to the hearing, would that designated spokesperson please give his or her name, title, and affiliation for the record?

First, the Federal Aviation Administration.

MR. DONNER: Good morning, Madam Chairman. My name is Bud Donner. I'm the manager of the Accident Investigation Division, Federal Aviation Administration.

CHAIRMAN CARMODY: Thank you.

American Airlines?

CAPT. AHEARN: Good morning, Madam Chairman. My name is Tim Ahearn. I'm vice president of safety, security, and environmental for American Airlines. I'm the chairman -- here on behalf of American Airlines. I'd also want to acknowledge the tremendous losses suffered by the families of the victims on Flight 587 and as well offer our condolences and sorrow for the losses. Thank you, Madam.

CHAIRMAN CARMODY: Thank you, Mr. Ahearn.

Airbus?

DR. LAUBER: Yes, Madam Chairman. I am John Lauber. I'm vice president of safety and technical affairs for Airbus North America. And I too would like to thank you for your statement of condolence on -- on behalf of all of the parties. It certainly captures the sentiments of all of us at Airbus. And we look forward to contributing to the investigation to make sure that this never happens again. So thank you. Excuse me. Thank you.

CHAIRMAN CARMODY: Thank you, Dr. Lauber.

Allied Pilots Association.

CAPT. PITTS: Good morning, Madam Chairman. I am Capt. Don Pitts, chairman, Safety Committee. On behalf of the 14,000 pilots represented by the Allied Pilots Association, I would like to add to your comments our heartfelt sorrow for those who have suffered as a result of this accident.

CHAIRMAN CARMODY: Thank you, Capt. Pitts.

I would like to also thank publicly all of the private, municipal, county, state, and federal agencies that have supported the Safety Board throughout this investigation. They're really too numerous to mention, but we owe them a great deal.

On October the 21st of this year, this Board of Inquiry held a pre-hearing conference here in this facility. It was attended by the Safety Board's Technical Panel and representatives of the parties to the hearing.

During that conference, the areas of inquiry and the scope of the issues to be explored were delineated and the selection of witnesses was finalized. Copies of the witness list developed at the pre-hearing conference are available in the foyer.

There are numerous exhibits that will be used in this proceeding. Copies of the exhibits may be ordered through our Public Inquiries Branch at 202-314-6551 and may also be found on the Board's Web site, which I noted previously.

The witnesses testifying at this hearing have been selected because of their ability to provide the best available information on the issues.

The investigator in charge of the accident will summarize certain facts about it and -- and the investigative activities that have taken place to date. Following this, the first witness will be called.

The witnesses will be questioned first by the Board's Technical Panel, then by the designated spokesperson for each party to the hearing, and finally by the Board members.

As chairman of the Board of Inquiry, I will be responsible for the conduct of the hearing. I will make all rulings on the admissibility of evidence and all 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 and will be available for inspection at the Board's Washington office. Anyone wanting to purchase the transcript, including the parties to the investigation, should contact the court reporter directly.

Let me just note here, in case of an emergency of some sort such as a fire, the building alarm system will activate and a voice message will instruct persons to vacate the building. You should proceed then to the nearest exit. There are emergency exits up front on either side of the stage and of course at the back of the room.

Also, for convenience, restrooms and telephones are in the foyer on your left as you enter -- as you exit the room.

And also, I would ask to provide the appropriate setting for the hearing that if you have cell phones, pagers, or beepers, that you put them on "silence" as so not to disrupt the proceeding.

Mr. Benzon, are you ready to proceed with the summary?

MR. BENZON: Yes, ma'am.

CHAIRMAN CARMODY: Please do so.

SUMMARY STATEMENT

MR. BENZON: Good morning. On November 12th, 2001, at approximately 9:16 a.m., American Airlines Flight 587, an Airbus A-300, crashed into a neighborhood in Belle Harbor, New York. And this occurred shortly after takeoff from Kennedy International Airport. The plane was on a scheduled flight from Santo Domingo, Dominican Republic.

(Slide)

MR. BENZON: As depicted in this slide, the vertical stabilizer and rudder were found in Jamaica Bay, about one mile from where the main wreckage eventually impacted. The engine struck the ground several blocks north of the main wreckage, and then the remainder of the aircraft impacted at the intersection of Newport and 131st Street. All 260 persons on board died as -- as did five residents of Belle Harbor.

I will be stepping through a timeline of events from takeoff until aircraft impact very shortly.

(Slide)

MR. BENZON: Safety Board investigators from our Northeast Regional Office arrived shortly after the accident to coordinate NTSB activity with local authorities and to secure perishable evidence. Later that day, a full team of 40 NTSB investigators and support staff arrived at the accident site and began work in a dozen different specialties.

(Slide)

MR. BENZON: Board member George Black, former chairman Marion Blakey, public relations personnel, and NTSB Transportation Disaster Assistance representatives accompanied the investigators. Other investigators simultaneously began background work on the accident back here in Washington, D.C.

Because the aircraft involved in the accident was designed and built by Airbus and certified by the French government, the Bureau Enquetes Accidents provided a French accredited representative and investigators to assist in the investigation.

(Slide)

MR. BENZON: The Safety Board spent about one week at the accident site to document -- documenting the wreckage in place. This slide depicts the accident site about two days after the accident.

During this week, the engines were removed for future teardown examinations in Tulsa, Oklahoma, and the majority of the vertical stabilizer and rudder assemblies were recovered from the water underneath the final flight path of 587. These components were removed to an unused hangar at Floyd Bennett Field close to the impact site for initial visual examination.

(Slide)

MR. BENZON: In addition, an NTSB aircraft performance engineer was dispatched to Toulouse, France, to begin working with Airbus engineers on aerodynamic loads calculations.

(Slide)

MR. BENZON: To date, the investigation activity has also been accomplished in Stade, Germany, where the vertical stabilizer was built. The NTS -- I'm sorry. The NASA Langley Hampton, Virginia facility for composite material examination. The NASA Ames Mountain View, California facility, home of the most sophisticated motion simulator in the world. Sandia National Laboratory in New Mexico. The Ford Motor Company CAT Scan facility in Detroit, Michigan. And the U.S. Army Proving Ground CAT Scan facility in Maryland.

Now I'd like to go into the accident sequence itself a bit.

(Slide)

MR. BENZON: Based on radar and FDR data, Flight 587 took off approximately 101 seconds behind Japan Airlines Flight 47, which was a Boeing 747. The FDR indicates that the flight -- that Flight 587 encountered to wake vortices generated by JAL Flight 47. The second wake encounter occurred about 10 seconds before the ending of the FDR data. And following the second wake encounter, the aircraft responded to flight control inputs. Both wake encounters averaged about 0.1 G lateral movement, that is side to side.

(Slide)

MR. BENZON: And during the last eight seconds of FDR data, the plane experienced three stronger lateral movements, two to the right, and one to the left. These lateral force excursions were consistent with rudder movements.

The left-pointing horizontal arrows on this slide show where the accident aircraft encountered the two wake vortices. The right-pointing arrows show the direction of travel of the vortices as they were carried by the wind. And the vertical arrows show where the JAL 747 was by the time of the two vortex encounters.

(Slide)

MR. BENZON: Now, we can see the wake encounters on the vertical acceleration traces of the FDR. Here is the first wake encounter.

(Slide)

MR. BENZON: And here is the second wake encounter.

(Slide)

MR. BENZON: And here, on the rudder position trace, is where we believe the vertical stabilizer broke away from the airplane. Currently, it appears that the rudder was still attached at the time the vertical stabilizer separated from the fuselage.

(Slide)

MR. BENZON: We now have three visual presentations to show you. The presentations that follow depict the accident events somewhat graphically but not exceedingly so. If any family members wish not to see this material, we'll pause for a moment now so you can relocate.

(Pause)

MR. BENZON: Okay. The first presentation was taken by a construction crew working at JFK with a video camera and it filmed both the departure of the

Boeing 747, that's JAL Flight 47, and American Airlines Flight 587. And the video is playing now.

(Video presentation)

MR. BENZON: Security cameras from the Metropolitan Triborough Bridge and Tunnel Authority at the Marine Parkway Bridge also recorded most of the accident sequence itself. This tape includes two simultaneous video clips of the accident airplane in the far distance. The image is very, very small. The clips have been time correlated by using surveying techniques and radar data.

The left clip shows the airplane flying through the frame from left to right, and the right clip shows the airplane on a somewhat parabolic descent from left to right. And shortly thereafter, you'll see an image of some smoke observed rising from the ground.

Now, we will show this video twice, once with a white circle around the very small image of the airplane and again without the white circle. Based upon our correlation, we believe that the vertical stabilizer separated while the airplane was in view in the left clip. However, careful examination of the video in our laboratory revealed no images of any object falling off the airplane.

In the right clip, you will note a lighter colored smear or smudge develop as the clip plays a bit. The staff believes that this could be misting fuel, it could be smoke, or even flame that spread from the airplane after the engines broke away from the wing. Again, we could find no images of anything falling off the airplane.

(Video presentation)

MR. BENZON: I notice the -- the smear there.

(Video presentation)

MR. BENZON: Last, a video animation of the accident takeoff and the loss of control about a minute and a half later was completed by the Safety Board, and we will show it to you in a minute. The animation is based upon derived information from the flight data recorder.

I need to brief you a bit on what you're going to see because it's kind of a complicated little clip. You'll first note that we are superimposing selected wording from the CVR transcript and other sources over the image of the airplane. These words only appear for a few seconds and will not impede the view of the airplane.

A little lower on the instrumental panel portion of the animation you will see the elapsed time, altitude, and an airspeed read-out.

The big round object, the blue and brown object, is an attitude indicator that will show you the pitch angle of the airplane and its roll angle or its bank angle.

To its right is the airplane's control wheel. Next to it is a vertical accelerometer that will tell you how heavy the pilots feel in the seat, how many G's they're experiencing.

A sliding triangle on the rudder pedal indicator tells you how much the rudder pedals are deflected. And the rudder surface indicator, along with the tail section depiction, tells you how much the rudder itself is deflected.

The red lines on the tail section depiction show the rudder limiter, and you will see these red lines come closer together. They're in a chevron shape and they'll kind of squeeze together as the air speed increases.

And last, you will note the lateral acceleration indicator that indicates the amount of side-to-side forces that are existing at any given moment during the flight.

We'll run the first run of the full animation in real time from taxi to the end. Now, keep in mind that the entire flight was only about a minute and a half long, and some events occur very rapidly, especially near the end of the animation.

Also, the flight data recorder quit working before the crash. The animation will stop at that point, but the CVR text, which continued to record, will continue to scroll. And next, we'll then run the full final segment at one-half speed so you can better see the relative motion of the airplane and its controls. And finally, we'll run the final segment again in real time.

And we can play that now.

(Video presentation)

MR. BENZON: And that's the JAL flight on the top of the screen.

(Video presentation)

MR. BENZON: When the air speed begins to increase, that's the time that he begins the takeoff roll.

(Video presentation)

MR. BENZON: And again, the things to watch out for are yoke movement or control wheel movements that are quite dramatic and the rudder position.

(Video presentation)

MR. BENZON: Okay. The takeoff roll is beginning.

(Video presentation)

MR. BENZON: The yoke comes back for the rotation. And he broke ground.

(Video presentation)

MR. BENZON: The gear and flaps are coming up now.

(Video presentation)

MR. BENZON: And he is rolling wings level.

(Video presentation)

MR. BENZON: We think that's the first wake encounter.

(Video presentation)

MR. BENZON: And the second wake encounter.

(Video presentation)

MR. BENZON: Now we'll be running the end portion of the tape in slow motion, one-half speed.

(Video presentation)

MR. BENZON: First wake.

(Video presentation)

MR. BENZON: Second wake, and notice the rudder on the right side.

(Video presentation)

MR. BENZON: Now, this time will be real time. And if you want to notice on the right side of the screen when the image of the rudder disappears, that's when we believe it departed the airplane. Again, this is real-time.

(Video presentation)

MR. BENZON: First wake.

(Video presentation)

MR. BENZON: Second wake.

(Video presentation)

MR. BENZON: And the tail's gone.

(Video presentation)

MR. BENZON: Okay. I would like now to summarize the accident sequence of events using a map of the New York area, if I may. Next slide, Chris.

(Slide)

MR. BENZON: Okay. The yellow arrow on the -- in the upper right-hand corner of the slide shows the liftoff point from the runway. And the flight path down to the south over the Rockaways. Next slide.

(Slide)

MR. BENZON: This is the first wake encounter at 9:15 and 36 seconds. And next slide.

(Slide)

MR. BENZON: This is the -- when the captain comments about the wake, and that occurs at 44 seconds after the minute. And next slide.

(Slide)

MR. BENZON: At 9:15 and 51, he encounters the second wake. Next slide.

(Slide)

MR. BENZON: And at 9:15 and 58 and a half seconds, we believe the vertical stabilizer left the airplane. Next slide.

(Slide)

MR. BENZON: The fuel spray or fire or whatever you'd like to call it occurred at 9:16 and six seconds at this location. And note that's right over the coastline for the -- the peninsula there and right where a lot of our eyewitnesses were. Next slide.

(Slide)

MR. BENZON: And this last slide shows the wreckage locations, the vertical stabilizer and rudder in the water. The left engine and right engine are a little farther into the peninsula. And the main impact site is about halfway between the two beaches.

(Slide)

MR. BENZON: I'd like to now -- to describe some of the investigative activity that has been accomplished and will not be subjects of this hearing -- not be a subject of the hearing. These subjects for the most part are no longer active areas of investigation because the staff believes that they are not associated with the reason this tragedy occurred.

I must reemphasize, however, that this public hearing is not the end of the investigation. Any area of inquiry can be reopened with sufficient reason, and we simply are not finished with some of our inquiries in different areas.

Concerning sabotage. Numerous criminal investigation agencies led by the FBI were immediately involved with the Safety Board in careful examination of all recovered wreckage on scene. There was no evidence of high-speed object impacts, supersonic gas washing, micro particle pitting, or explosive residue on any aircraft component.

The Board also discovered no unusual indications on the flight data recorder or the cockpit voice recorded that would indicate foul play. And last, the sequence of events itself as previously described is not consistent with sabotage.

Interviews with those associated with the ground operation of the flight were conducted. Passenger background checks were accomplished by the FBI and the police. And the efficiency of airport security measures was also examined by law enforcement authorities.

In short, no evidence of sabotage was -- was discovered by the Board or any law enforcement agency.

Concerning weather at the time of the accident, at 9:25 a.m., about five minutes after the crash, a special weather observation was taken. And it revealed that the winds were out of 270 degrees at eight knots. The visibility was 10 miles. A few clouds were present at 4800 feet and the temperature was 42 degrees Fahrenheit. There was no indication of any adverse weather at all.

Concerning air traffic control activities, all air traffic control directions and clearances given to Flight 587 and spacing between 587 and the Boeing 747 were in accordance with current FAA regulations and guidelines. However, the wake vortex encounter itself experienced by Flight 587 is a topic of this hearing.

Concerning the aircraft's engines, teardowns of both engines and the auxiliary power unit revealed no indications on either engine or the APU of uncontained failure, case rupture, in-flight fire, or pre-impact malfunction. In addition, the flight data recorder engine parameters revealed no anomalies.

The staff therefore believes that the engines did not contribute to the cause of this accident.

Concerning bogus or unauthorized aircraft parts, in late February of this year investigators became aware of a group of apparently bogus aircraft components that were allegedly being shipped to the United States from Italy. However, no bogus parts were discovered to be associated with Flight 587.

Concerning eyewitnesses, the Board has received about 350 accounts from eyewitnesses either through direct interviews that we or the police conducted or through written statements obtained by the Board. A summary of those statements has been previously been made public, and the full witness reports are available in the public docket, which is now open.

A number of witnesses reported seeing fire either on the fuselage, at the engines, or at or near the wings. Some reported an explosion. Some saw no fire. Some saw the airplane wobbling, dipping, or moving side to side, and some saw something separate from the airplane.

Investigators believe that the observations of fire and smoke are normal in an in-flight event such as this. Flames, smoke, and misting fuel often occur as aircraft engines rip off the wing during similar situations.

In similar events in the past, the disruption of air flow into the engines also often causes loud bangs and large flames to emit from either the back or the front of the engines themselves, and these are collectively known as compressor surges. It's a known phenomenon.

In short, many of the statements we have received are quite consistent with the sequence of events that occurred.

Concerning aircraft systems, to date investigators have found no indications of rudder system anomalies. And the investigation in this area does continue.

Concerning aircraft structures, structures investigators continue to look for preexisting damage to the vertical stabilizer. But again, to date investigators have found no indications of any structural anomalies on the airplane.

It must be noted that even if damage did exist to the airplane's vertical stabilizer, the stabilizer structure remained intact until the loads it sustained were very, very high. The external aerodynamic loads of the internal loads for the vertical stabilizer are a topic of this hearing.

But it should be noted that the extensive calculations accomplished by Airbus and independently by the Safety Board reveal that the physical loads that the vertical stabilizer experienced were significantly above the ultimate maximum limits required by the French and American certification standards. In fact, the sustained loads were near the structural test limit demonstrated during the certification process.

Concerning Flight 587 maintenance records, all periodic maintenance examinations of the aircraft were on time and in accordance with current FAA guidelines. The last visual inspection of the airplane or of the vertical stabilizer and rudder specifically was conducted on December 9th, 1999, during a heavy maintenance check. Nothing unusual was noted during that visual inspection.

On the morning of the accident, a pitch trim and a yaw damper would not engage during a pre-flight check. The computer controlling these components was reset by a mechanic and this appeared to solve the problem. There were no open maintenance items regarding the vertical stabilizer and rudder system when the aircraft took off.

Concerning flight data recorder problems, the analysis of the flight data recorder, a vital tool in aircraft accident investigation, was much more difficult than it needed to be because signals from some FDR parameters were filtered before they reached the flight recorder. As a result, the readings on the recorder show what gauges were telling the pilots but not necessarily what was actually occurring on a real-time basis to the aircraft.

In 1994, the Safety Board recommended to the FAA that such filtering be removed from information sent to the flight recorders. And yet in 2001, this investigation was hampered by totally unacceptable filtering of the data. In addition, the sampling rates of such data are simply not adequate.

The staff and the Board are addressing these issues separate from this hearing.

Concerning NTSB recommendations, the Board has issued two recommendations to the FAA so far during this investigation, and I -- I believe they're very important ones. These two are considered so important that we could not wait to the conclusion of the investigation to put them out.

The two safety recommendations address the fact that many pilot training programs do not include the information about the structural limits for the rudder and the vertical stabilizer on the airplanes the pilots fly. Significantly full rudder inputs, even at speeds below maneuvering speed, may result in structural loads that exceed certification requirements.

However, pilots may have the impression that the rudder limiter systems on their airplanes prevent cyclic full rudder deflections from damaging the structure, and this is simply not true.

The structural certification requirements for transport category airplanes do not take such maneuvers into account. Therefore, such cyclic rudder inputs, even when a rudder limiter is in effect, can produce loads that may exceed the structural capabilities of the aircraft.

The staff is continuing to evaluate whether the pilots caused the rudder to move in this case or if a rudder system anomaly could have contributed to the movement. Regardless, the staff believes that the rudder movement resulted in most, if not all, of the loads imposed on the vertical stabilizer during this event.

Now, concerning the recommendations themselves, specifically, the Board asks the FAA to require the manufacturers and operators to ensure that pilot training programs do three things. Pilots need to be explained that the structural certification requirements for the rudder and the vertical stabilizer exist. And an explanation is needed concerning what a full or nearly full rudder deflection in one direction can -- can do to an airplane. And lastly, it needs to be explained to the crew force that on some aircraft, as speed increases, a maximum available rudder deflection can be attained with relatively light pedal forces and small pedal deflections.

Madam Chairman, this concludes my opening statement.

CHAIRMAN CARMODY: Thank you, Mr. Benzon.

Ms. Ward, are you prepared to call the first witness?

MS. WARD: Yes, I am, Madam Chairman. I'd like to call Mr. Dominique Chatrenet and also Mr. Dominique Van den Bossche.

Whereupon,

DOMINIQUE CHATRENET

having been first duly sworn, was called as a witness herein and was examined and testified as follows:

Whereupon,

DOMINIQUE VAN den BOSSCHE

having been first duly sworn, was called as a witness herein and was examined and testified as follows:

MS. WARD: Please have a seat, then. Thank you.

(Pause)

MR. MAGLADRY: Thank you, Ms. Ward and Madam Chairman.

MS. WARD: Mr. Magladry, I need to qualify the witnesses first.

Mr. Chatrenet, would you please state your full name, your current employer, and your business address?

MR. CHATRENET: Yes. My name is Dominique Chatrenet. I'm working for Airbus. And my business address is Airbus France, Route de Bayonne, Toulouse, in France.

MS. WARD: And what is your current position and how long have you held that position?

MR. CHATRENET: I am working for Airbus Engineering. I am vice president, head of the Flight Control and Hydraulic Department -- and I'm leading the situation since year 2001.

MS. WARD: And could you briefly describe your duties and responsibilities, also including the education and training that you may have received that qualifies you for that position?

MR. CHATRENET: Yes. So the domain is in charge of the flight control system, which includes primary flight control system and the ILS system as well, the autopilot system, the hydraulic system, and the -- and flight control, those activities which are associated with these systems.

The domains has a little more of 300 engineers working in Germany, Great Britain, and France.

MS. WARD: Thank you.

Mr. Van den Bossche, could you please state your full name, your current employer, and also your business address?

MR. VAN den BOSSCHE: Dominique Van den Bossche, Airbus, 316 Route de Bayonne, Toulouse, France.

MS. WARD: And how -- and what is your current position, and how long have you held that position?

MR. VAN den BOSSCHE: My current position is head of department in the Engineering organization in Dominique Chatrenet's domain. I'm in this position since 2001.

MS. WARD: And could you also briefly describe your duties and responsibilities and any education or training that you may have received that qualifies you for that position?

MR. VAN den BOSSCHE: As head of the primary flight control actuation and hydraulic departments, I manage a department which primary activity is development of flight control and hydraulic equipment for all the aircraft of the Airbus family, A-300 to the S programs. And I -- the department counts about 100 engineers shared over France and Germany.

In addition to the management of this department, I'm personally involved in technical committees, international or national, like SIE committees -- or ISO.

I received a Masters degree in hydraulic engineering in 1971. I joined Airbus at that time as a development engineer for the S-300 primary flight control actuation system. I then was involved in the A-310 and A-300-600 developments, A-320, A-340, as well as assigned as a -- as the primary flight control actuation and head of group -- head of group in '88. And I was assigned to my current position in 2001.

MS. WARD: Thank you, Mr. Van den Bossche.

Madam Chairman, I find these witnesses qualified and now turn it over to Mr. Steve Magladry for questioning.

CHAIRMAN CARMODY: Thank you.

Mr. Magladry?

MR. MAGLADRY: Thank you, Ms. Ward and Madam

Chairman.

TESTIMONY OF MR. CHATRENET AND MR. VAN den BOSSCHE

MR. MAGLADRY: Good morning, Mr. Chatrenet.

MR. CHATRENET: Yes, good morning.

MR. MAGLADRY: Good morning, Mr. Van den Bossche.

I'd like to begin the questioning this morning with a discussion of the rudder control system for the accident airplane, the A-300-600.

Mr. Chatrenet, can you please provide an overview of how the rudder is controlled? I understand you have a brief presentation for those purposes?

MR. CHATRENET: Yes. Yes, I --

MR. MAGLADRY: For -- for those that cannot see the illustrations, this information has been provided in the Docket Exhibit 9-A, page four.

MR. CHATRENET: Yes. So this is an illustration of the rudder control system of the A-300 dash 600.

(Slide)

MR. CHATRENET: So starting from the pedal in the front part of the fuselage, the motion of the pedal is transmitted to the rear of the fuselage, first through rods and then to cables starting from the front quadrant and with a pair of cables running along the fuselage down to the rear quadrant of the fuselage.

At this stage, the motion of the pedal will react against the strings of the artificial feed unit which provide at the same time the trim function.

In this rear assembly, the motion coming from the autopilot servo actuator, which are here, will be transmitted to the whole linkage and will carry on the orders from the autopilot to the rudder.

At this level, a differential unit will authorize to add the orders coming from the “u” number servo actuator, which is here, and which provides for the yaw damping and turn coordination function.

The results of this addition will then go through the rudder travel limiter, which is illustrated there. And finally, this motion will be the input of the three servo actuators which will drive the rudder.

(Slide)

MR. CHATRENET: This is basically a same picture that's showing the functionality. We can recognize here the rudder pedals, the cables, the spring, and the trim function. The addition of the autopilot order at this stage. The addition of the yaw damper orders. The limitation provided by the rudder travel limit. And then the three actuators.

The rudder travel limit controlled by the

FLC's computer while the autopilot actuator are controlled by the autopilot computer and the yaw damper by the AVC computer.

MR. MAGLADRY: Just for clarification, some control surfaces have the ability to, as they say, "break out." The pilot's controls would move -- can move independently of the other pilot's controls. Is that the case with the rudder pedals for the A-300-600?

MR. CHATRENET: Could you clarify your question, please?

MR. MAGLADRY: Can the rudder pedals move independently? The pilot's and the first officer's?

MR. CHATRENET: No. No. They are rigidly connected together.

MR. MAGLADRY: Thank you. Now I'd like to focus attention first to the yaw damper operation. And could you please describe its function?

MR. CHATRENET: The -- the yaw damper function, the main function is to provide the yaw damping of the aircraft through the use a yaw rate measurement which will compute the rudder order by the flight augmentation computer and which will drive the input of the rudder actuators.

The yaw damper has also the function of providing an automatic turn coordination to help the aircraft to fly in coordinated turn without the need for pilot doing that.

The yaw damper order is additive -- is added to the orders coming from the pilot input from the rudder pedals.

What is important also to notice is that the activity of the yaw damper will not move the pedal in normal operation. And overall, the yaw damper authority is limited and is roughly equal to one-third of the authority of the pilot coming from the pedals.

This function is computed in the AVC computers, and this function is a monitored one.

MR. MAGLADRY: Do you have an illustration of the yaw damper system?

MR. CHATRENET: Yes, we could -- we could show another slide. And maybe Dominique Van den Bossche will explain more about the monitoring function, for instance.

MR. MAGLADRY: First, is the -- is the -- how -- is the yaw damper engaged all the time or --

MR. CHATRENET: Yes, the yaw damper is engaged all the time.

MR. MAGLADRY: And you mentioned that the yaw damper does not normally back drive the pedals. Are you aware of any failure modes which could cause the yaw damper to back drive pedals?

MR. CHATRENET: Yes. There is one. If there is a jamming of the controls downstream of the -- of the differential additional, if you like, then the motion of the yaw damper would be back driving the rudder pedal in the opposite sign. But in this case, obviously, the rudder would not move at all.

MR. MAGLADRY: Could you please repeat that?

MR. CHATRENET: In the case of a jamming in the control downstream of the addition of the two orders of the yaw damper and the rudder pedal, if there is a jam here -- we may come back to the -- to the illustration.

(Slide)

MR. CHATRENET: So, for instance, if at this stage this control is jammed, then the orders coming from the yaw damper would make such that the sum of the motion here plus the motion here is zero because at this stage this cannot be moved because it is jammed, which means that in this case the yaw damper may move the pedal. But in this case, once again, this would not move, which means that the rudder would not move at all.

MR. MAGLADRY: And in that case, the -- the pedal would go in the opposite direction?

MR. CHATRENET: Exactly. Exactly. At -- on the opposite direction and exactly to the same amplitude that's the motion of the yaw damper.

MR. MAGLADRY: Would a -- would the seizure of a bearing in the rudder frame assembly at the differential mechanism, would that also cause a coupling with the yaw damper and pedals?

MR. VAN den BOSSCHE: The seizure of the bearing within the differential assembly would jam everything.

MR. MAGLADRY: Thank you. Can you talk about the authority limits of the yaw damper in normal operation?

MR. VAN den BOSSCHE: Yes. The authority of the yaw damper system is plus or minus 10 degrees of rudder at speeds below 155 knots. And the authority is electronically limited beyond. The authority of the actuator itself start to stop is to plus or minus 12 degrees of rudder.

MR. MAGLADRY: Could you please display the illustration again which shows the entire system?

(Slide)

MR. CHATRENET: Want this one?

MR. MAGLADRY: I think it's later.

(Slide)

MR. MAGLADRY: Yes, that one. Could you please -- that illustrates well how the yaw damper authority changes with air speed. Can you just talk us through that illustration? Can you please just talk us through that -- that first box where it says "variable gain"? Dominique -- Mr. Chatrenet, please? Yes. Yes.

MR. CHATRENET: This illustrate the maximum authority of the yaw damper as limited by the AVC computer. So it start at 10 degree at low speed and then it reduces as a function -- as an inverse function of the square of the speed.

MR. MAGLADRY: And it looks like you've highlighted 250 knots there.

MR. CHATRENET: The maximum authority would be around 4.4 degree, around the speed of 250 knots.

MR. MAGLADRY: And you chose that speed why?

MR. CHATRENET: This is just to illustrate the area where we were on Flight 587.

MR. MAGLADRY: Thank you. And please describe the rate limiting function?

MR. CHATRENET: The rate limiting function will just limit the output of the yaw damper between plus or minus 39 degree per second.

MR. MAGLADRY: And is this approximately what the rudder servos can achieve in terms of rate?

MR. CHATRENET: No, the rudder servo can achieve a higher rate of defection.

MR. MAGLADRY: And what is that?

MR. VAN den BOSSCHE: It's 60 degrees per second when the three systems are active. Which is a normal case by the way.

MR. MAGLADRY: I'd like to move on to what monitors are in place for the yaw damper system. So could you please describe the monitors that are in place to make sure that an inappropriate command is not transmitted to the rudder servos?

MR. VAN den BOSSCHE: Okay. I'll just get a pointer.

(Pause)

MR. VAN den BOSSCHE: This slides -- this slide shows the general arrangement of the yaw damper actuator and the two flight augmentation computers.

The yaw damper actuator is a duplex system that includes two cylinder and piston assemblies, number one, number two, which are supplied from two independent hydraulic systems.

Each of the piston and cylinder assembly is connected to a flight augmentation computer, number one, number two. Each flight augmentation computer includes two different channels. One is a command channel and the other one is a monitoring channel. Each channel received information from its own set of sensors.

The function of the command channel is to compute the rudder position with -- which is required for the function, the shwar(ph) damping, for instance. And two, performs the servo loop control of the piston and cylinder assembly.

The function of the monitor channel is to make the same sort of computation from its own sensor set. This monitor channel also receive a position information of the piston. And this monitor channel makes a comparison between the position calculated and what -- and the actual position of the piston. And if there is any discrepancy, the system is -- switch offs. This number one system is switch off.

Normally, both yaw dampers are simultaneously active and priority is given to number one, owing to a mechanical device. So when number one is switched off, number two automatically takes the relay.

This principle is very basic and applies to all the actuators, autopilot for instance.

MR. MAGLADRY: Thank you. You mentioned that if a fault is detected by the comparator it will transfer control. Will there also be an oral warning?

MR. VAN den BOSSCHE: Yes. There would be a single chime in the cockpit.

MR. MAGLADRY: Can you please describe in a little more detail about the -- the function of the comparator?

MR. VAN den BOSSCHE: Yes.

(Slide)

MR. VAN den BOSSCHE: This slide shows a little more detailed description of the same system. The yaw damper actuator is that box which includes several valves. Some of our winding is shown there. And the position transducer which is used for the -- could you please -- slide on?

(Pause)

MR. VAN den BOSSCHE: Thanks. And the position transducer, which is used for servoing the piston.

This is the other position transducer which is used for the monitoring function.

This is the flight automation computer number one with the command lane and the monitor lane. And this is flight automation computer number two. Here are the sets of sensors which are the initial reference system, the one, two, and three. The air data computers one, two. And the electrical flight control unit, which is a spoiler computer that transmits the hand wheel position.

All these sensors are transmitting their information in digital format through airing 249 busses to the computers.

Monitoring function are both software in that area. And hardware in that area.

MR. MAGLADRY: I'm not sure that it was clarified but FAC-1 and FAC-2, could you define those terms?

MR. VAN den BOSSCHE: Yes. This is a flight augmentation computer number one, which controls the yaw damper servo actuator number one. And this is the flight augmentation computer number two that controls actuator number two.

If we go to the detail of the monitoring functions there --

(Slide)

MR. VAN den BOSSCHE: This "A" -- this "A" square represents the monitoring of the initial -- of the yaw rate that comes from the initial -- systems. This is information coming from the three units. And monitoring of those signals consist in monitoring the digital data transmission. This box looks for flags for no refresh of the computer data.

MR. MAGLADRY: What happens if the air -- one of the air data computers sends a higher air speed to FAC-1, for instance?

MR. VAN den BOSSCHE: This box also selects the data by a vote with the three of them. The highest is eliminated and the -- and the average is selected.

MR. MAGLADRY: The average of the values are selected?

MR. VAN den BOSSCHE: Yes. Box "B" I hardly can see it.

(Pause)

MR. VAN den BOSSCHE: The green box -- is monitoring of the lateral acceleration information. This is also a digital information and the digital transmission is monitored the same way.

"C" monitors the yaw rate.

Again, monitoring of the digital transmission.

"E" monitors -- "E" monitors the air speed. It's also a monitoring of the digital transmission.

And the box "F" is the actual calculation of the surface order, surface position.

All that is digital. To this point, there is a digital to analog converter and all the rest is analog. The computed signal, the computed rudder position from this command lane is sent to a voter. The other computed position is sent to the same voter. And the two positions are voted with zero, which means that the highest is eliminated. And the final position -- the final order there is the lowest of both.

There's a comparator here, "C1", which compares the information calculated there --

(Pause)

MR. VAN den BOSSCHE: Which compares the -- the position calculated there and the output of the voter. If there is a discrepancy higher than two degrees for a time longer than two seconds, the system is identified as failed.

The same hardware comparison is performed there between the signal calculated by this lane, the monitoring lane, and the output of the voter.

Now, the second monitoring function deals with the power loop, and this is a comparison between this position, which is a calculated position -- which is a calculated position of the rudder and the actual position as measured by this transducer on the actuator.

The position -- the position computed the other -- excuse me -- is going through some kind of a simulation model of the actuator. And the signal at this point is supposed to be exactly what -- the position of the unit. So the comparison takes place in both lanes at this time. And if a discrepancy exceeds two degrees for a time longer than 100 milliseconds, the system is identified as failed.

MR. MAGLADRY: Thank you. Now I'd like to move to some observations about the flight data recorder information.

Mr. Annibale, could you please display Exhibit 13-A, page 79?

(Pause)

MR. MAGLADRY: Please bear with us while we get that displayed.

MR. CHATRENET: Page 79?

(Slide)

MR. MAGLADRY: There we have it.

CHAIRMAN CARMODY: I'm sorry. Did we -- Mr. Magladry, did you identify the exhibit itself?

MR. MAGLADRY: Yes. It's 13-A.

CHAIRMAN CARMODY: Thank you.

MR. MAGLADRY: Page 79.

CHAIRMAN CARMODY: Okay. Thanks.

MR. MAGLADRY: And this presents flight data from the accident flight. It provides rudder pedal information and rudder surface information.

Can you please make any comments with regard to could the yaw damper -- the malfunction of the yaw damper created -- or normal operation of the yaw damper caused these motions?

MR. CHATRENET: So the -- as we said earlier, the design principle of the yaw damper, thanks to the monitoring function, allows to consider as extremely improbable any -- or runaway of the yaw damping function.

The maximum authority of the yaw damper in this vonger(ph) speed is only 4.4 degree, which is less than the rudder defection which is shown in this graph.

The yaw damper activity, as it said, would not move the pedal in other cases when the rudder would not move. So as the rudder is shown to move during this time period, it excludes a rudder jamming, which means that the -- in this circumstances, the yaw damper could not move the pedals.

Moreover, we have checked also that during the flight control checks prior to the takeoff, the yaw damper is working as per design and is just showing the turn coordination we have at this stage. And also during the alignment of the aircraft with the runway, there is some yaw rate because the aircraft is turning to the runway. And at this stage, we see also on the traces that the yaw damper is performing as per design during this period of time.

MR. MAGLADRY: So as -- you're saying as we saw in the simulation when Mr. Benzon -- that Mr. Benzon presented, we saw while taxiing out the -- the rudder moved and flight data traces did not show --

MR. CHATRENET: Yes.

MR. MAGLADRY: -- pedal movement and --

MR. CHATRENET: Yes. And -- and it's -- it's pretty visible on what we have been -- what we have been shown. The rudder pedal does not move, but we see the rudder pedal moving according to the yaw rate when the aircraft is aligning with the runway.

MR. MAGLADRY: So this indicates there was no jam between the rudder pedal --

MR. CHATRENET: Yes.

MR. MAGLADRY: -- and the --

MR. CHATRENET: Yes.

MR. MAGLADRY: -- yaw damper --

MR. CHATRENET: Yes.

MR. MAGLADRY: -- linkage? And again, the maximum authority at this particular air speed, which is around 250 knots, is four degrees?

MR. CHATRENET: Is only 4.4 degree.

MR. MAGLADRY: Thank you. That concludes my comments on the yaw damper. I'd like to move on to the yaw autopilot.

Mr. Chatrenet, can you please describe the operation of the yaw autopilot system?

MR. CHATRENET: So first the -- the autopilot is engaged and disengaged at pilot discretion. And when the autopilot is not engaged, the associated autopilot servo actuator are not clutched to the mechanical linkage of the control surface or of the control.

Now, when the autopilot is engaged, then the servo actuators move the whole linkage between the pilot controls and the actuators.

The pilot can always take over control of the aircraft either by disconnecting or by -- by overriding the autopilot.

On the yaw axis, we have to bear in mind that on the A-300-600-R autopilot, the yaw axis is only active on rudder when the slats are extended and the autopilot is engaged, which means that as soon as the slats are retracted the autopilot is no longer engaged on the yaw axis even if the autopilot is engaged.

And we have evidence that all along the Flight 587 the autopilot was never engaged.

(Pause)

MR. MAGLADRY: Do you have an illustration of the autopilot actuator system?

(Pause)

(Slide)

MR. VAN den BOSSCHE: This is the actuator.

MR. MAGLADRY: Okay. This is Exhibit 9-C, page two?

MR. VAN den BOSSCHE: Yes. This is the same picture.

MR. MAGLADRY: Could you show me how the -- the autopilot, as you say, clutches to the output?

MR. VAN den BOSSCHE: All right. So first, this autopilot servo actuator is dual and two of this assembly, two similar assemblies, which are both driving the same output lever, which is there. The output lever is connected to the mechanical linkage that drives the autocontrol.

The autopilot -- both autopilot could be active simultaneously, and there is a mechanical device that gives priority to number one.

When autopilot is not engaged, the unit is active. I mean that the piston is -- which is there is servoed, that the movement of the piston is not transmitted to the output because the clutch mechanism is not on.

The clutch mechanism consist in this lever, which has got a V-shaped cam in it which can be pushed against this roller when the cylinder is moved upwards. It is shown in a detached configuration when the roller is in contact with the V-cam. It's engaged, it's clutch, and the movement of the piston can be transmitted to the output.

This engagement cylinder is controlled by a solenoid valve, which is that one. And when the solenoid valve is -- which is the configuration which is shown on this picture, the pressure coming from the input goes to this chamber and pushes the piston upwards. It is clutched.

MR. MAGLADRY: So until that occurs, the autopilot is not -- cannot make any commands to the rudder?

MR. VAN den BOSSCHE: No. The movement of the piston cannot be transmitted to the rudder.

MR. MAGLADRY: And that does not incur -- that does not occur until you engage the autopilot?

MR. VAN den BOSSCHE: Sure. Yes.

MR. MAGLADRY: What failure mode could occur to engage the clutch if the auto pilot was not engaged?

MR. VAN den BOSSCHE: I may show you what is first the monitoring function of that system. So let me first tell you that -- in addition to this engagement solenoid valve, there is another valve which is a main valve which purpose is to turn off the hydraulic upstream of that one and two -- unit.

MR. MAGLADRY: This would be -- I guess this would be a good time for you to describe the monitoring functions of that clutch.

MR. VAN den BOSSCHE: Picture three, please.

(Slide)

MR. VAN den BOSSCHE: So this is a busy picture. It shows here the servo actuator in less detail than it was shown before. But you can identify the clutch lever, the piston, the output, the clutch solenoid valve, and the main solenoid valve.

I did not mention that the position of the lever was detected by a pair of switches which are shown there.

This is the flight control computer which is associated with this particular module of the autopilot servo actuator. And the computer makes the actuation of the engagement signal from the cockpit and makes the acquisition of the switch signal.

These signals are processed both by the monitor lane, which is that one, and by the control lane, which is that one. This is a two-lane system similar to what I've shown for the yaw damper.

(Slide)

MR. VAN den BOSSCHE: Okay. Thank you.

There are two types of monitoring functions which are hardware. This is the hardware monitoring which is performed by the command lane. This is the hardware monitoring function performed by the monitor lane. And there is also some software monitoring functions.

This logic condition 1-N is generated when the signal from one switch do not correspond to the signal from the engagement lever. And when 1-N is generated, these open this switch, which opens the circuit to the clutch valve.

A similar logic generates the condition 1-C here in the other lane. And this logic condition opens another switch that opens a circuit to the other wire of the clutch valve.

And there is a third logic condition which is software-calculated, there, which is logic 2-C, which acts on the main valve if necessary. This one is mainly used for detecting inadvertent engagement of the clutch.

MR. MAGLADRY: Okay. So there appears to be a number of levels of redundancy of detection. If you have -- if you do not have the autopilot engaged but yet the actuator is the clutch to the output, this will be detected from what you just described. And what will be the result of a detection?

MR. VAN den BOSSCHE: The result of the detection will be first to passivate the servo actuator and to disengage the autopilot.

MR. MAGLADRY: Will there be a warning associated with this?

MR. VAN den BOSSCHE: Yes, there would be.

MR. MAGLADRY: And I can't recall, and I'm sorry, did you note whether the autopilot was engaged during the -- at any point during this flight?

MR. VAN den BOSSCHE: No. The pilot was not -- has never been engaged during the flight.

(Pause)

MR. MAGLADRY: What would happen if the autopilot failed to engage from a previous flight? Would the -- would the pilots be able to detect that?

MR. VAN den BOSSCHE: This would have been seen when the aircraft was on the ground. The controls would have been stiff, held by the autopilot servo actuators.

MR. MAGLADRY: How -- how -- how stiff would they be? And would they -- would this be something the pilot would detect when he's trying to do his control sweep?

MR. VAN den BOSSCHE: Well, if the pilot wanted to make -- override the servo actuator, he would have to apply a load on the pedal which would be of about 150 pounds.

MR. MAGLADRY: Could we please display Exhibit 9 -- 9-C, page three?

(Slide)

MR. MAGLADRY: Can you please describe in this illustration -- this is the -- this is the autopilot system actuators and how they're coupled together. Can you please describe how the pilot can override these actuators?

MR. VAN den BOSSCHE: May I have the pointer?

(Pause)

MR. VAN den BOSSCHE: The output lever, which is actually this lever, includes a detent a spring system which consists in a cam, that V-shaped part there; a rudder which is pushed by a spring; and the force necessary to override which is to disengage the rudder from the V-shaped cam is that force of about 150 pounds at the pedals.

MR. MAGLADRY: Okay. So I guess in summary if the autopilot for some reason did not engage from a previous flight and it was not detected and the pilot attempted to do a flight control sweep as was observed on the ground prior to takeoff, he would experience an additional 150 pounds to override this autopilot actuator and move -- move the rudders?

MR. VAN den BOSSCHE: Yes.

MR. MAGLADRY: Is that true?

MR. VAN den BOSSCHE: The control would have been reported to be very stiff and they won't have takeoff.

MR. MAGLADRY: Okay. Thank you. Can you please describe any in-service events for both the yaw damper and yaw autopilot that you think may be relevant to this accident investigation -- may or may not be relevant? Yes?

(Pause)

MR. VAN den BOSSCHE: Sixty-five, please.

(Slide)

MR. VAN den BOSSCHE: So this is an event which -- which is linked with the yaw damper servo actuator and the flight augmentation computer. And what happened is that the yaw damper has shown a runaway on the ground which resulted in a rudder offset. And this condition has been identified during the flight control check.

The cause for this failure has been identified as a flight augmentation computer electronic bolt failure when applying a modification. And this defect was intermittent and has not been seen at the -- accident -- after the mode has been embodied.

The yaw damper runaway on the ground has not been detected as per design because on the ground the power look monitoring is not active.

MR. MAGLADRY: So this monitoring you described previously in the yaw damper, it's only active after the airplane --

MR. VAN den BOSSCHE: It's --

MR. MAGLADRY: -- is in the air?

MR. VAN den BOSSCHE: Yes, it is.

Corrective action, no corrective action has been defined. It has been confirmed that the pre-flight check was appropriate for identifying the defect and it worked.

This is the in-service failure mode of the yaw damper that I have. Would you like autopilot?

MR. MAGLADRY: Please.

(Slide)

MR. VAN den BOSSCHE: So the event was uncommanded rudder -- rudder oscillations during approach. And this -- two different scenarios have been experienced this is the first one.

The first one was a combination of two failures. First, a clutch solenoid valve failure. It was a failure to declutch caused by some contamination, some pollution of the solenoid valve. Plus, another failure which was a cross-connection between the two main valves. I told you that the servo actuator was a dual unit. It has got two main valves. And it happened that the wires between the main connector and the solenoid valve were cross-connected. And therefore, the monitoring function that has been shown which switch off the main valve was not about to do it because it was addressing the wrong valve.

So this was the first failure mode which was really failure to disengage.

Another failure mode that resulted in uncommanded rudder oscillations was linked to the servo valve, to the electronic servo valve which has a high flow gain around zero.

Corrective actions have been launched. First, mandatory inspection of all the actuators, three axis, spare actuators, mandated by analysis directive. A modification of the acceptance test procedure to make sure that the cross-connection would be detected. Modification of the aircraft maintenance manual procedure for the same objective. And modification of the test procedures after installation of a autopilot servo actuator.

At the manufacturer a quality survey has been launched, and the manufacturing process of the solenoid valves has been modified.

Similarity with Flight 587, first no -- no oscillations. The events before resulted in oscillations plus or minus three degrees with a period of several seconds, -- like that, for the first case. And plus or minus one degree with a frequency of six hertz for the second case. So nothing similar.

Evidence that the aircraft took off with the autopilot not -- not engaged and in declutch condition. During the flight, the autopilot was never engaged. All these monitoring actions were performed on this aircraft.

The solenoid valve cross-connection was to be checked on the accident airplane servo actuator but this has not been possible due to the condition of the unit, so this has not been checked formally.

And of course, if the servo actuators had given an order, the pilot would have react in all -- in the opposite direction.

MR. MAGLADRY: A theoretical scenario here. If the autopilot -- although the autopilot was established to not be engaged, if for some reason there was a spontaneous failure mode that clutched the autopilot actuator, could the accident flight have experienced similar oscillations?

MR. VAN den BOSSCHE: No, I don't think so.

MR. MAGLADRY: And -- and why is that? What -- what is different about the flight configuration of this airplane versus the -- Miami airplane?

MR. VAN den BOSSCHE: Because monitor functions would have operated on this -- on this unit. Assuming that there was no cross-connection, and I'm saying that there was no cross-connection because the unit -- the aircraft has been inspected for that.

MR. MAGLADRY: Are you aware of what was causing these oscillations on this flight?

MR. VAN den BOSSCHE: The -- you're talking about the in-service event?

MR. MAGLADRY: Yes.

MR. VAN den BOSSCHE: Yes. What was causing the oscillation was the abnormal closed-loop system which resulted from the unit being in synchronization mode and being clutched.

MR. MAGLADRY: This airplane was on approach with -- with -- and its flaps were down, I presume?

MR. VAN den BOSSCHE: Yes.

MR. MAGLADRY: And the accident airplane --

MR. VAN den BOSSCHE: Had flaps retracted with --

MR. MAGLADRY: Flaps retracted --

MR. VAN den BOSSCHE: -- logic condition which inhibits the yaw servo actuator.

MR. MAGLADRY: I'm sorry?

MR. VAN den BOSSCHE: The -- when the flaps are retracted, the yaw autopilot servo actuator is inhibited. This is a logic condition.

MR. MAGLADRY: So even if for some reason it was cross-connected and the autopilot spontaneously engaged, the commands would not have reached the actuator because the flaps were up?

MR. VAN den BOSSCHE: Yes. That's flaps yes.

MR. MAGLADRY: Do you have any other in-service events concerning the yaw autopilot?

MR. VAN den BOSSCHE: No.

MR. MAGLADRY: Okay. I guess that concludes my discussion of the yaw autopilot. I'd like to move on to some questions concerning rudder feel and trim.

Mr. Annibale, could you please display Exhibit 9-F, page four?

(Slide)

MR. MAGLADRY: This is an illustration of the rudder frame assembly, and it points out the artificial feel and trim unit and rudder trim actuator. Certainly, more components that control this system. Could you please describe the operation and purpose of this -- the artificial feel and trim system?

MR. CHATRENET: So the -- the purpose of the artificial feel is through the -- the spring which are in it to provide basically two function. The first one is of usually to signal to the pilot increases defection on the rudder command. And the second function is to bring back the rudder deflection to zero when the -- when any force is released from the rudder pedal.

So there is a centering function and there is an artificial feel function provided by these springs.

MR. MAGLADRY: How does the rudder trim actuator work?

(Slide)

MR. VAN den BOSSCHE: There is a trim actuator. It is an electromechanical actuator which drives a -- an irreversible screw jack which -- which changes the zero load position of the springs.

MR. MAGLADRY: And if this actuator were to fail and drive the rudder trim actuator, how fast would it move --

MR. VAN den BOSSCHE: The maximum rate of the rudder trim actuator is 1.2 degrees per second. So if it would have failed and drive the control, its signature would have been a 1.5 degree per second movement.

MR. MAGLADRY: And the rates of the rudder change in the accident flight, have you studied the approximate rate of change of rudder position in the accident flight?

MR. CHATRENET: They are -- they are far in excess of 1.2 degree per second.

MR. MAGLADRY: Are there any in-service events that are relative -- relevant to the accident investigation?

MR. VAN den BOSSCHE: Fifty-five, please.

(Slide)

MR. VAN den BOSSCHE: So there has been several incidents which resulted in uncommanded rudder trim movement. And it happened that right at the beginning, the logic was a little different. And in the early incidents, trim runaway remained hidden when the autopilot was engaged. And -- the autopilot disconnect resulted in a jerk of the rudder control to reach the trim position.

Several causes have been identified. The first cause was -- inadvertently moved a rudder trim knob.

Can you show 57, please?

(Slide)

MR. VAN den BOSSCHE: The origin -- original shape of the knob was at one, and this was prone to be moved by objects or documents lying on the center pedestal. This could have been the cause of some events.

Fifty-five, again.

(Slide)

MR. VAN den BOSSCHE: Another source has been the interference between the knob and the mounting plate which resulted in a lack of clearance and a jam of the knob when operated.

Fifty-seven, again.

(Slide)

MR. VAN den BOSSCHE: This is a mounting plane. This is a trim switch. This is the trim knob. And dimensions of this components right at the beginning necessitated an adjustment. And if the adjustment was not correctly performed or was changed for any reason, there could be a lack of clearance between the knob and the mounting plate, resulting in a jamming.

Fifty-five, again.

(Slide)

MR. VAN den BOSSCHE: There has been a case of reset out of neutral due to a wrong trim indication at the trim indicator. And there has been switch failures as well.

Corrective actions were -- were identified as mandatory modifications. So the trim geometry has been changed to what I've shown on the slide before.

Dimension of the switch shaft and of the knob have been changed to make impossible the lack of clearance with no adjustment.

The rudder trim has been inhibited when the autopilot is active to prevent otherwise hidden by the autopilot operation.

And a third switch stage has been added to prevent one failure of the switch resulting in the -- in the runaway.

Similarities with Flight 587, first, as I said before, there is no evidence of a one point degree per second rudder movement. The autopilot was never engaged. The slats were retracted, by the way. All of the mandatory modifications were incorporated. And if there had been a trim unaware the pilot reaction would have been opposite.

MR. MAGLADRY: Okay. I have no questions.

CHAIRMAN CARMODY: Mr. Magladry, I'm wondering if this would be a good point for us to take a short break. I think the witnesses have been under questioning for over an hour and I think we could use a little break.

Do you have just one more item you want to finish before we do that or is this a good time for you?

MR. MAGLADRY: I have two questions with regard to the feel system and then we'd move on to the rudder travel limiter.

CHAIRMAN CARMODY: All right. Well, do you want to do the two questions? And then we'll go to the last.

MR. MAGLADRY: Mr. Annibale, could you please display Exhibit 9-F, page six?

(Slide)

MR. MAGLADRY: Mr. Chatrenet, can you please describe this illustration?

MR. CHATRENET: Okay. So the -- this shows the basic characteristics of forces versus displacement which are provided by the springs in the artificial feel unit.

So first, you see around zero deflection what we call the threshold or breakout force. This is roughly about 22 pounds. This breakout force has two objectives. The first one is obviously to prevent any inadvertent input on the control on the rudder pedals that might result from the motion of the pilot and so on.

MR. MAGLADRY: So you must push with 22 and a half pounds before the pedal will start to move?

MR. CHATRENET: Yes, exactly. Exactly. We must push this amount of force before there is any perceptible displacement.

So the first objective is to prevent any inadvertent input on the rudder control. And the -- this will be probably discussed or developed later on, but this is an appropriate force in order to avoid this kind of unintentional input. And we have some guidance and some evidence that this is an appropriate force.

The second role of the breakout force is to provide a positive return to zero deflection or actually to the trim deflection whenever the pilot would release the pedal. So it should be very simple for the pilot to come back to the zero deflection position or to the trim position just by releasing the feet from the pedal. And thanks to the breakout, this will be positive and back to this -- to this position.

So this is for the breakout forces about 22 degrees.

Now, further to these forces, you have a gradient of force versus rudder deflection from the breakout to the maximum force. And this is in order to provide the pilot with the feedback of what are the control inputs on this axis.

At this stage, to get a better understanding, we must introduce some kind of a notion of closed loop control inputs. What does it mean, closed loop control inputs. It mean that it's a continuous tuning of the control inputs made by the pilot in order to -- to obtain the desired outcome of the aircraft motion.

This is the basic I would say piloting technique, closed loop control input by opposition to open loop control input for which the pursued objective is to get a given deflection and generally a maximum deflection.

So coming back to the gradient of forces beyond the breakout force, this is designed in order to provide precise control capability in case of closed loop control input only. This has nothing to see with open loop control input.

And for this, we must design the gradient of force in order to allow the pilot to get a precise control of the aircraft.

This is a part of the design of the flight control system which is main -- made in very close relationship with the pilots at the design stage, at the testing stage, whether on ground, on our iron bars, on our simulators, and later in flight. And this is obviously one of the characteristics which contribute to the handling qualities of the aircraft and which are even discussed with the pilots community later on after the entering to service of the aircraft.

CHAIRMAN CARMODY: Mr. Magladry, excuse me. I'm going -- I'm going to stop you now.

MR. MAGLADRY: Yes.

CHAIRMAN CARMODY: We have a large number of family members who have just arrived and they want to come in. So I think a break would be appropriate now.

May I ask any NTSB employees who are in the audience to please return to your offices and watch from there because we may need the extra seats. Certainly come back later if there is space, but the families have come down to hear this and I don't want them to be held out any longer.

So let's -- let's come back at about 10 of 12. Thank you so much. Sorry to break it off, but we'll return to it.

(Brief recess)

CHAIRMAN CARMODY: Mr. Magladry was questioning the witnesses, and I believe you were not quite finished, Mr. Magladry. So please resume.

Please -- please come in from the doors and close them. Thank you.

MR. MAGLADRY: Yes. I'd like to begin again with the questioning concerning the field characteristic curve.

Mr. Annibale, could you display that, please?

(Slide)

MR. MAGLADRY: Mr. Chatrenet, you described what this illustration presents. And the breakout forces for the pedals are around 22 pounds. And it appears that to achieve maximum deflection of 30 degrees of rudder, it would require approximately 75 -- 67 pounds.

My question is, how does Airbus determine this range of forces?

MR. CHATRENET: Actually, I was not in charge of flight control at the time the design was made. But at least I can tell you about what I've heard about the reasons.

We -- we had a good record of good handling qualities and good perception when we designed the A-

300-B2-B4, which was the aircraft before the A-300-600. And of -- of relevance were that on this aircraft the control forces in roll and the control forces in yaw were perfectly consistent and matching together. This is important. I'm not a pilot, but I can understand that from a pilot point of view roll and yaw axes are related. And it is important that the forces on the roll axis and the forces on the yaw axis must be well balanced, well harmonized.

This was the case on the B2-B4, and we had a good record of pilot satisfaction in terms of consistency between the two axes.

We had nevertheless a suggestion coming from the pilots that the roll control forces might be a bit lower in order to allow for more precise or ease of piloting. And it was at this state -- at this stage a general tendency to go to lower forces, lower forces because on the control point of view it allowed for more precise control of the flight path.

So we decided when going from the A-300-B2-B4 to the A-300-600 to lower the roll forces by roughly something like 30 percent. And this was made possible thanks to the introduction of the electrical control of the spoilers which reduce the amount of friction in the control and therefore which allowed for less control forces on the roll axis.

And we have basically kept the same consistency that we had between the roll and yaw axes and which gave satisfaction on the B2-B4 aircraft, and we kept the proportion for the A-300-600. This is how we have determined the maximum forces for the rudder feel system of the A-300-600-R.

MR. MAGLADRY: If I understand you correctly, the -- on the -- you -- you commented on the roll system. Is it true also that the A-300-600 rudder pedal forces are less proportionally than the B2-B4?

MR. CHATRENET: Yes. By -- the proportion of the reduction of the roll efficiency.

MR. MAGLADRY: Thank you. Are there any certification requirements that drive the determination of your rudder feel forces?

MR. CHATRENET: The -- the only certification requirement we have only stipulate maximum level of forces.

MR. MAGLADRY: And do you -- do you recall what those are? What the maximum forces are?

MR. VAN den BOSSCHE: On the -- on the pedals, the -- guidelines give us a maximum of 56 decanewtons, which is 120 pounds. This was the maximum given by the guideline.

MR. MAGLADRY: So you're saying that it can't exceed 120 pounds approximately to achieve full displacement of the rudder is the only certification requirement relevant to this.

Okay. I'd like to proceed with some questions about the rudder travel limiter design.

MR. CHATRENET: Okay.

MR. MAGLADRY: Mr. Annibale, can you please display Exhibit 9-D, page two?

(Slide)

MR. MAGLADRY: This is an illustration schematic of the rudder travel limiting system on the A-300-600. Can you please walk us through this illustration, Mr. Chatrenet?

MR. CHATRENET: Maybe Mr. Van den Bossche will --

MR. MAGLADRY: Mr. Van den Bossche?

MR. CHATRENET: -- than me.

MR. VAN den BOSSCHE: May I use our own picture? Therefore I will be able to use a pointer.

(Pause)

MR. VAN den BOSSCHE: So this is about the same.

The variables stop consist in -- first in this lever, which is connected to the output of the summing mechanism which I have talked about before. This lever is hinged around a fixed point, and the other end of the lever is connected to the linkage to the servo actuators.

This lever has got some kind of a roller here which is -- which however is limited by the V-shaped cam of this arm. This arm is hinged on structures there and can be moved by this actuator back and forth. And it also drives the position transducers.

When the V-cam is shown in this position, the travel of this lever is relatively large, from this point to that one. And when the V-cam is moved to the right, the travel is limited to this -- is limited to this reduced stroke. This the low speed, this is the high speed.

The actuator includes a screw, an irreversible screw, that is such that when a load is applied on the -- on the cam, the cam is not pushed back by the pilot load.

MR. MAGLADRY: Is it true to describe this system as a -- a system which limits the pedals in order to limit the amount of rudder restriction?

MR. VAN den BOSSCHE: No. This limits the sum of the pedal movement plus the yaw damper movement.

MR. MAGLADRY: So it's the combination of the two?

MR. VAN den BOSSCHE: Yes.

MR. MAGLADRY: The yaw damper, which is always active, and the -- and the --

MR. VAN den BOSSCHE: Yes.

MR. MAGLADRY: -- input provided from the pedals are summed and then it is restricted at this point?

MR. VAN den BOSSCHE: Yes.

MR. MAGLADRY: And those -- those plots above noted as "feel limitations computer," this is the -- can you please describe that?

MR. VAN den BOSSCHE: This is the low which has been explained earlier. This is a limitation in rudder degrees versus air speed. From zero to 165 knots, the maximum rudder movement is 30 degrees. And then it is reduced according to the slope to a minimum of point -- 3.5 degrees at 395 knots.

MR. MAGLADRY: Why do we limit rudder deflection at higher air speeds?

MR. CHATRENET: So, at this stage I may answer. From a handling quality point of view, the main use of the rudder or the big deflection needed from the rudder are needed at low speed. It is for -- some cross wind landing, which is usually at low speed, or for compensating the asymmetry from an engine failure. And the engine's first asymmetry is also at its biggest value when the aircraft is flying at low speed, which means that when the rudder is designed in order to provide this maximum rudder deflection at low speed, the rudder which is needed at higher speed is smaller. And on our Airbus aircraft, the border is set roughly at 165 knots or 170 knots.

At higher speed than this 165 knots, the maximum rudder deflection is not necessary. Therefore, the variable stop is there to limit the rudder deflection. And this limit has been set according to handling qualities consideration.

Mainly, the curves are low, the rudder deflection which is sufficient to provide, first, the rudder deflection which is needed to compensate statically for an engine failure and, second, to provide for yaw damper activity on both sides of the static rudder deflection needed for compensating an engine failure. This is how the curve is determined at the speed higher than the 165 knots speed.

MR. MAGLADRY: So for instance, I notice you chose one point there at 9.3 -- the rudder is limited to 9.3 degrees at what appears to be 250 knots.

MR. CHATRENET: Yes.

MR. MAGLADRY: And as you have done the analysis, that is -- that is the amount of rudder you need to compensate for an engine out at -- at 250 knots plus --

MR. CHATRENET: Plus what is needed for the yaw damper to operate on both sides of the static rudder deflection.

MR. MAGLADRY: Is it exactly 9.3 or is it something less than that value? Is there a margin you've included?

MR. CHATRENET: The margin is basically what is needed for the yaw damper to -- to operate.

MR. MAGLADRY: Is this method driven by a certification requirement that -- that you have the ability to compensate for engine out at this air speed plus yaw damper? Or is that something -- a formula that Airbus derived?

MR. CHATRENET: No, it is -- these are basic design principle to -- to allow both capability to compensate the engine failure and still yaw damper activity.

MR. MAGLADRY: Is this -- the yaw damper provides turn coordination and dutch roll and engine out compensation. Which aspect -- is it the engine out compensation that --

MR. CHATRENET: No. The engine out compensation coming from the AVC computer from the yaw damper is only working during a go-round with the autopilot engaged which is at very low speed. So at higher speed, at speed around 165 knots and above, it is only for dutch roll damping and turn coordination. And --

MR. MAGLADRY: So --

MR. CHATRENET: -- turn coordination basically is no longer active, if you like, at speed above 250 knots. So the turn coordination is working between 165 knots and 250 -- and lower speed as well.

MR. MAGLADRY: Okay. So if I understand this correctly, it's both at -- that profile is the sum of what you would need for -- to compensate for an engine out at a particular air speed --

MR. CHATRENET: Yes.

MR. MAGLADRY: -- plus if you were to perform a coordinated turn?

MR. CHATRENET: Yes. Plus a capability to -- to damp the dutch roll -- of the aircraft in turbulence.

MR. MAGLADRY: And how big is that? Can you put -- can you quantify how much rudder is necessary for a turn coordination --

MR. CHATRENET: Yes.

MR. MAGLADRY: -- at those air speeds?

MR. CHATRENET: Precisely it would be difficult just from memory. We have made a study. We have a technical note which describe and which substantiate the -- the design of this curve. And this could be given for the record if needed.

To give you, I would say, half figures, when -- when the TLU is giving basically 10 degrees, there is something like around seven degrees needed for engine out compensation and three degree for yaw damper activity. But I would prefer to give the exact figure and the actual figure through our technical note that might be provided for the record.

MR. MAGLADRY: Madam Chairman, is it -- would it be acceptable for him to present the data from a technical note that's not currently an exhibit?

CHAIRMAN CARMODY: There's not an exhibit available to the rest of the parties?

MR. MAGLADRY: Do you have an illustration --

MR. CHATRENET: No, not -- not available here, but later on during the -- during the public hearing we could -- we could give you a copy of this note.

CHAIRMAN CARMODY: Is it something that could be reproduced now? If you have a copy, perhaps we could have it reproduced.

MR. CHATRENET: Not -- not right now but --

CHAIRMAN CARMODY: Oh.

MR. CHATRENET: -- today or tomorrow it could be done.

CHAIRMAN CARMODY: What -- I'm sorry. What is it you're presenting then? I thought you were presenting it now but you have no copy?

MR. MAGLADRY: He's presenting it from memory and --

MR. CHATRENET: Yes.

CHAIRMAN CARMODY: All right. I see, I see.

MR. MAGLADRY: So to summarize, I guess, Airbus has -- has chosen this formula not because of the certification requirement that -- that it's the sum of the -- the rudder needed to compensate for an engine out plus, on top of that, you'll be able to make a coordinated turn.

MR. CHATRENET: And to damp the dutch roll in case of turbulence, that's right.

MR. MAGLADRY: Okay. Thank you. Now I'd like to refer to -- we don't need to display them, but I'd like to refer to Exhibit 9-B, pages four through six. This describes the A-300-B2-B4 rudder travel limiter configuration. This is the -- the B2-B4 preceded the A-300-600. Can you please describe the difference in operation of these two rudder control systems?

MR. CHATRENET: Yes. If you like, I have some -- some slides to show the difference between the two systems.

MR. MAGLADRY: Please.

(Slide)

MR. CHATRENET: So I have said that maximum rudder deflection was only needed at low speed and that it was appropriate then to limit the maximum rudder deflection at high speed. There are basically two main principle of limitation I am aware of. The first one is known as the variable ratio type of device. With this type of device, the rudder pedal inputs comes here. And then through a variable ratio which is driven by speed, the output of this device is only a ratio of the input. Basically, to have an order of magnitude, this ratio would be one at very low speed and something like one above six at high speed, which means that -- that the ratio is divided by something around six.

And then, the output of this variable ratio device will drive the input rod of the rudder servo actuators. This translates into a characteristic between the achieved rudder deflection as a function of the rudder pedal deflection. At low speed for a given rudder pedal deflection, you get the maximum rudder deflection. And as speeds -- as speed builds up, you get a lower deflection from the same rudder pedal deflection.

This is a variable ratio type of device. This is the type of device which is fitted on the B2-B4 type of aircraft.

MR. MAGLADRY: To summarize, I guess, is that -- is it true that you would be able to -- the way that the pilot would be able to distinguish this from the -- the A-300-600 system is that at high air speeds the pilot would push -- if he chose to push full on the rudder, the displacement would be the same as he would experience on the ground where he had full authority of the rudder, is that true?

MR. CHATRENET: This is true, yes.

MR. MAGLADRY: Okay.

MR. CHATRENET: Then, the second type of device is called the variable limit, and this device is associated with the fixed ratio type. So in this case there is a constant ratio basically of one, if you like, between the rudder pedal's output and what is driving in fact the input rod of the servo actuators. And the limitation is obtained by the set of stops which I would say with their amplitude is varied according to the speed.

So in this case, you have the same ratio between the input and the output of the device but the range of displacement which is allowed by the device is reduced as the speed increases and is translated into the same kind of chart where then you have the rudder pedal deflection and the rudder deflection. And you see that the ratio is always the same, which means that you have always the same gain between your pedal deflection and the rudder deflection but the available range is reduced when the speed is up.

MR. MAGLADRY: Okay. And equating that again to what the pilot would feel or how he would understand the difference in the two systems, if the pilot pushed at high air speeds on this type of system, the pedal would be restricted for less travel than at lower air speeds?

MR. CHATRENET: This is true.

MR. MAGLADRY: Okay. Thank you.

MR. CHATRENET: So just -- just to comment about this -- both types, both types are obviously functional. They are certified on various type of aircraft. We have said earlier that the B2-B4 is fitted with a variable ratio type whereas the A-300-600-R is fitted with a variable limit fixed ratio. This device, as has been explained, is also monitored.

The variable limit fixed ratio type of device is most commonly used. We have made an approximate computation which show that the 9000 aircraft out of 12,000 aircraft in service are flying with variable limit or fixed ratio types or similar type of device where there is a fixed ratio between the rudder pedal and the rudder.

And we have -- we have selected for the A-300-600-R the variable limit device because of the advantages of the system. And the system first offers by principle a constant ratio between the rudder pedals and the rudder deflection which is basically consistent with what we have between the control wheel and the ailerons.

So as I said, the -- from a handling quality point of view, roll and yaw axis are to be considered together. And it's important to -- to have some kind of consistency between the two axes. This is a way to achieve some consistency between the roll control and yaw control by providing the same type of constant ratio between control wheel and aileron on one side, between rudder pedal and rudder on the other side. It is a less complex system. The variable limit is far simpler. And the failure modes -- and the failure modes of the system are less severe.

MR. MAGLADRY: Can you elaborate on the failure modes?

MR. CHATRENET: The failure modes -- the -- the advantage of the variable limit is that any failure mode will not be an active one. It will not change the -- the rudder deflection without any rudder pedal movement or will not affect the gain between the rudder pedal and the rudder, whereas with the variable ratio we have to take care of this kind of failure that deserves a particular -- particular treatment in order to avoid the consequences of the failure.

Remember that normally the safe position of all of these device is to come back to a low speed configuration when you provide the pilot with the maximum authority. If -- with the variable ratio, by doing that, you would multiply the -- the authority of the pilot with a factor of six, which you must do with care before -- to avoid this kind of I would say active consequence of the failure.

With the variable limit, the failure mode will just open the limit between no change, any -- of the aircraft at the time of the failure.

MR. MAGLADRY: Are -- are you saying that there are failure modes of the ratio type device that actually will move the rudder?

MR. CHATRENET: If they are not properly addressed by the -- by the failure analyst, yes, it could move. For instance, if you have a trim position, say a trim position of half a degree in close, for instance, and if your -- if your variable ratio changed to low speed instantaneously, this rudder deflection would change from 0.5 degree to three degree at the time of the failure.

MR. MAGLADRY: I see.

MR. CHATRENET: I'm not saying that -- that it is -- must be taken into account properly in the design of the -- of the system in order to avoid this kind of failure.

MR. MAGLADRY: Now, Mr. Annibale, could you please display Exhibit 9-B, page five?

MR. CLARK: Let me ask a quick question, sir. You made a comment earlier about harmony between the pitch and the roll controls. Would you explain what you mean by "harmony"?

MR. CHATRENET: I was referring -- referring to harmony between roll control and yaw control, between the --

MR. CLARK: Oh.

MR. CHATRENET: -- control wheel and the yaw -- and the pedal.

MR. CLARK: And what do you mean by "harmony"?

MR. CHATRENET: It's basically when you have the same fixed ratio between the control wheel and the ailerons and between the rudder pedal and the rudder. The perceived efficiency of these controls when the speed will build up is consistent, which means that for the same amount of control wheel you will get higher aileron efficiency when the speed builds up. And similarly, for the same rudder deflection, you will have higher efficiency when the speed builds up. So both axes behave similarly.

MR. CLARK: Is that a force issue or a position issue? To achieve harmony, is it position or force?

MR. CHATRENET: It should be a force issue. From the pilot point of view, it should be a force issue.

MR. CLARK: And you may not be the right person to ask, but how much consideration of stability and control goes into the -- the design schedule that you've put in, both from the control loading and from the limiter?

MR. CHATRENET: Could you -- could you --

MR. CLARK: Sure. The -- what considerations regarding stability and control -- what -- what is evaluated about stability and control in this design?

MR. CHATRENET: So basically, the flight control design is first designed with pilots during the design phase. Then it is tested on the ground before the aircraft actually flies. We have simulators to test it. Then it is very comprehensively tested during flight test where we made hundreds of maneuvers which are similar to the maneuvers of the aircraft in service and hundreds of other maneuvers which are far beyond what the aircraft will be expected to see in service. And it's during all this process that the flight control people and pilots are checking that the design is appropriate.

To develop this point more in-depth, I think that following witnesses will be more expert than me to -- to discuss this point.

MR. CLARK: Fair enough. Thank you.

MR. MAGLADRY: Could we display that -- that illustration again?

(Slide)

MR. MAGLADRY: This illustration is somewhat complicated. But what we've presented here is both Airbus's estimate of what the -- the rudder was doing during the last few seconds of the accident flight, what NTSB's best guess -- best analysis has produced for where the rudder is during that flight. I've also included a simulation of what the yaw damper was doing from models of the yaw damper system.

There are two -- two points that I would like you to comment. The red trace is the Airbus simulation of the rudder. And at -- there are two points towards the end there where the trace appears to exceed the rudder travel limiter. The rudder travel limiter is that line that brackets both of the traces and ends up at 7.57 there. Yes, where you're pointing is one -- is the first one, and then the next one is above that.

Can you comment on these places where we see the -- it appears that the rudder is exceeding the rudder travel limiter?

MR. CHATRENET: Okay. So for the -- for the first -- for the first exceedance, we show that the rudder deflection is basically constant and is consistent with the theoretical travel -- rudder travel limiter at the very beginning of the -- of this short sequence of time. After that it is constant.

In order to -- to explain this point, we are ready to -- to anticipate on the following explanation. But Mr. Van den Bossche explained that the TLU is driven by electrical motor. And this TLU has capability to move the variable stop, the cam which builds the variable stop, up to a certain amount of force which could react against the input of the rudder command, which means that if the rudder controls are already applied against the stop and if they are applied against the stop with a given level of force, then the electrical motor can still drive the cam and move the stop as a function of speed up to a certain level of force applied.

If the force is applied on the control in excess of this limit, then the electrical motor which drives the TLU which actually stop moving the TLU. And this is what happens during the -- the first event you have shown on the screen.

So the -- if you like, the -- the TLU should move according to the speed, should close a bit according to the speed, but because of the forces which are applied on the control, the -- the servo actuator which moves the cam can no longer move the cam because the forces are too high.

The last point --

MR. MAGLADRY: So you're saying you -- the -- the variable stop actuator was stalled by the forces applied by --

MR. CHATRENET: Actually, it was stalled by the forces.

MR. MAGLADRY: -- by the pedal forces or yaw damper forces?

MR. CHATRENET: Yes. The last -- the last point which shows a bigger discrepancy is explained by two facts. Is that a third -- the event we have just mentioned, when the forces has been raised from the control input, then the -- the -- variable stop actuator, the actuator of the TLU started to move again and to follow the speed profile. It started at the maximum deflection rate. But before -- because it was stalled for a certain period of time, it was still behind a bit the theoretical schedule. This is the first explanation.

The second explanation is we are exactly in the time of the estimated separation of the fin from the fuselage. So in this period of time just -- we can imagine that even if the TLU was actually holding firm the control input inside of the fuselage, at the time of the separation when the fin bended and went away, the control rod was likely to be under tension -- under tension. And this tension, it's -- it is sufficient to allow or to consider four millimeter of deformation of tension to explain the difference -- the difference we see between the theoretical TLU and the -- the estimated rudder position.

MR. VAN den BOSSCHE: May I come back to a detail, Mr. Magladry?

MR. MAGLADRY: Certainly. Yes.

MR. VAN den BOSSCHE: You said that the actuator -- variable stop actuator could be stalled either by the force from the pedals or the yaw damper. No. The yaw damper with no force on the pedal cannot stall the variable stop. You need a force on the pedal anyway.

MR. MAGLADRY: Okay. So the pedal -- you would have to have the pedal against the stop and -- and -- to get the pedal stop, it could be the sum of the pedal input and the yaw damper input to get it to the stop. And then you would have to push harder with the pedal to achieve the high force. And do you know what that force at the pedal would be to stall the actuator?

MR. VAN den BOSSCHE: The force at the pedal is about 110, 120 pounds.

MR. MAGLADRY: So to achieve that characteristic, you're saying that a force would have to be applied of 100 -- approximately 110 to 120 pounds at the pedal. Along those same lines, discussion of force, the dark green plot at the -- at the top where -- where it shows -- where it's exceeding the rudder travel limiter, you move the cursor to the left, yes. And to that peak. This -- this plot is flight data recorder pedal position scaled so that it is what rudder would be achieved if you put in the pedal that was shown on the flight data recorder. It's also summed with the estimate of the yaw damper.

So this is an estimate of what rudder was commanded by those two combinations because we've shown that the rudder command is the sum of the pedal and the yaw damper. But yet, it exceeds the rudder travel limiter by approximately five degrees at that position. Can you explain this?

MR. CHATRENET: Yes.

CHAIRMAN CARMODY: Excuse me. Would you be sure and point to whatever it is you're explaining because it's a little hard to follow sometimes.

MR. MAGLADRY: Yes. We have someone moving the cursor to the -- to the exact peak. But it's the dark -- dark green trace --

CHAIRMAN CARMODY: Mm-hmm.

MR. MAGLADRY: -- in -- in the illustrations. This -- by the way, I'm sorry, this is Exhibit 9-B, page five, if you want to follow along.

And so can you explain why we aren't achieving what was commanded there by the pedals and the yaw damper?

MR. CHATRENET: Okay. I admit it's -- it's a complex figure, but there is a lot of information in it.

In order to get a better understanding, two things might be reminded before. First important thing is that the order coming from the rudder pedals will be added to the order coming from the yaw damper. And the sum of those is limited by the TLU, which means that you have always the relationship, which means when -- when the rudder is on the TLU, which is the case on several time sequences, you have always a relationship -- rudder, pedal, rudder plus yaw damper equal TLU when it is on the stop.

The second things we have to be remind in order to understand this figure is that the linkage between the rudder pedal, which are in front of the fuselage at the cockpit location, and the place where the rudder pedal input is summed with the yaw damper, which is at the rear of the fuselage, this linkage has, like any mechanical linkage, some kind of elasticity.

We could assume, for instance, that the rudder pedals are deflected and bring the rudder to the stop. In order to deflect the rudder pedal to go in this position, you have to apply the forces which are the forces of the artificial feel device. Then, if you apply additional forces and a significant one, you can somehow play with the elasticity of the linkage.

Also, the rudder would not move further. Also, the rudder is still on the stop by pressing hard on your pedal. You can get a rudder pedal position as recorded on the -- the FDR because the rudder pedal position recorded is sensed at the cockpit location. You can get a deflection that is higher than the deflection you have at the back of the fuselage when the sum is made with the yaw damper to go to the TLU.

And this kind of elasticity, which is a basic behavior of any mechanical linkage, is characterized so you can get a relationship between how many pounds give how many rudder of elasticity. And this has been measured with quite good confidence during the last ground tests that have been made on Flight 701.

So we have to be remind of these two aspect. The sum of the yaw damper plus the rudder pedal input is limited to the TLU. And then, there might be some elasticity.

So when -- when bearing in mind this, the -- the apparent discrepancies that you are showing at least on three occasions can be accounted for by this elasticity, which means that the pedals -- once the rudder was coming on the stop, the pedals have been pushed further by control forces applied on the pedal.

MR. MAGLADRY: And have you done -- you spoke about these tests. Can you estimate what force on the pedals would be required to achieve this kind of circumstance where you have -- you're commanding 16 -- 16 degrees of rudder but the rudder is only positioned at 11 degrees?

MR. CHATRENET: Yes.

MR. MAGLADRY: And what would that --

MR. CHATRENET: We have derived this characteristics from the ground test. And they are in the area of 130, 140 pounds of force, which is, by the way, consistent with what Mr. Van den Bossche said earlier, that beyond 110 pounds of force we expect that the TLU actuator would stall.

MR. MAGLADRY: Can this -- can this characteristic be achieved by a yaw damper or a yaw autopilot back driving the system?

MR. CHATRENET: No. This gives further evidence that any type of failure coming from either the yaw damper or the autopilot actuator or even the rudder trim would have moved the rudder obviously, might have moved the rudder pedal, but in which case they could not move the rudder pedal further than what is needed to be consistent with the rudder deflection. We cannot imagine how the pedal motion would be bigger than what is happening at the rear of the aircraft because of potential failure of the -- yaw actuator autopilot system, for instance.

MR. MAGLADRY: So you've -- you've examined data which tells you that a back drive from -- from the yaw autopilot will not cause the pedals to exceed --

MR. CHATRENET: To exceed this --

MR. MAGLADRY: -- normal relationship between pedals and rudder? It will -- it will --

MR. CHATRENET: Absolutely. You are right.

MR. MAGLADRY: Okay. There's one more thing that I'd like to -- to describe on this. And this is -- the light green trace is the yaw damper, our estimate of the yaw damper command from the accident airplane estimated yaw rates. And at time 8:45 approximately, where the cursor is, the yaw damper -- and as we move to 8:48, the yaw damper is attempting to command from four degrees right rudder to four degrees, approximately, left rudder. But you notice also during that time frame the rudder stays at 11 degrees -- approximately 11 degrees right rudder.

And as we talked about extensively, the rudder position is the sum of the pedal input and yaw damper input. This illustrates is that -- that pedal input can negate the effect of the yaw damper command. And -- and my question is, are there advantages to designing a system with this characteristic?

MR. CHATRENET: First thing is the yaw damper's apparent lack of efficiency. You have said that the -- the -- looks like the yaw damper is no longer active, is only happening if forces are applied on the rudder pedal, which means basically that the rudder pedals are moved by the pilot in a way that is actually compensating what the yaw damper is doing.

So it needs the pilot to -- to apply significant forces to apparently cancel the effect of the yaw damper. This results from a design choice or design principle to limit the sum of the pedal order plus the yaw damper by the TLU and to -- to put the rudder travel limiter, the TLU, at the end after adding the yaw damper order rather than before.

This is a design principle. It is justified by two facts. The first one is that the TLU always offer sufficient margin to allow for normal operation of the yaw damper. In these circumstances, for instance, the yaw damper will command for between plus or minus four degree of rudder and the TLU is set at around 10 degree, which means that every time the TLU is set in order to allow full activity of the yaw damper.

It is even true in the case of one-engine-out condition. Even if we are in a one-engine-out condition, roughly speaking it would need seven degree of rudder and it would still allow for three degree of yaw damper activity.

So for any expected operation of the aircraft, the TLU always allows for the yaw damper to be active.

Now, if we assume that in some unexpected circumstances the control of the aircraft would require the full rudder deflection, say 10 degree in these circumstances. Ten degree is consistent with what is done for the design load and so on. So if we assume that some unexpected condition would require the rudder to be deflected at 10 degree. We can imagine, for instance, a thrust reversal deployment in flight or a collision with another aircraft.

In this case, we prefer to give higher authority to what is coming from the rudder pedal than what is coming from the yaw damper. It would not be appropriate to say that if the aircraft is requiring 10 degree of rudder deflection. If the airplane is designed for 10 degree of rudder deflection, we would only allow the aircraft to give seven degree because the yaw damper would be removing three degree. So it's a -- it's a question of design principle.

More authority is given to the rudder pedal than to the yaw damper. And the whole system is consistent. The loads are computed accordingly. The failure of the yaw damper are contained accordingly because in this case the failure of the yaw damper anyway are contained by the TLU. So this is irrational for our architecture.

MR. MAGLADRY: I have a specific question about the -- the rate -- the response of the variable stop actuator.

Mr. Annibale, can you please display Exhibit 9-B, page seven?

(Slide)

MR. MAGLADRY: This illustration is derived from flight data recorder information about the air speed of the accident flight. I've taken this information and taken the derivation of the -- of the air speed to get the rate of change of air speed. And we talked about the variable stop actuator is a jack screw that adjusts the travel limiter.

Would the variable stop actuator be able to keep up with the rate of change of air speed that occurred in this flight?

MR. VAN den BOSSCHE: The maximum speed -- maximum rate of the actuator is one millimeter per second or 0.04 inches per second in this area of the known linear limitation curve, this is 240 knots. This is equivalent to a speed variation of four knots per second. The peak that I can see at the time -- one is of about four knots per second. So the actuator is capable of following such movements.

MR. MAGLADRY: And so for all intents and purposes, up till -- excluding that one spike at four knots, it appears to be able to keep up with the rate of change of air speed up until the point of -- of approximately eight -- FDR time 8:50 --

MR. VAN den BOSSCHE: Yes.

MR. MAGLADRY: -- where it spikes up to 14 degrees per second.

MR. VAN den BOSSCHE: Yes.

MR. MAGLADRY: Is that significant?

MR. VAN den BOSSCHE: I don't know where the --

CHAIRMAN CARMODY: Excuse me. We can't hear you, Monsieur. Would you speak a little closer to the microphone? Thank you.

MR. VAN den BOSSCHE: Well, at this point, the actuator will not be able to follow. And I guess this is close to the vertical stabilizer separation.

MR. MAGLADRY: Mr. Chatrenet, do you feel that -- that the rate of change of air speed is significant, that inability to -- the VSA to keep up is significant at that point?

MR. CHATRENET: No. For what we have -- for what Mr. Van den Bossche has explained, the four-knot-per-second capability is well capable of keeping up with all the speed variation we see basically up to the estimated time of feel separation. The speed variation is well contained within the -- the -- capability.

MR. MAGLADRY: This may be difficult to calculate in your head but I know you're very capable. Can you estimate what the maximum discrepancy would be between the theoretical value and the -- and the -- and the value due to its inability to keep up? In other words, what's the maximum amount of error at this point in terms of allowable rudder?

MR. VAN den BOSSCHE: I'm not sure I understand the question.

MR. MAGLADRY: At a theoretical value of 268 knots, the rudder travel limiter should be at a certain position.

MR. VAN den BOSSCHE: Mm-hmm.

MR. MAGLADRY: But because the rudder travel limiter cannot keep up, what position would it be in?

MR. VAN den BOSSCHE: The rate of the actuator depends on the load which is applied on the variable stop and rate reduces when the load is high. So to -- to fully understand what happens in terms of variable stop position variation, it should be associated to the load on the pedals. I can't tell you more.

MR. MAGLADRY: Okay. Thank you. Can you please describe any in-service events that occurred with rudder travel limiting systems that are relevant -- may or may not be relevant to this accident investigation?

MR. VAN den BOSSCHE: We have been reported once a variable stop actuator failure which was supposed to be associated with a reported stiff pedal thing. The teardown examination of the actuator has shown a bearing hot point or seizure to a point that the unit was quasi-jammed. And it was quasi-jammed at the position of 26 degrees of rudder deflection. So the actuator failure has been explained. The stiff rudder feeling could not be explained from this figure.

MR. MAGLADRY: Did that occur in flight or --

MR. VAN den BOSSCHE: It occurred in flight. And of course, there has been an associated warning.

MR. MAGLADRY: Is that an oral warning?

MR. VAN den BOSSCHE: Yes, it was.

MR. MAGLADRY: Mr. Chatrenet, did you get an opportunity to review the CVR transcript?

MR. CHATRENET: Yes.

MR. MAGLADRY: And it would indicate any oral warnings or failures of these systems. Did you notice any oral warnings prior to the --

MR. CHATRENET: No.

MR. MAGLADRY: -- fin separation?

MR. CHATRENET: No. We did not -- not notice any single chime or oral warning before the estimated time of the fin separation.

MR. MAGLADRY: I'd like to move on to the rudder servo installations, and that will be my final area of discussion. Can you please describe the operation characteristics of the rudder servos?

MR. VAN den BOSSCHE: We have three rudder servo actuators.

MR. MAGLADRY: Could you pause just for a moment?

For anyone that would like to follow along in the -- in the exhibits, Exhibit 9-E, pages one through four provide illustrations of the rudder control system.

CHAIRMAN CARMODY: Thank you, Mr. Magladry. What were the pages again, please? 9-E?

MR. MAGLADRY: 9-E, one through four.

CHAIRMAN CARMODY: One through four. Thank you.

(Pause)

MR. VAN den BOSSCHE: Are you going to display the illustration?

MR. MAGLADRY: I don't think it's necessary. I think everyone has the illustration. Unless you -- okay. Unless you think it augments your presentation.

MR. VAN den BOSSCHE: So there are three servo actuators which were working -- which are working in parallel, three simultaneously active. And they are controlled from the variable stop output by control rods, the input rod of each of the actuator being a spring rod.

The maximum surface deflection allowed by this actuator is plus or minus 30 degrees. That corresponds to the stops on the linkage. And there is a slight over-travel beyond 30 degrees to reach the position where the piston bottoms the cylinder.

The actuator force is 21,000 pounds for each actuator. And the rate of the rudder when the three actuators are active, which is a normal case, is 60 degrees per second.

CHAIRMAN CARMODY: Excuse me. Was that six-zero?

MR. VAN den BOSSCHE: Six-zero.

CHAIRMAN CARMODY: Six-zero, thank you.

MR. MAGLADRY: Why do you have -- this is kind of a general question. Why do you have three servos on the -- on the surface?

MR. VAN den BOSSCHE: We have three servos to deal with failure cases. The failure cases which are considered as engine out are engine non-contained burst. The effect of such a failure is first you lose an engine and then you lose -- you may lose another hydraulic system. So the airplane is in a asymmetry configuration, one engine, and may have lost hydraulic systems, one associated with the failed engine and the one which has been damaged by the debris from the burst engine.

In that case, you need the rudder to compensate the asymmetry. This is why we need three rudders from three independent hydraulic power sources.

MR. MAGLADRY: In that case, you would have one rudder, and it -- it would have the capacity to displace the rudder at -- up to its capacity?

MR. VAN den BOSSCHE: The full deflection -- is -- is possible.

MR. MAGLADRY: With three actuators, you have a lot of force capacity. At any point during the flight envelope, can air loads stop the three rudders -- rudder actuators from achieving the commanded position?

MR. VAN den BOSSCHE: No. In any normal configuration the air loads are lower than the sum of the three servo actuator forces.

MR. MAGLADRY: Do you need this capacity of the actuators? Could they be reduced and the safety of the airplane be the same?

MR. VAN den BOSSCHE: The actuators are sized for compensating the engine failure. And there's a condition that I've described before. They cannot be reduced.

MR. MAGLADRY: What about the rate of these actuators, 60 degrees per second? I noticed earlier that the yaw damper is limited to 39 degrees and I believe the autopilot is limited to 34 degrees. Why do you have the actuators that can achieve rates of 60 degrees?

MR. VAN den BOSSCHE: We do not need 60 degrees per second, but the actuators incorporate a damping function which is there to prevent the rudder to be blown back to its stops on the ground when the systems are not pressurized. And this damping function generates a resisting force. Because of this resisting force, when the rudder is equated with less than three systems, the maximum rate is reduced. And the requirement has been to keep a 15-degree-per-second rate in the event of double lightweight system failure. And the result of that is 60 when everything's normal.

MR. MAGLADRY: This is referring back to Exhibit 13-A, page 79. And this -- this illustration, as we discussed before, shows rudder pedal sweeps and rudder surface position.

Can we please have that displayed by Mr. Annibale?

(Slide)

MR. MAGLADRY: Are these rudder positions and rates consistent with normal operation of the rudder control system?

MR. CHATRENET: They are a pretty high rate of deflection. They are -- they are allowed for by the system. The system is capable of providing this 60 degree per second rate of displacement, but with my experience and knowledge, I would qualify them as pretty high rate of deflection.

MR. MAGLADRY: So these can be achieved by normal operation of the rudder servos but you'd say that -- you'd categorize them as high rates, is that true?

(No response)

MR. MAGLADRY: There's no need for you to comment on that. What I want you to comment on, is the system capable of producing these rates?

MR. CHATRENET: The system, when everything is operating, is capable of providing high rate of deflection, which is generally, from my own quality point of view, felt as a good picture of the system.

MR. MAGLADRY: My final question is, can you provide information on in-service events that are relevant -- may or may not be relevant to this accident investigation?

MR. VAN den BOSSCHE: The in-service event -- you mean on the servo controls or --

MR. MAGLADRY: On the servo --

MR. VAN den BOSSCHE: On servo controls.

MR. MAGLADRY: -- servo controls.

MR. VAN den BOSSCHE: The in-service event we have had on servo controls are force fighting issues. It's not exactly relevant but we can go through it if you like.

MR. MAGLADRY: Please.

(Pause)

(Slide)

MR. VAN den BOSSCHE: We found one case on the A-300-600 of servo control attachment fitting rupture. The cause of the rupture has been identified as some backlash in the input mechanism of one of the three units, generating a wrong input signal, generating force fighting, and a fatigue rupture of the attachment fitting.

To cope with that, a mandatory check of the desynchronization has been defined and is performed every 1300 flying hours. This check was basically defined for large synchronization and is being further refined to be able to detect some small desynchronization movement just due to free play.

MR. CLARK: If I may, what -- what motion did the rudder take when that failure occurred?

MR. VAN den BOSSCHE: When the failure

occurred, the motion is still held by the two valid servo actuators.

We have had other failures of the same family, I'd say, which were not servo control failures but spring rod failures resulting either in force fighting or rudder offset.

The event was -- was in sometimes the rudder remains partially deflected after takeoff. And the root cause of that has been identified as spring rod jammed, which means with the level of internal friction higher than the -- the spring force and jammed out of neutral.

The -- the discrete friction registered from two factors, internal corrosion and swelling of plastic components, of polyamete sliding components.

Corrective actions have been defined and have been made mandatory. The first was to increase diameter of the ring hose in the spring rod body and to change the material of the sliding components from polyamete to PTFE. And it was at this occasion that the first desynchronization check has been introduced to be performed every 1300 hours.

If we like to identify whether there is similarity with Flight 587, first the spring rods have been examined and it has been discovered that prior to the accident they were serviceable and were working. The spring rod modifications that I mentioned had been incorporated before the accident. And the rupture of the attachment fitting was static and not fatigue, as it would have been in the event of force fighting.

And in the event of an offset caused by these control rods, the pilot reaction would have been opposite in all.

MR. MAGLADRY: I guess I have one more question. Take -- take an event of remote failure of two servos and these two servos drive the rudder in a particular direction, overpowering one of the other servos. How would that be transmitted back to the pedals and in what proportion?

MR. VAN den BOSSCHE: I'm not sure I have understood. Could you rephrase that question? In which circumstance you --

MR. MAGLADRY: This is a theoretical circumstance --

MR. VAN den BOSSCHE: Yes.

MR. MAGLADRY: -- that you did not present here. If -- if there were some failure that caused two of the servos to drive in a particular direction --

MR. VAN den BOSSCHE: Yes.

MR. MAGLADRY: -- and overpowering the third servo, this -- this motion presumably would be transmitted back through the control linkage and -- and move the pedals. Can you quantify how much rudder motion would be -- would occur before -- before you'd see pedal motions?

MR. VAN den BOSSCHE: In that condition, the two valid servos would drive the failed servo through its pressure relief valve. So the two valid servos would be capable of driving the rudder with a reduced hinge movement capability. It means that it would be -- it wouldn't be possible to drive the rudder beyond a certain angle. But in no case there is by driving.

MR. MAGLADRY: Do you know how much -- say the rudder -- the rudder was driven to 10 degrees. Would the pedals be driven a proportional amount?

MR. VAN den BOSSCHE: I'm saying that the pedals cannot be back driven.

MR. MAGLADRY: Are there --

MR. VAN den BOSSCHE: I may not understand your question.

MR. MAGLADRY: Are there -- there must be -- there are stops on the rudder servo actuators.

MR. VAN den BOSSCHE: Yes.

MR. MAGLADRY: And as the servos displace, the stops would contact the control linkage and move the linkage and -- back to the pedals, is that true?

MR. VAN den BOSSCHE: Yes, if there was no hydraulic power at all. When driving the rudder you would be able to back drive the linkage through the input lever stops, that's correct. But in the circumstance you mentioned, which is two valid servos driving one failed servo --

MR. MAGLADRY: I'm sorry. Maybe I misrepresented that. It would be two failed servos. So they're not responding to a command from the pedals. They're -- they're runaway, I guess we would call it, or a hardover. And as those servos drive from -- away from the commanded position, they would pick up the linkage and back drive the pedals. And my question was, in what proportion -- if you had that instance of failure and you had 10 degrees of rudder as a result of two servo failures, what would be the result of the pedal displacement?

MR. VAN den BOSSCHE: I still have difficulties in understanding your failure conditions. Are you telling me that two servos could runaway, both together, and not the third one?

MR. MAGLADRY: That's the failure scenario that I'm --

MR. VAN den BOSSCHE: Oh, yes.

MR. MAGLADRY: -- theorizing.

MR. VAN den BOSSCHE: Yes, it's a very hypothetical case.

MR. MAGLADRY: Yes --

MR. VAN den BOSSCHE: And in that case, of course, the rudder could be -- the rudder control could be back driven --

MR. MAGLADRY: Yes.

MR. VAN den BOSSCHE: -- and the pedals would be behind the rudder position to an amount of four degrees, let's say.

MR. MAGLADRY: So is --

MR. VAN den BOSSCHE: If four degrees is a clear answer to the input lever stops plus stroke of the spring rods.

MR. MAGLADRY: So if we were to look at flight data from a -- from a -- this failure scenario, we would see the rudder move first and then the -- then the pedals would follow later --

MR. VAN den BOSSCHE: No.

MR. MAGLADRY: -- after the -- after the rudder moved four degrees?

MR. VAN den BOSSCHE: No. The movement of the pedals is still ahead of the movement of the rudder on the traces we have been shown.

MR. MAGLADRY: But in this -- in this scenario, if the -- the rudder would move -- this failure scenario, the rudder would move four degrees and then the pedals would move --

MR. VAN den BOSSCHE: Yes.

MR. MAGLADRY: -- is that correct? Okay. And then my next question would be, as you already answered, is this what we saw in the accident sequence?

MR. VAN den BOSSCHE: No.

MR. MAGLADRY: Thank you.

Madam Chairman, this ends my line of questioning.

CHAIRMAN CARMODY: Thank you, Mr. Magladry. I know that Mr. O'Callaghan has a number of questions of these witnesses and there may be others. But I would suggest that we break for lunch for one hour.

Mr. Clark, did you want to say something?

MR. CLARK: If I may --

CHAIRMAN CARMODY: Sure.

MR. CLARK: -- I've got a -- just a --

CHAIRMAN CARMODY: Fine. Why don't you --

MR. CLARK: -- quick follow-up and then I'll try to get out of there.

CHAIRMAN CARMODY: -- follow up?

MR. CLARK: Okay. On the -- on the types of failure modes, are there failure modes in which the rudder can move farther than the limiter would allow?

MR. VAN den BOSSCHE: No, I don't think so.

MR. CLARK: Are there failure modes that you've identified that would --

MR. VAN den BOSSCHE: Oh. Well, it could move on a limited quantity due to some elasticity effects.

MR. CLARK: Okay. And then, for example, the two minus one failure where two actuators have failed and are driving the third, would that allow the rudder to move beyond the limiter --

MR. VAN den BOSSCHE: In that --

MR. CLARK: -- control?

MR. VAN den BOSSCHE: -- in that case, yes.

MR. CLARK: Okay. And we would have to go to the blowdown limits of the two minus one --

MR. VAN den BOSSCHE: Yes.

MR. CLARK: -- to see how far it may move that?

MR. VAN den BOSSCHE: Yes.

MR. CLARK: Are there any failure modes that you've identified that would promote a cyclic type of motion out of the rudders?

MR. VAN den BOSSCHE: No. It's runaway.

MR. CLARK: Any kind of failure mode?

MR. VAN den BOSSCHE: Yes.

MR. CLARK: None?

MR. VAN den BOSSCHE: No.

MR. CLARK: Okay.

MR. VAN den BOSSCHE: Just runaway.

MR. CLARK: Okay. Thank you.

CHAIRMAN CARMODY: All right. Thank you.

I suggest we adjourn for an hour and return at 2:30. Thank you.

(Whereupon, at 1:25 p.m., on October 29, 2002, the proceedings were adjourned for lunch, to reconvene at 2:30 p.m., the same day.)

AFTERNOON SESSION

2:34 p.m.

Whereupon,

DOMINIQUE CHATRENET

having previously been duly sworn, was recalled as a witness herein and was examined and testified as follows:

Whereupon,

DOMINIQUE VAN den BOSSCHE

having previously been duly sworn, was recalled as a witness herein and was examined and testified as follows:

CHAIRMAN CARMODY: People have been asking how long the hearing is like to run till tonight. I intend certainly to go until seven, possibly later if we're in the middle of something. But we have a lot to cover and the pace has not been crisp up until now. So I intend to be here till seven.

The rest of the week we'll start at eight in the morning and again probably go fairly late at night. So we have many witnesses, many subjects, and I don't want to waste time.

Everyone, please come in or close the door if you're not coming in because we want to get going here. Thank you.

We are going to start with Mr. O'Callaghan's questions of these two witnesses. Please proceed.

MR. O'CALLAGHAN: Thank you, Madam Chairman.

Good afternoon, gentlemen. My questioning has to deal with the simulator work and calculation of side slip and those sort of things. And I understand that you've prepared a presentation that introduces that matter. So if you're --

MR. CHATRENET: Yes.

MR. O'CALLAGHAN: -- ready to proceed, please do so. Thank you.

MR. CHATRENET: Thank you.

(Slide)

MR. CHATRENET: So I would like to start to introduce the work we have been doing with the simulation by some basic quality consideration about the role of fin and rudder.

So the fin is basically designed to provide -- lateral direction or stability on our aircraft. And it is thanks to the fin that the aircraft has a tendency to remain in or to return to a straight no-side-slip flight.

On the left picture you see an aircraft flying straight basically with the velocity of the aircraft contained within the plane of symmetry of the aircraft. In these conditions, the pressure on both sides of the fin are equal and no lateral force applies to the fin.

On the right picture we see -- we see an aircraft flying some kind of sideways, which means that the aircraft velocity is no longer in the plane of symmetry of the aircraft. And the angle between the plane of symmetry and the velocity is called the side slip.

In this condition, the pressure on both sides of the fin are not equal and the lateral force is developed from the fin which in turn will cause a yawing movement on the aircraft. And the ensuing movement will have a self-natural tendency to bring back the aircraft velocity within the plane of symmetry of the aircraft, which means basically that the aircraft has a self tendency to align itself with the -- with the air like a weather vane would do or -- or to come back basically to -- to side slip naturally to zero side slip.

(Slide)

MR. CHATRENET: Now, what is the role -- what is the role of the -- of the rudder. One of the fundamental role of the rudder is to provide the lateral forces and associated wing movement to compensate or to oppose the effect of an engine failure or any other yawing asymmetry.

On this sketch we see an engine providing full stress on left side while the right engine is assumed to be failed. In this case, the thrust asymmetry -- thrust on one side and no thrust on the other side -- will have a tendency to make the aircraft yaw around its center of gravity.

Therefore, the rudder may be used to provide by its deflection lateral forces which multiplied by its lever arm will cause a yawing movement resulting from this rudder deflection which will be able to compensate for the wing movement associated with the engine failure.

The second main role of the rudder is to allow for cross wind landing. When the aircraft is coming to land and when there is a significant wind acting across the runway, the trajectory of the aircraft must still remain in the axis of the runway. And if the aircraft heading would be the same as the runway ending, the aircraft could not maintain a trajectory in the ending. The aircraft would drift away from the runway axis. This is why the aircraft is compensating this kind of natural drift by putting some heading change relative to the runway and flying with some kind of a crab angle in order to allow the aircraft trajectory to keep in line with the runway.

But this kind of aircraft situation cannot be tolerated at the time of the touchdown. At the time of the touchdown, the landing gear of the aircraft is not designed to support this kind of significant angle relative to the runway, and the aircraft must be brought back in line with the runway. And at this stage -- at this stage, because the wind is coming from one side, the aircraft must fly with side slip.

And as the aircraft has a self-tendency to align the nose into the wind in order to create this side slip, the rudder must be deflected in order to compensate for the natural lateral direction -- of the aircraft.

So the second case when we must use the rudder is to provide for this kind of landing with cross wind.

Now, we will try to illustrate some effects of the rudder use. I have said that the aircraft has a self-tendency to come back to a zero side slip condition and therefore rudder application is not necessary to bring back the aircraft to this zero side slip condition. This return is natural. It is damped but it is also oscillating like it is shown on this figure. The aircraft has a self-tendency to come back to this stage but after several damped oscillations. This kind of oscillation is also commonly called dutch roll.

We have been this morning addressing several issue about the yaw damper. The yaw damper function is illustrated here as its contribution to the angling quality of the aircraft. With small rudder deflection automatically applied by the yaw damper system, you can change the behavior of the aircraft from the blue dotted curve to the green solid curve, which is far more damped than the original one, which means that the yaw damper provide this kind of improvement in damping and therefore improvement of comfort.

And this is an automatic function that do not -- that does not require any action from the pilot.

Now, on the other side, if we assume that some cyclic inputs are made to the rudder at a specific time intervals which is coincident with the natural frequency of the aircraft, even with small inputs at the beginning we can achieve some kind of oscillation of growing amplitude, then at the end stabilizing. But the amplitude is far greater than the amplitude of the initial oscillation.

(Slide)

MR. CHATRENET: This is the illustration of the forced oscillation principle. If you put some impulses at the frequency of the natural oscillation of the aircraft, you can get higher oscillation than simply damped oscillation.

Let me try to -- to use a comparison. It might be like a child's swing. If you take a child's swing and if you offset it from the equilibrium position and just release it, then the swing will come back to the vertical equilibrium state after several damped oscillation.

Now, if you take the same swing, you offset it by the same amount, you release it, but each time the swing comes close to you, you just push a little, small impulse but at the right frequency, and then you can obtain a motion of your swing which will be higher than the initial offset. You can this way illustrate the forced oscillation principle. And this is relevant to some kind of inequalities analysis of Flight 587.

Another effect of the rudder use that should be emphasized is that if the rudder is capable of creating stabilizing side slip on the aircraft, this will also roll any aircraft because of the side roll effect. And this not peculiar to our -- to our aircraft, this is peculiar to almost all aircraft of the same kind of architecture.

So let's illustrate this.

(Slide)

MR. CHATRENET: Let's do it again.

(Slide)

MR. CHATRENET: So you see first rudder side slip and roll. So the -- it's true that we can induce roll by the use of rudder.

So use of rudder for roll control induces large, indirect, and delayed roll response. And the fact that it needs first the side slip to establish before the roll resulting from the side slip can roll the aircraft, introduces a significant delay in the reaction of the aircraft in roll to a given rudder input. And because of the delay we must be careful because this kind of high efficiency compound with the delay could lead to overcontrol.

On our aircraft now we have a pretty powerful roll control through the ailerons and spoiler only, the roll control of the A-300-600-R is pretty efficient. To have an order of magnitude at the speed of 240, 250 knots, it can generate a roll rate as high as 30 degree per second. And therefore, the use of rudder for boosting roll control is neither necessary nor appropriate.

(Slide)

MR. CHATRENET: So after this I would say overall and general introduction of handling qualities matter, let's explain how we have analyzed the accident parameters we had.

What were the objectives of all this analyses which have been performed since -- since the accident date and which have been devoted a lot of energy on the Airbus side.

The first objective was to compare the aircraft motion as it is recorded on the DFDR with a computed motion of the A-300-600-R simulation model. So comparing what is on the DFDR with what can be obtained with a simulation model of the aircraft.

The second objective of this simulation analysis was to derive wind profile during the event, if any.

The third objective has been to reconstruct a continuous time history of all control surfaces between the sample recorded data or based on the sample recorded data. In order to have a good analysis of the phenomena, we must rely on some continuous curves whereas the sample data on the DFDR are only recorded at their sampling period, which is some -- most of the control surfaces at two PPS.

And the last objective was also to compute thanks to the simulation model the parameters which are not recorded on the DFDR which we are -- which are nevertheless necessary to be an input for the load analysis and to understand the load analysis. Citing namely the side slip. The side slip is not recorded on the aircraft. There is no side slip vane on the large transport aircraft. So we have to deduce from one way or another the side slip. And the rotation rates as well are not directly recorded on the DFDR.

So these were the objectives of our analysis. We have used two different methods and we have cross checked the results of the two methods against each other at least for the main parameter for -- which is very relevant for the load analysis, which is the side slip time history.

So for the side slip time history, we have used the handling quality model analysis in order to derive a side slip history from this simulation. And we have used another method which is completely independent of the model which is a side slip computation by -- based on integration of the lateral acceleration, which is basically a kinetic mathematical method.

So how do we perform our simulation analysis. How do we run our simulation model. We start with an

-- the time history for the control surface time history, which is continuous. To give you an idea of what is continuous in our mind, we run our simulation model at 64 points per second. And we assume that at 64 points per second we have a good -- a good continuous curve for all parameters which are relevant.

So we feed this continuous control surfaces time history into a model of the A-300-600-R. And this model is our model, the model we have since the certification of the aircraft. We have not been changing this model since. It's the model that -- on which we have been relying to certify the aircraft. We have made some simulation. We have used the iron bird. So this -- this simulation model was run at this time, was accepted by the -- authority. And by the way, this simulation model is also the same one which is provided for the training simulator.

So this model is an old one. We have not changed it since, and we have used basically the model that is available since the certification date of this aircraft.

The result of the simulation when you put as an input the control surface position is to give some parameters for the aircraft motion. So we can compute, for instance, all the acceleration, the NY acceleration, the load -- the vertical load factor. We can compute the speed, the rate, and we can compute also the attitudes, like the pitch angle, the bank angle, the heading, and so forth.

In the same time, in the same process, starting with what we believe are the true continuous control surfaces in time history, we reproduce or we introduce in our model the treatment which is made by the DFDR or mainly by the stack computer, which means the -- the filtering of some of the parameters. Some of the parameters are filtered. So this should be taken into account before comparing anything to the DFDR. And this is done -- this is done mainly for the rudder deflection, aileron deflection, and elevator deflection.

So by using this process, we obtain control surfaces time history as if recorded -- exactly as if recorded on the DFDR. And then we compare both results with what we have on the DFDR, what are the actual recorded parameters. So we compare both the aircraft motion with the DFDR parameter and we compare the as -- as-if recorded control surfaces position with the DFDR.

And whenever we are not happy with the comparison, we make an iteration and we change the continuous control surface time history until we are sufficiently happy with both comparison, comparison with the aircraft motion, comparison with the recorded rudder position, aileron position, elevator position. And we have made hundreds of iterations until we are pretty satisfied with the results.

(Slide)

MR. CHATRENET: This is an illustration of what we can get from this analysis. In red we have the lateral load factor computed by the model whereas in blue we have the recorded points from the DFDR with their sampling. And we show that basically we have a good match of the lateral acceleration of the -- of the last seconds of the flight.

The assumed time of fin separation is around here, so we have basically a good representation of the last 12 seconds of the flight before the separation. We have put in dotted line here the result of our model because obviously our model, the certified model, cannot account for the fin separation.

(Slide)

MR. CHATRENET: Same illustration. Here is the heading angle, heading angle resulting from the model, from the simulation, compared with the points recorded on the DFDR.

It is important to note that our simulation has been run during these 12 seconds up to now while assuming no lateral gust, no -- any lateral vortex for this simulation. So up to now, these results can be obtained without any assumption for wind.

(Slide)

MR. CHATRENET: And this is the result of the second comparison. Here we have the rudder as it is used in our simulation. So this is the rudder position which drives the simulation. This is the rudder filtered, which means it is the parameter as if recorded on the DFDR. So you see here the effect of the filtering of the processing before being put on the DFDR. And then we compare with blue dots which are the DFDR truly recorded points. And you see that we have a pretty, pretty good match of all these points.

The second method is called the kinetics integration of the DFDR parameter. This method is completely independent of any aircraft model, and it provides basically the result of the integration of the acceleration relative to -- relative to the Earth, which means relative to the ground. It provides basically ground side slip. Ground side slip would be equal to air side slip in case of no wind.

(Slide)

MR. CHATRENET: This shows basically the

process. We start from the acceleration as they are derived from the DFDR. Then we have to make some angular corrections in order to provide the direct derivative of the main parameters in the correct access. For the angular correction, we use the DFDR altitude where to correct by bank, pitch, angle, and so on. And then by a mathematical integration, which is basically a trapezoidal type of integration, we can get the side slip as computed by this method, called the NY integration.

And then we can cross check the side slip, which once again is a ground side slip, once again which does not rely on the model. We can compare with the side slip computed by the aircraft simulation.

(Slide)

MR. CHATRENET: So the overall result is the following one. We are still talking about the same 12 seconds before the estimated time of fin separation. And we can compare in red the side slip coming from the simulation, coming from the model, resulting from the control surface position with the side slip coming from the integration method. We see that we have a pretty, pretty good agreement of both methods at the end of this time period.

We have still to work in this area, but

remember that blue is ground side slip, red is air side slip. The difference in between might be accounted by some lateral wind, for instance, which was not the case up to now in our simulation because we had pretty good results up to now without taking into account any lateral wind.

If there was some wind, this may account for the small difference here. Basically, it's only one degree of side slip. One degree of side slip at this speed, 250 knots, means roughly speaking five knots. Five knots of lateral wind, not more.

So as a summary of this analysis, we have been able, thanks to the -- to the use of the model, we have been able to propose a continuous rudder deflection time history. And we think that this continuous rudder time history has been established with a very, very high degree of confidence.

The side slip time history, which is very relevant for the load analysis which is necessary for the load analysis that will be described by following witnesses, has been also determined. And for this purpose, we have used two methods. We have cross checked the methods, and we have obtained consistent results with the two methods.

(Slide)

MR. CHATRENET: The comparison between the DFDR recorded parameters and the aircraft motion derived from the simulation are in good agreement, which means that basically the aircraft model and the aircraft from the Flight 587 behave in a similar way.

And all the lateral motions of Flight 587 can be accounted for -- I would say almost entirely because at this stage we have not used any lateral wind assumption -- almost entirely by the roll and yaw surface deflection. The good match we have up to now is obtained without any lateral wind assumptions.

I think the system analysis has been covered this morning.

MR. O'CALLAGHAN: Thank you, Mr. Chatrenet, for that very comprehensive presentation. Many of the questions I have have been covered in your -- in your presentation, but I'd like to go over just a few things just for emphasis and for clarification.

So back on your summary slide, the one you just showed, I guess -- can you repeat again just what were the major factors that affected the motion of the airplane?

(Slide)

MR. CHATRENET: This -- this one?

MR. O'CALLAGHAN: Yeah. For example, like your last bullet there. Basically, just under -- understand the simulation match then is -- is good with -- so good with the motions that you've driven with -- with the control surface positions you've driven with that that accounts, in your opinion, for almost entirely all the -- all the side slip angle and the other motions we saw, is that -- is that right?

MR. CHATRENET: Yes. At least at the end. The only area where we could still improve the matching is the area where we have seen the side slip ground and the side slip air differ slightly which is at the very, very beginning of the -- of the sequence. And as I have said, we do not expect to see a big amount of lateral wind, something around five knots, which is very small, which means that at the end the lateral motions of the aircraft will still remain resulting from at least 95 percent as a result of the control surface position.

MR. O'CALLAGHAN: Okay. Thank you. So these -- these results, can they also be used to examine the question of whether any other parts separated from the airplane prior to when we think the vertical fin came off? For example, the rudder?

MR. CHATRENET: This -- this might be -- used from the fact that up to the estimated time of the fin separation basically the model and the Flight 587 behaved in a similar way, which means that the aircraft is complete up to this time. After, we have seen that basically there is a sharp pop in the lateral load factor that the model cannot account for and which might be the evidence that at this time the aircraft is no longer behaving like the model because the aircraft is no longer complete.

MR. O'CALLAGHAN: Thank you. Along those same lines, if I can refer you to page -- looks like page 95 of Exhibit 13-A.

Could we have that one up there, please?

(Slide)

MR. O'CALLAGHAN: Now, the -- the lower chart shows the time history of the side slip angle from one of your simulations and an inertial side slip angle calculated by the NTSB in much the same way as your -- as your derivation of side slip angle from the lateral accelerations. And we see there at -- at about 9:15:58 and a half or so, the -- the simulator side slip angle and the integration side slip angle start to diverge. Can you just comment on the reason for that?

MR. CHATRENET: So if -- if the -- if you are referring to the divergence we see at the -- at the end of this time history, I -- I've explained that the model cannot account for the separation of the fin. So the -- the big divergence we can see between the side slip at the end to my interpretation is linked with the separation of the fin, which means that basically the -- the aircraft cannot behave like the model which has a fin on it.

Before that we -- on this exhibit the side slip comparison is not exactly the one that I have shown earlier. And we have made this progressive analysis with the side slip. We have been discussing our results with NTSB. And in the last stages we have completely included the various corrections which are necessary on the accelerometers. And we have included the correct synchronization of the parameters that were not done before. And this is to my interpretation the explanation of this last iteration which may account for the difference we have seen between the curves as shown in this one.

MR. O'CALLAGHAN: Okay. Thank you. And just to summarize then, the divergence at time 9:15:58 and a half or so is again another indication along with other evidence that has been presented that the fin came off at that time?

MR. CHATRENET: Exactly, yes.

MR. O'CALLAGHAN: Okay. Just a couple

questions about the fidelity of the simulator and how it -- how accurate it is in representing the real airplane. Are there regimes of flight or combinations of angle attack or side slip beyond which the simulator model does not represent the -- the airplane too accurately? And how do those ranges compare with the -- the ranges of angles of attack and side slip that have been analyzed for this accident?

MR. CHATRENET: Yes, there are obviously areas where the model is not completely at least substantiated by -- by testing. Basically, the model we use is initially based on wind tunnel test results. These wind tunnel test results have their own range of validity of parameter. By continuity, generally this model is expanded beyond the validity of the parameter for continuity reasons. And for instance, when some parameters are linear, their domain of validity is basically unlimited or so it is outside of what has been tested in -- in wind tunnel.

When the aircraft is flying, we are performing a lot of flight testing dedicated -- purely dedicated to identify our model and to tune the model until we get a good matching with the flight test results. So basically, we have validity -- we have a range of parameters which have been tested in flight and which have allowed to derive some adjustment coefficient that will be used across the whole range.

Beyond this range of parameters validated by flight tests, we have the range of parameter -- we have the range of parameters validated by wind tunnel tests. And beyond, we have the range which is expanded by extrapolation or by linear -- the linearization model.

In the parameters that we encountered during the few -- the few last seconds before the fin separation, the angle of attack and the side slip within the range of parameters which have been supported by flight tests.

MR. O'CALLAGHAN: Okay. I think that that's key, that basically for -- for where the -- for where the simulation is taking place, the ranges of angle attack and side slip are -- have actually been validated by flight tests, not just wind tunnel data?

MR. CHATRENET: Yes.

MR. O'CALLAGHAN: Okay.

MR. CHATRENET: Yes.

MR. O'CALLAGHAN: Thank you. Mr. Chatrenet, you mentioned that some external winds were required in the longitudinal axis to help match angle attack and load factors. And you mentioned also the possibility of introducing lateral winds on the order of five knots or so to help improve the match of side slip angle. Any speculation on what the source of these external winds might be?

MR. CHATRENET: These might be turbulence or wake -- or wake-associated turbulence.

MR. O'CALLAGHAN: Okay. Thank you.

MR. CHATRENET: The -- the magnitude of them are about five to seven knots in vertical wind up to now. So once again they are small. They are small. Five -- five to seven knots is a small to moderate turbulence.

MR. O'CALLAGHAN: Yes. And in any case, their overall effect on the -- on the motion of the airplane compared to that of the flight control inputs is -- you mentioned a ratio before.

MR. CHATRENET: Laterally it will remain small, yes.

MR. O'CALLAGHAN: Okay. Just a couple questions on -- on the yaw damper. Mr. Magladry questioned you extensively on that earlier in the day. I just want to explore how the yaw damper affects the motion of the airplane.

And if I can reiterate a little bit of my understanding of what the testimony this morning was and to see if I've got it right, but essentially question you why -- why the rudder traces are the way they are and the way they were driven in the simulation. The way I understand it is the pilot can input or -- pedal input and move the rudder to the limit and the yaw damper may be attempting to move the rudder back towards neutral. But in doing so, it makes more pedal travel available to the pilot. So then, if there's force continued to be pushed on the pedal, then -- then the effect of the yaw damper is negated or compensated for and the rudder will move back to the -- back to the rudder stop. Is -- have I stated that correctly so far?

MR. CHATRENET: That is correct, yes.

MR. O'CALLAGHAN: So now, if -- if the -- let me ask it this way, I guess. How would -- how would the use of a pedal limiter in combination with the rudder limiter change or alter the rudder positions obtained from the recorded pedal inputs?

MR. CHATRENET: Please, could you say it again?

MR. O'CALLAGHAN: Okay. How -- if -- if -- if in addition to the rudder limit there was also a pedal limiter so the pilot could only move the pedal a certain distance regardless of what the yaw damper was doing, some -- for example, in the first instance, if he moves the -- if he steps on the pedal and the rudder moves to the limit, then even though the yaw damper were to take away input or move the rudder back towards neutral, if there were a pedal limit the pilot could no -- could not move the pedal any further, then how would -- if -- that implementation of a pedal limiter I'll call it. If that were in the system somewhere, how would that alter the rudder trace that would -- that would result from the pedal inputs?

MR. CHATRENET: So actually, I have no -- no simulation, no -- no simulation to substantiate any good answer to your question because the -- the design is not like that. So it's speculative and I cannot support what might be the answer of the aircraft in this -- motion.

Let me say that in any case the yaw damper will not be capable of adding anything to the pedal input, which means that because we have the -- downstream. So the -- the yaw damper activity, which would be in addition to the pilot authority, would have no effect anyway.

The only effect, according to your assumption, would be to allow the yaw damper to remove some authority from the pilot when the yaw damper would be acting against the pilot. And basically, the assumption you are referring to some kind of additional limiter at the level of the pedal is somehow related to the discussion we had this morning about putting the TLU at the most downstream position or putting it upstream after the pedal position.

And once again, it's -- it's an architecture choice, a choice for our system design. Because the TLU is sufficiently wide to authorize the yaw damper to act completely with full necessary travel even in case of engine failure, if we think that we have a condition where more rudder deflection would be needed, which means basically the TLU deflection would be needed. We prefer to prevent the yaw damper to remove any pilot authority in this condition. And this is done at the expense of half of the oscillation or the -- yes, the oscillation that the yaw damper may ask for.

MR. O'CALLAGHAN: Okay. And I think I did hear you mention that the pedal limiter would allow the yaw damper to remove rudder motion -- can't -- it wouldn't be able to move it beyond the TLU limit, but it would be able to move it back more towards neutral?

MR. CHATRENET: Yes.

MR. O'CALLAGHAN: Is that --

MR. CHATRENET: Yes. But never to neutral. You remember that the -- the yaw damper authority is always less than the pilot authority. It's basically one-third of the pilot authority.

Remember also that when we are talking about cyclic inputs on the rudder which frequency is in the range of the natural aircraft oscillation frequency, only small rudder inputs are necessary to get a forced oscillation with high amplitude.

So also I have no simulation to -- to -- to support your assumption, but we can imagine that the pilot authority would still remain big enough to cause this kind of force oscillation.

MR. O'CALLAGHAN: And again, recognizing fully that without a simulation these are all speculative, but we can, like you say, use our imaginations a bit. And so with -- with a square pedal input but with a yaw damper that could say attenuate the -- the resulting rudder, what kind of effect would the attenuated rudder have on the side slip angles that would develop compared to say to -- if -- if the rudder were fully square?

MR. CHATRENET: I cannot support any answer because we have not made any simulation like that. So we could not tell you which kind of either attenuation or -- I don't know. I could not answer precisely because we have not made any simulation to support this kind of assumption, which is not the way the aircraft is designed. So we have made many, many simulations but based on the actual design of our aircraft.

MR. O'CALLAGHAN: Okay. Thank you. Speaking -- I guess -- moving a bit to different design, can square inputs such as those were -- were -- that were determined to have occurred on -- on the accident airplane, can -- can those be obtained by -- with square pedal inputs on the fly-by-wire fleet of Airbus airplanes?

MR. CHATRENET: I'm afraid that any comparison with the fly-by-wire aircraft is difficult to make at this stage. These aircraft are too much different in terms of design. And it's mainly because of the flight control loads that we have implemented in the fly-by-wire aircraft.

Remember, for instance, also it is not relevant to the Flight 587. But nevertheless, it is worth to -- at least to mention it. The fly-by-wire craft, they have control loads which, for instance, allows the rudder to move as a consequence of the side stick motion involved. So even with no input from the pedals, the rudder would move when you move the side stick.

Similarly, with no side stick input but with the rudder pedal motion, the aileron and spoiler will move as well as a result of the flight control load, which means that the basic handling quality would be heavier. Our fly-by-wire aircraft is completely different and not comparable at all with the handling quality of the A-300-600-R, which makes any comparison very difficult or even irrelevant.

MR. O'CALLAGHAN: Okay. Then, my final question would just be on -- on a fly-by-wire aircraft -- I think it's somewhat relevant in how you're looking at how different designs work and as -- as airplanes are designed in the future how different technology can -- can be brought to bear. So my final question would then just be on a fly-by-wire aircraft, what kind of rudder or side slip generally would result from square rudder inputs? Even in the absence of a simulation, without -- as -- how is that different from say older technology aircraft?

MR. CHATRENET: So a main first difference is that in the roll and yaw axis the fly-by-wire aircraft have a bank angle protection system, which means that the aircraft is not likely to go to excessive bank angle.

So as a consequence of that, the -- the likelihood of any upset in lateral is far, far remote, not to say almost inexisting of the fly-by-wire. So this is one first difference which say that the aircraft is unlikely to be upset in lateral.

The second difference is that with the fly-by-wire, when you are deflecting the rudder pedal, you are asking for a side slip. So there is a relationship between the rudder pedal deflection and the side slip you obtain at the end. But this side slip is obtained with constant bank angle, which is a significant difference. We have explained that an indirect effect of the use of rudder was to create roll and so therefore roll rate. And roll rate -- if you do not stop roll rate, the aircraft will bank, bank, bank, and roll over.

With the fly-by-wire aircraft, when you are asking just for a rudder pedal deflection, then the bank will stabilize. So it's not -- it's not a roll rate -- it has no effect on the roll rate. This is one observed effect.

MR. O'CALLAGHAN: Okay. Thank you very much, Mr. Chatrenet.

Madam Chairman, that concludes my questioning.

CHAIRMAN CARMODY: Thank you, Mr. O'Callaghan. Before I move to the parties, are there any additional questions from the Technical Panel?

(No response)

CHAIRMAN CARMODY: All right. Then I will move forward. Just for purpose of preparation and expediting the procedure, I will -- I will tell you the order of the parties that I will use today. I'm going to start with the FAA and then American and then Allied Pilots, finishing up with this witness for Airbus. So may I ask the FAA to begin?

MR. DONNER: Thank you, Madam Chairman. FAA has no questions.

CHAIRMAN CARMODY: I like to hear that. Thank you, FAA.

MR. DONNER: I plan to repeat it several times.

(Laughter)

CHAIRMAN CARMODY: I'll move now to American. Mr. Ahearn, please.

CAPT. AHEARN: Thank you, Madam Chairman. I do have a few questions.

Let me start off with a little bit of the evolutionary process of the B2-B4 aircraft moving to the 300-600 aircraft. Can you tell me, Mr. Chatrenet, why the variable lever arm was originally chosen for the B2-B4 aircraft?

MR. CHATRENET: So as I said, I was not yet in the handling quality and flight control business at the time of the design of the A-300-600-R, so I was not yet also at the time of the B2-B4 design area. But as far as I've been told, the choice of the VLA was some kind of legacy coming from the experience of the initial partners that started the Airbus story, mainly the British one and the Sud Aviation one.

CAPT. AHEARN: Okay. And even though this is somewhat from a historical perspective, are you aware of whether or not the RTL was considered for the B2-B4?

MR. CHATRENET: I'm not aware of that. But I could not guarantee because this is only from memory from other people in charge of this at this time.

CAPT. AHEARN: Okay. And let me offer that question to Mr. Van den Bossche as well. I believe he stated earlier that he was part of the system design?

MR. VAN den BOSSCHE: Yes. Some years before. So I was involved in the system, and by the way, I was in charge of the development of this particular variable lever arm unit. But I have not been involved in the architecture story in the -- studies coming to that choice on this time.

CAPT. AHEARN: Okay. Let me -- maybe I should direct the questions to you because you were involved at the time. Are you familiar with whether or not the RTL system was considered for the B2-B4?

MR. VAN den BOSSCHE: I think comparison had been made by somebody at this time.

CAPT. AHEARN: And do you know why it was not chosen?

MR. VAN den BOSSCHE: No.

CAPT. AHEARN: Do you know if any other systems were considered other than the -- the two aforementioned?

MR. VAN den BOSSCHE: As far as I know, a review of existing systems in the industry at the time has been performed.

CAPT. AHEARN: Okay. And again, I'll direct this question to either one of you gentlemen. You can choose who answers it, if that's okay.

But in looking at the B2-B4 as part of the investigation, we have quite a bit of data on the A-300-600 and the force gradients that are used. Have you provided or do you have the B2-B4 force gradients available as part of this investigation to show the differences as to how this airplane evolved from model to model?

MR. VAN den BOSSCHE: What -- what -- I have no figure like this. Maybe -- maybe, Dominique, you have.

But basically, what we know is that the yaw control forces have been reduced between the B2-B4 and the A-300-600-R, in comparative ratio that the forces have been reduced on the roll axis when going from the B2-B4 to the -- to the A-300-600-R.

And as we had a good experience with the ratio we had on the B2-B4 between yaw and roll, we have kept basically the same ratio between the -- the yaw forces when going from the B2-B4 to the -- to the A-300-600-R.

CAPT. AHEARN: Okay. One last question on the B2-B4, and that is the breakout forces.

MR. VAN den BOSSCHE: Yes.

CAPT. AHEARN: Do you know what the breakout forces -- we know the breakout forces on the 600 are approximately 22 pounds. Do you know what the breakout forces are on the B2-B4?

MR. VAN den BOSSCHE: It was the same.

CAPT. AHEARN: Same, 22 pounds?

MR. VAN den BOSSCHE: By the way, I found the figures. The maximum force on the B2-B4 was 125 pounds. Breakout was at 22.5, which is identical to A-300-600. That's for rudder.

CAPT. AHEARN: Okay. And Mr. Chatrenet, you testified earlier that on the roll axis that the roll control were approximately 30 percent lighter on the 600 from the previous model, the B2-B4. I assume that's throughout the flight envelope so that at 250 knots I would anticipate that the full deflection is approximately 70 percent of what it was in the B2-B4, is that correct?

MR. CHATRENET: No. The control forces for a given control wheel displacement have been reduced by 30 percent. But at the same time, the roll efficiency has been increased when going from the B2-B4 to the A-300-600 thanks to better use of the spoilers.

So at the same time we have reduced the control forces on the roll axis and we have increased the roll efficiency.

CAPT. AHEARN: Therefore, 250 knots, do you have any sense of the force required on the 600 relative to the B2-B4?

MR. CHATRENET: On -- on the roll axis?

CAPT. AHEARN: On the roll axis, yes.

MR. CHATRENET: On the roll axis --

CAPT. AHEARN: Yes.

MR. CHATRENET: -- they have been -- the amount of forces on the A-300-600 for a given control wheel deflection are 70 percent of the forces needed for the same control wheel deflection on the B2-B4.

CAPT. AHEARN: Okay. Now let's move to the rudder for a moment and the transition from the B2-B4. Because it's my understanding that the B2-B4 rudder deflection, you would have the same feel throughout the flight envelope, that you in essence would have four -- four inches of rudder deflection throughout the same -- throughout the flight envelope, is that correct?

MR. CHATRENET: The B2-B4 has a VLA system, yes.

CAPT. AHEARN: Okay. And then when you transition to the 600, the -- the -- the pedal movement changes and it changes throughout the flight envelope. As an example, at 165 knots, I believe it is a four-inch deflection. And then at the 250 knot, it's approximately 1.3. And then at cruise, it is significantly less than that, is that correct?

MR. CHATRENET: In terms of displacement, yes, it is correct.

CAPT. AHEARN: Okay. So from a control harmony standpoint, when you showed a slide earlier that talked about control -- flight control harmony between the roll moment and the pedal moment throughout the flight envelopment, you were actually really talking about the speed at 165 knots, were you not? That there really isn't control harmony between the roll moment as well as the rudder moment throughout the flight envelope, is that correct?

MR. CHATRENET: It's correct at 165 knots. But later on, at higher speed, we maintain, if you like, the same ratio between the control wheel and the ailerons and between the rudder pedals and the rudder deflection, which means that basically you have to adapt your control deflection as speed builds up in the same way in roll and yaw axis.

CAPT. AHEARN: And that is significantly different than the B2-B4 which is where you received much of your commentary about the control harmony when you developed the 300 system, correct?

MR. CHATRENET: On the B2-B4 at higher speed, yes, the -- you had the effect of the VLA.

CAPT. AHEARN: Let's move to the rudder system. Talking about the A-300-600 airplane, in designing the rudder traveler limit, did you determine -- how did you determine if an average pilot could make small force or displacement inputs on that airplane?

MR. CHATRENET: Yes, of course. Of course. We have made -- so maybe flight -- maybe testing first on the simulator. And later on this has been confirmed by many hours of flight testing.

We have tested many maneuvers during the --

the -- what we call the "mise-en-point" period of the aircraft, during the certification exercise, during the demonstration to the potential customers. And for this purpose we have made many maneuvers which require the use of the rudder pedal, including the use of the rudder pedal at high speed. And for instance, the performance flight testing which requires to show the performance of the aircraft when engine out is covering the -- the wall flight envelope including the clean condition speed as high as 250 knots -- and so on.

So we have made a comprehensive set of maneuvers which are representative of maneuvers that might be expected in airline.

On top of that, I mentioned already the -- how we tune the model. For tuning the model versus flight test, we make dedicated flight tests which are called data package flight testing. And this -- the data package flight test includes many maneuvers where we needs -- where we ask the pilot to obtain a precise side slip without the flight envelope including at high speed.

So we have tested the aircraft both in normal operation, both in I would say extranormal operation, including in the speed range we are considering, so including the speed range where the TLU affect the rudder pedal behavior. And we never had any difficulty for the pilot to obtain this kind of precise, precise closed loop pilot input or control input.

CAPT. AHEARN: And could you comment a little bit more on the high speed tests? Were there any conclusions from that high speed test that addressed the issue of -- excuse me, rudder pedal sensitivity, specifically at this speed? In other words, where you are going into what I'll define as a steady heading side slip. How did you or did you get multiple data points throughout the flight testing at a speed of approximately 250 knots?

MR. CHATRENET: Yes, we have -- we have several points which -- which require to fly at 250 knots and to get specific side slip, and we never had any adverse comment of our pilots -- pilots in order to get this side slip.

CAPT. AHEARN: And in getting that side slip, they were able to do that at 250 knots at full rudder deflection, or you have -- interim points or intermediate points?

MR. CHATRENET: No, we ask them to perform some kind of closed loop inputs in order to get a desired side slip. So this included intermediate rudder pedal deflection at 250 knots or around.

CAPT. AHEARN: Okay. Let me just address the force. We have addressed the distance of 1.3 inches. How about the forces of 10 pounds or less with breakout force of 22 pounds?

MR. CHATRENET: Please say again?

CAPT. AHEARN: You've -- you've addressed the issue of distance, the movement of the rudder pedals to approximately 1.3 or less than 1.3 inches. At the same time, you are calling upon the pilot to use very light forces on the rudder pedals on this airplane. In fact, at the air speed that this airplane was flying at, 250 knots, you have a breakout force of 22 pounds and a total deflection at 32 pounds, which means to get to full stop you only have to apply, after breakout, putting the force of 22 pounds on, an additional 10 pounds to get the full -- to full deflection. Do you have any data points that show how you tested throughout this flight envelope as well?

MR. CHATRENET: We have -- we have also a data package flight testing plus the certification flight testing.

Once again, when you have cited the displacement, first, the displacement was either 1.4 or 1.3 inches. It is only the displacement of one pedal. So you have to remember that the actual differential movement is twice as high as that. And the pilot is probably more -- more sensitive to the displacement.

Nevertheless -- nevertheless, when talking about closed loop control input, the displacement by itself doesn't matter a lot. We have made several research activity according to which we can still have the -- the displacement. We can still reduce the displacement by the factor of two without any impairment of the capability of the pilot to provide for precise, precise closed loop pilot input. So it is not a question of displacement.

Now, if we are talking about the ratio between breakout forces and -- and the forces needed to obtain a given objective or a given aircraft outcome, the first thing is that the breakout force must be sufficiently high to make the pilot fully aware that it is starting to do something because there is -- it should not be very good for the aircraft if just by putting some inadvertent pressure on your pedal you would move the rudder.

So the first thing is that this threshold must be positive information that you start to do something. Now, when you have start to do something, you have applied 22.5 pounds. And then you can adjust. And what we have seen up to now, that this -- the gradient we have between two -- 22.5 pounds and whatever is associated to the limitation or to the maximum deflection is pretty appropriate for allow -- allowing the pilot to make precise, precise piloting.

You know, precise piloting is generally associated with light forces. High forces are detrimental to a very precise because you have to apply forces and in some occasion to maintain them for a long period of time, and then you lose in terms of precision.

CAPT. AHEARN: Let me ask one final question on this issue as it relates to the pilot's ability to make fine -- fine movements of the pedals. What type of testing did you do in turbulent air?

MR. CHATRENET: In turbulent -- in turbulent air, we -- we fly the aircraft obviously in turbulent -- in turbulent air. Generally, we find the highest turbulence when we make the icing flight testing. And in this case, there is no need for the pilot to act on the rudder pedal. In turbulent air, the yaw damper is working. The yaw damper is designed for that. And it is -- there is no need for the pilot to -- to work on the rudder pedals to, I would say, improve the behavior of the aircraft in turbulent air. Just let the yaw damper work for you.

CAPT. AHEARN: So, am I to interpret that your interpretation that a pilot flying in turbulent air should not use the rudder pedals at all?

MR. CHATRENET: It is not needed.

CAPT. AHEARN: And they shouldn't use them at all?

MR. CHATRENET: I think I'm -- I'm not the most appropriate witness to discuss this, but as a design principle or a design responsible, we are designing the yaw damper for the purpose of no need of the pilot to fly on the rudder pedal in turbulence.

CAPT. AHEARN: Okay.

MR. CHATRENET: It is the way we are designing the yaw damper. And for instance, we have been refining the -- the yaw damper, fine tuning the yaw damper, especially to provide better -- to turbulence of the aircraft, for instance, which means that basically it should be left to the yaw damper to do this work.

CAPT. AHEARN: So in the case of where you dispatch an --

CHAIRMAN CARMODY: Excuse me. Mr. Ahearn, unless you're through with that, I think he has answered that question where -- you can move on to another question.

CAPT. AHEARN: I was just going to ask him one more question about yaw damper out of service, ma'am.

CHAIRMAN CARMODY: All right.

CAPT. AHEARN: Okay. In the case of where you have yaw damper out of service, you would -- you would certainly recommend utilization of the rudders at that point?

MR. CHATRENET: In case of a complete yaw damper failure?

CAPT. AHEARN: Correct. Or dispatched. I mean, you can dispatch the airplane without the yaw dampers in service.

MR. CHATRENET: In case of yaw damper failure, we first recommend -- in case of total yaw damper failure, remember, the system is -- is a duplicate system. So it's a double redundant system.

In case of a total yaw damper failure, we first recommend to reduce the altitude and the flight envelope aircraft -- of the aircraft in order to get in area where the natural damping of the aircraft is better than in attitude. So this is the first thing.

The second thing that we recommend to -- to damp any oscillation that might result from flying into turbulence through the control wheel only. Through the control wheel.

CAPT. AHEARN: And obviously, if that is not effective, you would recommend utilizing the rudder, correct?

MR. CHATRENET: So we do not recommend to use the rudder.

CAPT. AHEARN: Okay. Well, --

MR. CHATRENET: This could be discussed later. It is more an operational matter.

CAPT. AHEARN: I agree.

CHAIRMAN CARMODY: Yes. We -- we've exhausted this one. Let's move on.

CAPT. AHEARN: Let me just ask one question regarding the fixed ratio system. You alluded to earlier that the fixed ratio system was safer than the VLA or ratio changer. Could you just explain why you believe that?

MR. CHATRENET: Please, could you rephrase your question?

CAPT. AHEARN: I believe in your presentation earlier that you represented that the fixed ratio system or the rudder travel limiter was safer than the VLA or ratio changer. Could you explain why?

MR. CHATRENET: No, I have not said that. I have said that the failure cases were less severe with the fixed ratio and TLU system. But I have not made any qualification about safety.

CAPT. AHEARN: Okay. Thank you. Let me move on to another area of questioning, please.

From a design standpoint, can the rudder operating system be designed to limit or reduce loads on the vertical stabilizer?

MR. CHATRENET: It is not done that way. We select an architecture of the system, and then the loads are computed accordingly. And the witness in charge of loads will explain how we start from the design of the system as -- as selected according to handling qualities and to flight control design criteria and then the loads for load. And then the loads are computed accordingly.

So if we select this system, we compute the loads accordingly. If we select another system because we think that another system is most appropriate or more appropriate, then the loads will be computed in another way.

But the -- the loads computation do not drive the design of the flight control system. It is not this way around. It is the other way.

CAPT. AHEARN: Okay. So that's not on the Airbus, the A-300-600. Would you -- would a yaw damping system that cannot be overridden limit side slip? Would you agree to that?

MR. CHATRENET: Excuse me?

CAPT. AHEARN: A yaw dampening -- if you had a yaw dampening system on the airplane that could not be overridden, would that in fact limit side slip?

MR. CHATRENET: This is basically the question I had earlier, and we have no -- no simulation to support this kind of -- of assumption because the aircraft is not designed like that. So we cannot substantiate any -- any answer.

CAPT. AHEARN: You alluded to 9000, I believe, of 12,000 airplanes flying that have a similar system to what you described as the system on the Airbus 300-600. Are you familiar with how many of the airplanes of those 9000 have a yaw dampening system that cannot be overridden to limit side slip?

MR. CHATRENET: No, I am not well aware of the -- of the architecture of these -- these aircraft.

CAPT. AHEARN: How about a -- a hinge moment limiter or what is commonly referred to as rudder blowdown?

MR. CHATRENET: Mm-hmm.

CAPT. AHEARN: Would that also limit the side slip of an aircraft?

MR. CHATRENET: The -- the blowdown principle is -- is similar to the TLU. It's simply because once the -- assuming that the hinge moments are linear, it will give a natural stop of the rudder deflection as a function of -- of the air speed of the aircraft.

CAPT. AHEARN: Okay. And again, are you familiar with, of the 9000 airplanes that you represented earlier, how many of them have a blowdown system -- rudder blowdown system?

MR. CHATRENET: To my knowledge, I think that the 737 has a kind of blowdown system with a fixed ratio type.

CAPT. AHEARN: Okay. So that would be included in the 9000?

MR. CHATRENET: Yes, yes.

CAPT. AHEARN: Okay. How many hydraulic flow restrictor -- obviously, that -- that -- again, same type of question. Would a hydraulic flow restrictor limit the rudder rate -- reduce loads -- thereby reducing loads on the vertical stabilizer?

MR. CHATRENET: I think that, from a -- from a design point of view, the -- the flow restrictor is -- is needed when you have no TLU, no physical limitation. If you have a physical limitation, like an RTL or limit, the flow restrictor is not necessary.

You get the limitations through the RTL.

It's once you don't have any RTL, and as your system on most big transport aircraft are at least double redundant, you must provide sufficient deflection with only one system -- one hydraulic system operative, which means that generally you have two system operative. And if you are just relying on the hinge moment to limit your system as natural, then you use flow restrictor to reduce the maximum rudder deflection. But if you have an RTL, it is not necessary.

CAPT. AHEARN: So then, the -- obviously, the A-300 only has the RTL. Are you aware of any other transport category aircraft with the hydraulically-powered rudder that does not incorporate at least one of these features that we mentioned? That being either the hydraulic restrictor, blowdown or -- or a yaw dampening system that cannot be overridden? Other than the A-300.

MR. CHATRENET: Please, could you -- could you make your question precise on this aspect?

CAPT. AHEARN: Sure. We talked through a number of secondary protection that would be available to the manufacturer should they choose to use them, one being a yaw damper system that can't be overridden, one being a -- a hinge moment limitation or rudder blowdown, and the last was a hydraulic flow restrictor. I believe that most of the 9000 airplanes that you alluded to earlier have at least one of those secondary protections in their system. The A-300-600 does not.

Are you aware of any other air transport aircraft with a hydraulically-powered rudder that doesn't incorporate at least one of these features other than the A-300-600 and the A-310?

MR. CHATRENET: If you are referring to the flow restrictor, as far as I know the flow restrictor are fitted on the 737 where there is no RTL. So it is a substitute of the RTL. So we think that through the use of the RTL we do not need flow restrictors.

So I think that the comparison is not exactly relevant in this case. So you cannot say, for instance, that a flow restrictor is an additional precaution. It's not -- it's only a substitution for no RTL. Once you have an RTL, it is not necessary to put a flow restrictor.

CAPT. AHEARN: Okay. Let me -- let me try the question in a different approach. Are you aware of any other transport category aircraft other than the A-300-600 or the A-310, which are the only aircraft with this type of rudder control system, that have experienced rudder doublets or triplets resulting in loads that exceed ultimate load?

MR. CHATRENET: I think that I cannot agree with the -- with the terms of your question.

CAPT. AHEARN: Okay. Well --

MR. CHATRENET: Because -- no. We will have to -- to address this aspect during the loads -- the loads presentation because you have -- you have made some assumptions in your questions.

CAPT. AHEARN: Okay. Can you clarify those assumptions? All I'm looking for is that this, to me, appears to me to be the only aircraft of this type that has experienced rudder doublets or triplets resulting in loads that have exceeded ultimate load. Are you aware of any other aircraft types that have experienced doublets or triplets resulting in an exceedance of ultimate load? Because I'm not.

MR. CHATRENET: In -- in history, what -- what do you mean that -- whether we know if other aircraft of other manufacturer have experienced during their in-service life some high loads events? We have not access to any database. I don't know even if these databases exist to be in a position to tell you that we have reviewed all these databases of all aircraft flying and we can say or we cannot say if other aircraft have also experienced high loads. That's simply because the database does not exist and we cannot qualify the -- the loads history of the aircraft which have not been built by Airbus.

We can know what is the -- the -- the history of the records of our fleet but not the fleet of other manufacturers. So I think we cannot -- we cannot provide you with -- with -- with, say, a good answer to this question.

CHAIRMAN CARMODY: Thank you. Yes. The witness has answered this question sufficiently, Mr. Ahearn. Obviously, he can't give you the answer you're looking for or he's not comfortable with the assumptions. And I understand that. I think you should move on to another area, or perhaps you're finished.

CAPT. AHEARN: I'm just going to move on to one other --

CHAIRMAN CARMODY: All right. Thank you.

CAPT. AHEARN: Thank you.

CHAIRMAN CARMODY: If you need to address this question to other witnesses, that may be appropriate. But I think we've beaten this one to death.

CAPT. AHEARN: Thank you, ma'am.

CHAIRMAN CARMODY: Thanks.

CAPT. AHEARN: Let me refer to Exhibit 9-B, page five. And if we could bring that up on the monitor, please?

(Slide)

CAPT. AHEARN: Just a couple questions on this one, Mr. Chatrenet or Mr. Van den Bossche.

I just want to make sure I understand. When -- when you're looking at this chart, does this chart not show the yaw damper moved in such a manner that it increased the rudder rate and motion beyond what was commanded by the pedals?

MR. CHATRENET: The yaw damper is acting against the yaw rate. So it's fighting against the yaw rate. So by no means the yaw damper can increase the yaw rate coming from the rudder pedal. So normally it is fighting against it.

CAPT. AHEARN: Okay. I would agree with you in the first movement of the pedals. But as you continue to get multiple movements of the pedals, the second movement and the third, they appear to become more in line with the pedal movement.

(Pause)

MR. CHATRENET: No. In this -- in this area, for instance, once you get the maximum -- the maximum deflection, then, first the yaw rate has not started to -- to -- we should get in this figure the yaw rate. We don't have the yaw rate. But basically, the yaw damper provides something which is basically proportional and opposed to the yaw rate.

So we cannot see how this deflection can be in the same sign of the yaw rate. We do not see the yaw rate on -- on this. So just what we say is that at this time, at this time of rudder reversal --

MR. VAN den BOSSCHE: The pointer -- there is no pointer.

MR. CHATRENET: Okay. There is no pointer. Maybe on the --

CAPT. AHEARN: On the slide that you have there -- I don't know if you're looking at the same slide, but it should be on your monitor in front of you. The lighter --

MR. CHATRENET: We could --

CAPT. AHEARN: -- yellow -- I'm sorry. The lighter green line is the yaw dampener movement.

MR. CHATRENET: If you allow me, I would show a slide where I can have the point --

CHAIRMAN CARMODY: Would you identify the slide we are looking at just for everyone's --

CAPT. AHEARN: Yes, ma'am. It is Exhibit 9-

B, page five.

CHAIRMAN CARMODY: Right. Okay. And we looked at this quite a bit earlier, as I recall.

CAPT. AHEARN: We did. Yes, ma'am. I just have two questions.

CHAIRMAN CARMODY: Mm-hmm.

MR. CHATRENET: So -- okay. At the time of this reversal, the yaw rate was still resulting from the last rudder application. And the yaw damper was fighting against it. Just at the time when it is reversed, the yaw rate has not yet enough time to build up. So basically, you see a rudder and yaw damper in the same direction. But as soon as the rudder has sufficient time to cause a yaw rate to establish, then you see the yaw damper which will act against -- against the rudder pedal deflection in order to damp the yaw rate.

So I think simply we are missing on this figure the yaw rate which -- to -- to show that basically the yaw damper is acting against the yaw rate every time. It is not -- not increasing or -- or amplifying the yaw rate which is commanded by the rudder.

CAPT. AHEARN: Okay. So maybe we need to add that to this chart to see what's going on because it does appear that it is increasing the rudder movement.

MR. CHATRENET: It's simply because the -- the rudder reversal at the first instant, this rudder deflection will just call -- will just cause yaw rate derivative, yaw rate acceleration. And then this acceleration around the yaw axis has to be integrated before it generated -- generates yaw rate. And then, when the yaw rate speeds up, then you see the yaw damper to act against it.

But you need an integration so you have a time constant in between.

CAPT. AHEARN: Okay. So we need to -- we need to add another line to this chart in order to see if in fact the yaw damper is working with or against the pilot commands?

MR. CHATRENET: It might help. But this would be discussed with the NTSB as well, too, to substantiate that. Basically, this -- this yaw rate has been reconstructed by the NTSB. We have made the same computation and we obtained very close -- very close results.

CAPT. AHEARN: Okay. Your movement of the arrow actually goes to my next question, which is, between 8:47 and 8:48, it appears that -- on my chart it's a light yellow line, but you know which one is the yaw damper movement -- that this line goes flat at 8:49. Do you have any reason or any understanding as to why this movement failed? Could it be that it possibly wasn't keeping up with acceleration?

MR. CHATRENET: Basically, we reached at this stage a maximum authority of the yaw damper, which is around 4.3 degree, likewise explained by Dominique Van den Bossche this morning.

CAPT. AHEARN: Okay. So that --

MR. CHATRENET: So it is saturated by the yaw rate simply because the yaw rate asked for the maximum deflection. We see it here. We see it there.

CAPT. AHEARN: So that --

MR. CHATRENET: After that time, I'm not -- I'm not confident about all the simulation which are done beyond -- beyond this point, which is the estimated point of puncture. But assume that the yaw rate at this stage is sufficiently high to saturate the -- the yaw damper authority.

CAPT. AHEARN: Okay. And then, Madam Chairman, just one final question, please.

Could you tell me how Airbus determined how much rudder was needed at higher speeds? Basically, what I'm going to is you had a -- you had a gradient on one of your charts earlier that showed you'd have 30 degrees of deflection at about 165 knots. At the 250 knot speed, you had approximately 9.8, I believe. And then at cruise it was approximately 3.5.

What I'm really looking for is how is that gradient developed?

MR. CHATRENET: So this -- this gradient was developed by computing for each speed -- for each speed what was the static rudder deflection which was needed to compensate for an engine failure with wind level.

CAPT. AHEARN: So it's purely on engine out?

MR. CHATRENET: It's engine out plus -- plus an adequate margin for allowing the yaw damper to work on both sides plus and minus around this value.

CAPT. AHEARN: Do you have any idea why it would be so large at 250 knots, the 9.2 or 9.8 degrees? I don't remember what the number was exactly. But that's -- that's about a third of the full rudder deflection at a substantial speed.

What I'm referring to, and I know this is not your area of expertise. It may be something else that we'll talk to one of the other witnesses about. But in an FCOM that was put out by Airbus, it talks about at high speeds to accommodate an engine out, the amount of rudder required to counter an engine failure and center the side slip is small. I don't know that I would really call 9.8 or 9.2 degrees of deflection "small." And I'd appreciate you commenting on why the RTL allows so much rudder deflection at 250 knots?

MR. CHATRENET: We have proposed this morning to add to the record a technical note which justifies this -- this selection of the RTL by the universal speed. Remember that at this speed, around 250 knots, for instance, from memory, it basically should need seven degree of rudder to compensate for the engine failure and three degree for the yaw damper activity, something around there, or six plus four, something like that.

So it's not the raw TLU value which is needed to compensate for the engine failure. It is only part of it in order to keep the margin for the yaw damper to operate beyond this value.

CHAIRMAN CARMODY: Mr. Ahearn, was that your last question?

CAPT. AHEARN: Yes, it is, Ms. Carmody. Thank you very much.

CHAIRMAN CARMODY: All right. Thank you. Now we move to Allied Pilots, please.

CAPT. PITTS: Good afternoon.

CHAIRMAN CARMODY: Capt. Pitts.

CAPT. PITTS: Gentlemen, earlier today you commented that both the variable ratio and the variable limit systems as used on the rudder design are certified. The 605-R model, the aircraft in question, has a variable limit. Can you describe for me the certification basis of the dash 605-R rudder system?

MR. CHATRENET: The certification requirements of the FAR Part 25. And there is no -- no specific requirements which address -- which address specifically any choice of architecture for the rudder control.

CAPT. PITTS: So --

MR. CHATRENET: There are some rules to compute the loads associated to the design.

CAPT. PITTS: So when this aircraft -- the -- you're telling me that the certification basis for the dash 605-R is in fact the first model of the A-300 which you put in the field, the B2-1A?

MR. CHATRENET: Excuse me? The -- could you -- could you say again your question?

CAPT. PITTS: I'm asking if the certification basis of this aircraft, the dash 605-R --

MR. CHATRENET: Mm-hmm.

CAPT. PITTS: -- is in fact the first aircraft you fielded, the A-300-B2-1A.

MR. CHATRENET: The certification, no. I'm afraid I have not understood completely your question.

CAPT. PITTS: Well, sir, the certification basis is a term of art. And if -- if we were to look at the revisions of this model, we would see that the B4-605-R is in fact the 17th revision of the basic design.

MR. CHATRENET: Mm-hmm, mm-hmm.

CAPT. PITTS: Is that correct? And I'm asking you, what was the certification basis in compliance with the Part 25 requirements for certification used for the B4-605-R model?

MR. CHATRENET: It was the regulation which was in -- in force at the time of the certification of this aircraft.

CAPT. PITTS: So the B4-605-R model went through the same process for certification as the B2-1A?

MR. CHATRENET: The B2 -- the B2-B4 was certified according to the requirements that were in application at the time of the B2-B4 certification. And the 600-R, according to the certification requirements that were in force at the time of the certification of the 600-R. So it might be that there have been some evolution in between. Possible.

CAPT. PITTS: So are you saying then that there was a difference in the certification requirements between the initial certification of the A-300-B2-1A?

MR. CHATRENET: I'm not in a position to identify right now from memory the differences between the certification bases, but this can be found. It's -- it's in the public domain.

CAPT. PITTS: In terms, then, of the -- the change from a variable ratio to a variable limit philosophy on the flight controls as it pertains to the rudder, was there a revisiting of the certification as was originally accomplished on the design?

MR. CHATRENET: There was a complete -- if you like, a complete review of all the certification bases that were to be applied to the 600-R. And we have checked that the design, including the RTL design, was satisfying the -- the certification requirement.

CAPT. PITTS: Okay. I'll move on. Earlier today, sir, you previously mentioned roll and yaw flight control force properties. I'd like to go back and revisit that just a moment.

Were the pitch control forces also balanced proportionally to such a light standard as you discussed with the roll authority from the ailerons?

MR. CHATRENET: No, the pitch control is a complete different issue. The pitch control forces, first they are made variable across the flight envelope. And -- and they are made variable also because the condition of operation are different. I mentioning the center of gravity possible variation between the forward limit and aft limit.

So also, from -- for roll and yaw axes, the variable parameter, if you like, is the speed for the pitch axis on top of the effect of the speed. You have the effect of the center of gravity. That's why, for instance, the feel system, the artificial feel system in pitch is different and a bit more complex than the artificial feel system in roll and yaw.

CAPT. PITTS: Okay. Then, in terms of this harmonious flight control handling properties that you mentioned earlier today, do you consider all three axes of the primary flight controls to be harmonious?

MR. CHATRENET: Not necessarily. I think I have made -- it's important that roll and yaw axes are harmonized. Pitch axis, it's -- it's a different aspect. Obviously -- obviously, a good aircraft is a balanced aircraft. It's -- I think there's a pitch axis on one side and the roll and yaw axes on the other side as a bit separated. It's different issues. The maneuvers that you are performing are not exactly the same. So I think they are not really comparable.

But for sure, roll and yaw must be made consistent. Pitch is another issue.

CAPT. PITTS: So then, from a Airbus design philosophy of the flight control, you would treat the roll and yaw systems, two of the three primary flight control axes, different than the pitch. Is that what you are saying? From an overall design philosophy at Airbus.

MR. CHATRENET: We would verify, I would say, first separately that each axis, pitch on one side, roll and yaw on the other side, have appropriate characteristic. And after that, it will be an outcome to see whether it is well balanced or not. But not from a design point of view to say, okay, we must make pitch and roll and yaw axes all together consistent. It is true for roll and yaw on one side, pitch on the other side. I would say at the beginning of the design pretty independently.

CAPT. PITTS: Sir, you mentioned "appropriate and consistent." Do you have an objective measure for those terms in relationship to the flight controls?

MR. CHATRENET: So we are -- we are already discussing about aspects that will be more deeply covered later on. But just let me say from a design point of view that we are designing the flight control system with a big help and a big contribution of the pilots anyway. And at several stages, at the design stage, at the stage when we test the system on the simulator, obviously at the stage when we test the system in flight, and even after when the aircraft is in service, the flight control design engineers have a permanent, permanent discussion with the pilots in order to check that the system is behaving like expected and is providing good handling qualities of the aircraft.

So, to my knowledge as a design responsible, this type of aircraft has now something like 15 millions flying hours. And on this particular aspect of control harmony, control sensitivity, and so on, we never, never have any complaint since the entering to service nor, obviously, during the design -- the design period. And we even had no I would say suggestion of improvement.

CAPT. PITTS: I see. So in -- it's your testimony that Airbus has not modified any of the three primary flight control systems to address any unfavorable reports or handling qualities of the aircraft?

MR. CHATRENET: Up to now we have no such --

we have not encountered such undesirable behavior on the -- on yaw axis, for instance, that would deserve some kind of addressing or modification or input on the yaw axis.

CAPT. PITTS: And the other two axes?

MR. CHATRENET: On the roll neither.

CAPT. PITTS: So there has been no modifications to the flight augmentation computers of the A-300-B4-605-R to improve handling characteristics?

MR. CHATRENET: From -- from what is coming from the pilots, there is no modification. From what is coming from the yaw damper function, as far as I remember, we have made some modification as an answer to some request of our customer to improve the -- some kind of fishtailing phenomena. And we have made some modification on the yaw damper function.

But this is not relative to any input coming from the pilot. And it was mainly to improve the comfort when the aircraft is flying in cruise in turbulence.

CAPT. PITTS: Fishtailing. Is there another term for that?

MR. CHATRENET: Lateral incomfort.

CAPT. PITTS: Lateral --

MR. CHATRENET: Lateral uncomfort.

CAPT. PITTS: Lateral uncomfort?

MR. CHATRENET: Lateral uncomfort for the passengers sitting at the rear.

CAPT. PITTS: Would those be lateral accelerations, sir?

MR. CHATRENET: Generally, it is a feeling which is difficult to -- to analyze. It generally comes out as a complaint. It's -- it's -- it's common to many, many aircraft at the entry to service saying, well, when the aircraft is riding into turbulence we think that we might impose a comfort in the rear part of the -- it's pretty subjective because each time it's very difficult to -- to clearly make a relationship between any complaint observed for the -- from the passenger or the flight attendant during a dedicated period of time. And generally, we do not have the FDR recording at this time to say, well, it's of use. We see some lateral load factors that might explain this. It's more an overall subjective assessment.

So we had some suggestions for improvement at the beginning. We have made a modification of the AVC computer. And since that date and since the introduction of this modification, we have no -- no -- any complaint in this area.

CAPT. PITTS: So there was a modification to the flight --

MR. CHATRENET: There has been a modification of the yaw damper, yes.

CAPT. PITTS: And when did that take place?

MR. CHATRENET: I could not recollect from my memory like that.

CAPT. PITTS: Who was the customer that complained about the fishtailing of the B4-605-R model?

MR. CHATRENET: I do not remember.

CAPT. PITTS: Are you --

MR. CHATRENET: But I could -- I could give you the -- we could -- we could retrieve the -- from memory, it was a Far East operator.

CAPT. PITTS: Are you familiar with numerous safety reports which number in excess of 30 from our pilots organization which speak to uncommanded rudder inputs and concerns about those?

MR. CHATRENET: Please, could you --

CAPT. PITTS: Uncommanded rudder inputs, fishtailing, lateral accelerations. Are you familiar with the reports that have been included and submitted for consideration in the public docket from the Allied Pilots Association to concerned pilots which speak to handling characteristics and concerns about fishtailing on the A-300-B4-605-R?

MR. CHATRENET: I -- I -- I am aware of this fishtailing aspect, yes.

CAPT. PITTS: And would those fall into that subjective category that you mentioned earlier?

MR. CHATRENET: As long as they are relative to comfort, comfort level for the passenger is a subjective assessment.

CAPT. PITTS: All right, sir. We had some earlier discussions about lateral accelerations and the need to address engine failure and landing at a crab -- cross wind control. Is it correct that you previously stated that the rudder should be used to oppose any other yaw asymmetry?

MR. CHATRENET: The rudder is the main control to correct big yaw asymmetry.

CAPT. PITTS: Big yaw asymmetry?

MR. CHATRENET: Big yaw asymmetry, like engine failure.

CAPT. PITTS: Then, just to touch upon some previous discussion, is it true that within your design philosophy that the rudder is not to be used as a primary flight control once in cruise or when in some other situation other than a big asymmetry?

MR. CHATRENET: No, but it should not be used like that except you can trim out any small lateral asymmetry. For instance, if you have a lateral asymmetry coming from an aircraft not perfectly symmetrical or a small asymmetry, you can use small rudder -- small rudder trim. But it's -- it is through the rudder trim anyway because it is an asymmetry that would build up very slowly and which requires only a very small -- very small amount of rudder.

CAPT. PITTS: What would be --

MR. CHATRENET: But you can use also the -- the -- the roll -- the roll trim.

CAPT. PITTS: What would be an appropriate pilot response to an in-flight yaw asymmetry in terms of which flight control to use?

MR. CHATRENET: If he's had an engine failure, it should be through the use of the rudder.

CAPT. PITTS: If it's a yaw asymmetry of any nature, sir, which would be the flight control that a pilot would be expected to use to counter yaw asymmetry?

MR. CHATRENET: This -- this question I am not the best expert --

CAPT. PITTS: Would --

MR. CHATRENET: -- from the operational side. It's not really relative to the flight control design.

CAPT. PITTS: So would --

MR. CHATRENET: It's more related to the

operation of the flight control design and the --

CAPT. PITTS: So within your design philosophy, you are not saying that the pilot should not use the rudder to counter a yaw asymmetry. It sounded like earlier that we did touch upon that.

MR. CHATRENET: What we have -- what we have explained this morning and this afternoon is that the -- the yaw damper function is there to -- to provide the yaw damping and to provide the turn coordination. Therefore, it is not necessary to use the rudder control by itself for providing -- yaw damping or -- or turn coordination.

For the engine asymmetry, it's obvious that you are to use the rudder. And it is what the rudder is designed for, compensating for engine asymmetry, allowing for cross wind takeoff and landing at the maximum allowed cross wind.

So this is -- this is what the -- the system is designed for.

CAPT. PITTS: Okay. So it almost sounds as if there is a limitation on when you would expect a pilot to use the rudder, maybe primarily for engine failure or cross wind landing control, is that correct?

MR. CHATRENET: It's a primary use of the rudder.

CAPT. PITTS: That's the primary use?

MR. CHATRENET: Engine asymmetry and cross wind takeoff and landing.

CAPT. PITTS: And how is that conveyed to the pilots, sir?

MR. CHATRENET: This is not in my -- in my field of expertise.

CAPT. PITTS: So when the --

MR. CHATRENET: It is an operational aspect.

CAPT. PITTS: In the conveyance of the flight control philosophy to the operators, there is no mention of this expectation that the yaw damper would be used almost in a primary mode to deal with the lateral accelerations?

CHAIRMAN CARMODY: Capt. Pitts, I'm not sure this is a question for this witness. I think he's already indicated it's not in his area. So perhaps hold it for later, if you like.

CAPT. PITTS: I'll move off that.

In terms of maximum force and pilot leg strength applied to the rudder, are you familiar with the 300-pound or less value that's mentioned in the Federal Aviation Regulations we use?

MR. VAN den BOSSCHE: This is the limit load, yes.

CAPT. PITTS: And how is that force to be applied and measured?

MR. VAN den BOSSCHE: Pardon?

CAPT. PITTS: In other words, the limit load would be 300 pounds.

MR. VAN den BOSSCHE: Yes. This is the load for which the mechanical system is designed for.

CAPT. PITTS: And you --

MR. VAN den BOSSCHE: -- strings.

CAPT. PITTS: Right. And your design has chosen to use a breakout force of 22 pounds, is that correct?

MR. VAN den BOSSCHE: Yes.

CAPT. PITTS: How is that force to be applied and -- and at -- where is the appropriate point to measure that force?

MR. VAN den BOSSCHE: First, that force has nothing to do with handling qualities. It is just an arbitrary force for designing the force strength, the complete mechanical linkage. And this force is applied on the pedals.

CAPT. PITTS: On the pedals?

MR. VAN den BOSSCHE: Yes.

CAPT. PITTS: I see. Directly on the pedals?

MR. VAN den BOSSCHE: Yeah.

CAPT. PITTS: During the measuring of forces for the rudders in Toulouse earlier this year, there was a discussion about the placement of the transducers and they were not chosen -- there was quite a bit of discussion about inappropriateness of using those at the rudder pedals. Can you speak to that?

MR. VAN den BOSSCHE: Two sets of transducers have been used for this test. NTSB test equipment was using transducer on the pedals. And the others' test equipment was using transducers on the control rod downstream of the pedals.

CAPT. PITTS: And you say that that will not have an impact on the handling qualities of the aircraft? Differences of -- of strength values, force values, and where those are measured?

MR. VAN den BOSSCHE: I'm not sure I understand. There is a direct relationship between --

CHAIRMAN CARMODY: Excuse me. I can't hear the witness. Would you mind speaking up? And I'm not sure -- Capt. Pitts, maybe you need to restate the question. I don't think it was clear.

CAPT. PITTS: I'm trying to understand why the forces are different as they're -- as they're measured at the various locations. And my understanding is, is that from a design criteria those forces are to be measured at the rudder pedals. And in fact, Airbus practice is to use a location other than the rudder pedals to measure those forces, is that correct?

MR. VAN den BOSSCHE: Yes, but there is a direct mathematical relationship between the force applied on the pedals and the force applied on the rod which is being used for the force measurement.

CAPT. PITTS: So regardless of which one we use, if you apply the mathematical correction you should get the same values?

MR. VAN den BOSSCHE: Yes, provided the force is applied with the right angle.

CAPT. PITTS: Provided the force --

MR. VAN den BOSSCHE: The force is applied to the -- with the right angle to the pedal because it is a question of momentum rather than force.

CAPT. PITTS: When I put my foot on the pedal, am I applying a right-angle force, sir?

MR. VAN den BOSSCHE: Probably.

CAPT. PITTS: Probably? So then, if we measured it at the rod, would we be sure that we are measuring the same value that a pilot might apply to the rudder pedal?

MR. VAN den BOSSCHE: I'm coming back to this issue of the 300 pounds which was the start of this conversation. Three hundred pounds is the force to be used for sizing strength-wise the components. For doing that, we select the worst condition, which is the condition for which these force produce the highest momentum in the pedal assembly. The forces that propose, we assume that this force is just perpendicular to the arm of the -- of the pedal. And this is it. This has nothing to do with handling quality.

CAPT. PITTS: So --

MR. VAN den BOSSCHE: And -- what?

CAPT. PITTS: I -- go -- I'm sorry.

MR. VAN den BOSSCHE: No, go on, please.

CHAIRMAN CARMODY: Capt. Pitts, I think he's answered the question. Do you have other questions?

CAPT. PITTS: I -- I just wanted to make sure that I understood that in his opinion that the tactile feel relationship at the pedal for the pilot applying force would be measured the same as the measurement techniques used at the rod.

Would we be able to -- would we be able to take that comparison forward and know what we're asking the pilot to do as they apply force to that rudder pedal?

MR. VAN den BOSSCHE: Well, for making this comparison, we probably need more that -- like the angles, as I said before.

CAPT. PITTS: Okay. Going back to the VSA and the electrical motors, you said that a force of 120 pounds could stall the function of this electrical -- this electrical motor which drives the VSA, is that correct?

MR. VAN den BOSSCHE: Correct.

CAPT. PITTS: And that would impact the rudder travel limiting system, is that correct?

MR. VAN den BOSSCHE: It would prevent the limiting system to further move, but the limiting system would remain irreversible.

CAPT. PITTS: Would it adversely impact the rudder travel limiting system?

MR. VAN den BOSSCHE: It would prevent the limiting system to move toward any -- any air speed configuration, if you like.

CAPT. PITTS: So if it failed to move to a higher speed configuration it would in fact be --

MR. VAN den BOSSCHE: That -- it would -- at least it would -- it would allow to keep it at the same position.

CAPT. PITTS: Would that be considered an adverse effect on the rudder travel limiting system, sir?

MR. VAN den BOSSCHE: No. And beyond that, there is a monitoring function which compares the achieved position of the rudder limiting system with the command. And as long as the command exceeds a certain threshold, which is five millimeters -- the -- the warning is displayed.

CAPT. PITTS: I'm not sure I understand, then. So you're saying --

CHAIRMAN CARMODY: Capt. Pitts, Capt. Pitts, I think we've done quite enough in this line of questioning. If you have something else, let's ask it. If not, I'd like to move on to the last party. The hour is 4:30. We've spent a lot of time on these same issues, and I think the witnesses have answered to the best of their ability. And I think we've done enough on this subject.

CAPT. PITTS: I apologize, Madam Chairman. It's a very complex system --

CHAIRMAN CARMODY: I know it is.

CAPT. PITTS: -- and in -- in terms of what we've heard today, there's been quite a bit of discussion about simulations. There are some references to some theoretical positions on the 9-B, page five chart that I'd like to address. And I'm not sure --

CHAIRMAN CARMODY: Is this coming to the end of your questioning?

CAPT. PITTS: There are several more.

CHAIRMAN CARMODY: All right. Well, I'd like you to limit them because I do think we've spent a lot of time on this and I think other witnesses may be able to address this better. And I think we need to move forward.

Which is the exhibit you're referring to now?

CAPT. PITTS: Exhibit 9-B, page five. The chart of the --

CHAIRMAN CARMODY: We've looked at this --

CAPT. PITTS: -- rudder position. Could you bring that up for us, please?

(Slide)

CAPT. PITTS: Sir, in -- using the digital flight data recorder time stamp of approximately 8:43.5, in your earlier statements you mentioned a theoretical limit there. Could you explain that in just a little more detail? I did not catch the exact meaning of what you meant by the red line with the square -- squared off top as being a theoretical value.

MR. CHATRENET: Are you talking about this -- this curve?

CAPT. PITTS: Yes. The Airbus simulated rudder position red line --

MR. CHATRENET: Yes.

CAPT. PITTS: -- 8:43.5. Yes, sir, right there. That squared sign.

MR. CHATRENET: This point?

CAPT. PITTS: Yes. Yes. Did you reference that as a theoretical point, theoretical limit earlier, sir?

MR. CHATRENET: We believe it is the best knowledge we can have of the rudder deflection at this stage because both it provides a good matching with the motion of the aircraft on one side, and secondly, when it is filtered like the stack is filtering the signal, it is perfectly matching with the recorded point on the DFDR.

CAPT. PITTS: Did that match all of the other values? When you mentioned it had a good match, did it match all other values closely?

MR. CHATRENET: Yes. All -- all of the other parameters. We have just shown some of them, like NY and heading. But it is also true for bank angle, pitch attitude, and so on. So we have a -- I would say a perfect match between the rudder position and more generally between the rudder position, for instance, and the filtered value in the DFDR.

And we have what we call an essential match between the flight parameters from the simulation on one side and from the DFDR, which is not unusual when using a model. A model is -- is -- it's the same model that we have since the beginning, so we have not done anything to the model. We have taken the model as is. And the model allows us to have a pretty good match with the DFDR parameter.

And to the standards of other incidents analyses and so on, we at this time have a good -- good -- pretty -- pretty good essential matching.

CAPT. PITTS: All right, sir. In one of your graphs you had a depiction of an A-300 and showed a balanced pressure on each side of the vertical stabilizer. And you had the plane of symmetry aligned with the fuselage reference line.

Are you familiar with the low pressure area generated by the vortex of a wing tip vortice?

MR. CHATRENET: When the aircraft encounters a -- the vortices, no, I could not tell you. It -- we -- it will depend on how the aircraft hit any wake vortex. Generally, the aircraft has a tendency to -- to flow above the wake vortex. So in this case, if the -- if the aircraft flows above the vortex, we'll have a certain repartition on the aircraft. If the aircraft hits -- and went inside of the core of the vortex, it would be another one. But I cannot -- I cannot illustrate this kind of different behavior.

CAPT. PITTS: The aircraft's handling characteristics have not been demonstrated moving tangentially through the core of a wing tip vortex, is that correct?

MR. CHATRENET: We have some -- some research analysis which is currently performed in order to characterize the -- the aircraft behavior. But this was not used at this stage. And as I have said, up to now we have a pretty good match of the lateral parameter of the aircraft without taking into account any assumption of lateral wind.

CAPT. PITTS: Those lateral winds, would those be straight-line winds, sir? Would they be rotational, such as we might expect to see in a wing tip vortex?

MR. CHATRENET: At this stage, at the beginning, they would be pure lateral.

CAPT. PITTS: So that would not be the case

-- that would not be a good comparison to a wing tip vortex?

CHAIRMAN CARMODY: Capt. Pitts, --

MR. CHATRENET: It depends.

CHAIRMAN CARMODY: -- we are having a witness in the course of the hearing on wake vortex. I think those questions should be addressed to him.

CAPT. PITTS: I understand.

CHAIRMAN CARMODY: This is not the proper witness.

CAPT. PITTS: I -- the concern is, as we talk about flight control design and certification, what consideration in the design and in the robustness of the design has included the possible encounter of a wing tip vortice.

MR. CHATRENET: Let me maybe develop a bit. What we are doing is that we first start to add some constant lateral wind. And if we get a good matching, it is sufficient to account of any rolling motion coming from the side roll effect. If after that it is not yet enough to put -- to get a good matching, then we have a pure rolling effect, but we do it progressively.

So first, we make an assumption, no wind at all. Is it good, is it valid. If it is sufficiently good, we are happy with that. Then if we try to refine the matching of the model with the -- with the aircraft, we add some lateral wind, pure lateral wind, which anyway includes some rolling effect through the side roll effect. And if it is not yet enough, then we add a pure rolling effect with no lateral acceleration.

But we made it -- this in sequence. So we are at the stage where we have nothing at all and we get a pretty good matching already. So what we expect to be necessary to even improve this matching is something very small, very small in lateral, and probably nothing in roll or very small in roll as well.

CAPT. PITTS: Okay. So in consideration, sir, of the fidelity of the digital flight data recorder and sampling rate and the difficulties that Mr. Benzon spoke to in the opening of this hearing, how much confidence do you have in the traces and the values that we're presenting here as we try to bring in external forces to match what we think happened?

MR. CHATRENET: We have -- we have a pretty good confidence in the -- in the time history of the rudder because we think that this time history is satisfying simultaneously two criteria. The first one is, once it is filtered, it is exactly matching with the DFDR recorded rudder position. And secondly, when it is input into the model, it gives some essential matching with the aircraft response.

CAPT. PITTS: What studies of the phenomenon known as adverse aircraft pilot coupling has Airbus conducted in terms of flight control design?

MR. CHATRENET: So in terms of flight control design, I think that we -- we -- this topic will be better addressed later on as human factors or operational aspect.

But let me say from a handling quality point of view, PIO or APC has an oscillating characteristic with a fixed frequency. That's why at this stage we have no evidence of fixed frequency and servo oscillation with some kind of similarity with APC phenomena or PIA phenomena.

CAPT. PITTS: Outside of this investigation, sir, has Airbus included APC into their flight control designs as a design philosophy?

MR. CHATRENET: It is --

CAPT. PITTS: In dealing with adverse aircraft pilot coupling issues?

MR. CHATRENET: It is a part of our, I would say, verifying or -- or, I would say, validation exercise to check that the aircraft are free of any APC tendency.

CAPT. PITTS: Back to the objective evaluation, did Airbus use anything along the lines of a Cooper-Harper rating scale to evaluate the aircraft pilot coupling issues and handling characteristics?

MR. CHATRENET: No, because we have other alternatives. We have alternatives from -- coming from the GA where you -- where we use mainly the certain 09 classification.

CAPT. PITTS: So you consider that a suitable substitute for a Cooper-Harper objective analysis?

MR. CHATRENET: Exactly.

CAPT. PITTS: One last question. It's three parts. Have there ever been any failures of the artificial feel and trim unit centering function on the A-300-B4-605-R?

MR. VAN den BOSSCHE: No. No failures have been told of the centering function.

(Pause)

CAPT. PITTS: I have no further questions, Madam.

CHAIRMAN CARMODY: I'll move now to Airbus. Any questions of your witness?

DR. LAUBER: Madam Chairman, I did have several questions for this witness, but in view of the hour, I'm going to limit it to one very quick question.

CHAIRMAN CARMODY: Thank you.

DR. LAUBER: Mr. Ahearn asked you a series of questions, Mr. Chatrenet, regarding various secondary rudder limiting devices, such as blowdown and hydraulic flow restrictors and similar kinds of things. Do you recall that?

Can any of those systems be effective against the dynamic build-up of side slip caused by cyclic rudder input that excites the dutch roll characteristics of the air frame?

MR. CHATRENET: No, I don't think so. I don't think so. We have shown the chart when we show that the -- the forced oscillation is rapidly growing and then stabilizing. This was obtained with pretty small rudder deflection and cyclic rudder deflection. So this is a basic, I would say, behavior of any type of aircraft if the rudder is actually moving with cyclic deflection even very small, provided that the frequency is matching with the natural frequency of the aircraft. We would get this kind of oscillation with growing amplitude.

DR. LAUBER: Thank you, Mr. Chatrenet. No further questions.

CHAIRMAN CARMODY: Thank you, Dr. Lauber.

We'll now move to the Board members to see any questions they may have.

Member Hammerschmidt, any questions from you?

MEMBER HAMMERSCHMIDT: Thank you. I just have a quick clarification question. Really, it pertains to something that Mr. Ahearn asked.

Mr. Ahearn, your last question, I'm wondering if it derived from a chart that's on page seven of Exhibit 9, Alpha. If you have that handy.

(Pause)

CAPT. AHEARN: Yes, sir.

MEMBER HAMMERSCHMIDT: You weren't too specific about which chart you were referring to, and I just wanted to pin that down.

CAPT. AHEARN: Actually, it was a chart that was presented by Mr. Chatrenet during his presentation. But, Mr. Hammerschmidt, it does in fact -- does in fact match the chart that is on this page.

MEMBER HAMMERSCHMIDT: Okay. Thank you. I was going to ask the same question that you did, so I just wanted to confirm that.

CAPT. AHEARN: Thank you.

MEMBER HAMMERSCHMIDT: That's all I have.

CHAIRMAN CARMODY: Member Goglia, any questions?

MEMBER GOGLIA: I believe -- I believe all my questions have already been asked. Why don't I just go through here quickly so I can --

(Pause)

MEMBER GOGLIA: I've already -- asked and answered.

CHAIRMAN CARMODY: We've had some very thorough questions.

Member Black, any questions from you?

MEMBER BLACK: Just a brief question. Did -- did Airbus do any testing about this change from the B2-B4 over to this new system? Did you look at pilot responses, your internal company pilot responses, controllability differences that they might have perceived between the two systems? I guess I'm talking about human factors testing and changing between the systems.

MR. CHATRENET: Formally speaking, I don't think that we have made, I would say, back-to-back comparison between the B2-B4 and the 600-R version.

But nevertheless, we have applied during the design process and the certification process of the A-300-600-R the same criteria, the same maneuvers. We have asked for the same type of control accuracy and evaluation that we have done for the B2-B4.

So even if there was no back-to-back

comparison of the two aircraft, both have been run through the same process of verification and validation of the handling qualities associated with both designs, with both flight control designs.

MEMBER BLACK: Thank you, sir.

CHAIRMAN CARMODY: And I have no questions of the witnesses, but let me thank Mr. Chatrenet and Mr. Van den Bossche for your time and for your testimony. It's been very helpful, and we appreciate your cooperation.

I'd like to now dismiss these witnesses with the understanding you may be called back later. There's always that possibility.

(Whereupon, the witnesses were excused.)

CHAIRMAN CARMODY: And before we proceed to the third witness, I'd like to have a break. So why don't we come back a little after five? Maybe five after five. Thank you. Thank you.

(Brief recess)

CHAIRMAN CARMODY: Let me say while people are taking their seats, we're going to start with our third witness, who is Capt. Larry Rockliff.

And I want to ask all parties to please in their questioning be direct, concise, and brief, and not ask the same questions repeatedly. I would also ask the same of our staff, the NTSB Technical Panel, that they be -- certainly, we want the information, but let's think about our questions and ask them quickly and move forward.

Ms. Ward, would you call the next witness, please?

MS. WARD: I call Capt. Larry Rockliff. Please raise your right hand.

Whereupon,

LARRY ROCKLIFF

having been first duly sworn, was called as a witness herein and was examined and testified as follows:

MS. WARD: Thank you. Please have a seat.

(Pause)

MS. WARD: Capt. Rockliff, would you please state your full name, your current employer, and your business address?

THE WITNESS: My name is Larry Bruce Rockliff. I am vice president of training for Airbus North America Customer Services. And I work in Miami Springs, address 4355 Northwest 36th Street.

MS. WARD: How long have you been in your current position?

THE WITNESS: Been in the current position for three years.

MS. WARD: And could you briefly describe your duties and responsibilities, including any education and training that you've received, to qualify you for your position?

THE WITNESS: My duties and responsibilities are oversight of all training for flight maintenance and cabin crew for North America and to implement the training policies of our parent company in Toulouse.

MS. WARD: Could you also list your -- list the FAA aviation certificates that you hold, any flight time that you have, and the aircraft that you've flown?

THE WITNESS: Okay. My career started out in the Air Force in Canada. In Canada, I completed tours on trainers, fighters, the Canadian air demonstration team the Snowbirds, and transports.

I hold two ATPs, a Canadian and an FAA. And I'm endorsed for check pilot privileges on 20 different regulatory bodies.

I'm type rated on A-300, A-310, A-320, A-330, and A-340. I've instructed on each of those aircraft, and I've been involved in, excuse me, development of training programs for all of the Airbus fly-by-wire airplanes.

MS. WARD: Thank you. Madam Chairman, I find this witness qualified and now pass it over to Capt.

Dave Ivey for questioning.

CHAIRMAN CARMODY: Thank you. Capt. Ivey, please continue.

TESTIMONY OF CAPT. LARRY ROCKLIFF

CAPT. IVEY: Good evening, Capt. Rockliff. I'd like to begin by discussing the Airplane Upset Recovery Training Aid and how that was developed and who actually developed that program?

THE WITNESS: The Upset Training Aid -- the Industry Upset Training Aid was the compilation and work of aircraft manufacturers, airlines, unions, and input from the FAA and in fact the NTSB also.

CAPT. IVEY: Can you tell me when the development of the Training Aid actually began?

THE WITNESS: The kickoff for the Training Aid began in June of 1996.

CAPT. IVEY: And what was the motivation behind the development of the Industry Training Aid?

THE WITNESS: It was actually in response to initiatives from the NTSB and the FAA in -- with an interest that the NTSB had put forward to further education of flight crew to recognize and recover from upsets.

CAPT. IVEY: And it's my understanding that the FAA issued a handbook bulletin called, "The

Handbook Bulletin for Air Transportation," the HBAT 95-10. And that's Exhibit 2-E-16, for those that might be interested.

Are you familiar with that document?

THE WITNESS: Vaguely familiar now. I certainly was back in the mid '90s.

CAPT. IVEY: And what was the purpose of that document and how was it generated?

THE WITNESS: Well, I think that the purpose of the document was to, again, respond to the NTSB recommendations and to provide guidance to inspectors and for training providers in the form of upset training.

CAPT. IVEY: And why did Airbus get involved in the Upset Training Aid development?

THE WITNESS: Well, as I mentioned, it was an industry initiative. And as a significant member of the industry, Airbus was partnering with the other manufacturers in the capacity of the manufacturers' input.

CAPT. IVEY: And you mentioned the various manufacturers. Were there any other bodies that were involved in the development of this Industry Training Aid?

THE WITNESS: I'm not sure I understand what you --

CAPT. IVEY: Oh, such as the Airline Transport Association and a collection of the carriers, that sort of thing?

THE WITNESS: Yes.

CAPT. IVEY: Those bodies?

THE WITNESS: Yes. Actually, the kickoff meeting occurred at Air Transport Association headquarters here in Washington, D.C. All three of the manufacturers -- at that time there were three large air framers, McDonnell Douglas, Boeing, and ourselves, Airbus. A large cross section of U.S. carriers as well as Canadian carriers. And as the program evolved, there was actually participation from foreign carriers, Europe and Asia as well. And of course, the -- the unions.

CAPT. IVEY: And at the time that this kickoff occurred, were there any airlines that were actually in development or had in place upset maneuver programs or advanced maneuver training?

THE WITNESS: There was.

CAPT. IVEY: And who might they have been?

THE WITNESS: American Airlines, United Airlines, and I believe Delta was in the final stages of developing a program for themselves.

CAPT. IVEY: And when this group got together to begin the Industry Training Aid, were the programs that were at that time in place, were they reviewed?

THE WITNESS: In part. Yes, there was a review of the programs.

CAPT. IVEY: And what was the consensus, if you will, of, say, ATA or the bodies that were collected together to -- upon review of the United program, for example, and the American program. What was their opinion of what had been developed at that point?

THE WITNESS: Well, first of all, there are two points to answer that question. First is that in reviewing them with inputs from the collective group, there was recognition that there were some positive points, actually common points between all of the programs that existed. There were other points that were unique to particular carriers.

In the interest of -- of maintaining a fairly standard training package for the industry in the form of training aids, the decision was made at that time not to adopt any of the individual ones that existed because none of them were optimized to a particular industry training aid.

And so the goal was to continue in the -- in the spirit of the previous successful training products, such as controlled flight into terrain -- takeoff safety training aid, wake turbulence training aid. So this was a logical evolution.

CAPT. IVEY: And as the program became established, were there significant differences that were -- among the industry participants as to how this should be approached?

THE WITNESS: There was. Many of the carriers, certainly the ones who had already established programs, for all good reasons were trying to look for a product that would serve all of their fleets with a simplistic kind of approach and to proceduralize it.

The manufacturers, all three, were very consistent in our concerns for that kind of approach. We felt that upset training was more of an awareness training because the infinite number of variables that could be experienced versus distilling it into something very simple in the form of one-size-fits-all for recovery.

CAPT. IVEY: And so there was never consideration given to adopting something that had already been planned out? As an example, American's Advance Maneuvers Program or United's Upset Training

Program?

THE WITNESS: The point was raised, and it was rejected at the first meeting.

CAPT. IVEY: And why was it rejected?

THE WITNESS: Well, for the reasons that I had mentioned so far. There were -- there were good points, and definitely, good points that were contained in the programs that already existed would be applied. But there were also other points that were of concern to -- to some of the people, specifically Airbus and Boeing and McDonnell Douglas.

CAPT. IVEY: Can you enumerate on some of the points of difference?

THE WITNESS: Well, specifically, with the American Airlines product, the -- what appeared to be the emphasis on rudder at that time was a concern to manufacturers.

CAPT. IVEY: Any other areas of concern?

THE WITNESS: The utilization of simulation. There was a fair amount of discussion on automation, automation dependency. And those were pretty much the areas that -- that we focused on.

CAPT. IVEY: And you mentioned simulation. How did Airbus come down on the issue of simulators? For or against?

THE WITNESS: Well, at that time -- this was very early in the program. And I think that even the carriers were just in the infancy stage of it.

Airbus's position on that -- on the use of simulators at that time was we were not in favor of using simulators for upset recovery training.

CAPT. IVEY: And from the time that the industry group formed until the Industry Training Aid was developed, how long a time period was that?

THE WITNESS: The first meeting was in June 1996, and the package, which was distributed jointly between -- to all of the operators of the world, was produced in August of '98. Boeing and Airbus and Flight Safety Foundation distributed it to all of the operators.

CAPT. IVEY: And once the Industry Training Aid was developed and handed to all the operators around the world, were there differences that still remained among the participants?

THE WITNESS: The purpose of the Training Aid was, as I had mentioned a moment ago, not too proceduralized. And so because there was a lot of consensus that had to go on with any package that's done with a large cross section of -- of participants, the choice of how to utilize specifics of the package was left up to the carriers. So, by definition, there would be differences.

Airbus and Boeing were able to identify the specifics of the awareness that we were trying to put out and had tried to convey to the operators throughout the development phase in the form of our Technical Digest which came out earlier in 1998.

CAPT. IVEY: And once the Industry Training Aid was developed and handed out in 1998, have there been any changes to the Industry Training Aid since that time?

THE WITNESS: There is actually a change that's in process right now. And it's in fact in response to another recommendation of the NTSB and the FAA subsequent to -- to this investigation.

CAPT. IVEY: And could you enlighten us as to what that is?

THE WITNESS: Well, as Mr. Benzon mentioned this morning, the two recommendations that were -- were forwarded in February requested or required that the manufacturers were to identify some knowledge points and some education. So line by line, the recommendations of the NTSB and the FAA are being responded to both in the form of -- of other manuals, but in particular, the Upset Training Aid.

CAPT. IVEY: And you mentioned that during the development of the Industry Training Aid, Airbus was against the use of simulators for teaching advanced maneuvers. Could you explain to me why, specifically?

THE WITNESS: Well, first of all, the use of a simulator has some tremendous deficiencies or limitations for unusual, out-of-the-ordinary type flying. It was touched on a little bit earlier today, but specifically, the forces that a pilot would experience in terms of increased weight or G-loading, as we know of it, both vertically and laterally. These cannot be duplicated in a simulator, so those were concerns.

In addition, the actual fidelity -- the actual information that goes into providing the simulation, the actual copy of the airplane, is in a relatively narrow band as compared to what a -- an aggressive upset could actually cause upon a pilot.

So it was for those reasons specifically, but more importantly, it also came down to the fact that in simulators, the tendency is that training is procedure-based. And as I mentioned a moment ago, our emphasis was on awareness training and not procedure training, from the manufacturers' point of view.

CAPT. IVEY: And is one of the reasons that you were opposed to the simulation due in fact to earlier testimony that talked about the envelope protection in the fly-by-wire airplanes? Although the A-300 is not fly-by-wire, but was that part of the motivation for not being interested in the use of simulators?

THE WITNESS: Not at all. We were quite specific, as was the other manufacturer, that insofar as fly-by-wire aircraft, by definition, unintentional exceedance of certain parameters is what defines upsets and that fly-by-wire airplanes wouldn't normally end up in those situations. But we both -- in our case, for our response, we produce A-310, A-300 aircraft, and we still have A-300-B4 aircraft out there.

So that decision was on the basis of the conventional flight control systems and the -- and the likelihood of the possibility for negative training if it's -- if it's used improperly in the simulator environment.

CAPT. IVEY: If in fact simulators were to be used in your advanced aircraft, your fly-by-wire, would it require modification in order for the simulators to introduce upset maneuvers or advanced maneuver training?

THE WITNESS: It would -- it would require a degradation of flight control laws because of the -- the specifics of the fly-by-wire platform that we've got. The airplane will resist upset. And so we'd have to artificially degrade systems in order to get the airplane into those conditions.

CAPT. IVEY: We've had earlier testimony about envelope protection, if that's an appropriate term, on your advanced aircraft and the fly-by-wire. Is there an envelope protection in the A-300-600-R?

THE WITNESS: Not in the form of a fly-by-wire. There are certain cues that are available to the pilots in the form of -- of alpha trim, you know, angle of attack trim, and things of that nature, just as there is in a lot of other aircraft. You have stick shaker and things of that sort which gives you indication when you're approaching the edges of envelope in one direction or another.

But protection in the form of fly-by-wire, no.

CAPT. IVEY: And in your fly-by-wire airplanes, there is an envelope protection that's built into the design of the aircraft, is that correct?

THE WITNESS: That's correct.

CAPT. IVEY: Does that include the rudder or yaw system?

THE WITNESS: Specifically, the envelope protection is not considered in yaw. But as the previous testimony indicated, there are certain properties of the roll mode that would imply a feature that would -- that would augment yaw in that the airplane would not tend to roll. It would just -- it would just skid with the introduction of rudder.

So although it's not a specific protection, it is much more a stable platform than a conventional flight control system.

CAPT. IVEY: Turning for the moment to training, and in particular, I'd like for you to tell me what methods of teaching Airbus uses to train upset recoveries to pilots at your facilities in Miami?

THE WITNESS: In Miami, during the ground school phase, we present to all trainees who go through on transition training the upset training video, the industry upset training video. We do not have simulator exercises.

CAPT. IVEY: Is there any computer-based training that's associated over and beyond the video itself?

THE WITNESS: For upset recovery?

CAPT. IVEY: Yes, sir.

THE WITNESS: No.

CAPT. IVEY: And --

THE WITNESS: That is, at this time. It's in development, again, in response to the NTSB and FAA recommendations earlier this year.

CAPT. IVEY: And could you tell me what type of training is provided for upset recoveries in Toulouse on your advanced airplanes?

THE WITNESS: Can you explain "advanced airplanes"?

CAPT. IVEY: Well, I -- the A-310. I realize that the A-300 is not -- there's not a school -- it's my understanding there's not a school that's in Toulouse for the A-300, is that correct?

THE WITNESS: In -- in Toulouse, yes. We teach A-310 and A-300 in Toulouse. And --

CAPT. IVEY: And so the training is the same there as it is in Miami?

THE WITNESS: That's correct.

CAPT. IVEY: In terms of the flight crew operating manual, the FCOM as it's called, is there any methods for recovery that are incorporated in the FCOM for pilots to observe and read?

THE WITNESS: For upset recovery?

CAPT. IVEY: Yes, sir.

THE WITNESS: There is now, yes.

CAPT. IVEY: And how long has it been in there?

THE WITNESS: I believe it went in with a temporary bulletin earlier this year. And -- and if there's been a revision subsequent to that temporary bulletin, it would be included with that. And again, that was in response to NTSB recommendations.

CAPT. IVEY: And can you -- are you familiar with the steps in general as to what was inserted in the FCOM?

THE WITNESS: I'd have to -- I'd have to look at it again. We don't teach the A-300 in Miami at this time, so my -- my referral to that airplane would have to be by looking at an exhibit, if it's in there.

CAPT. IVEY: In terms of A-300 training, which major Part 121 carriers in the United States operate A-300s and have taken Airbus training?

THE WITNESS: American Airlines, Fed Ex, and UPS. American -- originally, when they received the airplanes back in the late 1980s, the initial cadre group of pilots were trained by Airbus, the very initial group.

The same was the case with Fed Ex. And actually, only one crew with UPS. UPS actually had some -- some folks train at Fed Ex for their initial --

initial cadre airmen.

CAPT. IVEY: And you -- you mentioned "initial cadre." Since that initial training, has any of those carriers been back to use Airbus training?

THE WITNESS: For wet training where our instructors conduct it?

CAPT. IVEY: Yes, sir.

THE WITNESS: To my knowledge, no. Certainly not in -- in Miami. I cannot speak for Toulouse.

CAPT. IVEY: Do you have any idea as to why they've not used your training?

THE WITNESS: Well, in the case of American Airlines and Fed Ex, they both had their own simulators. So it's fairly normal, quite usual, for Part 121 carriers to have the initial cadre go to the manufacturer, usually the project pilots. From that, they develop their own training programs, utilize their own resources.

Now, if there is a case where they haven't yet received their simulators, they may come and use the manufacturer's simulator, but for the most part, it would be what we call "dry training," where they use their instructors, their -- their check airmen, and simply use their equipment.

CAPT. IVEY: Has there been any discussions between Fed Ex, UPS, or American regarding differences in their approach to training? And let's focus specifically on upset training compared to what Airbus offers.

THE WITNESS: Nothing has been brought to my attention.

CAPT. IVEY: And what about the rest of the world? Does the foreign carriers use Airbus for their training?

THE WITNESS: Some do. Our -- our resources and our capacity is normally set up for entry into service of new aircraft. As you can imagine, carriers, as they receive more and more airplanes, have traditionally transitioned into conducting their own training.

So the usual is that foreign -- foreign carriers at least, we'd end up doing more than the initial cadre, but we wouldn't conduct the wet training for them indefinitely.

CAPT. IVEY: Is there a difference in philosophy towards upset maneuver training between Airbus and American? And has it been discussed between the two of you?

THE WITNESS: Yes.

CAPT. IVEY: Could you explain to me what those differences and the discussions were focused on?

THE WITNESS: Well, specifically, use of rudder is -- is a difference between what Airbus considers as a method for normal roll control than what American has supported in their AAMP program.

CAPT. IVEY: Has that been the major sticking point?

THE WITNESS: It's been an ongoing point since the end of 1995.

CAPT. IVEY: Turning for a moment to the AAMP, A-A-M-P, or the Advanced Aircraft Maneuvering Program, that American uses, did Airbus get involved in the development of that program initially?

THE WITNESS: No. We weren't invited to, although I was invited to observe it after it was complete. But insofar as the development, no.

CAPT. IVEY: Were any other manufacturers invited or any other members of industry and aviation invited to help in their development?

THE WITNESS: Well, only through testimony I'm told that -- that they were, but I don't know that firsthand from talking with other manufacturers.

CAPT. IVEY: And so the first real participation for Airbus in the Advanced Aircraft Maneuvering Program was at the conference where industry was invited to attend?

THE WITNESS: No, it was before that. I was invited by the -- the vice president of flight operations at that time to come and observe their AAMP program in the autumn of 1995, which was fairly early in the program. I believe they were just exposing their check airmen and instructors at that time.

CAPT. IVEY: There was an Airbus Industries presentation concerning Airplane Upset Recovery Training Aid at the 10th Performance and Operations Conference, and that was held in San Francisco, California, in September 28th through the 2nd of October in 1998, I believe.

THE WITNESS: That's correct.

CAPT. IVEY: Did you participate in that?

THE WITNESS: I did.

CAPT. IVEY: And did you participate in the presentation that was made there?

THE WITNESS: During the Q & A at the end of it, yes.

CAPT. IVEY: And just for clarification, that's Exhibit 2-F, those of you that have the exhibits.

And would you please describe the purpose of that presentation?

THE WITNESS: Our chief test pilot, Capt. Bill Wainwright, chose to -- to write a paper out of interest for all the operators because this Ops Performance Conference is -- is an invitation to all of the global Airbus operators in all of our aircraft. And so he chose to identify the evolution of the program and how the flight test pilots from the three manufacturers became involved.

CAPT. IVEY: And there are several items listed in that that really talk about the differences of opinion. And there seemed to be a conflict between the technical advice that was being given by the manufacturers and the operators with regard to training of pilots in the simulators. Can you tell me basically what the crux of that matter was and the differences?

THE WITNESS: Are you referring to a specific spot in his presentation that you'd like me to speak to?

CAPT. IVEY: If you could turn to Exhibit 2-F, page three?

(Pause)

THE WITNESS: Yes?

CAPT. IVEY: And in the first paragraph up there, right from the beginning there was a conflict between the technical advice given by the manufacturer's training pilots --

THE WITNESS: Mm-hmm.

CAPT. IVEY: -- and that expressed by those of the principal airlines already practicing upset training. Could you help me understand what this conflict was really about?

THE WITNESS: Well, I don't know that "conflict" -- it's a fairly harsh term. But for sure, there were differences of how best to approach the issue. In our case, the training representatives from the manufacturers, myself representing our Development Department in Toulouse and a counterpart from Boeing representing that company, we were trying to deemphasize the emphasis on rudder as a -- as a roll control in upset recovery. And we weren't having a great deal of -- of success in convincing our counterparts, the training people in the carriers.

So for that purpose, we requested that our -- that our troop, people who have been in that region that the test pilots who actually operate closer to the edge of the envelope, we asked them to come and -- and help out with their technical input.

There were other areas, but in particular, it was -- it was use of rudder.

CAPT. IVEY: And I think also the use of

simulators was featured in that presentation also, is that correct?

THE WITNESS: Mm-hmm. Yeah.

CAPT. IVEY: Again, on that page, it said that "The conflict remained until we finally achieved an agreement at the last meeting in January of 1998." That's right at the end of the second paragraph.

THE WITNESS: Mm-hmm.

CAPT. IVEY: So it took a while to get these differences ironed out. Can you explain to me how the operators were having such a difference of opinion between the use of rudder and the use of simulators as two of the differences? Why did it take so long?

THE WITNESS: I believe that probably the operators were quite convinced that the conclusions that they'd come to were valid. And it was a case of trying to convince them from the technical expertise from the -- from the manufacturers that -- that their conclusions were not valid for some of their -- some aspects of their training packages.

CAPT. IVEY: And you actually go on to say in the article that the difference -- of opinion between the three test pilots in the group, there wasn't any. There was never a difference. And so you have three manufacturing test pilots that are in agreement and yet the operators are resisting this approach to the Industry Training Aid. Is that a factual statement?

THE WITNESS: Not to the Training Aid but to certain components of the Training Aid.

CAPT. IVEY: Yes. I stand corrected.

THE WITNESS: Yes.

CAPT. IVEY: Yes. In particular, the use of rudder and use of simulators. Was the Training Aid designed to be a supplement to simulator training?

THE WITNESS: A supplement to simulator training? No. The Training Aid was intended to be a stand-alone package, just as previous training aids had been. And it was, as I mentioned earlier, in the very same spirit as -- as previous training aids.

Given that it was a tool or a product for the entire aviation community, a lot of carriers in other parts of the world wouldn't have the resources that a lot of our carriers have over here so that some of them would use it as -- as only the video, some of them only the workbook, some of them only the CDs, and some of they may have in fact also used them to develop simulator training programs.

CAPT. IVEY: And in earlier testimony, you stated that the use of simulators for upset training was not Airbus's opinion in which that should be used?

THE WITNESS: Yes. I think it's important to note that, again, this is a industry product and so that people will utilize it for exactly that. They'll -- they'll either use it for its total capability or partially, dependent on what their particular needs are or what they decide their needs are.

And from the Airbus point of view, we had those concerns. We still have those concerns about the use of simulator due to the high possibility of negative training if it's not conducted properly.

CAPT. IVEY: If simulators can't be modeled for unusual attitudes, should they be used at all in upset recovery training?

THE WITNESS: If the -- if a program is properly tuned and it is -- and it is kept -- the instructors are properly qualified and -- and parameters are tightly maintained so that -- so that the data that the trainee -- that the crew under training receives is valid, then -- then there may be some value to it.

However, there is a lot of risk. And so if you put it on balance and we consider the fact that it's an awareness education and not a procedure-based initiative, then there are probably other tools that are more appropriate than simulators.

The adage that -- one thing in our business of training that we've become fairly comfortable with throughout the years is that we can always bump up the level of training that we use. And at certain points we don't want to bump it any further. We stop at a simulator because it wouldn't be safe to go to an airplane.

But there's also other areas where it's equally practical to bump down in the level of -- of training device or training media that you use. And at Airbus, we feel that upset training is -- upset awareness training is definitely an area where that needs to be looked at.

CAPT. IVEY: So if airplanes are dangerous to actually perform the maneuvers and simulator modeling is inaccurate, then how does a pilot learn the basic skills so that they'll revert to what's being taught either procedurally or, as you say, awareness?

THE WITNESS: One area that the entire industry -- that there was total consensus on is that by the time a pilot is operating an airplane for a major carrier, a large airplane, they should have had some sort of basic training in unusual attitude recognition and recovery. At a certain point through primary flight training and as they work through their licenses, they are continuing to qualify to become a pilot. And there are certain components, there are certain pieces of becoming a pilot that are just part of that education, like in any other profession.

Once you're already in the profession and simply transferring or transitioning from one aircraft type to the next, it's very, very late to be teaching basic skills that were missed.

So there was unanimous agreement in that field that the proper place for this education is very early in a pilot's career. Then, afterwards, an academic computer-based training module, some sort of supplement to it, a refresher, would be much more appropriate than -- than primary skills when a person is already well established in their career path.

CAPT. IVEY: Turning to the simulators for a moment, has it been your experience that in the process of upset maneuver training that's being developed, is the aspect of stalling being ignored, or going past the stick shaker, in part of this program?

THE WITNESS: During the training itself?

CAPT. IVEY: Yes, sir.

THE WITNESS: Well, the -- the test pilots raised some -- some very important considerations with reference to upset recovery. And that is, the recognition of when an airplane actually is stalled because within most regulatory bodies, demonstration practices for -- for a stall, the pilots show their competency in recovering from an approach to stall and not a stall condition whatsoever, and they're vastly different.

The consequence of an airplane being stalled, when it's stalled, it's out of control but it can get back in control. And that has to be done first before recovery is articulated. Insofar as how operators employ that within their -- in their training programs, I have no -- I have no visibility on that.

CAPT. IVEY: Since the accident, are you aware of any modifications in training at Airbus or any of the other airlines that produce upset maneuver training?

THE WITNESS: Modifications in training?

CAPT. IVEY: Yes, sir.

THE WITNESS: Well, definitely in response to the recommendations of the NTSB. We're implementing education and -- and actually simulator training, not in upset recovery but in recognition and response to NTSB recommendations. And I'm not aware of what other carriers or manufacturers are doing.

I also note that the Aircraft Upset Training

Aid is jointly, with Boeing and ourselves launching it, addressing all of the items that the NTSB has recommended as well. And that will evolve over the next few months to include industry and the -- and the FAA as well.

CAPT. IVEY: You have participated in a simulator program involving upsets at American, is that correct?

THE WITNESS: That's correct.

CAPT. IVEY: And what was your view of the modeling of the simulator? Did it stay within the manufacturer's flight test data, in your opinion?

THE WITNESS: Well, I went in with the chief test pilot of McDonnell Douglas on the morning after a AAMP seminar or conference in Dulles. And we had a briefing on some modification work that had been done on the simulator, and so we were taken in the simulator to actually go through a demonstration of -- of how the -- the maneuver unfolded. So -- and that was in an MD-11 simulator.

CAPT. IVEY: And what was your view of the maneuver that you encountered?

THE WITNESS: It was a wake vortex or a simulated wake vortex maneuver. We had been briefed at that time that the evolution -- how the instructor would set the maneuver up would be to select some kind of a selection at the instructor's station and it would cause a little bit of a burble in one direction or another, followed by a fairly rapid -- very rapid roll to the opposite direction, and that in order to facilitate this particular input to the controls, the roll -- the roll surfaces were either partially or completely inhibited so that the airplane would develop a fairly high roll rate. And if the pilot didn't respond to it, they would end up with a significant attitude problem. You know, they'd be upside down.

CAPT. IVEY: And you mentioned the roll inhibition. Did it appear that the rudder was inhibited, too?

THE WITNESS: At that time, my recollection is it absolutely wasn't. As a matter of fact, the chief test pilot for McDonnell Douglas at that time suggested that since we knew that the roll surfaces had been partially or completely inhibited, we would simply use rudder to try and control the -- the roll moment, which he did. And we were able to work our way through it.

CAPT. IVEY: And just to clarify an earlier witness's statement, Mr. Chatrenet, there was a comment made that in cruise that normally the rudder is not used and roll is controlled by aileron. Could you as a pilot talk about how aileron and rudder are used to control an airplane?

THE WITNESS: Yes, I can. I think that we need to be clear and -- well, we need to be clear that aileron and normal roll control is -- is through ailerons and roll spoilers conducted through the yoke or in the side stick, depending on the type of airplane. And rudder is not a primary flight control to induce roll under any circumstance unless normal roll control is not functional.

So the consequence of that is that the ailerons, whether you're in cruise or whether you're elsewhere in the flight envelope, at a much slower or higher angle of attack, ailerons and roll spoilers would continue to be your normal, usual roll control.

Rudder, on the other hand, is used to control the yaw. It's -- it's used to zero side slip. Mr. Chatrenet spoke to it, I think, quite well, that for thrust asymmetry or drag asymmetry, whatever the cause, if you have a yaw condition or a side slip condition, the rudder is dimensioned and it is there to zero it out, for the pilot to apply rudder so that you end up with this zero or reduced loading. And that's throughout the entire envelope.

CAPT. IVEY: You'd mentioned earlier that one of the limitations of the simulator is the fact that a pilot in training cannot feel the lateral Gs or even the excess positive Gs, or negative Gs for that matter, in a simulator.

THE WITNESS: That's correct.

CAPT. IVEY: Do you believe that given the state of a simulator in the development that we're at at this point in time, with a level C in the case of American's A-300 simulator, that a half a loaf is better than no loaf at all? And that is to say that although a pilot can't experience all the G forces either in the pitch roll or yaw axis that they may be able to develop a means to recognize and to recover from upset maneuvers as opposed to sitting in a room such as this listening to a lecturer or interacting with a computer-based training device or a video tape. Do you think that a half a loaf is better than no loaf at all?

THE WITNESS: It's a -- it's a long question, and I'll try and keep the answer fairly concise. The half a loaf would be acceptable if it hadn't gone bad. That means that if it's -- if you're going to eat something that's going to make you sick, or in other words, if you're going to train something which is going to cause negative training, then I would not agree with that statement.

However, if it was edible, in other words, you were in the envelope of the airplane, the -- you could confirm and validate the fact that the training that you were trying to conduct was sound training and you were going to have a positive transfer of information to the trainee, then, yes, it could be. It could be positive.

However, there's -- there's a wide swath being not able to eat your half loaf and -- and having it acceptable. And so I think that in order to avoid that risk, we'd be better off dropping down a level.

CAPT. IVEY: In your opinion, when the AAMP Program was first started by American Airlines, do you believe that it was teaching excess rudder usage?

THE WITNESS: I do.

CAPT. IVEY: And in what areas were they emphasizing rudder too much?

THE WITNESS: Generally, the conditions that I had been exposed to in the presentation and with the ongoing evolution of the Upset Training Aid. I need to note that the author or the developer of the AAMP program was also a participant with the Industry Upset Training Aid. So it wasn't a snapshot. Only when I saw the program in the autumn of '95.

At that time, there was a considerable amount of emphasis -- or at least, I felt there was a considerable amount of emphasis on the use of rudder to induce roll at high angles of attack. And the conclusion and the validity of their -- the conclusion was that apparently, as validated in the simulators, the roll control of the airplane or the simulator was significantly stagnated or reduced. And so that the conclusion or the discovery was that the rudder was quite effective.

CAPT. IVEY: And so that was leading to a negative training? Would that be a fair --

THE WITNESS: Well, again, I come back to the basic premise. Rudder is not a flight control, a primary flight control, for inducing roll. It is there if the roll is not properly working.

Perhaps more to the point would have been to discover why the roll control wasn't working and if in fact it was because the airplane was at an exceedingly high angle of attack that perhaps reducing the angle of attack might have been the proper solution versus using a flight control that the pilot had never been exposed to before as a roll flight control and concluding that to be a solution.

CAPT. IVEY: And since the time in which you visited the AAMP program, has American made changes to the emphasis on rudder?

THE WITNESS: Well, there was -- we were told, "we" being Boeing and McDonnell Douglas and ourselves, that the company had -- had determined that use of coordinated rudder was appropriate and that just excessive rudder was not. So yes, that was something that American Airlines had conveyed.

CAPT. IVEY: In your opinion, is American Airlines' emphasis on training more to the recovery of an upset as opposed to recognizing the entry or the approach to an upset?

THE WITNESS: It's going back quite a long ways to -- to when I sat in on the -- on the presentation. And at this time I just can't remember clearly as to whether there was a great deal of emphasis on -- on recognition and avoidance versus recovery. Definitely, recovery was mentioned, but I can't speak to whether or not there was modules towards recognition and avoidance.

CAPT. IVEY: Based on when you went through the simulator, and that was early, I understand, do you believe that if that program had remained as it was then that American Airlines' pilots would have been conditioned to use rudder more than had they not emphasized rudder in the early stages?

THE WITNESS: I do. That which we experienced is not unlike what any pilot would do with any airplane regardless of type, regardless of place. If they're experiencing a roll for whatever reason, they will intuitively try and counter the roll with their normal roll control. If they exhaust their normal roll control, they will then go to rudder to try and -- to try and induce a roll.

And so, if in fact they are to experience something of that nature in the simulator, then they would be -- that is to say, that which the chief test pilot for McDonnell Douglas and I experienced -- they would find themselves in each iteration finding themselves using rudder to -- to arrest the roll rate and eventually start the recovery. That would be, in my opinion, negative conditioning.

CAPT. IVEY: And you mentioned just a few moments ago, which leads to my question, and that is, what does the term "coordinated rudder" mean to you?

THE WITNESS: To me?

CAPT. IVEY: Yes.

THE WITNESS: To me, coordinated rudder is zero side slip. Essentially, it's keeping the ball in the middle.

CAPT. IVEY: And in the case of the A-300, is there a ball?

THE WITNESS: There's not a traditional ball. There's a small trapezoid on the bottom portion of the sky pointer, an index on the top of the attitude indicator. And that particular index will move from side to side dependent upon side slip forces.

CAPT. IVEY: Works the same fashion as a ball?

THE WITNESS: Very same fashion. If the ball or if the trapezoid is in the middle, you have coordinated rudder.

CAPT. IVEY: And those two indications, the ball in airplanes -- even general aviation airplanes have balls -- and the trapezoid, what does that measure?

THE WITNESS: Side slip force on -- on the -- on our presentation, on the A-300.

CAPT. IVEY: And that would translate to a lateral G for a pilot?

THE WITNESS: Correct.

CAPT. IVEY: On his body. Do you think the term "coordinated rudder" is well understood by the pilot community at large? And I'm talking about airline pilot community.

THE WITNESS: I believe it is. When pilots are in the early phases of their careers, learning how to fly, in particular on -- on small airplane or even some -- some military trainers, they become quite used to keeping the ball in the middle. And as they transition up to the larger aircraft that have turn coordinators and yaw dampers, they also become accustomed to the fact that it's -- it's a fairly automatic process in those airplanes. Certainly on the A-300-600.

CAPT. IVEY: What type of rudder usage is taught at Airbus?

THE WITNESS: Proper use of rudder?

CAPT. IVEY: Yes, sir.

THE WITNESS: Well, that's what type of rudder is taught at Airbus. That is -- that is -- it's used for, obviously, the control check and the pilots are exposed to that. It's -- it's used for stressed asymmetry or drag asymmetry. Certainly, in the transition course there's a lot of practice that pilots going through courses would be exposed to in terms of thrust asymmetry. And cross wind takeoffs and landings.

In the abnormal phase for system anomalies, which is a normal part of transition on any airplanes, pilots would be exposed to that as well for -- for use of rudder. It is not taught as a roll control.

CAPT. IVEY: Is there ever a time that a pilot is instructed to use full rudder for any particular normal or abnormal condition?

THE WITNESS: If full rudder is required for a drag asymmetry or a thrust asymmetry. The pilot is taught to use sufficient rudder. They're not taught to use a given deflection. We've talked a lot about numbers and harmonies and things of that sort throughout the day. The truest harmony in the cockpit is between the man and the machine, and that begins the first day they transition on an airplane and it grows and it improves every day after that. And so sufficient rudder is to get the ball back in the middle.

CAPT. IVEY: And typically in the training program that Airbus teaches, is there ever a time where pilots are trained to use rudder at higher speeds? And let's use, for example, 250 knots.

THE WITNESS: Well, if there was a thrust asymmetry, sure. During the transition the usual case of -- of engine failure practice, engine failure demonstration is during the takeoff just after the refusal speed and just prior to the rotation speed. But the exercise doesn't conclude there. The pilot would then accelerate on through to the final takeoff speed. And dependent upon the training weights or the scenario that was -- that was going on at that time, they would likely end up in the area of 230, 240 knots.

CAPT. IVEY: And since the accident, has Airbus made any changes to their airplane flight manuals or to the FCOM regarding rudder usage?

THE WITNESS: Yes. Again, in response to NTSB and FAA recommendations, we -- we completed a Flight Crew Operating Manual bulletin in February of this year and -- and then with the subsequent revision.

CAPT. IVEY: Exhibit 2-N-6 in the FCOM under the "Abnormal Procedures for Landing Gear Unsafe Indication," part of the procedure was to be to accelerate to Vmax and perform alternating side slips in an attempt to lock the gear. Were you aware of that procedure?

THE WITNESS: I was. Or am.

CAPT. IVEY: And could you explain the term "Vmax"?

THE WITNESS: Vmax is the speed that we have identified on our airplanes that have got electronic flight instrument systems. And it is the maximum speed

-- the max limiting speed for a given configuration. So that if you have a certain configuration of flaps, there's a certain speed which you can fly it at, and beyond that speed, you're exceeding the -- the normal operating limits of it. So that would be defined as Vmax.

CAPT. IVEY: And since the accident the procedure has been changed to include a note about slowly using the rudder up to full deflection. That's 2-N-7. And do you know why this change was made?

THE WITNESS: Okay. It -- I would respectfully suggest that it's not a change, it's an addition. The -- the actual procedure and the guidance to the pilot is still that you would accelerate to Vmax in order to establish aerodynamic loads.

The purpose of the -- the checklist is for the unsafe gear to be exposed to loads, aerodynamic loads -- and of course, the faster you go, the higher the loads are -- in an effort to try and lock it down.

The notion of side slip, which is something that up until most recently we were very, very comfortable with throughout the world that most pilots -- all pilots were clear on what the definition is because every time a pilot lands in a cross wind, they're inducing a controlled side slip in the form of maintaining the heading and decrabbing an airplane, as was outlined in some of the slides this morning.

However, in various discussions that have gone on in the last several months in the -- in the wake of this investigation, considerations for side slip have not perhaps been considered in the context of steady state. And that was the purpose of clarifying this particular language in the operating manual.

CAPT. IVEY: Again, in the A-300 flight manual under "Limitations," VA is listed as the maximum design maneuver speed. VA. Would you explain what the term means?

THE WITNESS: VA is exactly as you stated, design maneuver speed. It's a design reference on transport category airplanes, and -- and that's why it's contained in the airplane flight manual and not the Flight Crew Operating Manual. It's not an operational speed.

CAPT. IVEY: And in part, the manual contains language that "allows full application of rudder and aileron controls as well as maneuvers that involve angles of attack near the stall should be confined to speeds below VA." And I would like to say again, "full application of rudder and aileron controls." Exhibit 2-0 -- 202 is the page that references that.

But there's no statement that concerns rates or inputs or amounts of displacement of the rudder in particular. Does the average line pilot have the information contained in his flight manual about VA limitations and ranges?

THE WITNESS: Well, again, I'd like to be clear on the fact that it's a design speed, it's not an operational speed, and that's why it's not in the operating manual. And I believe it's not in other manufacturer operating manuals as well.

This is something that is -- could probably be more clearly answered to you from -- from Flight Test or Engineering than -- than Training or Operations because we're just not exposed to it on that side of the -- the industry.

Now, the language that's in here, in the flight manual, is word for word out of FAR 25 because FAR 25 states that that verbiage must be in the AFM.

CAPT. IVEY: Do you think that VA and the definition of that speed is useful to an airline pilot?

THE WITNESS: I do not. I think that it's important to note that I've learned much more about the global understanding of VA in the -- in the last few months, but I also need to -- to clarify the fact that since being with Airbus I've had the opportunity to train airlines all over the world. And I've never had a flight crew member or anyone from a training department at all or flight ops department inquire about VA in reference to transport category airplanes.

CAPT. IVEY: And prior to the accident, would it be your opinion that the full application of rudder and aileron as well as elevator was protected as long as you were below VA?

THE WITNESS: No.

CAPT. IVEY: You were aware that that protection was not afforded?

THE WITNESS: No, I -- I wasn't aware. I mean, in -- in -- in transport flying, in operating large airplanes like this, the notion of full-scale applications, other than a control check on the ground, are not contemplated. And so on the basis of that, I hadn't considered that -- that notation whatsoever.

CAPT. IVEY: So in light of the accident, there's been a revelation for you as I'm sure there's been for many pilots about the full application of rudder and its consequences?

THE WITNESS: But I think it's also important to note that in the traditional context of -- of VA and the loads and in specifically the use of rudder for -- for various maneuvers in the certification, VA is not considered. The -- the yaw maneuvers are done right out to VDMD, which is dramatically higher than VA. So that in the traditional sense or perhaps the -- the recall of what VA may mean, it doesn't apply to those particular loads at all because they're extended much beyond in the demonstration.

CAPT. IVEY: We've talked about maneuvering speed, but prior to the accident what do you think pilots' knowledge was concerning rudder limiters?

THE WITNESS: What the pilots -- general pilots' knowledge? I should guess that it would be quite clear. It's part of the transition course. It's in the operating manuals. So there's no reason to -- to think that pilots wouldn't be aware of it. That's the purpose of a transition course when -- when pilots switch from one airplane to the other, is to learn the specifics of the new type aircraft that they'll be flying.

CAPT. IVEY: But I was thinking more in terms of pilot's knowledge thinking that a rudder limiter has been built into this airplane to reduce the amount of rudder travel and in essence protect me, the pilot, from being ham-footed and putting in too much rudder pedal and perhaps overstressing the tail. Do you think that that might have been the general knowledge of the pilot population prior to the accident?

THE WITNESS: I think it probably is, and it should remain. If the -- if the rudder is properly used, a full deflection of the rudder is needed for thrust asymmetry, for the purpose of the rudder, then -- then the pilot should have that conclusion properly.

CAPT. IVEY: And staying with the rudder system, how many pilots do you think use rudder on a normal flight once they have put the wheels in the well and are in climb, cruise, and descent prior to extending the landing gear for landing on an airport?

THE WITNESS: Well, throughout most of what you've described, the majority of the pilots are making use of the autopilot at that time. But I would say that by and large, certainly on our equipment that I've trained and taught on each of them, the pilots do not routinely use rudder to -- to coordinate because the coordination is done automatically by the system.

However, for any cross wind landing or any cross wind condition, they would certainly use it.

CAPT. IVEY: And the rudder pedals, is there a clear explanation as to the amount of reduction in rudder pedal travel on the Airbus A-300 as it relates to an increased air speed? Is that fully explained in the FCOM?

THE WITNESS: It is.

CAPT. IVEY: Rudder or rudder pedals?

THE WITNESS: Both.

CAPT. IVEY: So a pilot that has --

THE WITNESS: I need to note though, just for clarification on that, the operating manual that we use is not necessarily the manual that a carrier will use. They may use ours, and we'll likely use ours, as a blue print for drafting their own. But the document that's produced by Airbus identifies the fact that both pedals and rudder is reduced as the speed increases.

CAPT. IVEY: Yes.

THE WITNESS: Yes.

CAPT. IVEY: That leads me to my next question. Are you familiar with the American Airlines operating manual?

THE WITNESS: No.

CAPT. IVEY: What do you think pilots prior to the accident knew about singlets and doublets and triplets and rudder reversals?

THE WITNESS: Reversals, I'm sure they were aware of the terminology. The term "singlets" and "doublets" is not something that I think was fairly widely known other than people with flight test background.

CAPT. IVEY: Do you think that the entire rudder system has been adequately explained in the Airbus manuals and other airlines that have their own manuals regarding rudder pedal travel, rudder restriction, the limitations that need to be employed when you're -- in the use of rudder? Any kind of cautions. Do you think that's been adequately covered in your manuals as well as theirs?

THE WITNESS: Well, I can't speak to carriers because when a carrier produces their own document, they don't send it to Airbus to -- to audit, if you will, or to -- to ask their opinion.

In our manuals, I do. We have to -- we have to understand that you don't just a read manual and go out and fly the airplane. The next stage is the training in the proper environment of the simulator or the part task trainers. And throughout that period, from day one, the true man-machine harmony starts to -- starts to gel and mature. And it's in that process that each and every flight the pilot becomes more and more familiar with pressures, deflections, what -- what it really means to -- to speak with and listen to the airplane that they're operating.

CAPT. IVEY: Does the FCOM provide information and guidance to those carriers that use your manual or develop their own regarding the light pedal forces that are on rudder pedals?

THE WITNESS: No, because, again, to put numbers is of no value whatsoever to the pilot. The pilot doesn't fly on numbers. The pilot flies on feel and sensation and experience that they build up each and every time they're in the airplane. That's the purpose of transitioning from one type to another.

So although from the technical point of view, from the systems knowledge point of view, there are numbers that are put in from -- from an actual interface or -- to allow the pilot to better operate the airplane, the numbers don't seem to have any operational value. It's what they experience in the sims and actually in the airplane.

CAPT. IVEY: Do you think, prior to the accident, that pilots in general, airline pilots we're talking about, believe that if a rudder had been moved to full displacement in one direction, followed by the need for an opposite and equal full displacement, and having a rudder limiter system of any kind on the airplane and operating below the maneuvering speed, would have thought that a tail would break off an airplane?

THE WITNESS: I don't believe, first of all, that any pilot would have ever considered reversals of that nature because there's -- there's no time that -- that it would be appropriate to do such a control input. So it's -- it's a speculative question in that I don't believe it would ever be something that would be considered.

CAPT. IVEY: And is there training given by Airbus related to either singlets or doublets in the either initial transition or upgrade training?

THE WITNESS: No. In the education in response to NTSB recommendations we have highlighted that because it's something that has -- that we've been made aware of and we're responding to recommendations as we always do when -- when the NTSB submits something for us to -- to look at.

But again, I come back to the point that throughout the world pilots are not taught normally to -- to use roll as a -- as a normal roll control -- correction, rudder as a -- as a flight control to induce roll. So the notion of doublets or reversals, although they're equally inappropriate to -- to pitch, they also apply to rudder. And just as we haven't included such information about pitch, the same applies to -- to yaw.

CAPT. IVEY: And in the training, is there ever a demonstration or a requirement to show the loss of yaw dampers in an airplane --

THE WITNESS: There is.

CAPT. IVEY: -- or the demonstration of dutch roll?

THE WITNESS: I'm not familiar what's in the -- the program today. But I know that when I was based in Toulouse and teaching on that airplane, we did demonstrate yaw damper failures and recovery from dutch roll.

CAPT. IVEY: And my last question is, do you think that the most effective way to address training in advanced maneuvers is through ground school, computer-based training, or in the simulator, or any combination?

THE WITNESS: It depends to what extent you want to do the -- the upset training. Because I mentioned -- as I mentioned at the onset, there is an infinite number of variables that a -- that an airplane can get into. One attitude which -- which would be considered an upset, perhaps very, very high pitch, would be an entirely different recovery based upon what the energy state was, if the airplane was 150 knots or 300 knots.

So in the context of awareness, whether it's to develop an appreciation by the pilots as to where they are and to what the appropriate steps may be or -- or perhaps a buffet of -- of steps that the pilot may take, then there's an argument for perhaps saying that computer-based training or some sort of part-task trainer may be an appropriate medium.

A simulator in certain conditions may well be an appropriate medium if it's strictly contained in the -- in the normal limits. If the instructor has got solid and ample education, if the lateral and vertical forces are maintained in -- in such a realm that the pilot could have an expectation.

But the concern for using that particular medium is that -- the simulator medium, is that it usually implies procedure -- procedure training. And in that context, that's -- that's not what the manufacturers would recommend. We think that -- that because there are so many variables, an awareness factor is of more value.

So it's a long-winded and not a direct answer because it's such a complex issue. I think that unusual attitude training or awareness is very important. I think the NTSB was very proactive. I think American Airlines was very proactive to raise the point in the mid '90s. However, we do have to be very,

very cautious and conscious of where we take that particular training.

CAPT. IVEY: Thank you, Capt. Rockliff. I'd like to turn the microphone over to Dr. Malcolm Brenner for some subsequent questions.

DR. BRENNER: Yes, Captain. I understand you reviewed the American Airlines AAMP training video that was made at the end of 1997. It's a take-home video for the pilots. Is that correct?

THE WITNESS: Just in the last couple of days, that's correct.

DR. BRENNER: I wanted you just for a moment to focus your comments to this video because we have an historical interest on it. This is a video that the accident pilots had. We believe the tape was made about the time that they took the training. And so in case -- in the event of evolution of the program, this is as close as we think we can come to what they learned.

You expressed concerns about emphasis on rudder. Did you feel that in watching this video?

THE WITNESS: Not to what I had recalled before. There was less emphasis on rudder in terms of frequency of -- of discussion about rudder. However, there was discussion which, in my opinion, was incorrect use of rudder.

DR. BRENNER: What was that discussion?

THE WITNESS: Using it -- during the video the term "coordinated rudder" was -- was redefined. To me, it was a total new definition that I'd never heard before. As I mentioned earlier, "coordinated rudder" is -- is essentially to zero side slip or to -- to keep the ball in the middle. The video defined "coordinated rudder" as simply rudder in the direction of the roll. And -- and unless there was -- well, that's just not coordinated rudder.

DR. BRENNER: And you expressed a concern with teaching of procedures rather than awareness. Did you feel that in watching this video?

THE WITNESS: I did.

DR. BRENNER: Can you give an example?

THE WITNESS: Well, the steps. The presenter of the video identified various steps that -- that a pilot should go through in order to recover from -- specifically, from nose high and nose low type condition.

DR. BRENNER: The first officer involved in the accident came from a civilian background and as far as we can establish did not have a background in aerobatic flying. Are there particular concerns that would apply to a student like this?

THE WITNESS: There are concerns for any student regardless of what their background is if there is incorrect information in the training, particularly if it's a very well put together presentation with an effective communicator as an instructor. When you teach someone something, the importance, the criticality of it being correct can't be understated. And so any time something is not correct, then -- then there's a liability. And that pertains to any learner.

DR. BRENNER: I understand that you were involved in the investigation of a previous event, Flight -- American Airlines Flight 903 event that happened near Miami in 1997. And there is some material on this in the Exhibit 2 series.

Do you think there were issues in common between the Flight 903 event and the 587 accident?

THE WITNESS: Issues in common?

DR. BRENNER: Yes.

THE WITNESS: In both events, there was use of rudder which -- not when the rudder should have been used.

DR. BRENNER: Could you elaborate a little bit?

THE WITNESS: Well, again, as I've -- I've noted, rudder is used to zero yaw, zero side slip, not to induce roll. In both of these cases, rudder was used to augment roll, but it was very consistent with what had been defined as coordinated roll insofar as the AAMP presentation. And it also would be very much conditioned as a result of simulator exercises if the pilots had found that their normal roll control was ineffective.

DR. BRENNER: In Exhibit 7-LL, there's Airbus communications from about the time of the Flight 903 event expressing concerns that the tail of the airplane may have sustained structural damage as a result of pilot actions during the event. As a member of the Airbus team involved in the investigation, were you aware of these concerns?

THE WITNESS: I'm not sure that I have Exhibit 7-LL. But as a member of the Ops group, I do not recall at this time any -- any knowledge of loads. We knew for sure that the airplane had gone through some fairly violent maneuvering, but the Ops group -- we didn't discuss loads at that time.

DR. BRENNER: In training pilots on the A-300-600 simulator, I understand that most rudder training takes place at takeoff and landing speeds because of the functions. Do you ever train pilots to use the rudder at higher air speeds, such as 250 knots?

THE WITNESS: A takeoff exercise would continue through the acceleration phase to the -- to the final takeoff speed, which would take them up in that air speed range, 230 to 240 knots, dependent upon weight. The environment where an instructor may introduce the abnormals, i.e. the yaw damper failures or -- or any other particular anomalies, would be certainly out of the takeoff range. So, yes, a pilot would be exposed to it.

I think an important point to note with regard to the -- the speed environment is that pilots, regardless of which transport category airplanes they're flying, realize that the airplanes operate in a very, very large aerodynamic envelope. And -- and the effectiveness of the controls is -- is quite dramatic in terms of the amount of deflection needed to -- to achieve the desired outcome.

So it's pretty natural for a pilot, as they go through this acceleration phase, to -- to discover the fact that the rudder that they need to implement right at the -- at the failure incidence is quite a bit different than what they need at a much faster speed when they complete the acceleration phase or indeed throttle back when they -- when they reduce thrust.

DR. BRENNER: For airlines that do teach the use of rudder for roll control, what training should they provide on the human factors issues involved in the rudder design?

THE WITNESS: Well, first of all, they shouldn't teach rudder for roll control.

DR. BRENNER: Just -- given that there may be clients who would elect to do that, what recommendation would you have as far as training?

THE WITNESS: I would be working to encourage them not to do that. It just isn't a suitable teaching practice unless they're looking at a condition of degradation.

Now, the manufacturers have not said, "Do not use rudder." If your normal roll control does not function, it's -- it's either inoperative from a system malfunction or for whatever reason, then the only thing the pilots have left to induce roll is either differential thrust, which is not comfortable, or to utilize rudder. However, that's a fairly -- that's a long path to get down to that level of degradation to where a pilot would be exposed to using rudder.

If -- if a company -- if a carrier wanted to go down that level to expose pilots to it, then for sure, you would want to teach them to walk before you put them in a -- in a -- in a running type condition, which would mean that in very stable conditions you would start out with very, very small inputs to discover what the response would be with a flight control that you don't use for roll.

DR. BRENNER: Thank you very much, Capt. Rockliff. I appreciate your assistance.

That completes my questioning, Madam Chairman.

CHAIRMAN CARMODY: Thank you. Are there other questions for the witness from the Technical Panel? Yes, Mr. Benzon?

MR. BENZON: Sir, we've heard some comments where some may believe that an airplane like the A-300 could be flown with a missing vertical stabilizer and rudder. Would you clarify this issue for us that may be concerned about this?

THE WITNESS: If I understood your -- your question correctly, some -- there's been comments that the airplane could fly without a vertical stabilizer and rudder?

MR. BENZON: That's correct.

THE WITNESS: This is the first I've ever heard of it, and I couldn't respond to that.

MR. BENZON: I see. You don't have an

opinion on it at all one way or the other?

THE WITNESS: No.

MR. BENZON: Okay.

CHAIRMAN CARMODY: Additional questions? Yes, Mr. Jouniaux?

MR. JOUNIAUX: Yeah. In the simulator training that you conduct, do you develop any wake turbulence scenario during the simulator phase?

THE WITNESS: In the Airbus training?

MR. JOUNIAUX: Yes.

THE WITNESS: No, because wake turbulence, although there's been a lot of emphasis, and as I mentioned earlier, there's been a wake turbulence training aid, in large part this is an issue of small airplanes. I'm talking very small airplanes. Lear jet, perhaps small commuter airplanes on down. It's not a -- a major issue for large transport category airplanes to our data that we've received. And -- and we have questioned this with our competitors as well.

So because it's -- it's relatively routine and -- and the fact that pilots will experience turbulence in the form of wake and that they're normally expelled before anything dramatic occurs, we have had no reason to consider putting that in our simulators.

MR. JOUNIAUX: That's all. Thank you.

CHAIRMAN CARMODY: Thank you. Anything else from the Technical Panel?

(No response)

CHAIRMAN CARMODY: Then we'll move to the parties. Mr. Donner with the FAA?

MR. DONNER: Thank you, Madam Chairman.

Capt. Ivey asked my questions and Capt. Rockliff answered them, so I have nothing further. Thank you.

CHAIRMAN CARMODY: All right. Thank you. Mr. Ahearn with American?

CAPT. AHEARN: Thank you, Madam Chairman. A few questions, and I'll try to move as fast as I can.

It is going to involve some exhibits, if you need them, Capt. Rockliff. Some of them are not in the two exhibits but you referred to some of the issues associated with the terminology, such as "rudder reversal should not be considered."

And I'll refer to an A-310 incident in February of 1991 which involve repetitive rudder movements. At the time, did Airbus consider -- consider modifying the VA chart and its outcomes or putting a statement in its manual to explain that not all flight control movements below this speed are structurally safe?

THE WITNESS: I'm unable to comment on that at that time because I had transitioned over to the fly-by-wire and actually transitioned over to Miami from Toulouse. So I'm not aware. Perhaps someone else can respond to that.

CAPT. AHEARN: Okay. I'll try it with another witness. But you're not aware of any documents that went out, to your knowledge?

THE WITNESS: Not to my knowledge.

CAPT. AHEARN: Okay.

THE WITNESS: I'm not suggesting that they didn't go out. I'm just stating that I'm not aware of what --

CAPT. AHEARN: Okay. I'll -- I'll try Capt. Jacob.

Let me move to another document that is part of your exhibits. It's Exhibit 2-V as in "Victor," page seven.

(Pause)

THE WITNESS: Okay.

CAPT. AHEARN: This page demonstrates that Airbus in fact did issue revisions to its FCOM and Quick Reference Handbook after the 903 incident but said nothing about the dangers of rudder reversals. Do you know why at the time you did not include warnings about rudder reversals and potential structural failure post the 903 FCOM revision?

THE WITNESS: Again, I wasn't a part of writing this particular document. So for reasons why, I can't speak to. I know that in this same document there was references to the -- the loads and -- and the inappropriate use of rudder. But at that particular time we were dealing, we thought, with one carrier.

CAPT. AHEARN: I understand that there were comments but there were no changes to the FCOM. You commented but you didn't change anything in your FCOM, is that correct?

THE WITNESS: That I'm aware of. I'm not -- you know, I don't know.

CAPT. AHEARN: Okay. To that point, would you please clarify how Airbus typically notifies its operators of significant structural or operational limitations on its aircraft? Would the FCOM be appropriate documentation?

THE WITNESS: Can you clarify the question, please?

CAPT. AHEARN: Well --

THE WITNESS: How we would communicate which?

CAPT. AHEARN: When -- basically, what I'm referring to is the FCOM documentation. Is that how you would typically notify operators of any structural -- of significant structural or operational limitations on your aircraft?

THE WITNESS: If there's an operational limitation, the operating manual is -- is the appropriate document for it. If it's -- if it's an engineering issue, then they would be -- it would be communicated to the operators through the engineering channels.

CAPT. AHEARN: Okay. Thank you.

(Pause)

CAPT. AHEARN: I'm going to refer you back to the Industry Training Aid Upset Recovery document for a moment. At any place -- do you know where -- in the Industry Training Aid does it state that a particular use of rudder to recover from an upset situation may cause catastrophic -- catastrophic failure below maneuvering speed? Are you aware of that anywhere in the Training Aid at all?

THE WITNESS: Not off the top of my head. I'd have to go through the whole Training Aid. But I know that there's a number of entries in the Training Aid about the sensitivity of the use of rudder but the specifics of the wording I can't speak to at the moment.

CAPT. AHEARN: But nothing to your knowledge about structural failure?

THE WITNESS: No, I'm not saying not to my knowledge. I'm just saying at the moment I'm -- you know, I'd have to go through it to find whether there's a particular line. If you'd like, I can peruse through the -- the inputs that are there.

CAPT. AHEARN: No. For the sake of time, I'll not ask you to do that. I've read it and looked through it and that's the purpose of the question. I couldn't find it anywhere.

THE WITNESS: Well, actually, as we talk about it a little bit more I think there might be. Can you tell me which exhibit it is that's in there? Because I'd heard earlier today that you wanted -- one of the parties wanted to add a couple of pages.

(Pause)

CAPT. AHEARN: Capt. Rockliff, it's 2-Q as in "queen."

THE WITNESS: Yeah. Thank you.

(Pause)

THE WITNESS: Just today I received just before noon another couple of pages that I believe Allied Pilots Association wanted to include, which is the very next page, which would be, I suppose, 10.5.

And I think that there may be something on that page that talks about loads.

MR. CLARK: Is that an exhibit now?

THE WITNESS: I'm -- Mr. Ivey, can you respond to that?

CHAIRMAN CARMODY: I was going to ask the same question. Is this a new exhibit or is this a proposed exhibit?

CAPT. IVEY: I was handed two pages at the lunch break, and I think it's from the Allied Pilots Association. And the two pages are -- the two pages that would follow are Exhibit 2-Q-10. And it would be 10-A and 10-B. It would -- those two pages would fall between pages 10 and 11. 2-Q-10 and two new pages would be --

CHAIRMAN CARMODY: Are they -- are they sequential in the manual?

CAPT. IVEY: Yes, they are. They are -- if you look in the lower left-hand corner of the Industry Training Aid, 2-Q-10 is page 2.3-1. And the two additional pages that they provided are 2.3-2 and 2.3-3.

CHAIRMAN CARMODY: Does everyone have copies of these two pages that we're talking -- I think we need to have copies -- who does not have them? FAA nods that you do. You have them. Allied Pilots, do you have copies -- I guess you do since you distributed. Airbus? Perhaps we could get a copy for Airbus.

I have no objection to the exhibit, but I think everyone should have a copy if we're going to talk about it. Everyone has a copy? All right.

Airbus hasn't found it. Why don't you give them another copy? FAA has one. Yes, just the next table, please. Thank you.

Does the hearing officer have any concerns if we just include these in the exhibit?

MS. WARD: No, Madam Chairman.

CHAIRMAN CARMODY: Okay. Thank you. We'll include --

MR. CLARK: It's -- the only issue is if Capt. Rockliff is familiar enough to comment about --

THE WITNESS: Actually, I've located my copy out of my pocket.

CHAIRMAN CARMODY: Are you comfortable commenting on this, Captain?

THE WITNESS: Yes, ma'am.

CHAIRMAN CARMODY: All right. Please --

CAPT. AHEARN: Can you just refer to the page that you're talking about, Capt. Rockliff?

THE WITNESS: It's -- of the -- of the Training Aid, it's Section 2, page 2.3-2. So as Capt. Ivey noted, it would be the very next page.

And in the very last sentence of the first column leading to the completion of the second column, "When the rest of the airplane is symmetric, for example, in a condition of no engine failure, very large yawing moments would result in very large side slip angles and large structural loads should the pilot input full rudder when it is not needed."

CAPT. AHEARN: Okay. Again, I believe that is the certification test that they're referring to, but that does not refer to a catastrophic failure. I don't disagree that would put high loads on the airplane, but it does not refer to anything in the Training Aid that I've been able to discover that would talk about a catastrophic failure.

THE WITNESS: That's the reference that speaks to the structural --

CAPT. AHEARN: Okay.

THE WITNESS: -- that I recall.

CAPT. AHEARN: Thank you.

(Pause)

CAPT. AHEARN: I just want to -- from a point of clarification, I got a little off the calendar when we were talking about AAMP. Were you invited to see the AAMP program in 1995 or did you actually attend the AAMP program in 1995?

THE WITNESS: No. The vice president of flight operations at that time invited me to -- to attend the program. And I attended that with, I think, six or seven other airmen. They were all American Airlines check airmen or instructors.

CAPT. AHEARN: Okay.

THE WITNESS: It did not include the simulator. It was just the -- the day presentation.

CAPT. AHEARN: Okay. Post attending the portion that you attended at the -- with the non-simulator portion, when did you first provide any written input to American Airlines regarding AAMP training?

THE WITNESS: Written input?

CAPT. AHEARN: Correct.

THE WITNESS: First written input that I -- I think the first written input was a letter that was sent to the vice president of flight operations which was his request for the three manufacturers and a representative of the FAA to submit our concerns for some of the aspects of AAMP that we experienced in the -- in June of the following year, 1997.

CAPT. AHEARN: Okay.

THE WITNESS: However, that day I did communicate to the author of the AAMP program concerns about rudder in the form of what he was -- what he was presenting at the high angles of attack.

CAPT. AHEARN: As a commentary to the instructor and then written input in 1997?

THE WITNESS: Correct.

CAPT. AHEARN: Okay. And the captain -- the vice president of flight from American Airlines responded to you in November or October of 1997, I believe. Again, the date was right after your letter that came from not only you but also the other manufacturers as well as the FAA. But the vice president of flight did indeed respond to that letter, correct?

THE WITNESS: He did respond. His letter was dated October. It was not sent out until January of the following year.

CAPT. AHEARN: I'm not certain that that's true, but again, he did respond to your -- to your letter of June of '97?

THE WITNESS: Correct. And we received it -- all of the four authors received it in January.

CAPT. AHEARN: Okay. And there was no

subsequent correspondence from Airbus regarding the response that the vice president of flight provided you?

THE WITNESS: Response? There was lots of response.

CAPT. AHEARN: So you have subsequent written documentation to the letter that the vice president of flight provided you?

THE WITNESS: The response that we made following the vice president of flight operations' letter to us was -- was numerous. We started out actually the very next month working on our Technical Digest which would not only be for -- for his review but for all pilots at American and every other carrier in the world. And that was in the joint "FAST and Airliner" article. We had the, as Capt. Ivey noted, the Ops Performance Conference in San Francisco of that year. We had communication at that same time with American Airlines Flight Technical Department and the chief test pilot at Boeing. And at least to our understanding, from -- communicated from your Flight Technical Department, that was also subsequently going on at Boeing. We sent out the Training Aid in August of '98.

So it was continuous. There was -- there was a dramatic amount of response.

CAPT. AHEARN: Okay. But specifically to the issues associated with rudder issue, there was no changes to your FCOM, no documentation put into your FCOM about restrictions on the rudder below V sub-A

THE WITNESS: The FCOM was not determined to be the proper place. The Training Aid was the proper place because, as we've noted before, upset training is -- is -- is -- is a qualification or an education for pilots. And -- and the FCOM is not an education document to that extent. It's an operational supplement for pilots to operate their airplanes.

So we put the training where the training -- or the training information where within the industry it has become the accepted practice to put it, which is in the form of training aids.

CAPT. AHEARN: One final question on the AAMP. Can you tell me why you didn't accept the vice president of flight's offer to review the AAMP simulator data?

THE WITNESS: Why we didn't accept?

CAPT. AHEARN: Correct.

THE WITNESS: I wasn't given the option. And certainly, I was taking my direction from Toulouse, and no one in Toulouse had -- had provided any information to that effect that we had any visibility at all of the simulator data.

CAPT. AHEARN: So despite the fact that the vice president of flight did invite you and the other manufacturers -- it wasn't just Airbus, it was Boeing, McDonnell Douglas, and the FAA -- to your knowledge, no one at Airbus took them up on that offer?

THE WITNESS: Can you -- now you're saying that the vice president of flight operation offered to provide us with simulator information?

CAPT. AHEARN: Yes. In the letter that he sent you on October 6th, 1997, which you say you received in January of 1998. It's Exhibit 2-Charlie, if you want to refer to the exhibit.

(Pause)

CAPT. AHEARN: It's page nine.

(Pause)

THE WITNESS: And can you --

CAPT. AHEARN: Under the heading of "Use of Simulators," the last sentence in the first paragraph.

THE WITNESS: Mm-hmm.

CAPT. AHEARN: "On your next visit to our flight academy we'll be pleased to show you the beta readouts during this event."

(Pause)

THE WITNESS: The beta readouts was -- was only a small portion of the concern that we had for the use of the simulator. The -- the issue of reducing the roll effectiveness or partially inhibiting or totally inhibiting the roll was -- was the true issue in that particular area because as a result of it the -- the beta was -- was going to be questionable by the primary use of rudder that would be needed.

But further on in the letter, it was crystal clear that -- we responded to the vice president's request to provide input and his response back to us was his decision that he wasn't interested in our inputs. And so we chose to -- to approach -- or to work with your Flight Technical Department and all throughout the industry, including all of the pilots at American, through the -- through the facilities of our Technical Digest and the -- and the Training Aid.

CAPT. AHEARN: Okay. One final question again. You raised another issue that I want to ask on the Industry Training Aid. What did Airbus do to determine if its simulators could adequately represent flight during the ITA, or Industry Training Aid, recommended exercises?

THE WITNESS: I'm sorry. What did we do to determine the simulators were adequate?

CAPT. AHEARN: Correct. There were eight recommended exercises, simulator exercises, in the ITA. What -- what action did you take to determine if your simulators could adequately represent flight during these recommended exercises?

THE WITNESS: Well, during the development of the Training Aid, both Boeing and ourselves looked seriously at our simulators. In our case, we had the A-300-B4 simulator in Miami. And my colleagues who were leading the project in Toulouse did it with the A-310 over there as well as together. And by the way, Boeing also joined us in -- in our simulator in Miami, as I did in Seattle.

We discovered that the simulators in -- in some fairly simple maneuvers were not representative of what the airplane should actually be doing. In the case of our A-300, it was -- it was in a full stall type condition where power -- we could recover from it, which -- which is just, you know, holding the control column back and using power to fly out of it, which is absolutely incorrect.

In the Boeing simulator, in a nose-low condition, the airplane would continue to diverge and accelerate versus converge with an increasing load.

So in that regard, that amplified and

reinforced our sensitivity to the use of simulators. Insofar as what we did with the simulators afterwards with the Training Aid, as -- as I noted to Capt. Ivey, we chose not to use simulators for the Training Aid -- for upset training. We just do the academic portion. And so therefore, we haven't done any validation on them because we haven't conducted upset training in them.

CAPT. AHEARN: Okay. Just a few more, Captain -- question, Capt. Rockliff. Let me start off with a commentary that you had stated earlier. And I'm referring to the NTSB recommendation about actually the creation and the need for upset recovery training. You stated by the time a pilot gets to the airlines they should have already experienced upset training. Would you agree that the accident history associated with what led to the NTSB recommendation associated with the required upset training would not support that statement?

THE WITNESS: I'm sorry. If you can just --

CHAIRMAN CARMODY: I don't understand the question.

THE WITNESS: Nor do I.

CAPT. AHEARN: You stated that by the time pilots get to an airline they should have already experienced upset training. And yet, we have an NTSB recommendation that highlighted a number of accidents associated with loss of control and controlled flight into terrain, a significant number in both categories. And therefore, the NTSB came up with a recommendation that said there's a need for upset recovery training.

I think what I'm asking you is, as you look at what the recommendation coming from the NTSB, it actually is inverse of what you said in your testimony today.

THE WITNESS: Okay. Now I understand what you're asking. I think the NTSB was -- was right on target. They, like American, discovered that there was a deficiency in the pilots' education. And it was not acceptable to -- to simply leave that -- that deficiency open until such time as it was corrected back where it should be corrected in a -- in a pilot's primary education because there was a condition out there in industry where pilots perhaps have not been exposed to it. They need to have this awareness training. And that, I think, is what their initiative was.

And by the same way that American made that own conclusions themselves, I think the NTSB was -- was on target.

CAPT. AHEARN: Okay. Just two more questions, Capt. Rockliff. I'm going to refer you to Exhibit 2-N as in "Nancy," page six.

(Pause)

CAPT. AHEARN: And in your testimony I believe you stated that pilots knew this procedure was talking about steady state side slip.

THE WITNESS: 2-N -- I'm sorry.

CAPT. AHEARN: 2-Nancy, page six.

THE WITNESS: Yeah. Have it.

CAPT. AHEARN: All right. And again, I'll refer you back to what I believe you stated, that pilots knew this procedure was talking about steady state side slip, was, I believe, the terminology you used.

THE WITNESS: Mm-hmm.

CAPT. AHEARN: How would you interpret the words "alternating side slip"?

THE WITNESS: Because -- well -- Alternating side slip -- first of all, if the pilot is not maintaining a constant heading and if, you know, if you picture yourself in a particular condition where you're running through a checklist procedure, the first thing you want to do is control your flight path. And the way to control your flight path is through steady state side slip.

Now, alternating steady state side slip would simply be coming back to neutral and setting up the opposite direction where ultimately your heading varies exceedingly little from -- from the initial and the end point. And that is what is stated in the -- in the procedure.

CAPT. AHEARN: So you believe the interpretation of "alternating side slip" is the same as steady -- steady side slip, just -- just reversing it?

THE WITNESS: Correct. In other words, if you're maintaining a given heading of, say, north, you would establish the side slip with perhaps -- initially to deflect the slip stream to try and lock the gear down the airstream. And if that doesn't work, you're going to alternate, still maintaining north, in the opposite direction. If you didn't do that, there would be tremendous gyrations that the pilot -- that the flight would be going through for the exact same reasons that the previous presenter had indicated, that introducing yaw will create side slip and in turn induce roll. And you're not going to get the side slip load that's intended with -- with the procedure.

CAPT. AHEARN: Okay. Thank you, Capt. Rockliff. One final question. Would you agree that the 587 accident was not an upset recovery event, at least until the vertical stabilizer separated?

THE WITNESS: Was not an upset event. By definition of an upset, the airplane hadn't exceeded the attitude parameters. So in that particular -- you know, in that context, it was not upset. But the airplane was not in control, so it's -- it's a difficult question.

An upset, by definition that was established with the Upset Training Aid, does apply to pitches and roll figures. And -- however, if the pilot doesn't wait until that particular figure is achieved before they initiate a recovery. So in that context there was a recovery initiated pointing in that direction.

CAPT. AHEARN: Oh, I would agree that it was a -- a recovery -- that it was an event of recovery from the conditions that the pilot was experiencing. But I also agree with you that it wasn't an upset recovery under the traditional definition.

THE WITNESS: Correct.

CAPT. AHEARN: Okay. Thank you, Capt. Rockliff, and thank you, Madam Chairman.

CHAIRMAN CARMODY: Thank you, Mr. Ahearn. Capt. Pitts, any questions?

CAPT. PITTS: Yes. Good evening.

THE WITNESS: Good evening.

CAPT. PITTS: Capt. Rockliff, earlier you spoke of Exhibit 2-O, page two, the Maximum Design Maneuvering Speed VA graph.

THE WITNESS: Right.

CAPT. PITTS: Approved by the DJAC. And you made a comment that you were not exposed -- this was not exposed to our side of the industry. Is that -- is that correct, sir?

THE WITNESS: When I said "our side," what my intent was, was the operational side. It's a design maneuver speed which is used for certification and development of the -- of the aircraft. And it's in that context when I meant "on our side." Being after certification, the airlines use the airplane and, of course, the manufacturer also supplements with the training. It's in that context I meant "on our side."

CAPT. PITTS: In your opinion, is there good communications from the design and engineering side of Airbus to the operational side?

THE WITNESS: Excellent. Examples such as the operations conference that I had indicated. Not just Airbus, but the other manufacturer does the same thing and communicates with the operational side. Definitely.

CAPT. PITTS: If you had -- if this chart had been exposed to your side of the industry, would you have taken exception with the full application of rudder comment that is on the left side of the graph?

THE WITNESS: Would I have taken exception to it?

CAPT. PITTS: Yes, sir. From an operational perspective.

THE WITNESS: But it's not an operational speed so there would be no reason for it to be in an operational document.

CAPT. PITTS: So from an operator's perspective, you see no -- no problem with this statement being in any of the manuals that are -- that are used?

THE WITNESS: The statement, as I'd mentioned before, is word-for-word out of FAR 25. It's a requirement to put word-for-word in the -- the flight manual. So in that perspective, as a -- as a legal certification document, that's why it's in there. But the application for the -- for the end user, the airline pilots, doesn't have an operational consequence. And so for that reason, there would be no reason to have it in the operating manual.

CAPT. PITTS: Now, this is -- this is in fact not the flight crew operating manual.

THE WITNESS: The AFM, you're correct.

CAPT. PITTS: This -- this document here.

THE WITNESS: That's the -- that's the airplane flight manual.

CAPT. PITTS: And this -- this statement on -- on 2-O, page two, is not in the FCOM, did you not say that?

THE WITNESS: That's correct.

CAPT. PITTS: Okay. All right. You referenced the -- the certification in the FARs. I take it you heard my line of questioning earlier.

Part 25 speaks to the design of the A-300 airplane "containing a number of novel and unusual design features for an airplane certificated under Part 25 of the FARs. And special conditions are necessary to establish a level of safety for the model A-300-B equivalent." So to -- that established by Part 25 of the FARs. Was that shared with you from the Engineering Department as an operator?

THE WITNESS: Well, first of all, you'd indicated at the beginning of what you were reading that FAR 25 states specifics on the A-300-600?

CAPT. PITTS: As a special condition -- to special flight conditions for this aircraft.

THE WITNESS: I don't believe that the FAR 25 speaks to any particular airplane anywhere. FAR 25 is general for certification of all airplanes.

CAPT. PITTS: So Special Condition Number 25-52EU16, which speaks to parameters that I just read to you under Part 25?

THE WITNESS: Well, again, I'm -- I'm not involved with the certification portion of it. The specifics of FAR 25 apply to all new airplanes that -- that are certified. And so each manufacturer has to go through the different provisions.

If there's an operational consequence, if there's an operational component to it, then definitely, it will be transferred over to the operating manual. If it's just design criteria and -- and criteria to have the airplane certified without any value, operational value, to the pilot, then it would not.

CAPT. PITTS: Okay. Would a special flight condition be transferred over the operating manual?

THE WITNESS: A special flight condition?

CAPT. PITTS: Yes, sir.

THE WITNESS: Yes.

CAPT. PITTS: If -- under the category of "turbulence criteria," a reference to the "airplane flight manual must include recommended procedures for operation in turbulence, including turbulence penetration, air speeds, flight peculiarities in turbulence, and any appropriate special control instructions were issued against the design," would that show up in the FCOM?

THE WITNESS: There is reference in the FCOM to turbulence penetration and in the Quick Reference Handbook which the pilot would have readily available to them in the pilot for thunderstorm or -- correction, for rough air penetration.

CAPT. PITTS: Any references to limitations or parameters, prohibited maneuvers, use of primary flight controls, in that section, sir?

THE WITNESS: I don't have it available to me right now, and I haven't been exposed to that airplane for a number of years, so I couldn't answer that question.

CAPT. PITTS: When did Airbus know that alternating rudder side slips below VA could cause structural failure to the design of the A-300-B4-605-R?

THE WITNESS: I'm not quite clear on your question. Are you pertaining to the checklist item for the unsafe landing gear?

CAPT. PITTS: No, sir. No, sir. I'm -- we have had a number of comments here about restrictions to alternating side slips. And apparently, within the engineering community it was known that this alternating side slip could contribute to loads in excess of the structural design.

THE WITNESS: First of all, the engineering community -- I think you'd have to ask them that question. But I -- I think that it's real important to be clear that we don't start redefining things like alternating side slip versus rudder reversals, such as coordinated rudder versus what, you know, other components describe that to. And so if there was information that was -- that was known, I'm not privy to it. I wasn't aware in the training side.

CAPT. PITTS: So nowhere in the -- in the operational training community were there references to -- bear with me. Exhibit 7-Q, pages six and five -- five and six, with a 1991 event and a 1997 event where the load limits reached a 1.53 and 1.55 value in exceedance of ultimate limit?

THE WITNESS: I don't believe I have seven -- 7-Q, did you say?

CAPT. PITTS: I believe that's correct.

THE WITNESS: I don't believe that's in my package.

CHAIRMAN CARMODY: I don't think that's listed for Capt. Rockliff, Capt. Pitts. It's not one of the -- the exhibits listed for Capt. Rockliff are -- are not -- did not include 7-Q.

CAPT. PITTS: Okay. My -- my apologies. But I guess the -- that information was not shared with the operations and training --

THE WITNESS: I'm not familiar with the information you're talking about, so I can't respond to that.

CAPT. PITTS: There was no sharing of information about exceeding the load limits of the structure of the A-300 with rudder reversal application?

THE WITNESS: I didn't hear of any documentation on that.

CHAIRMAN CARMODY: Capt. Pitts, we've had questions about certification and questions about engineering of this witness, and this is a training witness. Could we please confine your questions to something that he can address --

CAPT. PITTS: Yes, ma'am. My apologies.

CHAIRMAN CARMODY: -- something that's relevant. I understand, but let's -- let's move on.

CAPT. PITTS: As we tried to -- to make the connection between what was handed over into the operations manual --

CHAIRMAN CARMODY: Mm-hmm. I understand.

CAPT. PITTS: -- it's difficult to follow the trail.

CHAIRMAN CARMODY: Yes, but I -- it's very clear that we're not following the trail, so.

(Pause)

CAPT. PITTS: Referring to Exhibit 2-S, page five, sir.

(Pause)

THE WITNESS: 2-S, which page, please?

CAPT. PITTS: Page five.

(Pause)

THE WITNESS: Okay.

CAPT. PITTS: In the expression of concern in that letter, why was there no concern expressed about structural failure, in your opinion?

(Pause)

THE WITNESS: You'll have to give me a few minutes to go through the letter because I'm not patently familiar with it. Can you refer me to a specific part of it so I can save time?

CAPT. PITTS: The section which speaks to rudder usage.

THE WITNESS: Okay.

(Pause)

THE WITNESS: Okay. I'm familiar now with the paragraph. Can you repeat the question, please?

CAPT. PITTS: The question was, in your opinion, why was there no concern expressed about structural failure? It seems that the -- the crux of the concern there is in departure from control flight, I believe.

THE WITNESS: Yes, that appears to be what's in here. Having not written the letter and having not discussed this specific with the author, I'd be speculating, so I think it would be unreasonable for me to speculate on that.

CAPT. PITTS: Okay, sir. In a transport category aircraft, would you agree that a very slow speed translates to a high angle of attack?

THE WITNESS: Very slow speed?

CAPT. PITTS: Very slow speed, the reference of very slow.

THE WITNESS: Normally, I think that, yeah.

CAPT. PITTS: All right, sir. Was the Industry's Training Aid primary concern about the use of rudder related to the potential for loss of control or for structural failure considerations?

THE WITNESS: There were various inputs. The -- the Training Aid's emphasis was on inappropriate use of rudder. And any time you're using rudder to induce roll, it's inappropriate, whether it's low speed high angle of attack, or high speed lower angle of attack.

CAPT. PITTS: You referenced the 903 investigation. Are you familiar with the parameters of the aircraft as it departed from control flight?

THE WITNESS: The parameters? The general environment, as part of the Ops group, I don't recall and I don't believe we, as the Ops group, saw the -- the DFDR. But I'm familiar with the general parameters.

CAPT. PITTS: Was that aircraft in a high angle of attack condition?

THE WITNESS: It was.

CAPT. PITTS: And had full left wing down commands been placed for the application of rudder?

THE WITNESS: I'm sorry.

CAPT. PITTS: Had the full left wing command input been placed into the flight control system prior to the input of rudder?

THE WITNESS: Again, I didn't see the DFDR, but I believe that in testimony the pilots had indicated that they were -- they were trying to roll --

roll left.

CAPT. PITTS: In a high angle of attack, condition, would the full left wing input into the aircraft and the aircraft continuing to roll to the right, would it be appropriate to use rudder in that condition?

THE WITNESS: Not in that condition, no, because they were situationally unaware of the fact that they were stalled.

CAPT. PITTS: Did the Industry Training Aid disclose that the rudder should not be used to reduce roll or to counter roll induced by any type of turbulence?

THE WITNESS: Repeat the question, please?

CAPT. PITTS: Did the Industry Training Aid disclose that the rudder should not be used to reduce roll or to counter roll induced by any type of turbulence?

THE WITNESS: The Industry Training Aid didn't reference using roll -- rudder as a roll source other than if normal roll source didn't function at all. It was very clear in the Training Aid that the normal roll power that -- that the majority of transport category airplanes have got is more than sufficient to provide the roll moments necessary.

CAPT. PITTS: What does the Industry Training Aid teach pilots about being prepared to use the full control authority in an upset situation?

THE WITNESS: It teaches that if the full control authority is necessary, the pilot should use it.

CAPT. PITTS: Does that include the rudders?

THE WITNESS: And that, by the way, is pretty natural for a pilot.

CAPT. PITTS: I would agree. Does that include the rudders?

THE WITNESS: Again, if normal roll control is not effective or is -- is disabled for whatever reason, then, yes, it would include rudder. But it would be rudder in the direction of the turn, not reversals.

CAPT. PITTS: Does the Industry Trade -- Training Aid address and try to correct a tendency of pilots not to use the full control authority which must be overcome when recovering from upsets?

THE WITNESS: There's certainly a propensity of pilots in the -- in the airline business to want to be very, very smooth for very good reasons, for safety and -- and passenger comfort. That is detailed in the Training Aid, and -- and I think rightly so, that if you have a dynamic maneuver, the maneuver will dictate the amount of -- of countermaneuver that the pilot has to do.

CAPT. PITTS: Would you agree that the Industry Training Aid is consistent with the AAMP teaching that rudder may be necessary at high angles of attack to consist -- to assist the ailerons to roll the airplane in an upset?

THE WITNESS: No, I would not. Now, I'm going -- if I may, I'm going back to my recall of the AAMP several years ago. I can't speak for it today.

CHAIRMAN CARMODY: Capt. Pitts, could I urge you to pick up the pace a little of your questions?

CAPT. PITTS: I'm -- I apologize, ma'am. I just want to make sure I don't repeat one.

CHAIRMAN CARMODY: Uh-huh. Yes.

CAPT. PITTS: I've tried to keep up closely with them.

CHAIRMAN CARMODY: Yes.

CAPT. PITTS: You mentioned use of the trapezoid earlier. How does a pilot normally determine the appropriate amount of rudder input?

THE WITNESS: Normally, the pilot doesn't need to because it's done automatically for them, not just done on the A-300-600 but on most new airplanes with turn coordination.

CAPT. PITTS: Would you expect a pilot to be using the trapezoid?

THE WITNESS: No. For normal -- normal routine maneuvering? The answer to that would be "no."

CAPT. PITTS: Would you -- would you have expected the pilots in this condition to have looked and used the trapezoid?

THE WITNESS: In which condition?

CAPT. PITTS: The conditions present for our aircraft 587 accident?

THE WITNESS: In that particular airplane or in that particular event, the -- the introduction of rudder initially would have driven the -- the trapezoid out of the middle place, which in fact would have been uncoordinated. So the -- the control input wasn't necessary in the first place because the turn would have been coordinated through the normal aircraft systems.

CAPT. PITTS: So the answer was, you would not expect them to have used the trapezoid or to have looked at the trapezoid?

THE WITNESS: Well, no. No.

CAPT. PITTS: Would you agree that the

Industry Training Aid, like the AAMP, teaches that rudder becomes more effective as the angle of attack increases?

THE WITNESS: That the rudder becomes more effective? The rudder is always effective. It's not a function that the rudder is becoming more effective. What would be correct to say is that when you get down to very extreme angles of attack where there may be components or parts of the wing that are starting to stall, then the rudder is more effective than what the normal roll control is. But since it's not a normal roll control any other time and that the emphasis of the Training Aid is to be unstalled in the first place, it's -- it's -- it's not really a practical -- it's not a practical notion.

CAPT. PITTS: But just in terms of aerodynamics, comparing one manual to the other, that they agree, would you agree that -- that they both teach the rudder becomes more effective as the angle of attack increases?

THE WITNESS: It doesn't become more effective. It becomes more effective relative to the roll control.

CAPT. PITTS: One last question. Would you agree that it's reasonable to expect a pilot to use whatever flight controls he feels are necessary to maintain control of the aircraft unless he has specifically been made aware of dangers or structural failure of the aircraft in using those controls?

THE WITNESS: Just repeat the question one more time, please?

CAPT. PITTS: Would you agree that it is reasonable to expect that a pilot would use whatever flight controls he feels are necessary to maintain control of an aircraft unless he specifically has been made aware of a danger of a structural failure of the aircraft in using those controls?

THE WITNESS: If a pilot has been taught to use controls in a certain way and therefore believes that it's the correct way to use them and feels that they should be used in a particular case, that would be a correct statement.

CAPT. PITTS: Would you expect a pilot to use whatever flight controls he has available, sir, to maintain the aircraft upright?

THE WITNESS: Yes.

CAPT. PITTS: Thank you. I have no further questions, ma'am.

CHAIRMAN CARMODY: Thank you. And Airbus, any questions for your witness?

DR. LAUBER: Thank you, Madam Chairman. I do have just a few. I'll try to make sure that we get through them very quickly.

Capt. Rockliff, you were asked a question by Mr. Ahearn regarding the 587 situation. And I think the two of you ended up in agreement that this -- the attitudes attained in this event did not technically meet the requirements or meet the definition of being an upset, is that correct?

THE WITNESS: That's correct.

DR. LAUBER: However, in looking at the flight data recorder information that was shown earlier by Mr. Chatrenet, specifically with regard to the rudder time history, would you agree that at least the initial rudder and aileron inputs made by the pilot in the case of 587 were consistent with what they were trained to do in AAMP?

THE WITNESS: Based on what I learned in the simulator when I went in the simulator back in 1997, they were entirely consistent with what the pilot would have been conditioned for.

DR. LAUBER: Okay. Thank you. Capt. Rockliff, you've been asked a number of questions with regard to the issue of specific language with regard to structural failure, and many of the references were to loss of control. Is loss of control, is departure from control flight in a transport category airplane a serious situation?

THE WITNESS: Yes, it is.

DR. LAUBER: Why is it -- why is it a serious situation?

THE WITNESS: Loss of control is a serious situation in any airplane. But obviously, in a transport category airplane, you've got a lot of inertias, a lot of differences. The adage that an airplane is an airplane is not quite correct. In certain components of aerodynamics, that may be applicable. But recovery from an unusual attitude in a transport category airplane requires some pretty skilled piloting.

DR. LAUBER: And in fact, isn't it true that the accident record shows pretty clearly that during recovery attempts from out of control or departure from control flight situations often lead to structural failure and structural damage?

THE WITNESS: That's true.

DR. LAUBER: Okay. Thank you. With regard to things that are on the record in -- in writing, communications between Airbus and American, could I refer you again to Exhibit 2-C, page three? 2-C, that's the letter from the four of you to Cecil Ewell.

THE WITNESS: I have it.

DR. LAUBER: And would you go down to page three, last paragraph, the sixth line from the bottom that begins, "Rudder reversals."

THE WITNESS: Yes.

DR. LAUBER: Would you read that sentence for us, please?

THE WITNESS: "Rudder reversals such as those that might be involved in dynamic maneuvers created by using too much rudder in a recovery attempt can lead to structural loads that exceed the design strength of the fin and other associated air frame components."

DR. LAUBER: Does "structural loads that exceed the design strength of the fin" imply catastrophic failure or structural failure?

THE WITNESS: It's -- it's -- yes, it does.

DR. LAUBER: That's what it says. Would you turn now to page 11 of the same exhibit?

THE WITNESS: Yes.

DR. LAUBER: Would you read the second-to-the-last paragraph that begins, "In closing"?

THE WITNESS: Okay. This is in response to our letter. "In closing, your suggestions and recommendations have been carefully analyzed.

Ultimately, as you aware, we are charged with the responsibility of the lives of our passengers and crew in a real-life, everyday environment, not one which is technically and optimally controlled as in a simulator or academia."

DR. LAUBER: Did those of you who received this letter find that to be an open invitation for further dialogue with Capt. Ewell?

THE WITNESS: We did not.

DR. LAUBER: Thank you. With regard to -- would you hand the witness Exhibit 2-S, please? Two-Sierra.

THE WITNESS: Yes.

DR. LAUBER: And this is a letter from Capt. David Tribout, who is the A-300 technical pilot for American Airlines, to Mr. William Wainwright, chief test pilot at Airbus.

THE WITNESS: That's correct.

DR. LAUBER: And this letter is dated 22 May 1997, is that correct?

THE WITNESS: It is.

DR. LAUBER: Do you happen to recall the date of the event in Miami, the Flight 903 event?

THE WITNESS: I do.

DR. LAUBER: What date was that?

THE WITNESS: May 12th, 1997.

DR. LAUBER: Ten days before Capt. Tribout wrote the letter, is that correct?

THE WITNESS: That's correct.

DR. LAUBER: Would you go to the second paragraph, please, that begins, "I am very concerned"?

THE WITNESS: Yes.

DR. LAUBER: Would you read that for us, please?

THE WITNESS: "I am very concerned that one aspect of the course is inaccurate and potentially hazardous. As you can see from the handout pages attached with this letter, it states that at higher angles of attack the rudder becomes the primary roll control. The program infers that aileron application in these situations is undesirable since it will create drag caused by spoiler deflection. The -- the instructor teaches that in the event of wake turbulence encounter, recovery from stall, ground escape maneuvers, et cetera, the rudder should be used to control roll."

DR. LAUBER: Okay. Thank you. And the letter goes on to ask a number of specific questions that obviously address a concern that Capt. Tribout had at that time. Would you turn to the next page, page four, please?

THE WITNESS: Yes.

DR. LAUBER: And this is Capt. Wainwright's reply to Capt. Tribout, dated 23 May, the day after the Tribout letter was sent. Would you read the first sentence, please?

THE WITNESS: "I share your concern over the use of rudder at high angles of attack and will be pleased to talk to Paul Railsback, Tom McGroom, and yourself to discuss the matter. At the moment, Monday, May the 25th, would be all right. Please let me know roughly what time would be convenient to you. I will telephone on Monday to confirm the arrangements. Regards, William Wainwright."

DR. LAUBER: And the remainder of that exhibit is the -- are the telephone notes that were taken by Capt. Wainwright that detail -- we've already heard some testimony on that. We don't need to go into it further.

Do you have Exhibit 2-V handy, Capt. Rockliff?

THE WITNESS: Two-Victor?

DR. LAUBER: Victor, yes.

(Pause)

THE WITNESS: I do.

DR. LAUBER: Two-Victor. Okay. This is the airline industry submission -- airline. It's the Airbus submission to the NTSB regarding American Flight 903, is that correct? And as such, this submission would have gone to the NTSB and to all parties in the investigation, which would, of necessity, include American Airlines.

THE WITNESS: That's correct.

DR. LAUBER: Is that correct? Would you turn, please, to page six?

THE WITNESS: I have it.

DR. LAUBER: There's a section there that's entitled, "Comments Concerning Unusual Attitude Recovery Techniques." Would you read for us, please, the very last paragraph, that begins, "Side slip angle"?

THE WITNESS: "Side slip angle is a crucial parameter during a recovery maneuver. This is probably not well understood by many line pilots, but it has a significant impact on an -- on an airplane's stability and control. Large or abrupt rudder usage at high angles of attack can rapidly create large side slip angles and can lead to rapid loss of controlled flight. Rudder reversals such as those that might be involved in dynamic maneuvers created by using too much rudder in a recovery attempt can lead to structural loads that exceed design strength of the fin and other associated air frame components. The hazards of inappropriate rudder use during wind shear encounter, wake turbulence recovery, or recovery from low air speed at high angle of attack, parentheses, (example, stick shaker), end parentheses, you should -- should also be included in any unusual attitude recovery discussion."

DR. LAUBER: Okay. Thank you, Capt. Rockliff. You had earlier testified to the effect or had listed a number of communications that had taken place between Airbus and American with regard to specific concerns with regard to rudder usage as taught during the AAMP program. I'm not going to belabor the point because I think that's already in the record and is adequately covered.

Madam Chairman, I have no further questions for this witness.

CHAIRMAN CARMODY: Thank you, Dr. Lauber.

We'll move now to the Board, and I'll turn to Member Hammerschmidt. Any questions for this witness?

MEMBER HAMMERSCHMIDT: I believe just a few follow-up questions.

Following up, really, on some of Dr. Lauber's references to the exhibits, I might mention that a number of us from the Safety Board had the opportunity to go through the Advanced Aircraft Maneuvering Program due to the kind invitation of American Airlines almost, I think, six years ago this week. I looked it up this morning. It was on November the 6th, 1996.

And so I found my work manual, my training manual in my files this morning. And something caught my eye concerning the use of rudder in roll recovery because I had undergone some primary flight training for rudder which really emphasized and a designated check airman had also made a lot of comments about how important the use of rudder is. And he had flown L-1011s, 727s, Airbus aircraft, et cetera.

But anyway, all that aside, I believe that the page that caught my eye is actually in one of our exhibits. It would be in Exhibit 2-Delta, page 13.

(Pause)

THE WITNESS: Yes, sir.

MEMBER HAMMERSCHMIDT: Okay. There on the -- the -- the left side of the training manual -- and this would be the AAMP training -- well, it describes it there now. Under that definition, would -- would you agree with what is said, beginning with, "the effectiveness of the rudder as a roll control," et cetera? Would you agree with all that -- all that statement?

(Pause)

THE WITNESS: No, I wouldn't.

MEMBER HAMMERSCHMIDT: Okay. And why not?

THE WITNESS: Well, as the -- the effectiveness of the rudder true relative to the normal roll control, the aileron and the roll spoilers, on a relative point of view, does become more effective. But the rudder itself doesn't necessarily become more effective because you're at a higher angle of attack. It's just in comparison to the normal and the usual roll control. So in that context, the first paragraph would need to be clarified.

Smooth application of coordinated rudder. Well, coordinated rudder is only needed if there is side slip that exists. Coordinated rudder in the -- in the definition of what the presenter had indicated when I observed the video with Dr. Brenner is not coordinated rudder. Coordinated rudder -- by simply augmenting normal roll control with rudder in the same direction is clearly not coordinated rudder.

So I do not agree with that statement.

MEMBER HAMMERSCHMIDT: I might mention just in passing for completeness that in the -- in the training manuals that we received in 1996, they did not

-- this particular page is virtually the same except it does not include that second paragraph beginning with "smooth application." That's been added sometime in the -- anyway, subsequently.

Without belaboring that point, when you said that -- more than a few times that American Airlines' emphasis on the use of rudder in its AAMP training was a concern to the industry group that was developing the -- the upset recovery training aid and that this, as has been pointed out, has been discussed with American Airlines on more than one occasion. Do you have an insight as to why there is this dichotomy of thought or of opinion concerning the use of rudder?

THE WITNESS: If -- if I misled you before by saying that there was a departure from American and the rest of the group, that was not intended. Definitely, the manufacturers. I think that there was a mixture amongst the -- the airline training people who were there. The arguments or the presentation and the rationale that the representative from American Airlines brought forward based upon his experience in the simulator and as by his own -- by his own statements in the video that I recalled yesterday, from his previous life, the effectiveness of the rudder, is what really created the dichotomy between the manufacturers and he and some of the others.

MEMBER HAMMERSCHMIDT: Okay. Very good. That's all I have.

CHAIRMAN CARMODY: Member Goglia?

MEMBER GOGLIA: Yes, Mr. Rockliff. I have a few questions. Most of them are rather quick to answer.

How long is the transition training at Airbus?

THE WITNESS: On the A-300-600?

MEMBER GOGLIA: Yes. Coming from --

THE WITNESS: The -- the actual work days are 25 days at Airbus.

MEMBER GOGLIA: And that includes sim time?

THE WITNESS: That's correct.

MEMBER GOGLIA: Can the A-300 be dispatched with the autopilot in-op?

THE WITNESS: I don't have an MEL in front of me and I'm not current on the airplane right now. But I would -- I would expect, yes.

MEMBER GOGLIA: Okay. And I understand I have you at a disadvantage there. And -- and what do you teach or do you teach location of the feet for the pilots -- my next questions all deal with the feet -- locations of the pilots' feet when they're hand-flying the airplane?

THE WITNESS: Again, it's hard to get into the notion of primary flight training as well as the transition environment that -- that we're really involved with in the Part 121 world. It's good airmanship, and I think that from the very first flight that a pilot ever takes when they decide to become a pilot that when you're manually flying the airplane, that is to say you do not have the autopilot on, that good airmanship would dictate that you would have your feet on the rudders. Not necessarily to use them unless it was a type of airplane that didn't have turn coordination, but to be there as you should with all controls in the event that some sort of an anomaly occurs.

MEMBER GOGLIA: Okay. Now, the next two questions go to standard operations. After takeoff and before the autopilot's engaged, I take it from your -- from what you just said to me that you would recommend feet on the pedals?

THE WITNESS: Absolutely.

MEMBER GOGLIA: Okay. What about after the autopilot engaged?

THE WITNESS: After the autopilot's engaged, I think that normal practice amongst airline pilots is

-- is they would monitor. They wouldn't necessarily have their feet on the rudders, nor would they have their hands following through on the -- on the yoke.

MEMBER GOGLIA: Okay. And again, on the A-300, does the ailerons and the roll spoilers have enough authority to overcome a jammed rudder?

THE WITNESS: Yes. All --

MEMBER GOGLIA: -- full deflection?

THE WITNESS: All Airbus airplanes do.

MEMBER GOGLIA: Okay. And you mentioned several times and you just mentioned in response to one of my questions about the deficiencies of some pilots, that we assume that they know certain basic airmanship skills they may have long forgotten or may have actually been trained out of them in their previous gyrations as they progress up the ladder.

Have you personally or Airbus corporately ever surveyed your pilots coming in to understand the width and breadth of that deficiency?

THE WITNESS: We do have a prerequisite that Airbus defines at the sale of an airplane insofar as the training is concerned because your first question, which was how long a course is, is predicated on a -- a current and qualified pilot on a transport category airplane. And with the datums that are established for both first officer and captain in terms of hours and -- and the type of equipment, that's the basis for which the course was designed.

With that, there's an expectation that the pilots have gained certain skills and have matured certain skills in normal piloting.

MEMBER GOGLIA: Now, as a follow-on to that, now that we're selling Part 25 airplanes to Part 91 operators, have you discussed any changes that you need to make in that training program because of the -- because of what's been happening?

THE WITNESS: The -- the training for Part 91 operators, you're talking in terms of corporate jets and private airplanes and that? Yeah, that's being managed out of -- out of Toulouse, as is all of our training policy and training production. We actually implement in -- in Miami, but all of our direction comes out of our headquarters where -- where we have a production and R and D department. And they are looking at that as the -- as the Corporate Jet Program moves forward.

MEMBER GOGLIA: And have you discussed ways to mitigate the deficiencies that -- that may pop up?

THE WITNESS: That, I think, is an industry issue as well. You're talking in terms of, perhaps, deficiencies of a pilot's education of becoming a pilot versus transition from type to type? I think that that's a issue that the whole industry was looking at very closely prior to September the 11th last year when we were starting to end up in an area where there was a global shortage of pilots. Certainly, we've experienced something quite different since then.

But once the economy gets back on its feet and -- and more people get back into airplanes and the pilots start getting back in the cockpits, I think that we will have to look at that.

MEMBER GOGLIA: Okay. No further questions.

CHAIRMAN CARMODY: Member Black?

MEMBER BLACK: Thank you, Madam Chairman.

Just a couple, Captain. You mentioned a few minutes ago that -- that you and Boeing looked at your simulators during this process to try to determine their validity in certain parts of the envelope. Or did you get outside the envelope or were you looking at it inside the tested envelope?

THE WITNESS: That's correct, sir. We were looking inside the -- the envelope. But what we were -- well, when I say "inside the envelope," maneuvers that we would expect would be inside the envelope for just how our simulators, knowing that -- that our motivation is to have absolutely top-performing equipment. And in just two examples of -- of a number of iterations, we discovered where the simulators were not in fact valid representations.

MEMBER BLACK: Is this the same comment you made, I think -- I know you don't have it before you, but you made a comment in your -- in the transcript of the interviews with Capt. Ivey about that Boeing had tested the Airbus 300 -- Airbus and Boeing had tested the 300 and the 75-76 simulators and found that they did not behave as expected in common upset scenarios. That's the same thing you're talking about --

THE WITNESS: It is, yeah. But to refine it more specifically, there were -- there were two maneuvers that I identified this evening, one being that in the 757 we placed the simulator in a nose-low, energy-increasing type scenario just to get a feel for how the air -- how the simulator felt. And -- and -- and very basically, what the simulator should have responded with is it should have increased the load factor even though we wouldn't feel that because the airplane was trimmed for a lower speed. In fact, it diverged. It continued to open up in the -- in the acceleration downwards.

And then in the Airbus, we -- we took it back to a stall condition and simply continuing to hold the control column aft, in other words, to exceed the critical angle of attack. We were able to fly out of it with power, and clearly, that's not correct, either.

MEMBER BLACK: Okay. Have you -- do you have knowledge of any other airline that has modified a simulator code to facilitate some sort of upset training?

THE WITNESS: I do not have knowledge of that.

MEMBER BLACK: Have you ever asked?

THE WITNESS: No, I haven't. No, I haven't asked.

MEMBER BLACK: You train a lot of people, and I guess from all over the world, Airbus has, one way or another. Have you -- how common is it -- well, I guess I would ask this in -- in with training and also I'm sure you review upsets that occur with your aircraft all over the world like you did the one on 903, American Airlines Flight 903. How common is it for pilots to essentially respond to the wrong upset event? In other words, they're in a roll event and they respond to a wind shear, or vice versa. Is that common?

THE WITNESS: I can't respond to -- to that to give you a qualified answer that they would actually identify an event as being something different and therefore inappropriately respond. I think it's -- it's reasonable to -- to look from a human factors point of view that -- that the very motivation of the NTSB in the early '90s, recognizing that pilots weren't recognizing certain conditions, you know, warranted the fact that education should occur. So I think that, you know, definitely, the possibility exists. 903 was clearly a case where the crew --

MEMBER BLACK: That was --

THE WITNESS: -- inappropriately --

MEMBER BLACK: -- that was the next question. Was the response in 903 appropriate? You were on the Ops group.

THE WITNESS: No.

MEMBER BLACK: Could you tell us a little bit about what happened with regard to response? Don't get into all of the data, but what -- what the situation was and what they should have done, you think?

THE WITNESS: Well, the -- in the case of Flight 903, the airplane was at 16,000 feet entering into a holding pattern with decreasing energy that the crew didn't recognize. Decreased back to the point that it was entering into a stall condition. What the pilots recognized and perceived due to weather in the area was a turbulence-related event that they deemed to be a microburst. And so they tried to facilitate or they tried to input a microburst recovery.

Certainly, a microburst doesn't exist at 16,000 feet. That's an event that occurs close to the ground, for one. Secondly is -- is the energy awareness, that -- that the crew were not in the loop with at that particular time, had them in a condition that had they properly identified it, they would have simply had to complete a stall recovery. And by simply checking forward on the control column, that single item, they would have recovered and successfully flown away.

MEMBER BLACK: Thank you, sir. I think that's all here. Thank you.

CHAIRMAN CARMODY: All right. Thank you, Member Black.

Are there any additional questions from any of the parties? And I would remind you, they can be questions not already asked or answered. Starting with the FAA?

(No response)

CHAIRMAN CARMODY: American?

CAPT. AHEARN: No thank you, Madam Chairman.

CHAIRMAN CARMODY: Allied Pilots?

CAPT. PITTS: No, thank you.

CHAIRMAN CARMODY: Airbus? How about the Technical Panel? Worn you out, have we?

Well, I think it's time to adjourn for the evening. We've gotten through three witnesses today. We have 18 to go. So at this rate, we'll be here till Monday. However, I'm confident we will make more progress in the next few days.

We will resume tomorrow morning at eight a.m. Thank you.

(Whereupon, at 7:35 p.m., on October 29, 2002, the proceedings were adjourned, to reconvene at 8:00 a.m, on October 30, 2002.)