NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

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In the Matter of: :

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THE INVESTIGATION OF THE :

USAIR, INC. FLIGHT 427, : SA-510

A Boeing 737-300, N513AU :

Aliquippa, Pennsylvania :

September 8, 1994 :

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Springfield Hilton Hotel
Caribbean Ballroom
6550 Loisdale Road
Springfield, VA 22150

November 17, 1995

The above-entitled matter came on for hearing pursuant to Notice, at 8:30 a.m.

Board of Inquiry

Jim Hall, Member, NTSB
Chairman

William G. Laynor, Technical Advisor
Office of Managing Director

Ronald L. Schleede, Deputy Director
Office of Aviation Safety

Michael L. Marx, Chief
Materials Laboratory Division
Office of Research and Engineering

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

Technical Panel:

Thomas Haueter
Gregory Phillips
James Cash
Thomas Jacky

Malcolm Brenner

Staff:

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C O N T E N T S

I N D E X

P R O C E E D I N G S

[Time noted: 8:30 a.m.]

CHAIRMAN HALL: Good morning. We will reconvene this board of inquiry and call as our next witness Mr. Jim Kerrigan, Principal Engineer of 737 Aerodynamics, Stability and Control, with the Boeing Commercial Airplane Group, Seattle, Washington.

Thank you for being here, Mr. Kerrigan.

(Witness testimony continues on the next page.)

JAMES WILLIAM KERRIGAN
PRINCIPAL ENGINEER, B-737
AERODYNAMICS STABILITY AND CONTROL
BOEING COMMERCIAL AIRPLANE COMPANY

Whereupon,

JAMES WILLIAM KERRIGAN

was called for examination and, having been duly sworn, was examined and testified as follows:

MR. SCHLEEDE: Mr. Kerrigan, please give us your full name and business address.

THE WITNESS: My name is James William Kerrigan, I work for the Boeing Company in Seattle, Washington.

MR. SCHLEEDE: And your position at Boeing?

THE WITNESS: I'm a lead engineer in aerodynamics, stability and control, working primarily on the 727 and 737 aircraft.

MR. SCHLEEDE: How long have you worked at Boeing?

THE WITNESS: I've been with Boeing just over 30 years.

MR. SCHLEEDE: Could you give us a brief description of your education and background?

THE WITNESS: I graduated from the University of Minnesota with a bachelor of science in aeronautical engineering, worked one year at General Dynamics before I came to the Boeing Company. Worked on the 737 for a long time at the Boeing Company, since its original certification.

MR. SCHLEEDE: And you participated in the investigation of U.S. Air 427?

THE WITNESS: Yes, I did.

MR. SCHLEEDE: In what capacity?

THE WITNESS: As a lead engineer, I have had about six to seven people working on that accident since it occurred.

MR. SCHLEEDE: And you are assigned to the aircraft performance group?

THE WITNESS: I am a member of the performance group, correct.

MR. SCHLEEDE: Did you work on the United 585 investigation?

THE WITNESS: Yes, sir, I worked on that investigation during its course as well.

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

MR. JACKY: Thank you. Good morning, Mr. Kerrigan.

THE WITNESS: Good morning.

MR. JACKY: Mr. Schleede alluded to your participation within this investigation. Could you be a little bit more specific in terms of what accomplishments you've provided during investigation?

THE WITNESS: Well, my group particularly works a lot on the simulator. We've been a member of the performance group. One of my engineers went to Washington, D.C. to help with the flight data recorder reduction and getting that ready for, getting data ready from the flight data recorder, recovering it. We provide support in terms of the simulator. We are the group that originally produced the simulator for the 737. We have, we arranged the simulator sessions and bring the pilots and everybody into those sessions, coordinate with the NTSB and the other parties.

And we also have set up the flight test data, or the flight testing that occurred in Atlantic City. Any testing that's done is usually coordinated by my group.

MR. JACKY: Okay. And what is the mandate of the organization when you're not conducting accident investigations?

THE WITNESS: My group is titled at this point Product Support. We basically support the product in the field, the 727, 737, 707. We deal a lot with the customers, customer support bases, any incident that happens in the fleet would normally be handled by my group if it involved stability and control of the airplane. We also deal with production support, any problems that occur in the production line of the airplane that require our attention. That's the primary functions.

MR. JACKY: And in support of this investigation, has your group been doing readouts of various FDR information that has been coming in?

THE WITNESS: Yes. Since the accident, of course, there have been quite a few other events that have been reported. There's been an increased awareness of the 737 and reported problems with the airplane. So there have been quite a few events where flight data recorders have been pulled. And they typically come into Boeing through my group as far as getting the flight data recorder readouts.

MR. JACKY: Thank you. Before we start talking about some of the flight tests that have been accomplished, I was wondering if you could give us a brief description of the 737 engineering simulator.

THE WITNESS: Okay. The 737 simulator is originally generated from wind tunnel data and analytical, empirical data that we have generated over the years on the various models. We look at the 737-300 simulator, of course, it preceded, it was preceded by two other models of the 737, the 100 and 200. So we had a simulator document already in existence for those airplanes.

Our approach to the 300 was to get into the wind tunnel and look for differences between the two airplanes. And generally, that difference was then applied to the 737-200 advanced simulator. That gave us a real leg up on the way we would normally do it on a new airplane.

That data then becomes our initial simulator document. The simulator is then compared to the flight test data that we take during preflight or precert and certification testing. And we do updates to the simulator based on that flight test data.

In the case of the 737-300, I believe there have been, in addition to the initial update to flight test, there have been three revisions to that document since that time. These are very substantial efforts on our part. Basically an update to the full simulator requires about 12 people working for 9 months. So it's like nine man years to update the document.

The simulator document is a rather substantial document, about 800 pages in it. And the update to that, from an aerodynamic standpoint, is a rather massive job.

MR. JACKY: You mentioned providing updates of the simulator model. What would prompt you to do an update of the model?

THE WITNESS: Well, the primary reason for putting out a simulator, well, there are several reasons. One is flight crew training. Another is for evaluations of things like accidents and incidents. And we would, if it came to our attention that there was an area in the simulator that was deficient, or things did not work quite correctly in terms of pilot expectations in the simulator, that it didn't fly like the airplane or in a certain area was not, didn't have the fidelity that we wanted, we would go in and update it.

And also the simulator is held up to some rather rigid standards by the FAA simulator branch.

And those, the requirements over the past 10 years, which is the period of time that this airplane's been in service, have become quite a bit more stringent. And when they tighten their tolerances, we quite often have to go in and revise the document to meet those tolerances.

MR. JACKY: Would the FAA as a matter of course require you to update it, or is it just whenever there's an upgrade to the requirements?

THE WITNESS: Well, if the rules have changed, if the tolerances have tightened. They don't mandate that we change it, but if we want to meet their requirements and have a training simulator that is up to the current FAA standards for flight simulators, we would have to revise it.

MR. JACKY: And is it Boeing Company's intention to have a simulator that meets that, the current regulation?

THE WITNESS: Yes. Yes. There's a big advantage in terms of flight crew training. It's obviously much safer to train to some of the unusual maneuvers and engine outs and things in a simulator as opposed to doing it on the airplane. Much cheaper and safer.

MR. JACKY: You mentioned doing things on the airplane. For the simulator model, is the entire envelope flight tested and then entered into the simulator document?

THE WITNESS: Well, when you sathe entire envelope, we fly the airplane during certification and precert and simulator testing from full stalls up to the placards of the airplane. So we would fly it up to the VFE, the placards at each flap down. We fly it to the dive placards flaps up. So in that regard we cover the whole envelope.

We don't necessarily do dangerous testing, high angle of attack, high side slip at the same time. That's an area we don't cover. And that's obviously an area that we got into in this current accident. So there are areas where we can't fly or won't fly. But we try to cover the entire envelope during that testing.

MR. JACKY: There was some talk yesterday about dynamic input of the rudder. Would that qualify as being, in your mind, a dangerous flight activity?

THE WITNESS: We had never tested a dynamic rudder input, to my knowledge, on the airplane prior to our Atlantic City testing. And it wasn't that it was considered dangerous in that what we did at Atlantic City would certainly have been an acceptable test. The only reason it really hadn't been done is it never had been required or asked for by anybody. It certainly is a reasonable test the way we conducted it.

As was pointed out yesterday, a full rudder input on the other hand is not something that we wanted to do on a customer's airplane. If we had thought of doing that during our original certification on the fully instrumented airplane, I don't think it would have been a problem to do that maneuver.

MR. JACKY: But the maneuver isn't required for certification of the airplane?

THE WITNESS: No. There is no requirement to do any kind of rudder step for certification.

MR. JACKY: Now, once you have a simulator model or simulator document, how do you as engineers utilize that information?

THE WITNESS: Well, the simulator document is then turned into a simulation of the airplane. We have computer simulators at this point in time where each engineer basically has a computer on his desk that allows a complete simulation on the airplane. We can do a lot of background simulation work there.

We also have the capability of attaching that to a simulator cab, a simulated airplane cab. In this case, you've heard the M-CAB mentioned. That's our primary tool. It's a multipurpose cab. We can simulate any airplane, from the 707 to the 757, I believe, in that cab.

And that allows us to work with pilots in the loop. And that has a computer generated image for a visual scene. It has a motion base which is about equivalent to what some of the training simulators are, in terms of its throw. It's not a large motion simulator, it's fairly restricted. But it does have a motion system on it.

MR. JACKY: And as you mentioned, the M-CAB simulator, that is the simulator that has been used for the wake vortex modeling and simulator sessions so far?

THE WITNESS: Yes, that's correct.

MR. JACKY: Is then the simulator model or the document, is that the information that goes to individual carriers or operators as far as their flight simulators are concerned?

THE WITNESS: Yes. We don't keep a separate simulator model for the training purposes. We have one simulator. It's generally used for engineering work and for flight crew training. In the case of a particular accident, such as this one, we may well go into that simulator and try to increase the fidelity in a certain area where we haven't emphasized it before.

And in fact, in this case, we did go into the wind tunnel early in the investigation, with the 737-300 model, and looked at some high angle of attack, high side slip areas where we had not previously tested. And that data has been incorporated into the engineering simulator for the purposes of this investigation. At this point, it hasn't been put into a training simulator. It may eventually make it into that. But to date, it hasn't been revised.

MR. JACKY: And earlier, when we were talking about the flight envelope and expressing that in the simulator, is there testing conducted at all flap settings?

THE WITNESS: Flight testing?

MR. JACKY: And then put into the simulator?

THE WITNESS: Yes. Flight testing, we do some maneuvers at every flap setting. Stalls in particular are done, I think, at every flap setting that exists on the airplane. Other data may not be done at each flap setting. For example, we have three takeoff settings on the 300 flaps, 1, 5 and 15. And we might not do everything at all three of those. We would probably do flaps 1, 15 and then pick a landing flap to do our flight testing at. And then interpolate between those.

MR. JACKY: Would you say that you have as much flight testing support as you would like for putting together the simulator document?

THE WITNESS: Well, I'm an engineer. We never get too much flight test data. I'd dearly love to have more.

But we do have a sufficient amount to do the job that we have to do.

MR. JACKY: Okay, thank you.

I'd like to get in and start talking about the simulator calibration flight test that was talked about yesterday. I was wondering if you might be able to describe the objectives that were held for that test.

THE WITNESS: Okay. The simulator verification test, which has been, was a part of our original performance group desires, or test plan, was primarily put into obtain more data at the flaps 190 knot condition than we previously had. We did have some data at that flight condition. But obviously, not nearly as much as we picked up in Atlantic City. We did a variety of maneuvers, some of which had never been done in the airplane before.

The primary maneuvers that we did were roll rate maneuvers, where we put a wheel at different settings, one-third, half, full wheel, rudder kicks, up to three-quarters of the rudder available, steady side slips, we did them at a couple of different speeds. We did some cross control where we put a rudder in one direction and wheel it in the other direction at the same time dynamically.

We also did some combined control maneuvers where we put the rudder and wheel in at the same direction at the same time. We did that, I think, up to half wheel and half rudder. The combined rudder and wheel at the same time would become a very dynamic, it would exceed the roll rates that we'd like to see on the airplane.

MR. JACKY: Okay. And could you briefly talk about the type of data sets that were collected during these test?

THE WITNESS: In terms of parameters?

MR. JACKY: Yes.

THE WITNESS: We instrumented the U.S. Air 737 that we used in the testing beyond what normally would be on that airplane for its required certification basis. We added, in particular, we made sure that we had both rudder pedal and rudder position column and elevator, which were already, the column was already on the airplane. We added elevator. And wheel and aileron were both instrumented.

We put a side slip pressure measurement on the airplane so we could get a measure of the side slip angle. It already had vane angle and the pitch roll and yaw were available. We put a special flight data recorder on the airplane which allowed us to measure the parameters more rapidly or more often than we normally would. We have a special FDR that Boeing had purchased for that test that allowed us to measure those things more often.

We also brought what's called a PAD system, and I'm not sure what the acronym stands for, but it's kind of a carry-on instrumentation package, which allowed us to measure the parameters even more often, up to like 23 times a second, and allowed us to pick up the roll rates and yaw rates, as well as the actual position of the airplane. And those two systems together gave us some redundancy. If we had problems with either one, we would still be able to recover data from the flight test.

MR. JACKY: And were there any changes made to the CDR system?

THE WITNESS: The CDR -- I'm not terribly familiar with what was done there. Mr. Cash did have, I believe, a separate recording device in addition to the normal cockpit voice recorder on the airplane, so that they could record the entire flight. Whereas the normal cockpit voice recorder only picks up 30 minutes, our tests, of course, our flights were substantially longer than that.

MR. JACKY: And how many flights were attempted for this phase of the flight test?

THE WITNESS: We really tested only two for the simulator verification. Both were conducted in Seattle. We did just two tests.

MR. JACKY: And during those two flights, how many test conditions were attempted, approximately?

THE WITNESS: I believe we picked up something over 100 conditions, counting the side slips as separate conditions.

MR. JACKY: Okay. And at least preliminarily, could you say that the objectives were met? Did you collect the data that you were looking for?

THE WITNESS: Yes. We did have, we didn't have any problems with the testing or with the data collection. I think we have a pretty complete set of data that we will be analyzing over the next several months.

MR. JACKY: Okay. Thank you. I'd like to turn to the wake vortex portion of the flight test now. And if you could briefly describe for us what the objectives of that flight test was.

THE WITNESS: Okay. The testing that was done in the, with the wake, the primary objective was to obtain data that we could use in a simulator to calculate the position of the 737 relative to the wake in the U.S. Air accident. The way we have introduced the wake into our simulator model required first that we make a, produce a wake model, a mathematical model of the wake that we could put into our simulators.

And also, simulators typically, at Boeing, at any rate, are point mass simulators. So the simulation deals only with the center of gravity of the airplane and calculates all the forces and moments about that point. In order to make the wake affect the airplane as it approached a wing, for example, we had to put together what we call a distributed lift model. We cut the wing into small slices, calculate the effects of the wake on the small slice, wherever it exists on the airplane, and then calculate the effect back at the center of gravity.

That model was put together for this accident investigation. And basically, we haven't had any data to verify that model. We also don't really have any data to verify the wake model prior to this Atlantic City test. So that was the primary purpose of that test, was to obtain data to support the verification of those two models. And the reason we want that data is, again, to go back to the U.S. Air 427 accident flight data recorder, and to try to determine from that data more precisely what happened to the flight controls during the course of that event.

One other objective, obviously, we did have a lot of CVR equipment on board, cockpit voice recorder. And the thought was that we might be able to find, identify some of the thumps and bumps from the 427 CVR and identify those.

MR. JACKY: Now, you mentioned using the information to further define what the cockpit controls were doing during the 427 accident sequence. Would that be by the use of the kinematic study?

THE WITNESS: That's correct, yes. We would use the kinematics of the airplane. We already have done that to define the motion of the airplane during the accident. And one step in that was to calculate the aerodynamic coefficients of the airplane in the presence of the wake. And that required that we locate the airplane relative to the wake.

And we do that with radar data, is the first step. But radar data is quite imprecise. It doesn't get you within the kind of precision that you need to really identify this. So this data will give us the precision. We had video cameras, as was mentioned yesterday, on the test airplane. We can locate very precisely the airplane relative to the wake.

You saw some video yesterday with the wake over different parts of the wing. And that will be our, one of our primary tasks, will be to go through that video data and precisely locate where the airplane is relative to the wake as we go through a test sequence. And with the extracted aerodynamic coefficients out of that data, we'll be able to tell what the effect is as the wake transverses across the wing of the airplane or the vertical, whatever.

MR. JACKY: Okay. We've talked about the data collection on the 737. I'm wondering if you could describe for us some of the other sources of data that were available during the flight test in Atlantic City.

THE WITNESS: The other sources of data?

MR. JACKY: Yes, as far as weather, or --

THE WITNESS: Oh, okay. Yes, we did use, as again was mentioned yesterday with the airplanes that were involved included the OV-10 from NASA. It was, one of its prime objectives in the test to gather weather data for us, as well as to transverse the wake, and give us information relative to the shape of the wake and the velocity distribution through the wake.

In addition, we needed weather data in order to correlate with the Pittsburgh accident. And that was primarily to be obtained through weather balloons. There are several weather balloons that are used in the area for soundings. Unfortunately, the one at the Atlantic City airport closed down two weeks before we started testing, unbeknownst to us. But we did obtain data from the area that we will use to try and determine how similar the atmospheric conditions were.

MR. JACKY: And what about on the 727, the vortex generating airplane?

THE WITNESS: We did have a flight data recorder set up on that airplane, or I guess they also had some separate instrumentation. And we will, we have received from that airplane the parameters that they recorded, so that we can identify speed and what-not of the lead airplane.

MR. JACKY: During the testing in Atlantic City, approximately how many flights were attempted, and during the flights, how many, well, let me ask you how many flights were attempted?

THE WITNESS: I believe there were eight flights attempted at Atlantic City. I think one was aborted for weather without getting any data. And at least one other we felt was not, there was no worthwhile data because of the weather, even though they took data. One other flight was specifically for the cockpit voice recorder with no cameras or data recorder from an aerodynamic standpoint. So basically I think it left six tests from which we thought we could possibly get reasonable data.

MR. JACKY: And out of these six remaining flights done, how many do you feel that you received reasonable data or good data from?

THE WITNESS: We took a total of 150 or about, a little over 150 test conditions that we felt, well, of that we felt about 120 were reasonable that we will actually reduce the data from.

MR. JACKY: Okay. You've brought along a videotape for us today. I was wondering if you need to set that up for us.

THE WITNESS: Yes.

MR. JACKY: Is that ready to go? Do we need to dim the lights? Please.

THE WITNESS: We have just a half dozen or so conditions here that we will view.

(Videotape played.)

THE WITNESS: The first condition that we're going to look at here is just the airplane flying. And this is the way we collected data that will be most useful in reducing the data. This is three miles behind the airplane, the lead airplane. And the pilots are just putting the left wing in the right wake of the 727, and just trying to hold it there. You see we have an inset showing what the flight crew is doing to the controls to hold the airplane in the wake.

And it was possible to fly in the wake with the wing tip or even the body centered in the wake, even though it took up to full control capability of the 737 to do that.

There is sound, but there isn't anything other than cockpit pilots discussion.

Second one is another condition that we did in, frequently, and that was to put the vertical tail in the right wake, or in one of the wakes, in this case the right wake. And that will give us the information that we need to determine what the aerodynamic effects of the vertical are. The camera gets a little fuzzy here as the wake hits the center camera. We get oil on the lens and it becomes difficult to see.

As he gets more and more into it, closer and closer to the body, it takes more and more wheel to hold the airplane into the wake.

This is also three miles behind the lead airplane.

Many of these conditions lasted for several minutes. We were able to hold the airplane into the wake for a long period of time. And we should be able to extract from that some very good aerodynamic data.

MR. JACKY: Were these conditions repeated daily or at different distances and time, the 727?

THE WITNESS: We flew a set of data at, on different flights. We tried to repeat the same things again and again in each flight to get more and more data. This is just a crossing intercept. And now they have an inset of the airplane flying through the wake. The glare there is, that was a T33 that was used as a chase plane to photograph and inform the airplane of what was going on. They are photographing through the top of the cockpit, so they do get a glare on occasion.

There's another crossing intercept from below. In the last case, in this one, it's a free response. There is no attempt from the pilots to try and control the airplane once it enters the wake.

And that wasn't a particularly hard hit into the wake. There wasn't much bank angle that occurred that time. And it hit, it's very sensitive to how you approach the wake. If you hit it just right, you hit a very large input. If you just glance off it, and glance from, particularly from the left to the right, then you get a very minor upset.

You see the wake is not, as Mr. Carriker pointed out, is not just a rope in the sky. It moves around quite a bit.

This is one of the more interesting ones, in that it got a pretty fair bank angle that occurred as he went through the wake. And that's primarily, it's a descending wake. And as he gets close, you'll see that the wake actually levels out a little bit due to the atmospheric conditions, and that as the airplane enters the wake, there's a flat spot. It's almost like flying into the end of a wake. And he stays in it longer because it is flat there, and gets one of the more dramatic encounters. He went up to a little over 60 degrees of bank. I was sitting behind the pilot during that event.

That's all there is.

MR. JACKY: Do you have any observations about the behavior or characteristics of the wake?

THE WITNESS: Well, again, as was stated yesterday, the wake does move around a fair amount. We are still reducing data from the wake. I believe that the wake probably was closer together than we originally estimated. There are some rules of thumb that they used, that typically the wakes are about 80 percent of the span of the lead airplane apart as they go on back. I think they were a little closer together than that in this case.

We originally thought from the testing, some preliminary testing in Seattle, that they were quite close together, I think it was reported 40 feet. I don't think that's accurate. I think it's closer to 70, probably. But we have some very good data both from the chase plane and from the vertical tail camera that most of those pictures were taken from that will allow us to determine the distance between the wakes for the various distances behind the airplane.

MR. JACKY: There was a lot of talk yesterday about the maximum amount of banking, upset or change that was seen while flying through the wake. In processing the data, would you have any assessment as far as what those maximum angles might be?

THE WITNESS: Well, certainly werofm the data can determine what the bank angles were that we got to. I don't think that's particularly significant. The purpose here of doing the free responses through the wake was primarily to take out the aerodynamic effects of the controls. We wanted a free response through the wake so that we could get a good calculation of the aerodynamics of the airplane and the wake combined without the controls being applied.

As Mr. Carriker pointed out, we chastised him on occasion for using the rudder when we didn't want the rudder used. We wanted to have the pure aerodynamic effects. And that's the important part. We will be able to extract from these flight conditions the aerodynamic effect, coefficient of rolling moment, that we find as we go through these different wakes.

We do find in some preliminary work that there doesn't appear to be a lot of difference between two miles and four miles in terms of the peak rolling moments that we're seeing. The shape of the rolling moment versus time may well be different. And that may affect how much of a roll impulse the airplane is going to receive out of that wake. But the peaks seem to be pretty consistent.

It's also, of course, very apparent that if you fly through the middle of the wake, you're going to get a much larger input that if you just glance off the side of it.

And it was stated yesterday that the, as you fly into the wake, you tend to get spit out of the wake. I think that's a bit of a misconception. What really happens is, once the airplane banks 30 degrees, 40 degrees, suddenly the lift vector of the airplane is pointed out of the wake to the side.

It was stated yesterday, if you fly directly into the wake and just stay there, you can stay there. If it's trying to push you up and out, you know, that's easily controlled. But the characteristic of the airplane as it banks right or left, it puts a big lift vector to the side. And that's really what pulls you out of the wake.

MR. JACKY: Okay. You mentioned processing the data. I was wondering if you could step us through some of the data processing that you accomplished while in Atlantic City.

THE WITNESS: Okay. We knew that we would like to have in Atlantic City as much information as we could relative to making sure that we had good data. It was a very tight test program. And we wanted to be certain that we were going to get good data and something that we could work with.

We did set up a computer wing that involved some pretty high tech computer equipment, much of which I know very little about. But my people were able to take a flight data recorder off the airplane, plug it into a device, I believe on the airplane, and download it into a cassette. We had basically a ground station set up at the, in the offices at Atlantic City.

We take that tape, put it into this computer and get it into our ring and actually plot the data on line within about two hours after the flight, and also do the aerodynamic extraction of data at that point and calculate what the rolling moments, what we were seeing. Just mainly to ensure that we were able to assure ourselves that we had reasonable data.

MR. JACKY: Okay. And since you've returned to Seattle from Atlantic City, if you could step us through, please, what procedures you've been doing to process the data there.

THE WITNESS: Okay. The data as it comes out, either the flight data recorder or out of our PAD system, needs to be looked at. We do have data spikes that occur, electronic anomalies that occur. We clean all that up. We go through some conditioning where we look at the position errors that are known to be on air speed and altitude. Those are corrected so we get down to the real air speed of the airplane.

We have side slip pressures that are measured. We have to calibrate the delta pressure that we're measuring from right to left to get a side slip angle. We have vane angle, which gets turned into actual wing angle attack. And we're pretty well through that process. We have of course documented and it is an exhibit, I believe, or some of the data is an exhibit from the flight test. That's -- and we're pretty well through that part of things at this point, ready to start with the extraction and comparison of the data to our simulator.

MR. JACKY: And I guess the next question would be, as far as where you are right now, in terms of the --

THE WITNESS: What we're doing at this point in time is primarily working with the simulator data to make sure that our simulation, basic simulation, is okay. We've taken perhaps 20 percent of the conditions that were flown and compared them directly to our simulator in something we call a proof of maps concept. We take the control inputs that were applied to the airplane, put those into our simulation, and compare the output of our simulator to the actual maneuver that the airplane was forced through by those same control inputs.

We do have some foils. And these, I believe, are taken out of exhibit -- did I have an exhibit number on that or not? Thirteen X-R. Put up foil 18.

CHAIRMAN HALL: This is Exhibit 13X-R. What page?

THE WITNESS: Page 18, it's the first one.

CHAIRMAN HALL: Thank you.

(Slide shown.)

THE WITNESS: There's a lot of information here, but to pass you through it very quickly, this was a maneuver that again, a bit of a maneuver that we hadn't flown before. It was one that Les Berven wanted us to add to our test plan. It starts off with a steady side slip at the far left.

At the far left side of the screen, we're in a steady side slip. We have basically put rudder in, we've got about 20 degrees of rudder. Let me run through the parameters just real quick here. The top is wheel angle, the pilot's putting in aileron, rudder pedal, rudder, bank angle of the airplane, the roll rate of the airplane, heading, yaw rate and side slip, and lateral acceleration in gees. Most of it's up on top.

At this point, we put full rudder pedal in. We're getting basically full rudder. And this is the 190 knot case. It took, for this case, which is a side slip to the left, pretty nearly full wheel. Not quite, but very close to full wheel, and that is basically the crossover point that was discussed yesterday.

At that point, the wheel was released. And gradually then the rudder was also taken out. And what we're doing is we're driving the rudder on the simulator and the wheel on the simulator to try, and then comparing the roll rate and what-not to see how closely they match. And that match is not perfect, obviously. We have about 3 degrees per second roll rate less on the simulator than what we had in the airplane.

And if you look up in that area, the simulator and the flight test airplane have a small discrepancy in terms of the amount of wheel it took to counter that amount of rudder.

Why don't you go to the next one, Rick. I believe it's page 20.

(Slide shown.)

THE WITNESS: This one is just a side slip in the other direction. In this case, we're doing the same thing. And it's pretty similar. It did take a fair amount less wheel in this side slip as the full --

CHAIRMAN HALL: Is this the next page, Mr. Kerrigan?

THE WITNESS: It's page 20.

CHAIRMAN HALL: Page 20.

THE WITNESS: It took a fair amount less wheel in this direction, and that was mentioned yesterday, that the airplane, or side slip right and left showed slightly different characteristics. But the dynamic match of the data, as we flew through the maneuver, is pretty reasonable. And that's what we'll be looking for.

Why don't you go on to the next one, Rick, which would be page 10.

(Slide shown.)

THE WITNESS: In this case, this is 170 knots. And in this case, you can see that the simulator and the airplane show a fair amount of difference in terms of the steady side slip that was encountered.

On the other hand, the dynamics look pretty good once you release the wheel. This may indicate that we have some work to do on the simulator. And that's a decision that will be made once we do a fair amount more of this kind of comparison. We'll need to get the performance group together and decide whether we want to do an update to the simulation or whether we feel we're close enough as we are.

Rick, go to page 28.

(Slide shown.)

THE WITNESS: This maneuver, this maneuver is -- okay. This maneuver is a rudder step. Basically it was flown by putting an amount of rudder trim in, holding the pedals fixed as the airplane was trimmed early on here. So we have rudder trim in that the pilot's holding the pedals centered, and then releasing the pedals, and that puts a fairly rapid rudder input into the system. This is the condition where we didn't want to go beyond the three-quarter of the rudder available at that point.

And again, you can see that roll rate and bank angle don't match exactly. And that's something that we may want to look at.

Okay, Rick, why don't you go to the next slide. I don't know what the number is. Number 42.

(Slide shown.)

THE WITNESS: Okay, this is a full wheel response at 170 knots. Here we were trimmed up at this point. And basically the pilot puts full wheel into the airplane. And as you can see, the roll rate that comes out at that particular flight condition is about

21 degrees per second, which is fairly snappy. In this case, the simulator is over-predicting just a bit. And what we saw in the other case is that it was under-predicting just a bit. And that's again, we would be wanting to look at a number of these to determine whether there's something there that we need to account for.

I think that was all of the matching, is that right, Rick? Put it up there for just a second.

(Slide shown.)

THE WITNESS: No, we'll wait with that one.

At this point, we are continuing the effort to try and make these comparisons. We will be probably doing that for the next several months until we are satisfied that we can identify how well the simulator matches. We need to make a decision as to whether we want to go ahead and update our basic simulator model or whether it's sufficient.

MR. JACKY: If the decision is made, if the decision is made to change the simulator model, what would be involved in doing that?

THE WITNESS: Well, it's a very time-consuming exercise, as I mentioned, to do a full simulator update would be on the order of 12 man months, or 9, yes, 9 man years. We would be looking at perhaps four man months to do this small portion of it. So it obviously will impact the schedule, depending on that decision that we reach.

MR. JACKY: And approximately when do you believe that that decision would be made or would be ready to be made?

THE WITNESS: I would estimate that we would have enough data by the end of the year to make the decision as to whether we need to go ahead and do the update or not. I would hope that we could get together, the performance group, sometime in December, mid to late December, to make that decision.

MR. JACKY: And from the wake vortex test, have you made any sort of assessment as to the validity of the simulation of the vortices so far?

THE WITNESS: We're working on that. And yes, we have done some comparison work. That's a much more difficult task. Trying to fly the simulator through the exact same path as the airplane flew requires that we get into the video data that we took on the airplane. There's a considerable amount of work involved. I do have a couple of samples of what we're getting out right now.

Go ahead and put the next slide up, Rick. That's page 46 in the exhibit, same exhibit.

(Slide shown.)

THE WITNESS: This is a through a wake. It was a crossing wake with about a 2 degree intercept with the wake. And we're about three miles behind the 727. We put a simulator wake strength of about 1400 feet square per second. Their cores were estimated to be about 70 feet apart at this point, based from video footage and about a 4 foot diameter on the wake is again what came from the video.

We estimated a path from the video, and I'll show you in a minute roughly how those came together. This shows that the trends are typically there, but obviously, something isn't lined up quite right, whether it's a model difficulty or just that we're not quite in sync with the wake. We don't know at this point.

There are some -- put that up a bit, move it up so we can see the bottom. One of the things that we see in the wake that's very apparent, if you look at the side slip, that angle there, you see a very sharp break in the flight test data, and another break over here. And that's as the airplane, the nose of the airplane, which is where the side slip is measured as you go through the wake, the side slip really isn't changing. But that's a local effect on the nose of the airplane. And you see a fairly sharp movement in the side slip angle.

Why don't you put the next slide up, Rick, real quick.

(Slide shown.)

THE WITNESS: The next one shows, page 47 shows the longitudinal axis. And that's pretty, not too much to see except again -- why don't you move it up, slide it way up, Rick. Again, you can see the vane angle of attack being influenced by the wake locally, being shoved down rather dramatically. And then this is the point at which the airplane comes out of the wake again. Now, that's an effect that we're not trying to simulate, because it isn't important to the aerodynamics. But it's very, it's another indication that you have moved through a wake.

Go ahead to the next slide, Rick, 48.

(Slide shown.)

THE WITNESS: This just shows the kind of thing that we get into when we're trying to match this. It shows the path of the right wing tip and the left wing tip of the airplane. This is the simulator as we're matching it, and then also the dashed lines are the wake, the position of the wake as we think it exists. We're flying through it on a fairly shallow intercept path. And the times there are basically so we can compare it to the next slide, which shows what we're getting out of the flight test.

Just put the next one up for a second.

(Slide shown.)

THE WITNESS: That's 49, I believe.

This shows the points here were actually measured from the video, to show where we think the airplane, or where the wake was, as the airplane flew by. And then the position of the wing tips, again, from the aircraft.

And trying to get the simulator to fly that exact same path, if the model isn't perfect, the simulator will try to fly off to the side, right or left or above or below. And that's the difficulty in trying to match this kind of data. And we're working real hard on trying to sort that out.

Go ahead to the next.

(Slide shown.)

THE WITNESS: This is 51. This is the one that we showed in the video. You see that the bank angle got to about 64 degrees during that maneuver. The simulator actually does a fairly, fairly decent job of getting to the same angle. The rates in the simulator are slightly higher than the rates on the airplane. You can see, as they talked about, they're putting wheel in as they enter the wake.

And then as they get to the wake, they put their hands up, as John Cox said yesterday. And they just let it be hands off until they start the recovery. And in this case, the airplane, as you can see, pretty well started its recovery by itself. The pilots didn't try to intercede until they were back to about 45 degrees of bank. So the airplane just naturally has some tendency to recover.

Just slide that up. Again you can see the side slip takes a very sharp break there as you go through the wake.

Okay, go ahead to the next slide.

(Slide shown.)

THE WITNESS: This is number 50, I believe. And the only thing I wanted to show here is that there is a very sharp break apparent in the flight test air speed indicator. And again, slide it up, Rick, as you go through the wake, you get a very sharp spike in the local angle of attack. And that actually took the vane up to where the stick shaker fired, I believe, on that one. We see some very sharp local changes to flow angles which will actually cause the stick shaker to fire.

That's fine.

MR. JACKY: Thank you.

So as of right now, do you believe that there will be some fine tuning of the simulator model?

THE WITNESS: I think that it's very likely that the simulator model may not have to be updated. The wake model may or may not. That's going to depend on the NASA data that we receive, as to whether we think we have to do something with that.

The distributed lift model is, if we want to get into the probabilities, I think, certainly isn't extremely remote. It's very probable that we will have to do something with that. This is the first time that we've had flight test data that we can actually compare to that model and make sure that we have something that we believe.

We also, in discussing with the gentleman from NASA who spoke yesterday, they've done some work with their 737-100, where they have been in the wind tunnel with wakes in the 737-100 model. Actually have done tailoff testing. So we should be able to get some of that data from them. And that could be very useful in helping us identify the parts of the model that aren't giving us a correct response.

MR. JACKY: So to that extent, do you believe that the flight tests were worthwhile?

THE WITNESS: Oh, yes, definitely. The data that we've taken on this testing I think is unique in the world. I don't think NASA's done any of this previously. If nothing else, I think there will probably be some doctorate theses that will be written across the country since this data is, I believe, basically available to the public. I think there will be a lot of work done with this data over the years.

MR. JACKY: Thank you. There was some discussion yesterday --

CHAIRMAN HALL: Mr. Jacky, are we through where we can get some lights now?

MR. JACKY: Yes.

CHAIRMAN HALL: And could we please get the cold air turned off up here? I've tried three times. I'm going to make a public plea this time.

(Laughter.)

CHAIRMAN HALL: Sorry, Tom, but I don't want to leave here with the flu.

MR. JACKY: Thank you. There was -- yesterday there was some discussion regarding the apparent 2 degree difference in the rudder angle measured between the airplane used on the flight test and the same ruder that would be expected in the engineering simulator. I was wondering if you might give us a small explanation about that, please.

THE WITNESS: Okay. Yes, basically during the initial testing of the airplane, we do a certain amount of testing where we take the rudder out to blow-down. We don't spend a lot of time gathering that data. But a blow-down model is put together. Actually, the way it goes into the simulator is as hinge moments on the rudder. That data is, initially comes again from the wind tunnel. It's compared to flight test data where flight test data is available. And we don't always have a lot of data to support it.

We've gone back and looked at the data, the blow-down data in particular that was used to calculate the hinge moments. And included in that, the blow-down from this particular airplane. And it revised the hinge moment data to reflect that, and it put that into the simulator.

It may have been a hole in our data in the past where we didn't have anything at this specific flight condition and rudder angle, side slip angle. We still had some work to do on that. Right now, we've put hinge moment data in that will match what we saw in Atlantic City. That may not be the final answer. I don't know whether this airplane is a bit unusual or, in regard to blow-down, or whether that's consistent with past data. We have a fair amount of data to look at yet before we'll know that for certain.

MR. JACKY: So there's a possibility this just may be one unique airplane?

THE WITNESS: It's possible. When we get into the kinematic discussion, during that, what we extracted from the accident airplane actually showed, we were predicting a rudder required that was on the order of 21 degrees. And actually, this data tends to support that level of rudder available on the airplane.

Our simulator was showing more like 18 degrees, 19 degrees at that point. So this actually falls in line with the data that we discussed back in May, during one of the all party meetings.

MR. JACKY: Okay.

THE WITNESS: So it tends to confirm the analysis that was done kinematically on the accident.

MR. JACKY: Would it then, could you make the assessment that it would give you more confidence in the kinematic data?

THE WITNESS: Well, it may give other people more confidence in the kinematics. I think we already had a fair amount of confidence in it. But, yes.

MR. JACKY: Have you made any sort of assessment as to whether or not this 2 degree rudder difference may be applicable to other series models of the 737?

THE WITNESS: Well, it certainly will be applicable to the 300, 400, 500 airplanes which are all basically identical in terms of the aft body and the vertical tail. The 737-100 and 200 is a separate simulation totally. There are differences between the airplanes and the aft body area. And of course, the calculation and prediction of the hinge moment data from flight test data was done totally as a separate effort.

So I don't think that there's going to be necessarily any carryover between the 737-300, 400, 500 and the 737-100 and 200. That's something that we can look at. But there's -- like I say, it's an independent effort to identify those hinge moments.

MR. JACKY: And there was some talk yesterday regarding the crossover point, in regards to lateral stability. What if any difference would there be in that crossover point due to an increase in the rudder angle?

THE WITNESS: Well, as was pointed out yesterday, I think in the simulator they felt that the crossover point was somewhat lower than what they saw in flight. It's curious that in doing a full rudder side slip right and a full rudder side slip left that there was, I think on the order of 10 knots difference in that crossover point.

I'm not sure that that's terribly significant. Crossover point is not a cliff. Nothing much happens in terms of sudden roll rates. If you're at a condition where you have full rudder and full wheel in, slightly above that speed you get a very slow recovery of the airplane. If you're below it, you get a very slow deviation of the airplane. But from a balance standpoint, you are at a point where the lateral control balances the rudder.

I know we're concerned, discussed a lot of, in the past couple days, of rudder hardovers being difficult to control if the lateral control can't overpower it. On the other hand, below that speed, if you have a rudder hardover, it can be a difficulty. If you're above that speed, and have a lateral control hardover, you don't have enough rudder to overpower that.

So it's a balance that is there on the airplane. The two are pretty much balanced, the lateral to the directional control. There is certainly no way to make them balance throughout the flight envelope, so that one can always handle a hardover on the other axis.

MR. JACKY: I'm going to ask you to turn to Exhibit 13X-P. And the exhibit doesn't have page numbers on it, but it's the last page of the exhibit that I'm wishing to refer you to.

THE WITNESS: Okay, I have it.

MR. JACKY: Okay. I was wondering if you could explain this chart to us, please.

THE WITNESS: Okay, we do have a foil of it, I believe, Rick. That shows up really well. We may have to dim the lights, though, for anybody to see it.

(Slide shown.)

THE WITNESS: This is a comparison across the Boeing fleet of twin engine airplanes. It shows the 737-200, 300, 757, 767, 767ER and the 777. This is just a comparison across airplane lines at 1.25 OEW and at the aft center gravity of the airplane.

MR. JACKY: What is OEW, please?

THE WITNESS: Yes, that's the operating empty weight. Basically, this is a fairly lightweight airplane, in the, which would be not untypical of a landing approach situation. And it shows that at this condition, which is somewhat lighter than the test airplane in Atlantic City, that the margins that the various airplanes have is not a lot different. The 737-300 at this point has about a 16 knot margin.

And what we're talking about here is, this is all relative to the maneuvering speed that is recommended for the various airplanes. For the 737-300, the maneuvering speed recommended is 190 knots.

And at this lightweight condition, the 737-300 with the hinge moment data from the Atlantic City test has about a 16 knot margin. So that says you get 16 knots below the maneuver speed at that weight before you would run out of lateral control.

And the reason for picking this, we had to pick a weight so we could do it across the airplane lines. And on the other airplanes, you can see that it's a little bit lower than some of the others, but it's not substantially different. It's within 10 knots of even the 767-200. And obviously, this margin on, goes down somewhat as the, as you get to the heavier weights.

We use 190 knots as a block speed on the 737. And that 190 knots, and as you get to the real light, or to the heavier weights, we'll give you less margin. And as we saw in the Atlantic City testing, we're getting pretty close to several knots, I think it was 185 or thereabouts, where the crossover point was found on that airplane.

MR. JACKY: They aren't shown on this chart, but I was wondering if you could give us a comparison as to how the 400 and 500 would play on this chart?

THE WITNESS: I haven't, no, I really haven't looked at those specifically to know the answer to that.

MR. JACKY: Okay, thank you.

We touched briefly on the kinematic study that has been ongoing on this airplane, or on the accident. And we'd like to refer you to Exhibit 13X-D, please.

THE WITNESS: Okay.

MR. JACKY: I was wondering if you could, before we get into this, give us a refresher as far as what the kinematic study was and is.

THE WITNESS: Okay. The kinematics basically are just, we're talking about the physics of the situation as opposed to the specific aerodynamics. What we have done with the U.S. Air 427 data is calculate from that data, taking the known position errors for altitude and air speed, and we're also able to calculate the side slip angle and the angle of attack, we have pitch, roll and yaw from the flight data recorder, and from that we can derive the rates.

And also then we can calculate an aerodynamic coefficient that will cause the airplane to go through the oscillation that we saw on the accident airplane.

Basically, it's physics. We know the path of the airplane. We know where it started, we know where it ended up. And we can actually calculate the forces that we don't know that will drive the airplane through that path. So that's basically what we're doing with the kinematics.

If the situation is fairly simple in that there's a control problem, something fails on the airplane, you could calculate that aerodynamically pretty easily as to what was causing the incident. The difficulty here has been, we've been pretty certain for some time that this airplane went through the wake of a 727. Since our Atlantic City testing, we're more certain than ever that it went through that wake.

That makes it more difficult to determine what the aerodynamic coefficients are that were applied to the airplane outside of that wake. Because we have to somehow account for the wake.

And that's really what we're looking to use this data for. As we get more and more information from the flight test, we hope to be able to locate the wake relative to the accident airplane much more closely. The kinematics study that's been done so far, we took the radar data from the airplane, from the 727 and 737, we know they were in the immediate proximity. We looked at basically the lift and the pitch that we were extracting from that data and used that to locate the wake relative to the airplane.

It would be -- we need some independent source that's not critical to the conclusion in order to locate that wake. And that was our attempt to do that. We used pitch and lift, which, you know, are not really a factor in the accident, to try and locate the wake so we could calculate a rolling moment and a yawing moment, which are critical to the cause of the accident.

And that's, to date that's been done and we came out in May with a time history of estimated wheel and estimated rudder position that reflected that kind of an approach. What we would like to be able to do, or what we hope to be able to do with the data that we have now is get an even more precise definition of the lift and the pitching moment that comes out of the wake encounters.

We have known wake encounters, we know where the wakes are. And with that, we'll be able to locate the wake from the 427 accident much more closely with regard to where the airplane was. And we will then recalculate, using the kinematics, the resultant force in all axes that it takes to match that time history.

So we will generate out of this data a new time history, predicted time history, of the rudder pedal, or the rudder and of the control wheel.

MR. JACKY: And in the update that you presented in May, was there any change to the rudder time history?

THE WITNESS: From what we had seen previously, we've done that a couple times. I think the initial calculation that predicted a rudder basically didn't have a week in it. That was our first attempt. We said, this is the aerodynamic coefficients that we need. And in order to get a feel for how large they were, we put them in terms of an equivalent of wheel and rudder. And that gave us this time history of rudder. When we put the wake in, that time history changed fairly significantly. And in May, we had taken another cut at that and had a slightly more, hopefully precise, positioning of that wake. And that did change the character of the rudder time history.

The final position of the rudder, I think, was pretty much the same in all cases. But how fast it came in, the profile was changed somewhat.

MR. JACKY: Was the profile or the rate increased or decreased?

THE WITNESS: The rate I believe increased over what we had seen previously. And it went up to, I believe in the earlier studies it looked like the rudder had gone up to some intermediate value, back down and then back up again. I think in the May estimates, we felt it had gone up to a level, stayed there and then gone up a bit further to another level later in the event.

MR. JACKY: And have you made any sort of assessment from that time history as to what sort of input or, what sort of input would give you that type of rudder history?

THE WITNESS: Well, at this point, obviously it's within the capability of the system. The rudder can move at that rate. It's not a particularly fast rate. I don't recall what the rate was. And the pilot, pushing on the pedal, obviously, would cause the rudder to go in that fast.

At this point, we haven't determined any particular failure mode of the system that would cause that. Obviously, that's been something that everybody's been working on for 14 months, to try and find something wrong with the rudder system that could cause this kind of an upset. And up to this point, we have not found any failure mode in the system that would cause this.

MR. JACKY: And from the simulator validation flight testing, and even from the wake vortex flight tests, do you see anything that would either, do you see anything that would make you believe that the time history or the final resultant kinematics output is going to change to a great extent?

THE WITNESS: That's something we really don't know at this point in time. I suspect that it will change. The distributed lift model that we used, as I said, has not ever been verified with flight test data. We're not able to do that.

Chances are that this will change somewhat. The wake model potentially will change. The simulator model, basic airplane, what we're seeing is that it's pretty reasonable. And we have to make a decision as to whether we think that's going to, the performance group will make the decision as to whether we think that will have a significant effect.

And what we need to do is update those models and then get into the kinematic, again, to try to extract these coefficients. So it's premature to say that they're going to change, although I suspect that there will be some change, particularly in the lateral estimate, the wheel required. We know that the rudder required to sustain the maneuver is very near full rudder. That, I don't think, will change. But the time history of lateral control system inputs I think is the most likely to change.

MR. JACKY: Were you in attendance when Mr. Cash gave his presentation on Wednesday?

THE WITNESS: Yes, I was.

MR. JACKY: Are you familiar with the information he presented regarding the sounds resultant of side slip?

THE WITNESS: Yes. I listened to his presentation with interest.

MR. JACKY: Can you give any sort of assessment as to whether or not his information would verify or lend more credence to the kinematic study?

THE WITNESS: Well, certainly, it's an interesting point. We had been wondering, of course, what had caused the engine sound to change. During the testing, I was suspicious of the actual engine swallowing a wake as being perhaps the cause of that.

Because there was a distinct sound change during that event. However, it appeared that Mr. Cash had pretty good correlation with side slip. So that's perhaps more likely the cause of that change in sound.

Yes, it would be very interesting to see what, how that correlates with the side slip that we have calculated kinematically. It should be very interesting.

MR. JACKY: The updated kinematic study data was used in a simulator session at NASA-Ames in July. I was wondering if you could briefly describe what were the objectives of that test and how that was accomplished.

THE WITNESS: Okay. Yes, we had actually set up a simulator session in Seattle using our M-CAB to demonstrate to a number of pilots what the crew of U.S. Air 427 had experienced, as closely as we could. The experiment basically was to take the flight data recorder from 427 to calculate the rates and accelerations that the aircraft went through, particularly during the early part of the upset.

What we were trying to determine, primarily, was if there were any sounds associated with that, well, let me back up. What we did is we correlated the flight data recorder with the cockpit voice recorder. We synchronized the two.

And we actually received permission to use the actual CVR, the actual cockpit voice recorder. That was played over headsets with the, into the pilots who were participating in the experiment, so they could actually hear the cockpit voice recorder as the simulator motion and visual system was being driven to the flight data recorder information.

So they were able to hear and feel and see basically the same cues that the crew of U.S. Air 427 was experiencing. And the primary purpose of that was to try and determine if there were any, if they would be able to determine what the noises were that we had heard in the cockpit, or on the cockpit voice recorder. And whether there were any cues that might indicate to them whether or not there was any reason to put in rudder. That was another aspect of it.

And as we got into the M-CAB, which has a very limited motion system, we found that, or we felt that we would be better off going to the NASA simulator where we had, as Mike pointed out yesterday, plus or minus 30 feet or thereabouts, both vertically and horizontally, so that we could do a better job, hopefully, of matching the accelerations. So that was the intent of it.

And we basically didn't find any, the pilots could not identify sounds, the thumps and the clicks, based on what they experienced. And I think we know the reason why now, because it is pretty apparent that the wake was what was causing these things, and we were not, had no way of simulating that at the time.

MR. JACKY: And as far as engineering or the ability to put the kinematic information in the simulator, do you feel that it was a valid session?

THE WITNESS: Yes, I think so. Mike mentioned there were some differences between the two, and that I guess is understandable. We were able to reproduce the accelerations, the small movements, up to a certain point in time in the time history very accurately.

Obviously, as you get into the, start pulling load a factor of more than a quarter or half a gee, the simulator is no longer able to do that. But up to that point, we thought we were getting a pretty reasonable representation.

MR. JACKY: Okay. And was the cockpit that was laid out in the simulator cab, was that identical to a 737 or were there differences?

THE WITNESS: Well, the M-CAB is pretty similar. It has got a lot of the common instruments. The cab that was present in the NASA vertical simulator, vertical motion simulator, was quite different. It's primarily a research vehicle and didn't really bear any resemblance to a 737.

MR. JACKY: One last topic I wanted to touch with you is the CDR team and their report. Did you have the opportunity to provide any assistance or did they ask you to provide assistance to that effort?

THE WITNESS: To the CDR?

MR. JACKY: I'm sorry, to the critical design review team.

THE WITNESS: Oh, okay. Yes. One of the engineers that was working for me on the accident early on was, has been working on the CDR later on, not under my direction. But he has participated in that evaluation.

Early on in the CDR, I participated briefly in helping them set up simulator sessions to evaluate some of the failures that were of interest to them. Basically we did a number of scenarios which included rudder and aileron trim runaways posed by the autopilot, lateral versus directional control power, including maximum rudder deflection. We did flight with zero and one half aileron rudder fuel force, controlled through the aileron transfer mechanism where the ailerons jammed at one half and full deflection, flight with one or two flight spoilers stuck up on the same side, and flight with a number two slat retracted and flaps extended to 1, 5, 15, 25 and 40 combined with a maximum flap asymmetry between 15 and 25.

And for the most part, I think that session satisfied the CDR team with regard to most of those items, so they did not become a part of the final recommendations. There were perhaps a couple that did. And we did then participate through one of my engineers in answering the recommendations, several of the recommendations that were made by the CDR team.

MR. JACKY: And one final, final point. Have you had any participation in the original certification in the 737 airplane?

THE WITNESS: I was, I've been on the 737 since before it became certified, back before first flight. Some of us are old enough to go back that far, even though the FAA doesn't have anybody that old, I guess, any more.

However, I was a very young engineer at that point in time, so I didn't get a whole lot of input into decisions that were made. But I did fly in the airplane a number of times.

MR. JACKY: And during that certification, were you aware of any sort of flight tests done at full rudder input?

THE WITNESS: Well, during the certification, I've gone back and reviewed some of the flight testing that was accomplished on the airplane. We did steady side slips for certification, primarily during the 100 and 200, I think it was primarily at the landing flaps. And there it was obvious that there was plenty of lateral control for full rudder.

During the 737-300 certification, which I also participated in, it was obvious that, again they did considerably more steady side slip testing at that point in time. Flaps 1 was flown both at 1.2V stall and at VFE. At VFE there is obviously plenty of lateral control. At 1.2V stall there is not enough lateral control to hold full rudder. And that was the certification testing done on that 737-300. That was true at both flaps 1 and flaps 5.

MR. JACKY: And was there any sort of flight test done to show the controllability of the airplane with a rudder hardover or rudder jam in the full or maximum position?

THE WITNESS: Well, not in terms of, certainly not in terms of the dynamic. That was not a requirement. Basically, it still isn't a requirement. There is no requirement in the FARs that requires you to demonstrate a rudder hardover. Basically the rudder system is considered to be a primary flight control system and the probability of that causing a hardover is deemed to be extremely remote.

MR. JACKY: And do you have any opinion as to that certification basis?

THE WITNESS: In terms of whether that's sufficient? I believe that it is, yes. I think that as Mr. Berven pointed out, we need to consider that these control surfaces are, their primary control of the airplane, the pilot has to have the authority through the control system to cover anything that's going to happen to the airplane. And if you start limiting it, you become, it becomes difficult to do his job when he gets an engine out or some other failure that the system is designed to handle.

So I think that what we have is sufficient.

MR. JACKY: I have no further questions, Mr. Chairman.

CHAIRMAN HALL: Any other questions? Questions from the technical panel?

MR. HAUETER: Just a couple.

One question I have, sir, is on the kinematic study, when do you anticipate that the next iteration could be completed, based on the data we have?

THE WITNESS: We're -- I have put together a rough schedule. I anticipate that probably the end of the first quarter next year, end of March, perhaps.

MR. HAUETER: Okay.

THE WITNESS: And that, at this point, I hope to have it documented at that juncture. So we'll have some preliminary looks at it ahead of that.

MR. HAUETER: Okay. And secondly, during your testimony, you mentioned that at the crossover point with lateral directional control, there was a slow recovery, you kind of indicated a benign maneuver compared to, say, Mr. Berven's testimony of a dynamic input in terms of being --

THE WITNESS: Well, again, if you suddenly step on the rudder pedal and wait four or five seconds before you do anything, it will be quite dynamic. And again, if it gets over pretty far before you put any wheel in to counter it, it will be pretty dynamic.

I'm just pointing out that the, if you put in a full rudder input at, in an area where it takes 90 percent of lateral control to control the airplane, that's not going to be a lot different than an area where it takes 110 percent lateral to control the full rudder input. I'm just saying, those two maneuvers aren't terribly different. It doesn't suddenly become much more dramatic from an upset standpoint.

The upset is about the same. You grant it when you put in the wheel, in one case, the wheels stop the roll rate pretty much and it will continue slowly on, and in the other case, it may continue slowly back. But it's, I don't see a clip there is all I'm really saying.

MR. HAUETER: Okay, thank you very much.

CHAIRMAN HALL: Other questions from the technical panel?

(No response.)

CHAIRMAN HALL: Well, Mr. Kerigan, if you happen to remember the names of any of the FAA people you worked with --

(Laughter.)

CHAIRMAN HALL: -- Mr. Donner would probably like to have some of those.

THE WITNESS: Well, one name, I was surprised, because I think Earl Chester still works in the Seattle office. And he was there during the certification of the 737, I believe.

MR. DONNER: And I believe you're correct.

CHAIRMAN HALL: Well, we will have to look at this incorrect testimony that's been presented by them.

(Laughter.)

MR. DONNER: I'd like to correct the record and assure the Chairman that the FAA has lots of old people.

(Laughter.)

CHAIRMAN HALL: That's apparent to the Chairman, Mr. Donner.

(Laughter.)

CHAIRMAN HALL: We have been joined by the distinguished former Chairman of the National Transportation Safety Board, Mr. Carl Vogt is in the back of the room. There's nothing more distinguished than a Chairman of the National Transportation Safety Board, so I want to be sure and welcome Carl. And

Carl, of course, was with the Board at the time of this accident and was the member on scene.

The technical panel has advanced us now an hour and 15 minutes, well, no, an hour and 45 minutes. So we will, before we go to the questions of the parties, we will take a break and return and start promptly at 10:30.

(Whereupon, a recess was taken.)

CHAIRMAN HALL: We will reconvene this board of inquiry, and Mr. Kerrigan has returned to his position. And we will ask if any of the parties have questions for this witness.

I see the hand of the Air Line Pilots Association. Any other parties have questions for this witness? If not, Captain, please proceed.

CAPTAIN LEGROW: Thank you, Mr. Chairman.

Good morning, Mr. Kerrigan.

THE WITNESS: Good morning.

CAPTAIN LEGROW: Just a couple of questions. You were talking about rudder hardovers and then you made some reference to lateral hardovers. I wonder if you could just elaborate a little bit on exactly what would be considered a lateral hardover, or how you could get a lateral hardover?

THE WITNESS: I don't know exactly what would cause one in either the directional or the lateral axes. But if you are going to look at a hardover in one, why not look in the other. A jam obviously, if a pilot puts in full wheel and it jams, or he puts in full rudder and it jams, could result in a full control input, whether it's a probable or extremely improbable event is a point of discussion, I guess.

CAPTAIN LEGROW: But isn't there redundancy in the lateral control?

THE WITNESS: Theer is some redundancy, depending on where the jam occurs. But again, it's very dynamic, if it were to occur.

CAPTAIN LEGROW: You were discussing some of the tests that were done in Atlantic City. And we're talking about a crossover point. And I believe you testified, and Mr. Carriker testified, as did Captain Cox, that during the flight test that was somewhere, something under 190 knots was 1 degree flap. Would you agree with that?

THE WITNESS: That's my understanding, yes.

CAPTAIN LEGROW: If I cold refer you to Exhibit 13X-P, please. And it will be the last page.

THE WITNESS: Yes, sir.

(Slide shown.)

CAPTAIN LEGROW: On your graph that you showed us, you showed for the 737-300 maneuvering speed plus 16 knots, or less 16 knots, is that correct?

THE WITNESS: Yes, at that weight, that's correct.

CAPTAIN LEGROW: Okay. Well, my understanding, the Atlantic City airplane, or the airplane used for the testing in Atlantic City, closely replicated the accident airplane. Would that be a true statement?

THE WITNESS: That's true, in terms of weight and CG, that's correct.

CAPTAIN LEGROW: Weight and CG. Well, I just don't understand, with the difference between the 5 knots that Mr. Carriker and Captain Cox testified and that you agreed to and the 16 knots that you show on this balance sheet, I guess it's called --

THE WITNESS: Well, again, this balance sheet was put at a specific weight relative to the operating empty weight of the airplane, so that we could get a comparison across airplane lines. In other words, it's done at 1.25 OEW, which is a landing weight that's typically used for these kinds of comparisons.

This was done a while ago. It wasn't done as a direct result of what we're talking about here, it wasn't prepared for this accident or this meeting, rather.

CAPTAIN LEGROW: So this was done prior to the test in Atlantic City, then?

THE WITNESS: I don't know if it was done prior to that or not. That has been updated for the rudder data that we took in Atlantic City. The 16 knots is indicative of the rudder blow-down that we saw in Atlantic City.

CAPTAIN LEGROW: Okay, so this would represent, to put it in some lay terms, a nearly empty airplane, without --

THE WITNESS: It's a, well, it's got 25 percent of the weight over and above the operating empty weight.

CHAIRMAN HALL: Excuse me, are you having difficulty in hearing in the back? That speaker is maybe out. Okay, if you could please try to speak closer to the microphones. We have people having difficulty hearing. Thank you.

Please proceed, Captain.

CAPTAIN LEGROW: Thank you, Mr. Chairman.

How would this 1.25 OEW compare to the accident airplane?

THE WITNESS: It is quite a bit lighter than the accident airplane. The accident airplane was kind of in the middle of the weight range for landing.

CAPTAIN LEGROW: About 110,000 pounds or something?

THE WITNESS: Yes, I think it was 108,000 or something.

CAPTAIN LEGROW: This would be something, what?

THE WITNESS: This is quite a bit lighter, I don't --

CAPTAIN LEGROW: Eighty-five thousand?

THE WITNESS: Yes, maybe 85,000, 90,000, something like that.

CAPTAIN LEGROW: During the wake vortices tests in Atlantic City, I assume that you rode in the cockpit for some of these tests?

THE WITNESS: I was present in the cockpit for one of the tests, yes.

CAPTAIN LEGROW: In your estimation, what would you estimate the core, the diameter of the core of the wake vortex?

THE WITNESS: I really haven't -- the view that you have out the cockpit is not real good for doing that. I didn't try to estimate the core. One of my engineers looked at the movies that we had taken, the videos that were taken, and estimated that in one of these conditions we looked at, it was about four feet diameter.

CAPTAIN LEGROW: I think that would probably be the consensus from what we saw. I'd like to refer you to the kinematic study. That would be Exhibit 13X-D. And you said in your testimony that you had a great deal of confidence, or you had confidence in this document?

THE WITNESS: Well, what I have confidence in is the methodology that we used to calculate, to go through and calculate these data. It obviously, the models that we are using as part of the extraction we hope to gain more confidence in that as a result of the Atlantic City testing.

CAPTAIN LEGROW: Okay. I refer you to page 6 of that document, please.

THE WITNESS: Okay.

CAPTAIN LEGROW: About two-thirds of the way down, and it defines the weight vortex used for the study. And the second would be the diameter. So you would agree that this is about four times greater than what --

THE WITNESS: Well, if you look at the paragraph immediately above, it says that we varied the diameter from a radius of, for a diameter of 4 feet to 16 feet during the evaluation that we did. And basically, in terms of the effect of the wake on the airplane model, we didn't see a lot of difference between 4 feet and 16 feet.

And a lot of the data that we ran was run at four fee during the evaluation. That doesn't appear to be a particularly strong influence. And basically, what we're seeing in the wake testing is a diameter of the smoke entrained in the flow. The flow field that surrounds that wake is much larger than that. As you put a wing tip, as you get, you know, 10 feet away from that, I would assume that you would start to feel the influence of that wake. You don't have to put the tip right in it before you feel, I think Captain Cox can confirm that.

CAPTAIN LEGROW: Okay, I'd like to refer you to page 19 of the same document.

THE WITNESS: Okay.

CAPTAIN LEGROW: And do you believe that this represents what you would find, from time 132 to time 141 is approximately 9 seconds. And I think Captain Cox and Mr. Carriker testified yesterday that they felt it was something on the order of two or three seconds.

THE WITNESS: Two or three seconds in the Atlantic City test data?

CAPTAIN LEGROW: Yes, sir.

THE WITNESS: Again, if you recall the videos that we've looked at, wakes can snake all over the sky. And if it has a shape that puts you in it for two or three seconds, as we experienced quite often in the testing, that's going to do something to the airplane. If it happens to be in, have a turn in it as you fly into it, and that's tracking the airplane, you could be in it for considerably longer than that.

This slide that you're talking about, it shows the airplane actually entering the influence of the wake, approaching it, and being into it for perhaps four or five seconds. And that represents basically a simulator run that we've made through this data set, where it's approaching the simulated wake and flying through it fairly, you know, in a physically correct manner, and still, like you say, staying in it for more like four or five seconds.

CAPTAIN LEGROW: But again, this is before the data from Atlantic City was gathered, is that correct?

THE WITNESS: That's correct. What we will do, hopefully, is be able to refine this association between the airplane and the wake. The positioning is something that we hope to be more precise on, yes.

CAPTAIN LEGROW: I have one other question. Like you, I've been around this business for 30 years or so and remember the initial testing. But in your opinion, with your vast experience in this business, and doing accident investigations, do you feel the expanded flight data recorders would be helpful in accident investigation?

THE WITNESS: Idon't think there's any question about that. Obviously, in accident investigations where we've had flight data recorders with a lot of parameters on them, we have been able to reach conclusions much more quickly and much more rapidly.

And I think even more important, perhaps than in accident investigation, is incident investigation, to be able to understand precisely what happened in an incident. We may be able to prevent an accident from happening later on. So I think it's very important that we have as many parameters as we can get.

Obviously, as an engineer, they won't let me have as many as I want. But we'll hopefully get an increased number.

CAPTAIN LEGROW: We're faced with the same thing. Thank you. I have no further questions.

CHAIRMAN HALL: Thank you, Captain.

Any other questions from the parties?

(No response.)

CHAIRMAN HALL: If not, we'll move to the front table. Mr. Clark?

MR. CLARK: In the, we've had two presentations on the kinematic studies done by Mr. Dellicker. And in one we had a rudder that could move somewhat slower and then another one that the rates were greater. Is it fair to characterize that the, in the slower rates, we were looking at deflections to the blow-down limit in four to five seconds? Is that --

THE WITNESS: That's something that I'd have to look back at it. But that's on the order, the correct order, I think.

MR. CLARK: We can pull the record out, if we need. But in that order.

THE WITNESS: Yes.

MR. CLARK: And certainly the graphs speak for themselves.

And then in the faster rate, we were looking at step inputs up into the 12 degree range in about a half a second, at least according to the charts?

THE WITNESS: Yes, I believe that's correct.

MR. CLARK: So there's a very distinct difference in rudder rates that can be, that can cause a match of the FDR data from Pittsburgh?

THE WITNESS: Right. And that primarily is the positioning of the wake and with respect to the airplane, that causes those differences.

MR. CLARK: And would that open up the portion of the investigation that deals with potential failure modes, for examples, having any kind of failure mode that may be limited to a slow rudder rate versus a wide open rudder rate?

THE WITNESS: Yes, in terms of, failures that could cause a particular rate, it may open it up somewhat. Now, obviously --

MR. CLARK: I'm not trying to put you on the spot as a rudder expert. But from the aerodynamic standpoint, you're comfortable enough with the numbers that there's a distinct difference between the two rates?

THE WITNESS: Well, there definitely is. And again, what we hope will come out of this evaluation is another curve which we will have even more confidence in. We obviously felt that what we presented in May was a step beyond what we had previously. And hopefully, this will be one step beyond that, now that we have the data to support it.

MR. CLARK: In your examination of the data to date for the, from the vortex tests, is there any evidence that the vortex flow field caused movements of the rudder directly?

THE WITNESS: No, I've looked at the data that we took. A lot of the cases that we ran, particularly with the fin in the wake, were mostly yaw damper on. So we definitely had motion of the rudder to the yaw damper limits.

We didn't see any motion beyond that, if the pilots were not moving the pedals. In those cases, where we're just flying through the wake, there is very, no perceptible, or no significant movement of the rudder in any of those cases. You may be able to see it move, side slip variation and compliance in the system will cause very small motions. But it's down in the tenths of a degree, if that large. I haven't looked at anything on a scale large enough to really identify if there is a magnitude there or not.

MR. CLARK: Okay. Is there, in your estimation, any way to calculate the forces on the tail and specifically on the rudder to see if the vortex flow field may be approaching the hinge moment limits of the rudder system?

THE WITNESS: The hinge moment limits of the rudder system?

MR. CLARK: Well, the rudder, the PCU can resist certain levels of hinge moments, when the rudders deflect, we're talking about the blow-down limit, the aerodynamic forces balance the hinge moments.

THE WITNESS: Yes.

MR. CLARK: Can you back out any of the flow field data from a vortex encounter directly on the rudder or on the vertical fin and make estimate of how close we are to approaching those hinge moment limits?

THE WITNESS: I thinkthat that probably is a possibility. I hadn't thought about that. But looking at the data where we ran with the yaw damper off, if you can see a motion at all of the rudder system, we know what the compliance of the rudder structure is in that area. So it may be possible to calculate what force is being applied to the rudder.

In terms of approaching any kind of limits, obviously if it was getting, what you would see if the forces being applied to the rudder were very large, you would see some, quite a bit of motion of the rudder compliance, and the rudder, when you get up near full rudder throws, the compliance is worth 1 or 2 degrees of rudder. I mean, as you slow down or speed up, you can see a pretty substantial bending of the components of the rudder in that area.

So I would, you know, if you're getting up anywhere near significant loads on the rudder, you would see some motion, considerable motion. But we should be able to estimate that. I think that's a possibility.

MR. CLARK: Okay. The, canyou give us an overview of future simulator tests that you anticipate? I know we've kind of bounced around various subjects, such as the kinematic studies, your background studies, background models, M-CAB, VMS.

THE WITNESS: Yes, I'm not sure whether, we certainly are going to be doing a lot of work on the simulator, and we may want to get into pilot evaluations again once we have updated all the models. As to whether we go back into like the NASA-Ames simulator, basically what we did with the NASA-Ames simulator is we did a backdrive of that through the flight data recorder from 427. That hasn't changed at all. The cockpit voice recorder obviously hasn't changed.

The only thing that would potentially change in that kind of an exercise is that the control inputs that we estimate based on the location of the wake relative to the airplane may change. If we decide that that is, that it's necessary to go back and evaluate those control inputs in that atmosphere, you know, we certainly can do that. I'm not sure that it would be necessary to do it.

I think it might, if we were going to do that, we might just want to go ahead and do it in the M-CAB. I'm not sure that NASA-Ames would give us a lot more information.

MR. CLARK: Okay. My understanding is that the roll response of the airplane changes significantly between a flat 1 and a flap 5 configuration. Is that true?

THE WITNESS: Between flaps 1 and 5? I don't think that there's a large difference between those two. By the time you get the landing flaps, you're generating a lot more lift with the flap systems. And when you put the spoilers up through the lateral control, you get a very substantial difference.

There certainly is a difference between flaps 1 and flaps 5, but I don't believe that I would call it all that substantial.

MR. CLARK: How does the crossover point change between those two configurations?

THE WITNESS: I haven't really evaluated flaps 5 other than to, we know that there is a, if you get to very low speeds, the lateral control system won't handle it. But I haven't really, we haven't done nearly as much investigating of that as we have flaps

1.

MR. CLARK: Okay. There were some earlier questions on the effect of the core diameter. And I guess, is it your understanding that basically the core diameter is not the issue, but in fact the entire flow field, the entire energy of the --

THE WITNESS: Right. There was some, we talked to the experts that we have in the Boeing Company relative to the wakes. And we had two of them, they had quite different opinions as to what the diameter of a wake really was. And basically one of them said 4 feet and one said 16.

So we looked at both. And we really, in terms of the effect on the airplane, couldn't see a large difference between those. It really didn't seem to make a tremendous difference on what was happening to the airplane for a particular value of the flow field. So we'll continue, you know, based on the Atlantic City test, we think that the flow is fairly restricted in diameter, and we will certainly try to determine that.

MR. CLARK: What, in your estimation, what is the effective flow field? What kind of diameter are we looking at? Not the core size, but the entire flow field?

THE WITNESS: I really don't have a good answer for you. The model that we've used, I believe, uses a one over the radius squared outside of the core, in a linear distribution within the core. And I'm not sure how many diameters outside the core that affects.

MR. CLARK: Do you have any estimate, or are we talking a flow field effective of something like 1 out of 100 feet or 25 feet?

THE WITNESS: I wouldn't think, yes, I don't think it would be that far out, perhaps. And obviously, you see a pretty distinct effective between the two, when they are 70 feet apart. So obviously, 35 feet from the center, you would see something. So it's, I'm sure, out there 50 feet or more.

MR. CLARK: So that's a radius. So if we're talking 35 feet on each side, we're looking at a 70 foot diameter that can be effective near?

THE WITNESS: Yes, I'm sure it's felt at least in that.

MR. CLARK: On the question of FDR parameters, are you familiar with EICAS filters, and how that affects FDR data?

THE WITNESS: Just vaguely.

MR. CLARK: I believe for the record the 737 does not use EICAS filters.

THE WITNESS: Yes, that's correct. I know there is a concern on some of the other airplanes. But our data, I believe, does not suffer from that.

MR. CLARK: I'd like to look at two exhibits, and we'll switch back and forth. Primarily it's Exhibit 9X-L, which is a part of Mr. McGrew's presentation. But are you familiar with that document?

THE WITNESS: Yes, I believe so.

MR. CLARK: And are you familiar with the graphs and plots and part of the summary table in that document?

THE WITNESS: Yes. Let me find it first. Yes, I have it, thank you.

MR. CLARK: We'll be in great shape as soon as I find mine.

Okay. I want to go through several of the events and basically, on page 5, there's a number of events and events 1 through 12 are Boeing conclusions that those were wake turbulence events.

THE WITNESS: Yes. In the process of evaluating these events, these have been compared to basically the test data from Atlantic City to determine whether that's a possibility.

MR. CLARK: Okay. And then on page 13, if we could have that graph up.

CHAIRMAN HALL: Would you clarify for us what this document is, what we're referring to here?

MR. CLARK: Would you characterize that, Mr. Kerrigan?

THE WITNESS: Okay. Basically, since the accident, we've had a fair number of reports of other incidents from various airlines that have come into the Boeing Company and to the NTSB. And we've gone through and, outside of the investigation, we've had a group looking into the causes of these accidents. We had blue water mentioned yesterday. That was explored, along with wake turbulence and any other potential causes for these incidents.

We, this is a summary of about, what is it, 25 incidents that we've evaluated, and some going back as far as 1993, but most of them are basically since the accident. And those have been compared to, like I say, wake turbulence data from U.S. Air, or yes, from the U.S. Air test airplane, and also from, in many cases, the certification autopilot hardovers and what-not on the airplane.

MR. CLARK: Okay. And the presumption for the comparison of the charts and graphs, that data does have similarities to wake vortex encounter, specifically the data from the Atlantic City test?

THE WITNESS: Right.

MR. CLARK: I'd like to bring up data plots from Exhibit 13X-K, page 18.

You don't have that in the --

CHAIRMAN HALL: The exhibit is 13X-K, the page is 18. Do you have that, Mr. Kerrigan?

THE WITNESS: I have it in front of me. I don't know the viewfoil of it.

(Slide shown.)

MR. CLARK: I believe this is the same event from 8/30/95, a Continental 737 incident. And what I'd like to address is, are you familiar with some of the Rod Wingrove studies from NASA, where he evaluated or looked at high altitude upsets?

THE WITNESS: I have looked at some of them, quite some time ago, not recently.

MR. CLARK: And basically the premise there is that if pitch attitude is relatively constant and the vertical gees are active, and the influence is from an external source, and then if the pitch attitude is moving and the gees seem to be following pitch attitude, the influence is more likely from an internal source, such as pilot input?

THE WITNESS: Right.

MR. CLARK: Okay. In this situation, we're looking at pitch attitude and vertical acceleration, which is on the top. Is that in your estimation consistent with an upset from an external source?

THE WITNESS: It would appear so, yes.

MR. CLARK: Basically the pitch is constant and the vertical gees are moving?

THE WITNESS: Correct.

MR. CLARK: And also in that same scenario down at the bottom, we certainly do have a roll oscillation?

THE WITNESS: Yes.

MR. CLARK: Okay. I'd like to go back to, or move on to Exhibit 13X-K, page 5.

(Slide shown.)

MR. CLARK: Now, this is plotted differently, but it's from the same data set that Boeing had in Exhibit 9X-L, page 7. I don't think we need to bring both up at a time. But in this situation, this is one of those that Boeing referred to as a wake turbulence encounter. And in the early parts of the data, from, say, 70940 to 70944, for example, is that consistent with some sort of external influence?

THE WITNESS: I would think so, yes.

MR. CIARK: And then later on, for example, from 70952 to 70956, are those consistent with external or internal inputs?

THE WITNESS: Well, obviously, pitch angle is starting to move around there. Making that judgment without going through and actually trying to recreate it is difficult to say out of hand. But certainly there's pilot input there as well.

MR. CLARK: Okay. And then looking at the typical frequency of the plot called VACC, vertical acceleration, there's a certain frequency rate. And I'd like you to compare that to the roll rate in that situation. Do those seem comparable to you?

THE WITNESS: A frequency rate?

MR. CLARK: The frequency of the disturbance in the vertical acceleration.

THE WITNESS: There is a bit of a frequency there, fairly difficult to pick out a rate. It doesn't appear to be too consistent with bank angle.

MR. CLARK: So the bank angle, we have a roll excursion to about 20 degrees in, oh, 4 to 6 seconds, something like that?

THE WITNESS: Right.

MR. CLARK: Kind of a slow roll-off?

THE WITNESS: Um-hmm.

MR. CLARK: And is that consistent with a wake vortex encounter, that type of roll-off?

THE WITNESS: Well, I think if you look at the wake testing from Atlantic City, you can find that there is perhaps no typical wake vortex encounter time history. It varies anywhere from a very large input if the pilot does nothing to fairly mild input if it's controlled directly.

As Mr. Cox pointed out, if you're on top of the controls when something like this hits, you don't get much of an upset. So you can get just about anywhere in between. So it could be consistent with that.

MR. CLARK: Could be, okay.

And this disturbance we see on the vertical acceleration lasts from say, 70936 to 71000, a little longer, maybe 24 seconds?

THE WITNESS: Give me those times again, 36 to --

MR. CLARK: It was 70936 to 71000.

THE WITNESS: There is definitely, yes, oscillations occurring in that period of time from whatever source.

MR. CLARK: And is that typical of a vortex encounter, to be able to stay in a vortex for 24 seconds?

THE WITNESS: Well, again, it's difficult to say what that vortex is going to look like. From the testing we saw, you can get into the vortex again and again. If you happen to be trying to follow the same path, if you looked at the testing that these guys did in Atlantic City, with some effort they were able to follow the core of the vortex for long periods of time. So it's not, certainly not impossible for that to be in continued flight in a vortex or about a vortex.

MR. CLARK: And then the bottom chart, that altitude change of about 800 feet over that time period is, that's not typically consistent with a vortex encounter?

THE WITNESS: Well, again, it all depends on what the leading airplane is doing. At this point in this evaluation, we haven't really looked at whether there's another airplane in the area, necessarily. We're looking at the data, trying to find similarities between reported events and known wake events. So the comparisons that we made in the other data set from, what was it --

MR. CLARK: That one would be on page 7 of --

THE WITNESS: Nine X, yes, 9X-L. It just shows that there are some similarities between the two.

MR. CLARK: Okay.

THE WITNESS: It doesn't mean that it's consistent throughout.

MR. CLARK: And then on, I'd like to refer to 13K, page 9. And that's the same data set as, that occurred on 7/18/95 that is in 9X-L, page 8. But I think we can just look at page 9.

THE WITNESS: Okay.

MR. CLARK: And basically that shows a roll excursion, and there is some activity on the vertical acceleration. I'd like to look at the, compare the timing of the pitch attitude data, second data line down, to the vertical acceleration, which is the second data line from the bottom. Can you perceive the frequency change in, or the timing of the events, comparing a pitch attitude to a gee excursion, for example, which occurs first?

THE WITNESS: Well, typically, the pitch angle, I think, well, pitch actually takes a while to catch up with angle of attack. So the angle of attack would change pretty much with the load factor.

MR. CLARK: With the pitch attitude. So in this case, the gee excursions we're seeing seem to be following the pitch attitude?

THE WITNESS: To some extent, that appears to be true.

MR. CLARK: And they're peaking out slightly, later in time.

THE WITNESS: Right.

MR. CLARK: In the Wingrove type data, is that more consistent with an input from inside the cockpit rather than --

THE WITNESS: It's certainly possible.

MR. CLARK: Okay. And then going back to the middle channel that shows the roll oscillations, that show a roll excursion occurring up to about 20 degrees over a 7 second period, again, is that consistent with a typical vortex encounter?

THE WITNESS: Well, I think the initial part of it may not be. I don't recall the particulars of this incident. Quite often there is a change in heading that is being made or whatever as the incident occurs. I don't remember the details of this particular event.

MR. CLARK: Okay. Thank you. I have no other questions.

CHAIRMAN HALL: All right. If we could get the lights again. Then, Mr. Marx?

MR. MARX: No questions.

CHAIRMAN HALL: Mr. Marx has no questions. Mr. Schleede?

MR. SCHLEEDE: I can't see my notes.

(Laughter.)

MR. SCHLEEDE: Mr. Kerrigan, is there any possible configuration of the wake in relation to the shift of the airplane that can theoretically cause a yawing moment?

THE WITNESS: Theoretically, I guess I don't know how to answer that. Empirically, we haven't found in the testing any indication that there is a strong wake or a strong yawing moment associated with entering the wake from a number of different directions.

MR. SCHLEEDE: I'd like to shift off to some other subject briefly, talk about yaw dump damper step inputs, hardover yaw dampers. From an aerodynamic standpoint, what type of effects do you get on the airplane at various speeds, say, cruise and approach? What kind of lateral accelerations would you expect?

THE WITNESS: Well, I don't know off-hand what the values are. They are certainly perceptible. I know that early on in the 737 program there were quite a number of problems that occurred with the yaw damper that have since been corrected. There have been quite a number of improvements made to that system over the years. Early on, there were occasions when the yaw damper kicks would, in particular I think at cruise, cause people to lose their balance in the back of the airplane, and there were some injuries involved in that.

MR. SCHLEEDE: Thank you. And one other area that Mr. Clark was pursuing, about the rate rudder movement, and he brought up that some of our work, previous work, has involved your working on possible scenarios such as a slat failure, causing the yawing moment. Do you recall your earlier testimony?

THE WITNESS: Yes.

MR. SCHLEEDE: And I've went through the testimony from Pittsburgh, or from the previous hearing, and at that time, it was an open item, whether or not number 1 slat could match the data. Could you comment on that briefly, where we stand on that?

THE WITNESS: Sure. Yes, we did look at, in the wind tunnel, the slat in an unusual attitude, kind of bent up and in front of the wing, to the extent that our loads people felt that that was a possibility, based on the damage that was, or based on the damage that wasn't done, the structure that was left at the accident, on the accident airplane.

And basically in the wind tunnel we saw very little yawing moment due to that configuration. And on that basis, we eliminated that from consideration. We don't feel that the slat which had a structural failure that was, could have been pre-existing, we think it was caused by impact, but could have been pre-existing, that that configuration that would have resulted would not have produced enough yawing moment to sustain anywhere near this maneuver.

MR. SCHLEEDE: Is that in our record, that conclusion, or enough for us to confirm that conclusion?

THE WITNESS: I would assume so.

MR. SCHLEEDE: Timing-wise, I didn't remember that we hadn't, yes, we were present during some of the wind tunnel testing and what-not. And on the same area, we had testimony and discussions about the possibility of a step input in the rudder such as someone jerking the cable, someone stepping through the floor or some other jerk on the cable. Do you recall that?

THE WITNESS: I recall that being discussed, yes.

MR. SCHLEEDE: Without going through it, I've reviewed the transcript, at that time, that was partially discounted because of the kinematic data that showed a rudder rate of maybe 6 degrees per second. Do we need to rethink that because of the recent rudder rate data that we have?

THE WITNESS: I don't know if that is a possibility or not. From a mechanical standpoint, whether you can get enough pressure by stepping on a pedal to cause this kind of an occurrence or not, I really don't know.

MR. SCHLEEDE: I was readnig from an aerodynamic standpoint. From what I get out of the charts here, now, that we could have up to a 30 degree per second rudder movement?

THE WITNESS: Yes, I think that's possible. Again, we will hopefully have another cut at that, based on the flight test data, which should give us hopefully a more accurate --

MR. SCHLEEDE: And would that be characterized as a step input?

THE WITNESS: Well, I mean, obviously, it's not at the rate limit of the rudder, at this point. The rudder is capable of moving at about 60 degrees a second, I believe, 50 to 60 degrees a second. So it's about half the maximum available rate. But a step input can basically be any rate you want it to be.

MR. SCHLEEDE: Thank you very much.

CHAIRMAN HALL: Mr. Laynor?

MR. LAYNOR: Just a couple.

Mr. Kerrigan, first of all, and you don't have to reach for it, but in Exhibit 9X-L that Mr. Clark was referring to, on several of the plots we show traces that are attributed to autopilot hardover. And we were wondering what the source of the data?

THE WITNESS: That data came from certification flight testing on the 737-300.

MR. LAYNOR: Conducted back on the original certification process?

THE WITNESS: Yes, on the 300, back in 1984, 1985.

MR. LAYNOR: Okay. Following up on one of Mr. Schleede's questions, I know you haven't finished your examination of the Atlantic City flight test data. But did you see any of that data, any of those flights on a preliminary look that indicated unexplainable yawing moments?

THE WITNESS: No. Not at this point. There has been no unusual yawing moments apparent.

MR. LAYNOR: Are you comfortable in your own mind that we've pretty much exhausted the examination of any other type of failures, other than aerodynamic rudder loads that could produce a yawing moment similar to what you see in the accident flight test data?

THE WITNESS: Yes. We've pretty well brainstormed what could cause that. And basically, in order to cause the kind of yawing moment that's required to sustain that maneuver, you would have to either be out near a wingtip or back at the aft end of the airplane. And that, we don't think there's anything else aerodynamically that could cause that kind of a yawing moment.

MR. LAYNOR: Okay. One last question, and this refers to one of Mr. Clark's questions also.

In testimony, and I can't recall whose it was, perhaps Mr. Berven's, we talked about increasing or changing operational procedures to, for the speed range, with the specific flap settings. And we were talking about going to flaps 5, a little bit prematurely, to what the current procedures called for. And presumably, that was to get closer to the, where the lateral control authority could offset a directional control movement. Did you say that that data is not available to support the change in that procedure?

THE WITNESS: Well, certainly, the simulator is valid for that. I just haven't specifically gone in and evaluated flaps 5 to any great extent. You know, there's an obvious advantage to going faster. You get closer to the, you have more of a controllable, you have more control as you go faster, obviously. The lateral control can overpower the directional control as you go in that direction.

So there is some advantage to increasing the operational speeds. Again, it's, there isn't a cliff there. You don't suddenly, you go faster than that speed, nothing really dramatic happens that's different. If you stay on the controls, as Mr. Cox indicated, if you're on top of things and you put in wheel to keep the airplane right side up, as the rudder comes in, you would see a difference between the two. But you wouldn't, it wouldn't be a startling difference.

MR. LAYNOR: Well, conversely, if you get the same speed, you have to pass through the speed range at some point in time, anyhow.

THE WITNESS: Right.

MR. LAYNOR: With the higher flap setting, can you explain again what the aerodynamic characteristics are that produce a higher lateral control authority?

THE WITNESS: Well, basically, it isn't as much a change in the lateral as it is change in the blow-down of the rudder. The faster you go, the more, the less rudder that you're able to get because of blow-down. And that's really what's determining, the determining factor in this crossover point.

MR. LAYNOR: But my point is, with flaps 5, presumably, you pick up some additional margin at a given speed. And I am curious as to what the change in lateral control authority is.

THE WITNESS: Okay. I understand. Well, the primary change is with regard to the spoilers. You are carrying more lift when you use flaps 5 than flaps 1. You're flying generally slower. And the rolling moment that you can get out of spoiling that lift is greater, and that's the difference between flaps 5 and flaps 1.

MR. LAYNOR: All right. Thank you, sir.

CHAIRMAN HALL: Mr. Kerrigan, first let me thank you for your presence here today, and the work you have obviously done.

And I certainly take note of your comments in regard to the flight data recorders. It's been said here many times that all of the parties and the agencies of the Federal Government involved in this investigation have expended thousands of man hours, literally millions of dollars in an investigation, that had that plane been equipped with the flight data recorder with adequate, with parameters that technology, current technology enables the recorder to be equipped with, we would not be here today, in the

Chairman's opinion.

And it concerns me that this fleet continues to fly in this country without the technology that is available today. And on every occasion, I'm going to encourage, because I think it's my responsibility to do so, the individuals that are in the position to make a decision on that to proceed with the recommendation that this agency has made or come forward, at least, with some recommendation that would address this issue.

As you know, I'm not an engineer, and I'm not going to refer to any of these charts or ask you any technical questions. I just want to ask you, have you done everything you think, you know, you put together a special roll team, is there any information that the Boeing Corporation has, that you have as the principal engineer for this airplane, that the public needs to know about, or the pilots that operate the airplane need to know about?

THE WITNESS: I don't believe so. I think, as was pointed out yesterday, all the information that we have has flown very freely between all the parties.

CHAIRMAN HALL: Very well. Well, I appreciate very much your testimony.

Are there otherquestions?

(No response.)

CHAIRMAN HALL: We appreciate your testimony, and of course, I encourage you and, as I know you will, because you are, we met very early, right after I came out to Boeing after this accident. And I know you have a number of individuals that have worked very hard on this. And let me just ask, on behalf of the public, that you continue your efforts, and that we continue to pursue every avenue that could lead us to a probable cause in this matter.

If there are no other questions, then, Mr. Kerrigan, you are dismissed.

(Witness excused.)

CHAIRMAN HALL: And we will call on the Chief Project Engineer for the Boeing Commercial Airplane Group out of Seattle, Washington, Mr. Jean McGrew. Mr. McGrew?

(Witness testimony continues on the next page.)

JEAN ALLEN McGREW

737 CHIEF PROJECT ENGINEER

BOEING COMMERCIAL AIRPLANE COMPANY

Whereupon,

JEAN ALLEN McGREW

was called for examination and, having been duly sworn, was examined and testified as follows:

MR. SCHLEEDE: Please give us your full name and business address.

THE WITNESS: My name is Jean Allen McGrew. My business address is the Boeing Commercial Airplane Company, Seattle, Washington, 98046.

MR. SCHLEEDE: And what is your exact title, working at Boeing?

THE WITNESS: I'm the 737 Chief Project Engineer.

MR. SCHLEEDE: Would you give us a brief description of your education and background?

THE WITNESS: I have a bachelor of science in aeronautical engineering, and a master of science in applied mechanics.

MR. SCHLEEDE: And how long have you worked at Boeing, and generally what positions?

THE WITNESS: Six years first as Chief Engineer in structures, and then Chief Project Engineer for the 737.

MR. SCHLEEDE: Thank you.

Mr. Phillips?

MR. PHILLIPS: Thank you.

Good morning.

THE WITNESS: Good morning.

MR. PHILLIPS: Prior to coming to Boeing, what did you do?

THE WITNESS: I spent many years with McDonnell Douglas, working in Long Beach in transport aircraft. I was involved in the design and development of the MD-80 series, DC-10s, a number of other related projects.

MR. PHILLIPS: You were employed as an engineer?

THE WITNESS: I was an engineer and a manager.

MR. PHILLIPS: Okay. Any particular area of specialty, aerodynamics, structures?

THE WITNESS: Actually, I was a specialist in aero-elasticity and flutter, and taught such at the University of Southern California.

MR. PHILLIPS: Okay. Just a few things today. First of all, I'd like to ask you a little more detail about your responsibilities at Boeing today. For your 737 Project Engineer, what does that job encompass?

THE WITNESS: Effectively, that encompasses managing the technical aspects of the airplane, and the support of the fleet. I'm really an integrator in making sure that the aircraft, or change to the aircraft, work together and work properly the first time. I have a very, very small staff. I'm supported by all the specialists as the need arises.

MR. PHILLIPS: So do you currently hold design responsibility for the 737 fleet?

THE WITNESS: For the current, the 300, 400 and 500s, I do. Not for the new generation.

MR. PHILLIPS: And in the area of continuing airworthiness, such things as service bulletins, service letters, you would coordinate that effort for Boeing?

THE WITNESS: No, actually that coordination is done via the service engineering organization. And I see, personally see those which are felt to be necessary to be reviewed. Normally, they go through the various engineering disciplines for review.

MR. PHILLIPS: Okay. Did you hold the position of Chief Project Engineer at the time of the U.S. Air 427 accident?

THE WITNESS: Yes, I did.

MR. PHILLIPS: Okay. And have you been involved in the accident investigation?

THE WITNESS: Constantly.

MR. PHILLIPS: Okay. Has it been a full time job, mostly?

THE WITNESS: Pretty much.

MR. PHILLIPS: I'd like to talk for a few minutes about the FAA's critical design review. Are you familiar with that process?

THE WITNESS: Yes, I am.

MR. PHILLIPS: And we've prepared an exhibit 9X-N, which is entitled Critical Design Review Executive Summary. And without going into repetitive detail of the CDR, which we've had testimony earlier this week on, I'd like to ask specifically about this exhibit. Is it, it's my understanding that this is an executive summary. Was this prepared by FAA in this form, or is this a paraphrased version by Boeing?

THE WITNESS: I frankly do not know. It looks like the executive review, but I have not looked at that recently.

MR. PHILLIPS: The point I'd like to make is that for technical reference, we have the, listed as 9X-A, we have the complete report as a document. But I'd like to refer to some pages in this executive summary, and if we need to cross check them, we can with the document.

THE WITNESS: Okay.

MR. PHILLIPS: What was your participation in the conception or inception of the CDR?

THE WITNESS: Only that when the requestor, or not the request, the proposal came in from the FAA that they wished to carry it out, I collected a couple of people to assist and lead in the team, or work with the team. I did not participate in any of their meetings.

MR. PHILLIPS: Okay. Were you consulted prior to the formation of CDR concerning the potential for CDR?

THE WITNESS: Oh, yes.

MR. PHILLIPS: Did you agree a CDR was an appropriate process at the time, and circumstances?

THE WITNESS: Well, it wasn't high on my list of favorite things to do. But I certainly agreed that it was a necessary thing.

MR. PHILLIPS: And in supporting that process, do you know how many people you've provided?

THE WITNESS: I would guess we had probably seven or eight, something on that order, over the period of the review, in and out. May have been more. Some people were there nearly full time with the team. Others as on-call.

MR. PHILLIPS: And how did you identify those people who participated?

THE WITNESS: That was based upon the specialties that were needed to support the team itself and their requirements and requests.

MR. PHILLIPS: Okay. Was there any discussion among yourself and the FAA management concerning the areas of study for the CDR?

THE WITNESS: No. I believe that that was specified by the charter that the FAA put forward, and as I recall, we did not question that.

MR. PHILLIPS: Okay. In Exhibit 9X-N, slide 4, we don't have page numbers, but on what's labeled as slide 4 on the lower left hand corner, could we put up

-- Rick, do we have that viewgraph? We don't. Okay, no problem.

We've got the exhibit. It's entitled Background. And the first bullet is the objective of the review was to assess the continued operational safety of the 737 flight control system and recommend corrective action for any deficiencies discovered. In forming that objective, why would you suspect the flight control system would be the prior, or the predominant concern for that review? Was that based on the accident, the 427 accident?

THE WITNESS: I think so.

MR. PHILLIPS: Okay. And the lateral and directional control systems were specifically studied?

THE WITNESS: Yes.

MR. PHILLIPS: And then the last bullet, Design, Maintenance and Operational Factors, do you agree that those were all valid areas for a CDR at this time?

THE WITNESS: Yes.

MR. PHILLIPS: Going on to the next slide, on page 5 of the same exhibit, the team, we heard earlier testimony that the team was composed of people outside the FAA. Did you on any occasion get to meet with any of these people?

THE WITNESS: Late in the CDR review, I met several of them. But not early, or through most of it, no.

MR. PHILLIPS: Okay. And then the next bullet, it says, the team looked only at what failures and malfunctions of the control system were physically possible, hazard assessment. I'd like to talk a few minutes about that, based on our earlier testimony. Based on your experience, what would you consider to be a hazard assessment?

THE WITNESS: I think in this case it refers to what we normally would call an FMEA, which is failure modes and effects analysis, qualitatively formulated in terms of the possible hazards that could exist, in terms of the system and its performance.

MR. PHILLIPS: Okay. Is FMEA any different than a hazard assessment or a fault tree analysis?

THE WITNESS: I think a fault tree analysis is considered a form of an FMEA. And frankly, since I don't use the word hazard analysis, or we don't generally, I think that's the best definition I can give you.

MR. PHILLIPS: Okay. A failure analysis would fit into the same category?

THE WITNESS: Yes.

MR. PHILLIPS: On slide 6, the second bullet says, conservative assumptions were used, or implies conservative assumptions were used in the process. The second bullet says that assumed that normal flight envelope for control position normally encountered should consider the potential for full flight control surface to fail or jam when at full limit deflection. Do you agree that's a conservative assumption?

THE WITNESS: I agree that's a conservative assumption.

MR. PHILLIPS: Do you have any comment or position on using that as a criteria for review of a flight control system?

THE WITNESS: When you say consider the potential for a function, no, I agree that it is reasonable.

MR. PHILLIPS: Okay. We've heard some discussion this week about whether the definition of normally encountered and specifically the FAA's CDR team leaders' concerns about defining that, what would you define as normally encountered?

THE WITNESS: My personal definition would be control surface deflection that was used on a regular basis, or up to that deflection was used on a regular basis in normal operating conditions.

MR. PHILLIPS: So if a full deflection was possible, the flight control wouldn't normally be used by your terminology, you wouldn't feel it would need to be considered in this?

THE WITNESS: No, I didn't say that. I think consideration needs to be given to all possibilities, but it needs to be a very rational consideration.

MR. PHILLIPS: Okay. Going to the next to last bullet on slide 6, we talk about continued safe flight landing, which includes consideration of work load strength, skill requirements and maintaining continuous control of the airplane. Using your engineering judgment, is consideration of pilots workload strength and skill a normal concern for an engineer?

THE WITNESS: Oh, I think so, yes.

MR. PHILLIPS: And how would that be applied to engineering judgment or principles?

THE WITNESS: I think the engineer in the design process needs to consider those elements in his design.

MR. PHILLIPS: Okay. And the last bullet, assumed worst case reaction of flight crew to identified failures and malfunctions. How would you, how would an engineer know what the worst case reaction would be?

THE WITNESS: I think that would be presumed to be just what it says it is, the worst possible thing that could conceivably occur.

MR. PHILLIPS: Would that include some input from operational, from the pilot staff which would define --

THE WITNESS: Sure.

MR. PHILLIPS: Okay. On slide 8, where we talk about the process, this is a continuation of the process of the CDR team, the second bullet says that extensive flight simulator exercises were conducted. Did you participate in that or arrange for any of that?

THE WITNESS: No, I did not.

MR. PHILLIPS: Okay. And then the third one is reviewed the 737 flight control system failure analysis. Were you involved in any of that?

THE WITNESS: I was not involved in their review of it, but I have looked at it.

MR. PHILLIPS: Along those lines, we heard earlier testimony that as a result of recommendations that we're going to discuss later here in the CDR, that Boeing has provided a new failure analysis related to the rudder control system. Are you familiar with that effort?

THE WITNESS: I am.

MR. PHILLIPS: Could you summarize that, give us a history of its genesis?

THE WITNESS: It was a request, specific request, from the FAA, the ECO in Seattle. And we took some of the team that had been supporting the CDR, and they spent a goodly amount of time in preparing it, and have submitted it.

MR. PHILLIPS: Have you seen the document?

THE WITNESS: I have seen it, and I have reviewed it quickly, but I am not intimately familiar with it.

MR. PHILLIPS: Are you familiar with it enough to know whether it discusses the probabilities of failures of certain actions on that system?

THE WITNESS: I believe that it does.

MR. PHILLIPS: Does it, do you recall or can you tell us whether it makes any findings on the probability of failure of the directional system?

THE WITNESS: I would be stretching that. I believe that it does, but I would have to review it to confirm the answer.

MR. PHILLIPS: Okay. The process for the FAA's review and feedback with Boeing on that, when do you expect that to be complete?

THE WITNESS: I frankly do not know what the status of that review is. The current effort has been with the CDR responses, and awaiting the return of that submittal of data from the FAA.

MR. PHILLIPS: Okay. Do you have any general feeling about, are we talking about two months or three months?

THE WITNESS: On the CDR?

MR. PHILLIPS: Right.

THE WITNESS: My understanding, and that comes from this hearing, is it's expected around the end of November.

MR. PHILLIPS: Okay. And Boeing's prepared to support whatever needs to be done to --

THE WITNESS: Yes.

MR. PHILLIPS: -- meet that date?

THE WITNESS: Yes.

MR. PHILLIPS: Let's turn to slide 11, which is the summary of recommendations. And I believe this slide attempts to encapsulize groups of recommendations. And one of the ones I want to start with is the, I believe the area of improved maintenance of flight control components and assemblies. Are you aware of any significant findings by Boeing as a result of the CDR team's recommendations and your response that would indicate improved maintenance and flight control components and assemblies as required, if there any changes?

THE WITNESS: I'm familiar with a couple of them, in reviewing these before it was submitted. I think in the wheel well area, there are some concerns with the washing procedures and cleaning procedures. That's one specific one I recall.

MR. PHILLIPS: Okay. Any others?

THE WITNESS: None come to mind immediately. I would have to review our submittal.

MR. PHILLIPS: Okay. The number 5 on the same list is improved surveillance of design, manufacture and repair of replacement parts for flight control components. This, I would assume, involves the recommendations for S-FAR-36 PMA approvals?

THE WITNESS: Yes.

MR. PHILLIPS: Do you have any comment on that in regard to Boeing's position on that recommendation?

THE WITNESS: Boeing supports it.

MR. PHILLIPS: And do you recall the nature of the recommendations?

THE WITNESS: Yes, I think I do.

MR. PHILLIPS: Could you briefly summarize those recommendations?

THE WITNESS: I think the concern is with the availability of data and material for some of the third party shops, or agencies. And it is our feeling that the process needs to be developed so that they have the proper data so that they can accomplish that job. And if they have not the proper tools or the proper data, then they should not be working those units.

MR. PHILLIPS: Has Boeing made any determination that they don't have the proper tools or data to do the job they're doing today?

THE WITNESS: I think no initial determination.

MR. PHILLIPS: Okay. So your statement is, though, you support the concept of the recommendation?

THE WITNESS: Yes.

MR. PHILLIPS: I've skipped some of the other ones. Are there any that I've left out in the group that you'd like to comment on as being significant in your eyes?

THE WITNESS: Portions of item 2, I think are significant.

MR. PHILLIPS: And that's enhance flight crew training for response to failures in flight path upset?

THE WITNESS: That's right.

MR. PHILLIPS: Would you like to comment further on that?

THE WITNESS: No, I believe that that is an area that needs attention.

MR. PHILLIPS: And the Boeing response will reflect that?

THE WITNESS: You say will it? Yes.

MR. PHILLIPS: Yes, okay. How much additional activity do you expect to support the conclusion or resolution of these recommendations?

THE WITNESS: When you talk about all 27 recommendations, I find that very hard to estimate.

But if you talk about the 15 that we have responded to immediately, I expect a return from the FAA and probably a few months of continued work in those areas.

MR. PHILLIPS: Okay. And the support of that effort, does that carry over into your customer support function and your, other than engineering?

THE WITNESS: Yes. It would be both.

MR. PHILLIPS: I'd like to talk for just a few moments now about the actions or the activities on the 737 program since our last meeting, and particularly since the accident. Have there been any significant changes on the airplane since that time?

THE WITNESS: There are no significant changes put in production at point, but there are some significant things that have happened. Well, I take that back. The PCU AD, which we heard yesterday, I believe, about, is being carried out and is something on the order of I believe 75 percent complete within the fleet.

MR. PHILLIPS: Okay, that's the servo valve change?

THE WITNESS: That's right.

MR. PHILLIPS: Is there any other actions on the servo valve or PCU contemplated at this time?

THE WITNESS: Not by Boeing on the 737, no.

MR. PHILLIPS: Okay. No service bulletin or service letter activity?

THE WITNESS: With respect to the PCU?

MR. PHILLIPS: With respect to the PCU.

THE WITNESS: I don't know of any.

MR. PHILLIPS: Okay. How about the standby rudder actuator?

THE WITNESS: We have an improvement program in place on that. And it has been committed. And it is, I can't give you a date as to when the first units will be available, but they will be coming.

MR. PHILLIPS: Okay, so the engineering has been completed and is the change imminent?

THE WITNESS: The engineering is not totally complete. It has been committed, however.

MR. PHILLIPS: Okay. Do you have any knowledge to whether the FAA is interested in making that change in airworthiness directive?

THE WITNESS: I have no certain knowledge about it. I would not suggest that it needs an AD. But we wouldn't, we would not fight an AD on the issue, either. We believe that this change will eliminate all of the questions that some people have had with respect to the interaction of the standby with the rudder PCU. Testing surface will bear that out. But it clearly will eliminate the galling question.

MR. PHILLIPS: Do you have any concerns that galling is an issue in any of these discussions of these accidents?

THE WITNESS: Not of these accidents. Oops, let me back up. I understand that the levels of galling in the Colorado Springs incident, though I was not intimately involved in that investigation, and that it was a significant amount of galling. My understanding is, however, that that could not, was not sufficient, particularly with that particular unit as it was, to be involved in the incident. I have absolutely no concerns about the amount of galling that was found on 427, and we've all been, had every possible involvement in that accident.

MR. PHILLIPS: Has Boeing done any testing to confirm your position?

THE WITNESS: Not yet. But I believe that some of that is planned.

MR. PHILLIPS: Okay. Would you like to discuss that a little bit? Is that part of the accident investigation activities that are planned?

THE WITNESS: Yes, I believe we're mutually responding to the need for that testing.

MR. PHILLIPS: Okay. And do we have an approximate timetable when we'll be able to get into that testing?

THE WITNESS: Yes, we have an approximate timetable. We have a schedule.

MR. PHILLIPS: Okay, and give us a quarter of the year, do you have any idea? End of this year? First of next?

THE WITNESS: Barring some difficulties with our labor unions in Seattle, which have slowed some things up, I think, I suspect that we will be in the first quarter of next year, although I would like, certainly like to see it done before then.

MR. PHILLIPS: And so we're close to being able to get that testing started. But it's your expectation that that testing won't provide significant new findings for the accident investigation, is that true?

THE WITNESS: That's my expectation. But when doing a test, one should reserve judgment until the test is completed.

MR. PHILLIPS: I agree.

Concerning the yaw damper system, have there been any engineering changes or any plan changes, or are there any changes planned for the yaw damper system in the 737?

THE WITNESS: Yes.

MR. PHILLIPS: Could you describe those?

THE WITNESS: No. Because it is an evaluation, a study at this point, in terms of what the change should be. And the issue here is similar to that of the standby actuator in that the yaw damper, we think, is not involve in either of these accidents in any abnormal way. In the other event, we have had enough incidents inflight with respect to the yaw damper hardovers, specifically, that we believe its reliability should be significantly improved. There are several ways to do that. And we are looking at those ways. And I do not have a schedule for that.

MR. PHILLIPS: Do you consider the yaw damper reliability or failures of the yaw damper a significant safety of flight item?

THE WITNESS: No, I do not.

MR. PHILLIPS: Are you aware of any damaged aircraft as a result of yaw damper failures?

THE WITNESS: I'm not aware of any damaged aircraft. I am aware of, I'm aware of some cases of injury to attendants before we put in this yaw damper system. The airplane, as you're well aware, is a very stable airplane in the Dutch roll mode, unlike most jet transports. So it needs not a yaw damper in order to stabilize the aircraft. That yaw damper is effectively a ride comfort unit which reduces the disturbances for the comfort of the passenger and the crew.

MR. PHILLIPS: To the best of your knowledge, have any of these injuries been related to yaw damper failures?

THE WITNESS: I don't know of any.

MR. PHILLIPS: Okay. And along the lines of the, I believe the critical design review team also recommended the yaw damper modification, or at least a concern --

THE WITNESS: In reliability, yes.

MR. PHILLIPS: -- reliability. Is this response partially in relationship to their concerns or did this precede the CDR?

THE WITNESS: I can't say that it preceded the CDR. But it was pretty close.

MR. PHILLIPS: Okay, so, are there any yaw damper tests planned in the near future as part of this accident investigation, or for Boeing's concerns?

THE WITNESS: No specific yaw damper tests. But in the tests that we will be doing, that we talked about a moment ago, they will involve the yaw damper.

MR. PHILLIPS: Have you ever seen a yaw damper failure or ever heard of a yaw damper failure which commands the rudder to move more than 3 degrees, if a 3 degree yaw damper is installed?

THE WITNESS: No, we have no data on it.

MR. PHILLIPS: Okay.

THE WITNESS: We have had a few cases where data has been provided that appeared to show such a case. But upon review, it was not the case.

MR. PHILLIPS: Okay. Were you he for the testimony of Ms. Anne Evans the first day?

THE WITNESS: Um-hmm.

MR. PHILLIPS: And you're familiar with the quick access recorder program?

THE WITNESS: Yes.

MR. PHILLIPS: Do you support that effort?

THE WITNESS: Oh, absolutely.

MR. PHILLIPS: Okay.

THE WITNESS: In fact, I would like to see it expanded to other flight control surfaces.

MR. PHILLIPS: Would you like to comment on that more? We heard testimony that, I believe, that a lot of the U.S. operators don't use QAR data. Would you like to take it from there? Or do you want a question?

(Laughter.)

THE WITNESS: No, I don't care to address the issue of U.S. operators using QAR data. That's up to them. Some of our foreign customers do use them. But do, they use them for maintenance and reliability and prediction purposes. My comment about, I would like to see them used in other areas is that such measurements taken on a broad scale as these are done are similar to the measurements done by NASA on turbulence over the years, and provide data to the industry for what some of our design limits or considerations should be. So when you talk about what sort of an amplitude or authority limit we ought to be looking at on a control surface for design, clearly these kinds of data will provide us the answers for rational design approaches.

MR. PHILLIPS: Does Boeing Engineering currently have the capability to review QAR data and analyze it?

THE WITNESS: Mmm. I frankly don't know if we can reduce it or not. We certainly do flight data recorders.

MR. PHILLIPS: Right.

THE WITNESS: I'm sure, I suspect that we do.

MR. PHILLIPS: Okay. Is there any process there to analyze trims and components, or using QAR data?

THE WITNESS: Certainly. We can put QAR data results into our data bases and use them to establish trends in that sense.

MR. PHILLIPS: Okay. In the program that Ms. Evans described, are you familiar with the system that's in place now, the events we're looking for?

THE WITNESS: Yes.

MR. PHILLIPS: Okay. And there's been a request to add control wheel position on the QAR? Would you like to comment on that?

THE WITNESS: I think I just did.

MR. PHILLIPS: Okay. I'm getting explained to me here.

(Laughter.)

MR. PHILLIPS: You're right, you did.

THE WITNESS: Thank you.

(Laughter.)

MR. PHILLIPS: Moving on, I'd like to talk a little bit about the wake vortex flight testing. Did you participate in that effort?

THE WITNESS: I clearly did in the effort. I was not present during the testing.

MR. PHILLIPS: Were you responsible for providing the setup and support for that?

THE WITNESS: Right.

MR. PHILLIPS: Can you tell me how many people were involved on Boeing's behalf?

THE WITNESS: I can tell you precisely how many were involved in the basic test itself. That was something on the order of 28.

But in terms of getting ready for it, and the setting up of it and the negotiations and that, frankly, was many man months, involving quite some number of people, and a lot of phone calls with the parties and yourselves. And several disappointments, frankly. We had hoped to get that test going much sooner than we did. We had an airplane, at one point a customer was willing to let us use, a new airplane. That fell apart, for good reasons. And so it was becoming a very agonizing program. We wanted it to happen, I think as much as everybody else did. And thank God for U.S. Air coming through and providing that airplane. Otherwise, I think we'd be still worrying about an airplane.

MR. PHILLIPS: As the Chairman stated, I believe that --

CHAIRMAN HALL: We were going to order one at that point, but --

THE WITNESS: We'd have sold it to you.

(Laughter.)

MR. PHILLIPS: But Boeing was in the process of trying to acquire an aircraft for us when U.S. Air provided the airplane to us?

THE WITNESS: Yes.

MR. PHILLIPS: And we had several starts and stops, during that process, right?

THE WITNESS: Right.

MR. PHILLIPS: During that flight test, well, first of all, I'd like to ask, did you consider the flight test effort, did it generate the kind of data you expected or needed to do your work?

THE WITNESS: I have to say yes. Time will tell on that. But, yes, I'm sure that it will, or that it has.

MR. PHILLIPS: We've heard some discussion the last couple of days about directional versus lateral control. And specifically about certification basis issues along the lines of, does the certification basis guarantee that we have safe aircraft. Do you have any general comments along those lines?

THE WITNESS: Very general, because I think Mr. Kerrigan covered most of them, and others. Yes, I think the certification basis does provide a safe aircraft, certified at the basis as it is satisfied. And I believe that the history of the airplane substantiates that.

MR. PHILLIPS: Okay. Do you believe that a more stringent certification basis, if it was applied to the airplane today, would result in significant design changes to the directional control system?

THE WITNESS: No. I don't think that it would. It would provide, it would require significant more paper and reports and analyses to be generated. And it is possible that in that generation that something could come out. But I really don't think so.

MR. PHILLIPS: Okay. Moving along to roll events that's been discussed occasionally this week, I understand that Boeing has put together a roll team?

THE WITNESS: Yes.

MR. PHILLIPS: And could you tell us what that is?

THE WITNESS: Yes. Actually, I have a presentation, would you like me to do it at this point?

MR. PHILLIPS: If you'd like to.

THE WITNESS: Although I must say that my thunder has been all stolen.

(Laughter.)

MR. PHILLIPS: I believe we're talking about Exhibit 9X-L?

THE WITNESS: Yes.

MR. PHILLIPS: Okay. Mr. McGrew, as part of this discussion, are you going to tell us about the formation of the team, the foundation and things like that?

THE WITNESS: Yes. But apparently, I'm the only one with the viewgraphs.

(Slide shown.)

THE WITNESS: This roll team was started in, actually we started considering it in late August. And it was established about the second week in September, and charged with a mission which we'll show you here.

(Slide shown.)

THE WITNESS: We became very concerned that some of our customers were having roll incidents, and incidents that, the cause for which was not discernible upon inspection and testing of the airplane. We supported the customers with service engineering and engineering help to review this. But in a number of cases, there were no faults found in the mechanical systems of the airplane. That is not a usual event. And so we decided that the proper thing to do was establish a team of specialists to review all aspects of these roll events.

(Slide shown.)

THE WITNESS: And this is the team charter to establish the root cause of the unexpected roll events being experienced by the fleet, and the expected deliverables were the probable root causes of them in the supporting fleet and Boeing data. There were some other items they were asked to do as well.

(Slide shown.)

THE WITNESS: As part of this exercise, we have looked at some of the RS, or ASRS, aviation safety reporting system data, to see if anything was out of line greatly. And this chart describes anomalies over the last, I believe, of roughly eight years. Let's see, 1987 to the mid-1995 period. And you can see that color, that bar down there toward the bottom called loss of aircraft control is the one that we were concerned with. In this case, we think that loss of aircraft control means an uncommanded or a perceived uncommanded event in the aircraft.

(Slide shown.)

THE WITNESS: That bar is broken down into a wider distribution. And you see the number one candidate within that group of incidents, a total of the whole of those is 297, it says aircraft wake turbulence. And it stands out rather far above severe weather turbulence.

(Slide shown.)

THE WITNESS: So what we did was with the flight data recorder data that we had of a number of events, we began a, and we began two things effectively. One was reviewing all of the events themselves that we had data for at the time. And the other was starting back through another analysis of the airplane systems in this case, particularly the roll or lateral systems of the aircraft, seeking for failures which we could show or the data would show were common cause or probable cause for these events. That went on, the team's charter was for four weeks. They actually went, oh, about eight weeks. And somewhere around the sixth week or so, they started seeing a pattern in the data. And at that time, decided they had found something significant and put the package that you're going to see together.

Now, this precedes that, and these are Boeing conclusions. And airplanes and all data other than the date has been taken off. But we grouped that set of, I believe it's seven events in recent wake turbulence events, as wake turbulence events. We had a set of previous data, as you can see, going back to earlier in 1995 and clear back to 1993, which we were very certain were wake turbulence events.

We also knew, of course, that a number of the roll events that have occurred in service were caused by normal mechanical wearing out, and/or related reasons. And those we put in a known equipment faults category. And we had a few operational events where we understood, or think we understand, the event. And we grouped those in the known operational events.

There are a number of events that they're still working on now, and will decide upon as time goes on. Next chart, please.

MR. PHILLIPS: Jean, before we go on, could I ask about this list, if we have any of the blue water events included in there?

THE WITNESS: Yes. The blue water events are all in there.

MR. PHILLIPS: Okay. Can you point to any of them or pick them out? We don't need all of them, but just as an example.

THE WITNESS: Well, let's see, 6/26. The June 26th one is, and I believe -- the 18th? Okay, July 25th, then.

MR. PHILLIPS: July 25th, number 13?

THE WITNESS: No, that can't be right, which one?

MR. PHILLIPS: Number 15, yaw damper?

THE WITNESS: No, it has to be in one of the top ones, 18th, perhaps. Yes.

MR. PHILLIPS: Eighteen August, number 15, then.

THE WITNESS: July 18th. They must be in the first group there called recent wake turbulence events.

MR. PHILLIPS: Okay, so --

THE WITNESS: They must be number six and number seven.

MR. PHILLIPS: Okay, so if I understand what you're saying, then, there may be some confusion, but I guess we really can't say absolutely those are wake turbulence events?

THE WITNESS: Well, we think they are. We're going to show you why we think they are.

MR. PHILLIPS: Okay, but this could be subject to change with more data?

THE WITNESS: Yes. And as you realize, John, when Kerrigan was here, was questioning whether at least one of those events which is included in this is indeed a wake turbulence event. And I'm not here to debate the subject. But we will go back and review them.

What I'm going to do is show you why we think it may be possible to discern or distinguish a roll event caused by wake turbulence versus a mechanical failure in the air frame itself, or some other induced failure.

Yes?

CHAIRMAN HALL: Mr. McGrew, you are aware, are you not, that the NTSB is investigating some of these incidents as part of the investigation, and I believe we pulled the flight data recorders and --

THE WITNESS: Yes.

CHAIRMAN HALL: Werewe aware of your activity on this roll team?

THE WITNESS: I think so, but I'm frankly not sure. You were not a party of it.

CHAIRMAN HALL: Were we aware, Mr. Haueter?

MR. HAUETER: Not until the beginning of this week, sir.

CHAIRMAN HALL: Is this something, Mr. McGrew, you think we should have been aware of?

THE WITNESS: You should be made aware of it, yes. This basically, though, I would view as the normal investigation that we go through with a customer when a customer or customers are having a difficulty. And we work together to try to resolve it. We do not see --

CHAIRMAN HALL: Well, with the exception that these, this work is related to a customer concern that probably, in some way grew out of the two accidents of Colorado Springs and Pittsburgh, which the Board has been investigating, I would just ask that if you're going to be doing work on the 737 that impacts on this investigation that you try to be sure Mr. Haueter and the NTSB is aware of it. You can do what you want to, but as a courtesy, and being sure that we can represent to the public that everything is being done, I sure would appreciate it if you could be sure that in the future, that's just a request on my part, that we're not discussing items from your perspective that we're also investigating ourselves.

Please proceed.

THE WITNESS: Thank you.

Let's go on to the next chart, please.

(Slide shown.)

THE WITNESS: What we're going to do now is show you a sequence of flight data recorder traces that have been placed on the charts, very specially so that we could observe similarities and differences in the events. First one should be number 8, or 6. Yes, this just is the guide for the charts. So if you'd move to number 6, please.

(Slide shown.)

THE WITNESS: I must tell you frankly that we never considered this as part of an accident related event. We were looking purely for failure or the reason for failures or the reason for events in service. And so what we did, and if you would slide it up, well, I guess you can. Yes, you need to slide it up some, Rick, that's fine.

What you're looking at here then is three channels of flight data recorders taken from three different events. The solid black line that you see is measured data from the wake flight test, the vortex flight test that happened recently. The bottom green line is data from a certification test of a hardover, aileron hardover, in a 737-300. And the red line in this chart is from an in-service uncommanded roll event that an operator reported to us, and to the NTSB. As a matter of fact, of course, we get the data from the NTSB on these.

And there are some signatures we need to look at, and there are some explanations I need to make. First of all, all of the airplanes, the events that occurred here, did not roll in the same direction. Some were left and some were right. So just for comparison purposes, we have plotted those, we have turned over those which went this way and plotted them that way so that you could see the characteristic shape and time history. It doesn't destroy or modify the data in any way, but it does give us a way to compare. The speed, these are the speed traces in air speed. Air speed varies significantly, but we've normalized it so we can see the perturbations of air speed as a function of time. And down here, we have the normal load factor as measured in the airplane, as a function of time. And that is properly phased or properly oriented, it's not been turned over as such.

Now, what we want to point out in this particular chart is first of all that both -- no, let's start with the autopilot hardover. That is the green trace. You see that it is a relatively smooth trace without any large significant deviations, though there are some small ones. Both the black and the red trace show that these, we're calling them speed bumps in here, those are similar to the speed bumps that were seen in 427. So in that extent, we certainly are related to the accident.

If we go down to this trace, where we're looking at roll attitude, we see that the green trace which is a hardover, and this was electronically induced in the flight test, so that the aileron would go to its full autopilot authority, and then the pilot would count four seconds, and then take control of the airplane. These other events, the wake vortex, which is what the wake vortex gave us in roll, and of course, the uncommanded roll was that one. The other thing we noticed down here, and we'll come back to that in a minute, is that the green trace, which is the hardover trace, shows very little activity in normal load factor. There is out here, following the roll, of course, some increase as the aircraft banks and comes out of the maneuver. Here there is some significant load factor for an activity. But out here in the roll period, this area here, we see significant load factor, the incremental load factor changes. Up here we see that the roll from the hardover tends to be quite linear in nature and then recovery, where those which are the other rolls, tend to be convex and then move out and the pilot interacts at some point in here, and they proceed on.

I must point out in all of these data that we're going to show you here that the pilots took timely and correct action in that they immediately took command of the airplane when the event occurred and maneuvered it out of that event in a good fashion. So what we're going to do now is just go through a series of these and show you that we have, we think we have developed a relatively good correlation between wake turbulence events and the dissimilarity with mechanical failure events.

So if we could have the next one, please.

(Slide shown.)

THE WITNESS: I apologize to those who stayed up late tonight, we may put you to sleep with this one.

Again, now, let's see, can we go back for just a second to the one before?

To give you a feeling of the sensitivity of this issue, the red one shown here was an event in July 26th, and the comment by the crew afterwards of that event was, aircraft felt out of control, very mushy, didn't think they could control the aircraft. So these are significant events to the crew.

(Slide shown.)

THE WITNESS: This next one again is the wake flight test, an in-service uncommanded roll and the autopilot hardover. And you can see that the signatures in load factor are extreme in terms of incremental load factor, and do not look anything like the hardover case. We still have our speed bumps up at the top in the flight speed. And we still have the characteristic convex shapes as we enter the events themselves, which are different than the mechanical case.

(Slide shown.)

THE WITNESS: This event occurred on descent, by the way.

This next event is a little different. Here we're making a somewhat different comparison, if you'll pull it down, please, Rick. Now we still have our autopilot hardover roll. And we have our in-service uncommanded roll. But we have put up in the black now an in-service wake encounter which happened back in 1994, and was determined to be a wake encounter. And we again see, we have the characteristic speed bumps, and we have the characteristic roll-off at the start of the roll, and we have significant load factor events at the, near the peaks of the roll.

(Slide shown.)

THE WITNESS: This next one is another in-service wake encounter, in black, which occurred in 1994. And we see its characteristic speed bumps. It is compared to the same in-service uncommanded roll as we saw before, which was on descent. And we can see the wake, or the in-service encounter here has a sample rate which is lower than we had off the vortex testing, but does have the same general characteristics. And we have the significant load factor perturbations, unlike the mechanical failure.

(Slide shown.)

THE WITNESS: We're back to the wake vortex test comparison again, and an in-service event. In this particular in-service event, which occurred on approach in August of 1995, the comment was, the crew were very startled by the roll rate. And again, you can see the significant perturbations in load factor as the event occurs.

(Slide shown.)

THE WITNESS: The next event again compares the wake flight test and the autopilot hardover, and the in-service condition happened on descent, in August. And again, we see all of the significant similarities in the roll and the similarities in the load factor response and the significant speed bumps.

(Slide shown.)

THE WITNESS: In the next one, again we have the wake flight test, an in-service case and the autopilot. In the in-service case, this was also a descent. And this one, the pilot's comment was that it threw the flight attendant to the floor and scared the flight crew, more like a barrel roll. So it clearly was a very significant roll event to the crew. And again, we see the similarities that I've been describing.

So I won't go any further. There are a number of the others in here. And I'm happy to see everybody is still awake. But we think that several things have come out of this. One is that we have possibly or probably developed a process by which the airplane can distinguish between an in-service event that is caused by a failure and that which is caused by the airplane going through some significant wake turbulence. We think that can lead to maintenance of aircraft or improvement of maintenance of aircraft and not require aircraft to be on the ground for any length of time. We also think that this data indicates that the crews are behaving well and properly in these events, and that is something that we are very pleased to see.

CHAIRMAN HALL: Is our sound man out in the hall? Just come up here, Greg, and ask the question. Oh, here he comes.

MR. PHILLIPS: I wanted to ask, thank you very much for that description. I wanted to ask, related to that description, are you working with any operators specifically to provide data to you as part of this roll team event reporting?

THE WITNESS: Yes.

MR. PHILLIPS: Is it one or two or five?

THE WITNESS: Well, it's been one specifically, and several others know about it.

MR. PHILLIPS: Is there any effort to continue this effort and coordinate it into a bigger program with more operators?

THE WITNESS: That is my understanding.

MR. PHILLIPS: Okay. Another request I'd like to make is that as this event summary evolves and it's modified, as we learn more, the Safety Board would like to be provided updates of this summary.

I don't think I have anything else at this time. Mr. Jacky does have a couple of questions. I'll pass it to him.

MR. JACKY: Mr. McGrew, if I could ask you to please reference Exhibit 13X-L, please, page number 12. This is again the recommendation that the NTSB has made to the FAA regarding additional flight data recorder parameters added to the Boeing 737 airplanes.

THE WITNESS: I have it.

MR. JACKY: Okay. I was wondering if Boeing has had any sort of reaction to this recommendation in terms of service bulletins or anything?

THE WITNESS: Yes. Boeing has developed two service bulletins for retrofitting the 737 fleet, both for the 100s and 200s, and -- 200s, I think. I'm not sure about the 100s. And the 300s, 400s and 500s. And there have been aircraft through some of the maintenance stations that have both validated and incorporated those service bulletins in them. So we are supporting the effort.

MR. JACKY: Are you aware of any discussion within the Boeing Corporation of the addition of a portion or portions of this recommendation?

THE WITNESS: Portion or portions?

MR. JACKY: Specifically the rudder and rudder pedal.

THE WITNESS: Oh. Yes.

MR. JACKY: Have you done any sort of support to either the FAA's ARAC committee or to the ATA in regard to this recommendation?

THE WITNESS: Yes, we have provided data.

MR. JACKY: Does the service bulletin, bulletins that you have put out give any sort of estimation as to the number of man hours that it would take to install these types of sensors?

THE WITNESS: Yes, they do.

MR. JACKY: Okay. We've had some conversation in the last couple days regarding a visit to the TramCo Company regarding these types of times, or the time for the installation of these sensors. Do you have any sort of comment as to the comparison between the times listed in your service bulletins and the times come up in the TramCo visit?

THE WITNESS: A comparison?

MR. JACKY: Yes. How did the numbers that were estimated during this TramCo visit compare to the service bulletin times?

THE WITNESS: I do not know the answer to that.

MR. JACKY: Okay. The airplane that was used for the flight test, that was provided by U.S. Air, had the addition of control wheel, control column and rudder pedal sensors added to the flight data recorder on that airplane.

THE WITNESS: Yes.

MR. JACKY: Do you know if -- let me take that back.

Do you know if the times that it took to install those sensors compare to the times on the service bulletin by Boeing?

THE WITNESS: No, I do not.

MR. JACKY: Is there some way that we could be provided with those?

THE WITNESS: Yes, there is. And we'll so note.

MR. JACKY: Okay. And on the airplane that is going to be used for some of the future service, or I'm sorry, the future systems tests, have there been any sensor installations put onto that airplane as far as rudder or rudder pedal?

THE WITNESS: I don't know what the status on that is, since I was off for a month. But there will be.

MR. JACKY: Okay.

THE WITNESS: They will not likely be, though, the service bulletin type installations.

MR. JACKY: That was my next question, if they're going to be just a temporary type of installation --

THE WITNESS: Yes.

MR. JACKY: -- or a -- okay.

Do you have any knowledge about the proposed parameter list that would be included on the next generation of 737 airplanes?

THE WITNESS: Yes, I have seen the lists.

MR. JACKY: Okay. Do you know if that list includes both input and output parameters on the three control positions?

THE WITNESS: Yes.

MR. JACKY: Okay. Do you know if the parameter list will include rudder pedal force?

THE WITNESS: I should, but frankly, I would have to go look it up to answer the question. So I'll say no, I don't know at this point.

MR. JACKY: Would there be any consideration to do that, to add that parameter?

THE WITNESS: I'm sure there will be.

MR. JACKY: Okay. I have no further questions.

CHAIRMAN HALL: Very well. Mr. Haueter?

MR. HAUETER: Just a few.

Going to the list of recent events involving the 737, it's Exhibit 13X-C, you may not need it, but the majority appear to be called yaw damper events. One of my questions is, are those due to a malfunction back in the PCU portion of the yaw damper or in the yaw damper coupler in the electronics bay?

THE WITNESS: I do not know specifically without going through and looking at it, or looking it up. I can tell you that by and large, the coupler is, or in our review in the last year, turns out to be about 70 percent of the events. So I think I could answer your question without looking.

MR. HAUETER: Okay. And you're taking actions in terms of the coupler itself?

THE WITNESS: Yes.

MR. HAUETER: Some of the other events involving uncommanded rolls, are you taking similar actions in terms of those events, from an engineering standpoint?

THE WITNESS: Well, we're looking at them to see what the significance is and what's causing them. We did one interesting study, the roll team did one additional, an interesting additional study, in that they compared the number of events attributed to the lateral system to the number of failure events related to the pitch system. And since in the 737, the pitch system and the lateral system are very, very similar in terms of actuators and actuation mechanisms and so on, one would expect a failure rate that was about the same.

Surprisingly enough, and this was a clue, it's about four to one. In other words, there are four more lateral events associated with the system than there are with the vertical systems. Yet they are the same. Their implication is, what that set of numbers is what drove them to maybe there is some other cause to these events. And that led them into this wake encounter scenario.

MR. HAUETER: Okay. In several of the events we've looked at, there's been the finding of blue water in the EB or electronics bay of the aircraft.

THE WITNESS: Yes.

MR. HAUETER: Is Boeing taking any action regarding trying to prevent fluid contamination into the electronics?

THE WITNESS: Yes. Boeing has taken actions over the years as the airplane has developed, and the current configuration, as delivered today, is significantly more protective than earlier versions of the airplane. And there are service bulletins out there, available to the operators, that do bring up airplanes that were not delivered in those configurations to that standard or very nearly that standard.

But I must also tell you that in Boeing's view today that blue ice events that we had do not exhibit, or the components do not exhibit sufficient conductivity to have been the cause of those events. I'm not sure if that's shared by all of the operators. But we think that this is extremely unlikely that blue ice was involved in any of the electrical faults associated, or that were thought to be associated with that.

MR. HAUETER: Yes, I was going to say, do you have any data to support that finding?

THE WITNESS: Yes.

MR. HAUETER: Could you provide that to the Board?

THE WITNESS: The answer is yes. Have we not done that? Both. I mean, yes, we certainly can. The question is, did we? No, we have not.

MR. HAUETER: Okay, we'd like to have that, in terms of the data you have on it.

Changing a bit, going to Exhibit 9X-A, this is on the critical design review team, and once again I can read it to you if you don't want to look it up.

THE WITNESS: Okay.

MR. HAUETER: On page 41, the prelude to recommendation number 9, a lateral control, the team says there are potential single failures and combinations of latent and single failures that can cause a hardover or jam of the rudder at its limit deflection. Would you agree with that statement?

THE WITNESS: That a combination could do that?

MR. HAUETER: It says single failures or a combinations, and combinations, I'm sorry.

THE WITNESS: In a theoretical sense, I would agree with that.

MR. HAUETER: Okay. Do you have any ideas what those events might be in terms of theoretical failures or combinations thereof?

THE WITNESS: I think that they are all listed in the CDR. I think that what is missing is the combination or the probabilities associated with those events happening, which is what drives us to whether the situation or circumstances are satisfactory as is or not.

MR. HAUETER: Okay. I guess, the bottom of recommendation number 9, where they said be proven by probably the most rigorous means possible.

THE WITNESS: Right.

MR. HAUETER: How would you describe those rigorous means?

THE WITNESS: My understanding of it is, and I'm not an expert in that part of the process, by any means, is that it is an analysis procedure which uses verified data to establish the relative probabilities, and that the fault tree is put together in a logical, rational and correct fashion.

MR. HAUETER: Would you use test data besides just analyses?

THE WITNESS: Both.

MR. HAUETER: Both?

THE WITNESS: Well, and experience data from the service history of the airplane as well.

MR. HAUETER: Okay, thank you, sir.

CHAIRMAN HALL: No additional questions from the technical panel?

MR. HAUETER: Actually, I have one more. I'm sorry.

CHAIRMAN HALL: Go right ahead.

MR. HAUETER: I'm sorry, let me go back one more.

In your opinion, you've got many years, I know, experience on the aircraft, I mean, not the aircraft, but the aviation industry, when the 737 was upgraded, if you will, to the -300 series, in your opinion, should they have changed the certification basis of the aircraft and gone through it completely to take a look at it, the same as the 757-600?

THE WITNESS: No. I think that those decisions have to be based upon the history of the airplane and what the company can substantiate as its satisfaction of the regulations and its safety by and large. So I think that that should not be an automatic consideration.

MR. HAUETER: You don't believe over a period of years there should be an effort to bring all the aircraft up to a similar level of certification basis?

THE WITNESS: No, I don't. Not unless, not unless it is shown, the aircraft's experience shows, or analysis and recurrent, regular re-evaluation of the airplane shows it is needed. If you -- I like analogies. If you buy a toy wagon for your child, and it wears well and is still usable and workable when he's your age and has a child, should you go out and refit it again? It's perfectly functional and works, nothing wrong with it.

MR. HAUETER: I guess, using your analogy, we wouldn't put airbags in cars nowadays.

THE WITNESS: I think now we get into the arguing of this relative safety statistics of the automobile versus the airplane. And I think you'll lose.

MR. HAUETER: Well, I'm just saying, the technology improves, and we have the capability, why not do it?

THE WITNESS: Because you base the doing on the requirements for additional safety.

MR. HAUETER: I think that was the reason they put the airbags in. I'll stop now.

THE WITNESS: I agree. There was a good reason to put airbags in. There is a good reason.

MR. HAUETER: Thank you.

CHAIRMAN HALL: Questions from the parties? I see the hand of the FAA, the Air Line Pilots

Association and the Boeing Commercial Airplane Group.

Mr. Donner?

MR. DONNER: Just a couple, sir.

Mr. McGrew, I believe earlier you stated that a recommendation concerning enhanced flight crew training on upsets was a significant recommendation. Do you know if Boeing has made any changes in their training program?

THE WITNESS: I think they have not yet made any changes in their training program.

MR. DONNER: And then you also spoke about an improvement program on the standby PCU. Was that the installation of roller bearings?

THE WITNESS: Yes.

MR. DONNER: Are there any other aspects of that program?

THE WITNESS: Aspects? You mean other changes?

MR. DONNER: Any other changes?

THE WITNESS: Not that I'm aware of, no.

MR. DONNER: I had one more from someone at my table on your use of the phrase man months, and man hours, but I won't ask you. Thank you very much.

(Laughter.)

THE WITNESS: My apologies to the lady.

CHAIRMAN HALL: Captain?

CAPTAIN LEGROW: Thank you, Mr. Chairman. Good afternoon, Mr. McGrew.

Just a couple of questions. First, Mr. Haueter asked about some yaw damper events. I wonder if you could just briefly explain to us where the 737 gets its yaw damper input from.

THE WITNESS: It comes from its electronic signals.

CAPTAIN LEGROW: Straight input, I'm referring to.

THE WITNESS: You mean straight input?

CAPTAIN LEGROW: Yes.

THE WITNESS: From a rate gyro in the electronics bay.

CAPTAIN LEGROW: Are you familiar with the 757, 767 and 777 yaw dampers?

THE WITNESS: No, I'm not.

CAPTAIN LEGROW: So you couldn't speak to where they get theirs?

THE WITNESS: No, I could not.

CAPTAIN LEGROW: Is it possible, or would it be possible on the 737 to get it from the IRU?

THE WITNESS: I believe that it may be possible, yes.

CAPTAIN LEGROW: Would that make it more stable, in your judgment?

THE WITNESS: I can't say.

CAPTAIN LEGROW: Would it make it more reliable?

THE WITNESS: If it could be done, it probably would.

CAPTAIN LEGROW: On the Exhibit 9X-L, Lima, is my understanding correct that this was an in-house Boeing -- that's the roll team, Mr. McGrew.

THE WITNESS: Oh, I'm sorry.

CAPTAIN LEGROW: That was the in-house Boeing project?

THE WITNESS: Yes.

CAPTAIN LEGROW: And none of the parties to this investigation were invited to participate, is that correct?

THE WITNESS: One of the parties did have a participant, yes.

CAPTAIN LEGROW: And who would that have been?

THE WITNESS: From U.S. Air.

CAPTAIN LEGROW: U.S. Air did participate in that?

THE WITNESS: Yes.

CAPTAIN LEGROW: Just out of curiosity, why weren't the other parties invited?

THE WITNESS: Because frankly, we didn't consider this a 427 accident investigation issue. We considered this as a fleet issue with roll events occurring that we and the airlines could not explain. And so it, frankly, it never entered anybody's mind that it was 427 accident related. It was an industry push to find out what was going on.

CHAIRMAN HALL: Captain, could I ask your permission to butt in?

CAPTAIN LEGROW: Certainly, Mr. Chairman.

CHAIRMAN HALL: Was the blue water anything that would have been related to this investigation?

THE WITNESS: It is certainly something that conceivably could be, yes.

CHAIRMAN HALL: Were we aware of that before Monday of this week?

THE WITNESS: The blue water?

CHAIRMAN HALL: Um-hmm.

THE WITNESS: I'm sure, yes, certainly.

CHAIRMAN HALL: Well, then, why weren't we all participating on the work that was being done on that?

THE WITNESS: I guess, Chairman, first I must express my apologies for not informing you earlier. That was my mistake. And I should have done it. But I must tell you that we probably won't tell you when we change the brand of tires that we start putting on the airplanes, either. And it probably --

CHAIRMAN HALL: Mr. McGrew, I want to be as pleasant and as straightforward as I can. I'm sure you're concerned about the integrity and reputation of the Boeing Commercial Airplane Group, are you not?

THE WITNESS: I am.

CHAIRMAN HALL: I'm concerned about the integrity of this investigation. And anything that is going on or is going on at the Boeing Commercial Airplane Group that may impact this investigation, I think the investigator in charge should be aware of, and if it's appropriate, the parties should participate in. This, any time we get information right before a hearing on something significant like this, it concerns me more from the standpoint of public perception than anything else. And that's my responsibility, is to ensure the integrity of this investigation. And I intend to do that, and I just ask your cooperation in doing that, sir.

THE WITNESS: Yes, sir.

CHAIRMAN HALL: Please proceed, Captain.

CAPTAIN LEGROW: Thank you, Mr. Chairman.

Along these same lines, Mr. McGrew, did the U.S. Air participant that participated in this roll team know at the time that he came out to Seattle that that's what he was participating in?

THE WITNESS: Yes.

CAPTAIN LEGROW: Okay. Were you here for Captain Cox's testimony yesterday afternoon?

THE WITNESS: Yes, I was.

CAPTAIN LEGROW: Were you here when Captain Cox testified that of all the pilots on U.S. Air that were involved in these types of upsets, that he personally interviews, or one of his safety investigators interviews, did you hear that testimony?

THE WITNESS: Yes, I heard that.

CAPTAIN LEGROW: Would it not have been helpful to contact the Air Line Pilots Association, the likes of Captain Cox, at least on the U.S. Air incidents, and I'm assuming some of these incidents were U.S. Air pilots, to get their perspective?

THE WITNESS: I think it would be.

CAPTAIN LEGROW: Was there any attempt from Boeing to determine on these incidents that you classify as wake turbulence incidents the proximity of other airplanes to these airplanes during these events?

THE WITNESS: The team has tried to do that, and is continuing to do so. The difficulty with that is that the radar events, or radar tracking material that you need to confirm this is not kept for a very long period of time. And it generally is the case that by the time we get the flight data recorder or even the notification of the event, that that material is not available. But they are continuing to try to set up a process to do that.

CAPTAIN LEGROW: I suppose the FAA could help you in that area by providing the radar plots?

THE WITNESS: Yes. And we've talked to them. I might also suggest, Mr. LeGrow, that we at Boeing have offered to the parties and to the NTSB in the past to please send representatives at any time to come and sit with us as we go through this investigation. We would be happy to accommodate you.

CAPTAIN LEGROW: Mr. McGrew, I've been the coordinator of this accident since September 8th of last year, and I have received no such communication from Boeing Airplane Company.

THE WITNESS: Excuse me, Mr. LeGrow, but I made that same statement sitting at the stand back in January.

CAPTAIN LEGROW: There was testimony yesterday from Mr. Berven, Mr. Carriker and Captain Cox about the crossover on the 737. And I think most of the testing done in Atlantic City and in Seattle, we were talking about 1 degree flap at 190 knots, or thereabouts. Is there any other flap settings that you're aware of that are critical as far as the, or crossover that is known, known air speeds?

THE WITNESS: I'm not an expert by any means. But my understanding is there is a crossover for every condition.

CAPTAIN LEGROW: Could I refer you to Exhibit 13X-X, please?

THE WITNESS: I think I may not have that.

CAPTAIN LEGROW: Here.

THE WITNESS: All right, I have it.

CAPTAIN LEGROW: This letter is dated September 20th, 1991, to Mr. John Clark of the Safety Board, from Mr. Purvis of Boeing Company. And I would reference the first paragraph, in which he talks about a 10 degree flap setting at 150 knots. Are you familiar with this letter?

THE WITNESS: Yes, I have seen this.

CAPTAIN LEGROW: I just find it interesting that we have not received any information in the, at least that I'm aware of, during this investigation, and this letter is dated 1991. Could you explain that to us?

THE WITNESS: No. You have the letter.

CAPTAIN LEGROW: Is there -- could you briefly explain to us what the 737 uses to limit the rudder at various air speeds?

THE WITNESS: Dynamic pressure.

CAPTAIN LEGROW: And this is dependent upon data, is this correct?

THE WITNESS: Yes, it's dependent on yawing, or -- yes, side slip.

CAPTAIN LEGROW: If the rudder were limited to zero beta, would there be sufficient lateral control to stop the roll indicated by a fully deflected rudder?

THE WITNESS: I don't understand limited by zero beta.

CAPTAIN LEGROW: If you could limit it to zero beta, or zero beta values.

THE WITNESS: I'm sorry, I don't know how two do that. So I can't answer your question.

CAPTAIN LEGROW: You stated before you were employed with Boeing you were with Douglas Airplane Company?

THE WITNESS: Yes.

CAPTAIN LEGROW: You worked on the MD-80?

THE WITNESS: Yes.

CAPTAIN LEGROW: Are you familiar with the MD-80 rudder limiter?

THE WITNESS: I know that they have them. I'm not familiar with the system itself.

CAPTAIN LEGROW: Do you know if it uses a blow-down, or does it have a mechanical limiter?

THE WITNESS: I believe it has a mechanical limiter. But I submit, Mr. LeGrow, that that is the MD-80 and we are here on the 737s.

CAPTAIN LEGROW: I understand that, sir.

I have no further questions, Mr. Chairman.

CHAIRMAN HALL: Mr. Purvis?

MR. PURVIS: Thank you, Mr. Chairman.

Good afternoon, Mr. McGrew.

CHAIRMAN HALL: Mr. Purvis, if you want to go last, U.S. Air would like to ask a question. Would you like them to --

MR. PURVIS: Yes, I would like to go last, please.

CHAIRMAN HALL: General?

GENERAL ARMSTRONG: Thank you, Mr. Chairman. I apologize for the lateness. But I think there is one issue that should be clarified for the record. And that is that U.S. Air was participating and providing data on these events to Boeing and that we were simultaneously providing that same data to the NTSB. Therefore, we presumed that the NTSB was well aware that this activity was underway.

CHAIRMAN HALL: Thank you very much, sir. Appreciate that.

Mr. Purvis?

MR. PURVIS: Thank you, Mr. Chairman.

First, by way of clarification, and I think the General has just done some of that, especially on the first events, the NTSB, the first of these roll events, the NTSB was heavily involved, and including one of them was a blue ice event or blue water event, which was the Orlando event. And they had all the material on that. And then subsequently, the data has been provided.

For Mr. McGrew, just one question. In a number of the events that you showed through the overhead projector, on wake encounters, do you recall or do you know, did the crew perceive a higher roll rate, or, sorry, higher rolls than those that were in fact found from the flight data recorder?

THE WITNESS: Yes. That seems to be the consistent pattern of perceiving that they're seeing twice or better the roll rate that is actually, that the aircraft is actually experiencing.

MR. PURVIS: That's the only question I have. Thank you.

CHAIRMAN HALL: Thank you.

Just before we come to the front table, just an administrative announcement. Obviously we are not going to be able to conclude this morning, or this afternoon, as it now is, this hearing. But we will conclude it today.

But I assume once we finish the questioning of Mr. McGrew, we will at that point take a lunch break, and then return for our final witness and our wrap-up. I assume, Mr. Haueter, we have this room. And whatever time it takes to be sure that we adequately do the public's business here and the business of this investigation, we're going to do. But we will proceed with the questions for Mr. McGrew from the table, then take a lunch break and return.

Mr. Clark?

MR. CLARK: Mr. McGrew, you talked earlier about yaw damper failures, and I believe you said that 70 percent of the time we were looking at the coupler, and 30 percent of the time we were looking at other types of failures. Could you elaborate on that a little bit, some of the problems that may have cropped up?

THE WITNESS: I think we discussed this at the last hearing, as I recall. But the two other more common, or not common, but the two other failures are that a T valve or the sinker or the solenoid associated with energizing the yaw damper.

MR. CLARK: In some of these incidents, we see the yaw damper going hardover or behaving erratically. And I see one of the pilots talked about having a silent failure. I think that was Captain Cox. Or not a silent failure but a --

THE WITNESS: Passive.

MR. CLARK: Passive. Yaw damper quit. Does the -- what type of failure is normally associated when a coupler fails? Is there any particular type? Is it a passive failure? Does it quit? Does et go hardover, become erratic?

THE WITNESS: I believe that the most common failure is passive. And the reason I think that is because when you look at the maintenance records associated with yaw damper failures, there are far more maintenance records, or more records related to repairs than there events in service, you know, upsets and so on, by a big factor.

MR. CLARK: Okay. And for the T-valve type failure, when the T-valve is the culprit, what kind of, is that typically a passive failure or a creative rudder motion?

THE WITNESS: I apologize, but I don't know the answer to that.

MR. CLARK: Or the solenoid?

THE WITNESS: The solenoid is, can be either way, though.

MR. CLARK: Either?

THE WITNESS: Yes.

MR. CLARK: We'vetalked some about upgrading the flight data recorders. And you said you had two service bulletins. Is one for the earlier model Boeings and one for the later?

THE WITNESS: Yes.

MR. CLARK: Are the people that developed those service bulletins in your area, do you control their work or is that in another area?

THE WITNESS: No, that's really in service engineering area. But they work with the people in the project areas in the disciplines as well.

MR. CLARK: Okay. If we were working with your service engineers or they were making comments about how much time it took to implement a certain fix or a certain part of that, do they have the overall picture of what it takes to effect a change, time-wise, manpower-wise?

THE WITNESS: Yes, and in many cases, and this of course is one, we do what's called service bulletin validation, which means that the engineering people, the service bulletin people and the service engineering people all go together and do the incorporation, in this case with the help of a modification facility, so that they can actually track several things, one of which of course is the time it takes to do the job. And the other is, is the service bulletin accurate and proper, is the engineering done right, what corrections need to be made before we turn it out to the industry.

MR. CLARK: Okay. Some of the estimates for the times that it takes to implement these service bulletins, I'm talking specifically the 737 urgent fix that we've recommended, talked about certain time delays to work through the aft lavatory, aft lavatory has to be removed, or possibly alternate means of wiring around the aft lavatory. Their estimates of time in those areas would probably be pretty reasonable?

THE WITNESS: I would hope so, though I must tell you frankly, over the years, it's been my experience that most airlines will tell us that they have to double the times that we tell them, which is one of the reasons we've gone to the validation process. So I have to accept their numbers as good numbers.

MR. CLARK: Okay. What is your understanding about being able to accomplish these service bulletins on overnights or on a series of overnights or on a concurrently in a C-check without adding a significant amount of time?

THE WITNESS: My understanding, based on looking at the bulletins and talking to some people is that it probably cannot be done in a basic C, that it would require some additional time. And I believe that's a throughput problem in terms of sequencing work in spacing.

MR. CLARK: We've heard estimates that it takes two to three days to implement the service bulletin. But would it take that in addition to a C-check if they were done concurrently in your estimation?

THE WITNESS: I don't know the answer to that. I'm sure we can get it for you, though.

MR. CLARK: There's been a lot of issues raised on this flight test and crossover points and what was known when. What actions has Boeing taken at this time to address those issues that have come up?

THE WITNESS: We have been reviewing the data, you saw that from Mr. Kerrigan. We have talked to a number of people in terms of what the significance of the issue is. But we haven't come to any conclusions. Our basic position today is that the airplane has proved its airworthiness over the years and that this is probably not a significant item. We think that is absolutely not related to 427, the sequence that 427 went through.

MR. CLARK: And since that, Mr. Dellicker's work shows that there was a large rudder excursion. You still think that that's a separate issue, other than --

THE WITNESS: I think that, yes, there was a large rudder input. But whether that totally obstructed the control of the airplane and the controllability of the airplane is still in question. And the simulator, which I believe you have flown, I assume you have, indicates that that may be the case, that at that condition, that event, that there was sufficient wheel authority.

MR. CLARK: Well, from Mr. Dellicker's work, then, if the rudder went to the blow-down limit --

THE WITNESS: Right.

MR. CLARK: -- you believe the simulator today and the work going on with the flight test data indicates that there is sufficient wheel to effect a recovery?

THE WITNESS: Right.

MR. CLARK: In the areas, I believe, where in this case, we got blow at 190 knots, the indications from the flight test is that with full wheel, the airplane would continue to roll.

THE WITNESS: Below 190 knots.

MR. CLARK: How does that fit with your scenario that you could effect a recovery?

THE WITNESS: My scenario won't be validated or dis-validated until we do the upgrades that we need to do and recalculate Mr. Dellicker's work with these data. They are dependent very much, as you know, upon the vortex encounter and the strength of the vortex. And the analytical removal of that vortex, so that we can get back to the basic control surface motions.

MR. CLARK: And part of that is to try to back out the wake vortex effects and then look at the basic flight control induced aerodynamics?

THE WITNESS: Right. So that when you put them all together, then, you have the maneuver that we know the airplane went through.

MR. CLARK: And this is all going to be done within the investigation group that's, with Mr. Jacky?

THE WITNESS: Yes.

MR. CLARK: And frankly, you've seen him a lot more this last year than I have.

Mr. Berven raised an issue, there's been a lot of discussion on the probability areas of highly improbable. And I've heard comments about, once in the service life of an airplane. And then Mr. Berven raised the issue that that doesn't quite fit. Do you have any observations in that area, the 1 times 10 to the minus 9. When is the 737 fleet going to reach that milestone?

THE WITNESS: I would argue the calculation. I think I calculated it as 120 years. But I understand the principle, and I agree with the principle. Ten to the minus 9 means it's never going to happen, or not ever supposed to happen.

MR. CLARK: It's never going to happen, and you could go to a lower number and say that it would never happen in the service life of an airplane.

THE WITNESS: Yes, now you're getting into some statistical calculations.

MR. CLARK: Well, that's certainly not my area of expertise.

Okay, I have no other questions. Thank you.

CHAIRMAN HALL: Mr. Marx?

MR. MARX: I must apologize if I missed it already, but I wanted to get your feeling about the, whether you think a stuck standby rudder would be an unsafe condition?

THE WITNESS: No, I don't think so. Based on the analyses that we've carried out, the authority or the amplitude that that rudder would go to is of such that, since it could be overcome by the pilot, that it generally would not be considered an unsafe condition.

Now, I do, we do intend to test that, and we will confirm that.

MR. MARX: How would the pilot overcome?

THE WITNESS: With the pedals.

MR. MARX: Pedal. Are you aware of the testing that was done to substantiate anything that has to do with windup or compliance?

THE WITNESS: I know something about it, but I am not intimately familiar with it. I know that it was done.

MR. MARX: Do you know -- you know that it was done. Do you know if it was done assuming that the main PCU was operational?

THE WITNESS: No, I don't know that. I assume that it was.

MR. MARX: You just assumed it was?

THE WITNESS: Right.

MR. MARX: Okay. My concern really here has to do with the standby, and whether the standby could be intentionally, unintentionally or automatically put on. And we have a condition where the shaft and bearing is stuff off of null.

And first of all, I would like to ask you what you would expect would happen if you had the shaft and bearing stuck off null, with pressurization onto the standby, what would happen? Would the rudder move? In other words, if you had the valve in the standby situated, so that it will --

THE WITNESS: Yes.

MR. MARX: -- so that it will --

THE WITNESS: It's jammed. Your scenario has the valve jammed in an off center position.

MR. MARX: Right. Well, this would be a jam on the shaft, the bearings.

THE WITNESS: Oh.

MR. MARX: Which would be off null. In other words --

THE WITNESS: Could be.

MR. MARX: -- would you expect the rudder to move?

THE WITNESS: I don't know. I'm sorry to say, I would have to ask the experts.

MR. MARX: Do you know how the standby actuator, or the pressurization is put onto the standby? Can it be intentionally put on?

THE WITNESS: Yes, it can be.

MR. MARX: And how is that done?

THE WITNESS: There is a switch that allows it. Now, whether it can be put on when A and B are on, I'm not so sure.

MR. MARX: When the what?

THE WITNESS: Whether the standby can be put on while A and B systems are on, I do not know. Which is what I think you're talking about.

MR. MARX: Yes. That would be an intentional. Does anybody know that?

(No response.)

MR. MARX: All right. This switch that you say can be turned on, can that be unintentionally turned on, the switch?

THE WITNESS: I'm sure it can be.

MR. MARX: How else could the standby system be activated?

THE WITNESS: It's automatically activated, depending on flap position and on occurrence of hydraulic failures.

MR. MARX: Okay. Well, my understanding is, from reading Exhibit 9X-I, and we went over that the other day, it had to do with the fact that it would automatically come on.

THE WITNESS: Right.

MR. MARX: Do you know how that is accomplished?

THE WITNESS: No, I do not know what the circuitry is that drives that.

MR. MARX: I have no further questions.

CHAIRMAN HALL: Mr. Schleede?

MR. SCHLEEDE: No questions.

CHAIRMAN HALL: Mr. Laynor?

MR. LAYNOR: Since I had the same thing written down that Mr. Marx was talking about, I'd like to follow up on that a little bit. I had asked Mr. Kullberg if there had been an analysis of hat the effect of a galled input shaft on the standby actuator would be if you pressurized the standby hydraulic system. And I got the impression that there has not been any analysis. Is that true?

THE WITNESS: I don't know the answer to that, Mr. Laynor, but we will provide it to you.

MR. LAYNOR: Okay. If there has not been an analysis, I think we would also like to have an analysis. And particularly in view of Mr. McSweeney's comments, and I think you just concurred to them, that that would be viewed as a, not as a safety of flight event. And you know, I think that we'd better look at whether it's a safety of flight event, in the case of the standby actuators, is pressurized.

The other question along that line is whether you believe that the test of, the preflight tests of exercising the rudder system, is adequate to detect the effects of a galled shaft, and whether the effects of a galled shaft could be different in view of airloads on the rudder in flight, rather than on the ground. I don't know if I made myself clear, but I'm questioning the validity of the preflight test --

THE WITNESS: I understand.

MR. LAYNOR: -- to really determine that there is no problem here.

THE WITNESS: Ican't answer your question specifically. But we certainly can provide the answer to that. And I have to presume that, however, that it will satisfactorily show that. I do know that over the service life of the airplane that the standby actuators which have had difficulties have exhibited them at one point in time and been cleared out by maintenance. I think we have no evidences of a hardover or a locked up -- no, that's not right -- of a failed standby system that seriously affected the operation of the airplane.

MR. LAYNOR: Okay. I think perhaps we might want to pursue that in the upcoming systems group activity.

THE WITNESS: Yes.

MR. LAYNOR: With your current thinking, I suspect you're coming out with a service bulletin with the roller bearing --

THE WITNESS: Right.

MR. LAYNOR: -- modification. Can you tell me what time frame that will take place?

THE WITNESS: I can only give you a broad estimate. And I suspect it will be in the next six months or so. But don't hold me to that. It could be longer. It depends upon the vendor and his abilities as well.

MR. LAYNOR: When the modification is available, would it be the Boeing Company's intention to encourage an airworthiness directive or to make that modification mandatory?

THE WITNESS: I don't think we've decided that yet. We still hold a position that the standby is not a safety of flight item as it exists today, notwithstanding the analysis that we have promised you. So we'll wait and see on that. We are doing this as an improvement, I guess, in reliability and to eliminate those concerns in the future. And since I'm talking, I must say that I believe we've all agreed in 427 that the levels of galling in that unit were not significant with respect to this type of issue.

MR. LAYNOR: Well, I'm not sure we made exactly that analysis at this point in time.

Thank you, Mr. McGrew.

THE WITNESS: You're welcome.

CHAIRMAN HALL: Mr. Schleede wanted to be able to go after Mr. Laynor at one time.

MR. SCHLEEDE: Well, I think it may have been answered, but it didn't sink in to me. Again, it has to do with Boeing has made a determination that the galling of the standby rudder actuator is not an unsafe condition. Several people have testified. And the FAA has also said the same thing.

Again, in view of the unknowns that you spoke of here, and the questions about this analysis and what the possible effects are, how can you have that conclusion? Why wouldn't you reserve the drawing of that conclusion until the tests are concluded?

THE WITNESS: Well, since we've decided in the tests we'll do that.

MR. SCHLEEDE: So you --

THE WITNESS: Well, we've concluded that based on the evidence that we have to date, which is service history and analysis, and now we have agreed we'll do a test, so we'll substantiate that position or it will be --

MR. SCHLEEDE: Does your service history that you're discussing include the one event that we discussed earlier, the British Airways seized valve because of corrosion?

THE WITNESS: Yes, certainly. But in that particular case, the issue there wasn't a problem in flight. The issue there was if you needed the standby, you wouldn't have had it. That valve was broken off, or the ball attachment was.

MR. SCHLEEDE: So there would have been no operation from the standby?

THE WITNESS: Right. That would have been the issue in that case, not the air problem that you're talking about, I think.

MR. SCHLEEDE: Okay. And you have no other in-flight service history of problems with galled standby rudder actuators?

THE WITNESS: I think we've had indications of slightly erratic rudder, as I recall. And when they looked at it, they found galling in it and removed it.

Okay. And I assume you're aware that the allowable force that is in the maintenance manual for that unit is significantly below any force level that we've, anyone thinks would cause a problem, so that in the maintenance operation, one would normally catch any of those anyway, or that's the intent.

MR. SCHLEEDE: Okay. And that's a check of the lever arm, you're talking about?

THE WITNESS: Yes.

MR. SCHLEEDE: Thank you. That's all I have, Mr. Chairman.

CHAIRMAN HALL: Just as a follow-up to Mr. Schleede, you say that conclusion was reached at this point on the basis of what the service history and analysis, was that it?

THE WITNESS: Yes.

CHAIRMAN HALL: Have there been any tests that Boeing conducted?

THE WITNESS: Not that I'm aware of. Or no, I'm sorry, there were tests of the standby unit. And there were tests done on the standby unit off of 585, as I recall. And I do not know the details of those tests themselves, other than in that I do know that the conclusion in that unit was that it did not have anything to do with a ruder input.

CHAIRMAN HALL: Thank you.

Excuse me. Well, my -- yes. My point on this, Mr. McGrew, and you are the ranking official from the Boeing Commercial Airplane Group, I believe, you outrank Mr. Purvis, right? Even though he is the spokesperson?

THE WITNESS: I would not be so bold as to say that.

(Laughter.)

CHAIRMAN HALL: Well, let me just, since you are the ranking person, make a request to you, and I think we had this conversation in Pittsburgh. That if there's any test, if there's any analysis, if there's any information available at the Boeing Commercial Airplane Group that would assist in this investigation, if it has not been made available, and I would assume and take any representation that you have that it has been made available, that anything that has a bearing on this investigation be made available to the team.

I greatly appreciate the cooperation and assistance and am aware of the man hours and the resources that you, that this Boeing Commercial Airplane Group has dedicated to this investigation. I constantly have to read in the newspaper comments from some counsel in regard to this investigation that I find very upsetting. And I intend to do everything I can to be sure that we, the public confidence in the

National Transportation Safety Board and this party system of doing investigations, and in the work that's being done in this matter is protected. And I know you share that with me.

And I just do not want, because someone thought something might not be important, it would seem to me it would behoove us as we move forward in this, if it impacts the 737, I'm not saying whether it's a decision whether we should be involved or shouldn't be involved. But it's like the Holiday Inn, the best surprise is no surprise. And we would like to be informed of any information.

And that's -- but I appreciate your testimony, I appreciate, you know, we couldn't, it's clear that this investigation couldn't proceed without the cooperation of all the parties. And we have quite a bit left to do in this investigation. But I think we've made a lot of progress since our hearing in Pittsburgh. And a lot of that is a result of the time and effort of all the parties here and of the Boeing Commercial Airplane Group, and I appreciate that.

Do you have anything else, sir, that you would like to add, or any other suggestions on anything that we ought to be doing in regard to this investigation?

THE WITNESS: Yes, sir, I do have a very few items. Of course, we talked earlier at great length, Mr. Kerrigan, about simulator updates with the vortex test data. And we concur that that is a useful and necessary thing.

We also agree with your systems people that some additional testing in the air frame is in order, and we intend to accomplish that, along with your and the rest of the parties' cooperation.

We also would sugest, however, that we do some additional work with the cockpit voice recorder. We at Boeing believe that there may be more information, more data that can be gathered from that. And we would dearly like to help assist and offer our facilities along with your folks to work that problem.

There are several things in the data recorder, the voice recorder, that I believe deserve additional attention, not the least of which, of course, is the possibility of developing some side slip correlation that Mr. Cash showed the other day.

We also believe that the human factors group needs to be revitalized and perhaps expanded. We think that it ought to avail itself of what it can from the training that is being considered and developed in the industry, as well as possibly delving further into the records of incidents and past accidents, as well. We feel strongly that that team has not, frankly, gotten to the bottom scenarios that it needs to do that. And we would like to help and assist in any way we can, and encourage you to help that continue.

And with that, I think that's my comments.

CHAIRMAN HALL: Mr. Haueter, your comments and responses to that? And any comments you have, sir.

MR. HAUETER: Okay. I wanted to clarify the record, that the tests mentioned by Mr. McGrew will be done by the systems group as part of the complete investigation, via the standby testing or the tests done with the PCU. Those are being planned and will be conducted by the systems group.

(Witness excused.)

CHAIRMAN HALL: Very well.

Now, we face a decision here. Do the parties want to continue with the next witness or do you want to take a break until 2:00 o'clock and come back and then finish?

GENERAL ARMSTRONG: Short break.

CHAIRMAN HALL: Short break and continue. So why don't we look at a break of, well, why don't we come back at a quarter 'til, that will give everybody time. There were some cookies in the staff room I think we might -- the staff better hurry.

(Laughter.)

(Whereupon, a recess was taken.)

CHAIRMAN HALL: We will continue here in a moment. For the press that are still here, if there's any left, we will have a press availability. They may all be gone by the time we finish here. But if I could ask everyone to please take their seats in the audience.

The first thing I would like to do, before we call our last witness, is a friend to many of the individuals in this room, Joe Schwinn, who's the Deputy Director of Engineering and Air Safety for the Air Line Pilots Association, died of a heart attack this morning. There are many people here that know him and he has worked with the Board, and I would ask you to join me in a moment of silence for Joe Schwinn.

(Moment of silence.)

CHAIRMAN HALL: Thank you.

Mr. Purvis, you said you had something you wanted to clarify before we called the next witness.

MR. PURVIS: Thank you, Mr. Chairman. If I may, it has to do with Mr. McGrew's material that was presented during his testimony just concluded. And it's 9X-L, as in Lima. And on page, circle number 5, in the first grouping of that page, are five events listed under Known Past Wake Turbulence Events. And one of those listed, the second item, number two, dated September 8th, 1994, it's listed as wake turbulence, now, that is the accident.

And we're not concluding, for the record, we are not concluding that the U.S. Air 427 was caused by wake turbulence. It does infer an initial wake encounter. And that's been well discussed here, I think.

CHAIRMAN HALL: Yes.

MR. PURVIS: Thank you.

CHAIRMAN HALL: Okay. That will be clarified. And you might want to -- well, it's clarified for the record.

All right. Our last witness is Dr. Michael M. Cohen, a research scientist with NASA-Ames Research Center, Moffett Field, California. And Dr. Cohen, we appreciate your being here. And you ought to be very upset with Dr. Brenner putting you on last.

(Laughter.)

CHAIRMAN HALL: But we appreciate you waiting around for the hearing, and we appreciate your being here. Mr. Schleede?

MR. SCHLEEDE: Thank you.

(Witness testimony continues on the next page.)

MALCOLM MARTIN COHEN
RESEARCH SCIENTIST
NASA-AMES RESEARCH CENTER

Whereupon,

MALCOLM MARTIN COHEN

was called for examination and, having been duly sworn, was examined and testified as follows:

MR. SCHLEEDE: Dr. Cohen, please give us your full name and business address for the record.

THE WITNESS: Malcolm Martin Cohen, Mail Stop 23011, NASA-Ames Research Center, Moffett Field, California, 94035-1000.

MR. SCHLEEDE: Thank you. And would you give us a brief description of your education and experiences that brings you to your present position?

THE WITNESS: Okay. I hold a bachelor's degree in psychology from Brandeis University, a master's in physiological psychology from the University of Pennsylvania, and a doctorate in experimental psychology from the University of Pennsylvania. I have worked for about 24 years at the Naval Air Engineering Center and Naval Air Development Center, conducting research on human spatial orientation and the effects of gee-loading on human performance.

And then in 1982, I transferred to Ames Research Center, where I have been the Assistant Chief for the biomedical division, the Chief of the neurosciences branch, and now I'm back in the laboratory primarily as a research scientist.

Most of the work I've done has been involved with human spatial orientation and the effects of acceleration on spatial orientation. I'm a past president of the Aerospace Human Factors Association. I'm the current Chair of the Aerospace Medical Association, Human Factors Committee.

MR. SCHLEEDE: Thank you very much. Dr. Brenner will proceed.

DR. BRENNER: Yes, Dr. Cohen, what is human spatial orientation disorientation?

THE WITNESS: Human spatial orientation is the process whereby people can know how they are positioned relative to an external frame of reference, such as the Earth, such as gravity, such as the room in which they are seated or standing. And to accomplish this, the brain processes information from multiple sources. Vision is one of the sources that we use to know how walls are oriented and surrounding objects are oriented with respect to the body.

We have a vestibular system in the inner ear which is essentially a set of accelerometers that are angular and linear accelerometers. And these receptors tell us how the body is moving with respect to an external frame of reference. Gravity, or for example, when we're stationary on Earth, gravity provides an acceleration frame of reference. And then any movements we make are relative to that.

In addition, most of us are seated here, and in our skin, right now on our buttocks, we feel pressure receptors that tell us where the body is oriented with respect to up and down. And there are muscle spindle receptors and a whole host of other receptors inside the body that tell us how various parts of the body are put together. All this information is integrated by the brain. And as a result of that, we get a fairly accurate notion of where we are with respect to the external frame of reference that we're interested in.

On Earth, it's fairly straightforward. We usually can maintain balance pretty well. We know when we're standing up and when we're lying down, because all the inputs are typically in agreement with one another. Now, there are some places here on Earth where we can become disoriented. For example, there are mystery spots, places, so-called magnetic hills, places where the terrain confuses us. And so in these places it looks like a level terrain is moving up or down hill. You look at a car, there's a place called Magnetic Hill in New York where it seems to roll up hill, and it's strictly a visual illusion.

But generally we use vision very strongly as one of the inputs to determine our orientation. And when we have vision along with gravitational inputs, the vision frequently provides an overriding strong influence in terms of how we're oriented.

When you go into an aviation environment, you're no longer stationary, which means you can accelerate in any direction. The accelerations of the vehicle then produce forces that get combined with gravitational forces and give you a vector that is not necessarily straight down towards the Earth. In those cases, you can be disoriented.

Further, if vision is not present to override some of these confusing signals that you get, for example, if I suddenly slid to the right, I would feel pressure and I would feel my body moving with respect to this chair that I'm on. And I would feel that down is now changed in its direction, because the accelerative force gets combined with gravity. And so I would make an error, if my eyes were closed, not knowing whether I were accelerated or tilted to the side, in a gravitational frame of reference.

DR. BRENNER: So if I understand, then, orientation problems can be more severe in an aviation situation?

THE WITNESS: Yes, sir.

DR. BRENNER: Are there cases where orientation or disorientation has been involved in accidents?

THE WITNESS: Yes. Historically, there's some work that goes back very clearly to 1945, where a gentleman, A.R. Collar, at the RAF Farnborough, did an analysis of dark night takeoff accidents in the Spitfires during World War II, during attempts to intercept incoming aircraft. And on dark night takeoffs, the Spitfire was a very hot aircraft, at the time, and it would be accelerating throughout its transition from roll-out until it was airborne. It would accelerate, pushing the pilot back in his seat, giving him the feeling of a nose-up attitude.

The pilot would continuously push forward on the stick ever so slightly, not to have too strong a nose-up attitude. He would transition from being level to being in a shallow dive and the aircraft would still be accelerating. Throughout the entire trajectory, Collar's analysis showed that the pilots felt that they were in a climb. And the vector of the acceleration of the aircraft in gravity was back towards the back of the seat, the reaction forces. Hence the nose of the aircraft was up.

Without an external visual reference to tell them that in fact they were coming down, the pilots would fly into the ground. And Collar analyzed the distances involved and the accelerations involved. And there was close agreement.

Another condition where this kind of thing has been fairly well documented, in a case that I've been involved in, was with the Navy. In the last 1960s, there was a rash of A-7 catapult launch accidents. And in these cases, the A-7 off the catapult would climb up. And again the pilots apparently would fly the aircraft into the water.

Analysis of the trajectory suggested that the pilots always had a force pushing them back in the seat. The A-7 did not have an afterburner, and was stall sensitive. And so you wanted to keep the nose down. They actually went into a shallow dive. They flew into the water about where one would expect.

Again, only dark night clouded conditions. These types of accidents don't happen in the day time.

Another, the phenomenon has been called the somatogravic illusion. Your body feels like you're in a nose-up attitude, mainly, your whole surrounding feels to you like you're climbing, and you're slightly tilted backwards. This is merely the relationship between gravitational force and the vector to your acceleration combining.

Another case where it's been suspect has been in the Charlotte accident of July 2nd. And the NTSB, I believe, has felt that this could be contributory to it. And in particular in that case, there was a comment, down, push it down, where, after the aircraft apparently entered a cloud, encountered turbulence, did not have external visual references, there's apparently a feeling that they were excessively nose up. And they flew, again, into the ground. So in response to your question, yes, sir.

DR. BRENNER: Okay.

(Laughter.)

DR. BRENNER: Thank you. Are there other types of common forms of disorientation in aviation situations? I think you mentioned --

THE WITNESS: I don't understand the question.

DR. BRENNER: Okay. I think you were talking about -- okay, then --

THE WITNESS: Okay, we have somatogravic illusions. There are also visual illusions that take place. In the dark, a spot of light will appear to rise as the linear gee increases. That's called the elevator illusion. And there are a host of other illusions that are due to vestibular visual conflict, vestibular somatic visual conflict. This is simply that the different senses that the brain uses to determine orientation are providing different sources of information. But again, vision frequently will override that.

DR. BRENNER: Okay. How did you evaluate disorientation issues in this accident, 427?

THE WITNESS: All right. First of all, I read the description of the accident. And I was given copies of the flight data recorder and transcripts of the voice recorder. And had a chance to take a look at all these things together. Then in July, I believe it was the 11th, I had an opportunity to ride on the VMS, which, we had a simulation of the crash. And we have a viewgraph here, which provides the VMS.

CHAIRMAN HALL: Is our fellow with the lights still here? Bear with us a moment, and we'll get it.

(Slide shown.)

THE WITNESS: Okay, this is -- could you flip it over? It's backwards. Please. Terrific.

Okay, this is the VMS at Ames Research Center. It's a full 6 degree of freedom simulator that has a vertical thrust of plus and minus 30 feet, lateral thrust of plus and minus 20 feet, and a fore and aft thrust of 2.5 feet. It also has actuators that will give it pitch, roll and yaw motions. And it was used in the model that was developed by Boeing to maintain accuracy of a simulation, to the Boeing time T of 139 seconds into the incident. After that, it lost fidelity. But up until T equals 139, I understand, it was completely faithful to the conditions that were put in.

As with any simulator, there are limitations. If you could fly, if you could do everything in a simulator you could do in the aircraft, you could just get up and fly the simulator. Simulators are limited, you have to use washout, and various techniques to fool the pilot into thinking that he experiences what the actual aircraft does.

Now, there are full visual simulations on the VMS which are computer generated displays that were also put in on this simulation. So you had the external world created as well as the forces involved, up to T equals 139. And I had an opportunity to ride this with, first of all, a representative of the NTSB, and then with a pilot from ALPA, a pilot from U.S. Air, and a pilot from Boeing.

And during these rides, I had a chance to discuss what it was like, and to have them experience and me experience various conditions. On some cases, I closed my eyes to take it in the dark, just to see about the motion base, how it felt. In other cases, I kept my eyes open, looking out. I sat both right seat and left seat during this simulation.

DR. BRENNER: How many times did you run through this simulation?

THE WITNESS: I don't have the exact number, but it was probably on the order of 12 times, somewhere around that, because I did it multiple times with each of the four people. I don't really have the record with me.

DR. BRENNER: Okay. And if I understand, you did it sometimes just for motion and sometimes motion and visual, is that --

THE WITNESS: That's correct. And then also, in some of the later rides, we had a synthesized set of voice recordings, not the actual pilots. I never heard the actual pilots' voices, but I did hear a synthesized transcript of the voices played in at the same times that they occurred during the actual incident, or the accident.

DR. BRENNER: What were your impressions?

THE WITNESS: First, I was so surprised at how gentle it all was. I had thought that the upset would be more severe. It was a surprise, it did get my attention. But it was not a violent kind of an upset that would, if you will, make my eyeballs become uncaged or have me fail to know where I was and what my orientation was, relative to the outside world.

CHAIRMAN HALL: Are there going to be other slides? Excuse me, Doctor.

THE WITNESS: No, sir, just one.

CHAIRMAN HALL: Why don't we get the lights back up then, if we could.

DR. BRENNER: Do you believe, was it your impression that disorientation factors played a role in this scenario you saw?

THE WITNESS: Very strongly, no. The reasons were first of all, the clear external vision at all times being available. There was no case where I could not see the outside world. In talking with each of the pilots that rode with me, I asked them basically two questions in the course of discussions with them. And the kinds of questions I asked were, did you feel like you were disoriented, and did you know where you were. And the response was, yes, sure, all the time. I knew exactly where down was, I knew where the aircraft was.

The second question I asked them is, do you think you could have flown out of this. And again, each of the pilots said yes, they thought that they could. Now, I didn't ask them at what time in the evolution of this upset that they thought they could fly out of it. Because at some time, I'm sure they could not.

But their general feeling was yes, they could fly out of it, and no, they were not disoriented. I was not disoriented at any time. And the visual scene which was somewhat degraded from an actual 737 cockpit, the 737 would have given you more visual information than that which we provided in the VMS, at no time was there a question as to where down was, where up was, with respect to the external world.

DR. BRENNER: Now, if the pilots lost sight of the horizon as they were in the dive, would that cause disorientation?

THE WITNESS: In the simulation, first of all, they did not appear to lose sight of the horizon. Okay? Second, if they did lose sight of the horizon, it would be possible that they could have been disoriented, but unlikely. Because immediately, you retain a memory of where you are for a few seconds. Now, if there was a change in where they were moving and they had a good sense of how they were moving, even if they would lose external vision for a second or so, that should not bother them.

DR. BRENNER: Can surprise cause disorientation?

THE WITNESS: Now we're talking about a slightly different meaning. Surprise or startle can cause a person to do things that he otherwise might not do. I don't regard that as disorientation. That's another phenomena. That's a startle response.

But in terms of knowing where you are in space, unless the surprise is a surprising stimulus of the type that you process for knowing where your orientation is, surprise per se I don't think could cause disorientation of this type.

DR. BRENNER: The first officer was looking out a side window to see traffic. The jet stream is calling at the time of the incident.

THE WITNESS: Yes.

DR. BRENNER: And then very possibly, probably looked forward as the upset began. Could a sudden motion of this type cause disorientation?

THE WITNESS: If it occurs during the upset and there is a fairly rapid head movement during a turn, yes, there can be a momentary disorientation due to cross-coupling. That is, what's happening is your semi-circular canals are in one axis as you're turning, these are the receptors in your inner ear, and now suddenly you change the axis of stimulation and semi-circular canals do trigger eye movements that could for a second or so, a few seconds, cause you not to know quite where you are.

However, we had two pilots here. And the comment, I see the jet stream, and the time that the upset occurred, were about two seconds, or a little over two seconds apart. So it seems that if he did move his head, it probably would not have been violent. Although, again, I don't know.

And second, it seems that there was enough time elapsed between the comment that he was looking at the jet stream to the time that he probably was inside the cockpit with his surprise response, I guess it was, oh, sheez, that he was probably in position at that time. But again, I don't know.

DR. BRENNER: I think some of the thinking in the investigation is that the upset may have begun, actually, with the jet stream comment. So it may not have had that time frame. But if I understand, still, the --

THE WITNESS: That's possible.

DR. BRENNER: Okay. In the letter that you wrote to us, you said, perturbations of the flight path generally appear to have been followed by verbal comments from the pilots, indicating that they were fully aware of their trajectory and that they were not able to change it. Could you discuss that?

THE WITNESS: All right. First of all, the pilots are fairly taciturn. There are very few comments actually made, a few picked up on the hot mike. And the initial encounter with the turbulence was one pilot's, oh, sheez, the other's, ah, and that came out immediately after there was a slight offloading of gee down to about .85 gee and back in.

So that comment, the later comment of, whoa, comes in after there's another change in the gee loading on the aircraft. The hang ons come in at various times where there appears to be changes in gee loading, either slip or positive gee, in the second or so preceding the comments.

The pilots did have external vision. They could see where they were going. It was not a question of not knowing where the plane was going. And so for that reason, I thought that the pilots are commenting about a situation. At one point there's an oh, expletive, comment, where my interpretation, and this is beyond my area of expertise, I will admit, is a recognition, oh, boy.

DR. BRENNER: Okay. And then once again, your conclusion in terms of the role of disorientation the Board should, in its analysis, should consider for this accident?

THE WITNESS: I do not believe, I strongly do not believe, that disorientation in the sense of the pilots not knowing where they were in space or relative to the Earth, played a role in this accident.

DR. BRENNER: Okay. Thank you, Dr. Cohen. That completes my questions, Mr. Chairman.

CHAIRMAN HALL: Are there questions from the technical panel? Mr. Haueter?

MR. HAUETER: Excuse me, Doctor. I'm way outside of my area here. But you mentioned in many of your statements about pitch events, or pilots pitching over. Do you have similar analogies or statements about yawing of the airplanes, in terms of the pilots feel?

THE WITNESS: I do not have that data personally available. I have not worked on that. I would imagine, yaw is, now, an angle issue. A side slip is another issue. And with a side slip, there could be a change in your appreciation of where up is. As you slip to the right, up appears, the vector resolution can change. But again, with an external visual frame of reference, this shouldn't be a problem.

MR. HAUETER: Okay. And in your riding the event, did you believe it was startling?

THE WITNESS: The first time, yes, it got my attention. But it wasn't startling. It just, it got my attention. And I would imagine that some of the testimony that I heard the pilots make, when they fly through these things fairly often, once you feel it, you know that you're encountering some sort of wake turbulence, and I don't think it would be that startling.

But again, it's beyond my area of expertise.

MR. HAUETER: Thank you, sir.

CHAIRMAN HALL: Other questions?

(No response.)

CHAIRMAN HALL: Questions from the parties? I see the hands, two hands. Mr. Purvis, with the Boeing Commercial Airplane Group.

MR. PURVIS: Thank you, Mr. Chairman.

Dr. Cohen.

THE WITNESS: Hello.

MR. PURVIS: How many hours have you spent observing commercial, and I'll repeat commercial, airline crews during flight? Any?

THE WITNESS: Zero, sir.

MR. PURVIS: Have you done any papers or reports on anything to do with commercial airline crews and how they respond to unexpected upsets or the effect of upsets?

THE WITNESS: No, sir.

MR. PURVIS: Nothing?

THE WITNESS: Military aircraft, yes, but not civilian or commercial pilots.

MR. PURVIS: All right. The information that you have given, before you come to an opinion on whether commercial pilots can be affected, wouldn't you want to, you know, be either surprised or confused or affected by turbulence, wouldn't you want to observe or research the reports of commercial airline crews who have actually encountered these things?

THE WITNESS: Yes, sir. However, the testimony that I heard here from the pilots who say that they've flown through this have typically been, yes, it got my attention but I wasn't disoriented by it. And I was able to handle it. And again, the pilots that I flew through this simulation with also indicated they felt they could come out of it fairly readily. But you're absolutely correct.

MR. PURVIS: Have you reviewed any of the events where the crews, like both crews, reports where it was stated both crews were startled by a rate of roll?

THE WITNESS: I can believe that could happen, yes.

MR. PURVIS: They threw the flight attendant to the floor and scared the flight crew, more like a barrel roll, I think this was mentioned here.

THE WITNESS: I think that could happen, yes.

MR. PURVIS: Have you seen these reports?

THE WITNESS: No, I have not.

MR. PURVIS: There was another one where crew was visibly shaken, aircraft felt out of control, very mushy, again, that was mentioned, a female pilot apparently, she didn't think she could control the aircraft? Do you remember those? You haven't seen those reports?

THE WITNESS: No, I have not. But I believe that these things could very well happen.

MR. PURVIS: Have youreviewed any reports by commercial airline pilots in which they have in fact misperceived or over-perceived the severity of a wake upset?

THE WITNESS: No, sir.

MR. PURVIS: Have you reviewed reports by commercial airline pilots in which these pilots may have been confused, surprised or startled by upsets attributed to wake encounters?

THE WITNESS: No, sir. I'd like to make something clear. I was asked on this as a vestibular expert, namely, how we process vestibular information. And that was basically the basis of my testimony, namely, were the pilots disoriented by these conditions.

And given the ready access to external visual cues and the comments of the pilots who flew through the simulation with me, who were commercial pilots, I concluded, no, they were not disoriented. There may have been other things, that they made inappropriate inputs. I have no idea. This is beyond my area of expertise.

MR. PURVIS: So your opinions are limited to your expertise on disorientation, spatial disorientation resulting from vestibular or inner ear created illusions?

THE WITNESS: Or some aesthetic or other inputs that are using in generating a notion of where you are in space, yes.

MR. PURVIS: No more questions. Thank you.

CHAIRMAN HALL: Captain?

CAPTAIN LEGROW: Thank you, Mr. Chairman. I have just one question.

Good afternoon, Dr. Cohen.

THE WITNESS: Good afternoon.

CAPTAIN LEGROW: In your discussions with the crews of the pilots that you flew in the simulator with, you stated that at certain times during the event, the pilots, you asked the pilots if they felt they could control the airplane?

THE WITNESS: Yes.

CAPTAIN LEGROW: Was that with the assumption that they had control of the airplane over all three axes, control of all three axes?

THE WITNESS: I think that was the assumption that they made when I asked them, you know, could you fly, I would imagine that they assumed they had a perfectly flyable airplane to do this with.

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

CHAIRMAN HALL: Other questions from the parties? Mr. Clark?

MR. CLARK: There's been a few questions about surprise or startle factor. If a, one of the things we see and what's been alluded to is pilots may overestimate the magnitude of the upset. They may overestimate the bank angle. We may get a pilot report that says they banked up to 30 degrees and required 45 degrees of wheel. When we read out the flight data recorder, we may see that they banked 10 degrees and had 15 degrees of wheel, something like that.

Is that consistent with your observations or knowledge?

THE WITNESS: Well, that kind of thing is not uncommon. For instance, if someone were asked, how steep is the steepest hill in San Francisco, they might judge it to be 40 degrees or so. I think the maximum slope is like 17 or 13 degrees. So we tend perceptually to overestimate changes in slopes, fairly frequently.

However, if you're trying to maintain wings level of trying to do something -- now I'm going beyond my expertise -- one would see how the horizon changes with respect to oneself, and would presumably have sufficient visual feedback to correct that and not put yourself in a low attitude and not know it. So I think throughout you know what's happening. Even if you do overreact, you can immediately see what the result of that response is and correct it, relative to the outside world. Again, assumption on my part.

MR. CLARK: The fact that a pilot may not be able to accurately estimate the angles is, doesn't negate the possibility that he knows which way is up and what proper response to take?

THE WITNESS: Right. And also, remember, verbal reports and actual responses to maintain a null state frequently do not agree. Dr. Herschel Liebowitz did a lot of work, I think with the NTSB, in notions about judging how close a train is at an intersection. And you make errors. You know, a Boeing 747 flies a lot slower on approach than a 727 does perceptually. Of course, it doesn't really. But it looks that way. So our senses can deceive us in some ways.

But when you have external visual frames of reference with respect to orientation, usually we're pretty accurate.

MR. CLARK: And the fact that the estimates and the actual excursions doesn't mean that a pilot's disoriented. Or let me ask you, would that mean they're disoriented?

THE WITNESS: No.

MR. CLARK: Thank you.

CHAIRMAN HALL: Mr. Marx?

MR. MARX: No questions.

CHAIRMAN HALL: Mr. Schleede?

MR. SCHLEEDE: Yes, sir. A couple here.

You gave an example here, you gave an excellent example. I want to restricted my comments to no visual reference field. Because you gave us the first examples about the pitch, the takeoff, and pilots flying into the ground. Could you give us, in that condition, with no visual reference, something in a lateral roll?

THE WITNESS: Well, the leans, for example, can occur, if you very slowly put a wing down at a rate below threshold, you can be flying -- suppose you had a cloud bank that is at an angle, not horizontal, but slowly sloping upward to the left. And if you assume that that cloud bank is at first, say it's the Earth.

So you think that the clouds are horizontal, and you gradually, at subthreshold values, bring your plane to an orientation with respect to the cloud bank.

You could think that you're now flying straight and level. In fact, you're with one wing down and you will probably begin gradually to bleed off and lose a little bit of altitude. So this kind of phenomena can happen.

In terms of a slide slip, there has been some work done in terms of judgments of the vertical, using the horizontal sled. And typically, the judgment of where the vertical changes slowly if you only had a single visual stimulus, as you slip side to side. However, with a rich visual array, the outside world as a reference, you have no problems.

MR. SCHLEEDE: Some of us have heard the term, graveyard spiral.

THE WITNESS: Yes.

MR. SCHLEEDE: Are you familiar with that phenomenon?

THE WITNESS: Yes, sir.

MR. SCHLEEDE: Could you explain it?

THE WITNESS: Not very well. I've heard the term. From what I gather, it's a continuous acceleration going downward. I really can't describe what the psychological experience of that is. I've not done any research in that area.

MR. SCHLEEDE: Okay. Again, when no visual reference, let's say a pilot's got his eyes closed or he's in a situation where he has no outside visual reference, how does the pilot sense side slip or yaw?

THE WITNESS: Well, I would think he would have instruments.

MR. SCHLEEDE: I'm not talking about -- if you've got your eyes closed.

THE WITNESS: Oh, your eyes are closed. You would feel it in your body and your inner ear, the vestibular organs, particularly the utricular and sacular would provide you with different shearing forces that then get processed by the brain and are interpreted as either a slide or a tilting orientation. It's a slide if it is not corroborated by vertical semi-circular canals, which are our angular accelerometers. And so you could feel it as a slide. Or if the semi-circular canals also indicate a turn, then you could feel that your body is actually turning, with respect to down.

MR. SCHLEEDE: Could a pilot react inappropriately to those sensations?

THE WITNESS: I would assume so.

MR. SCHLEEDE: Have you done any research or tests?

THE WITNESS: No, sir. Wait, I take that -- not on pilots. I had done some work where we would put subjects in an oscillating centrifuge and have them move laterally plus and minus about a half a gee and have them try to set a line in the dark, so that it would look to them that it was vertical.

And in fact, there were oscillations in the line that corresponded to the changes in the lateral forces acting on their body. So in that case, using that visual, the direction of where up and down is, that line looked to them to be vertical, and yet it would change its orientation in the roll axis. That's a single line in the dark.

MR. SCHLEEDE: All right, thank you very much, Dr. Cohen.

THE WITNESS: Yes, sir.

CHAIRMAN HALL: Well, Doctor, we appreciate very much your presence here. I don't know, how much of the testimony have you gotten to listen to?

THE WITNESS: I got in on Wednesday evening, and so I heard most of yesterday and much of today.

CHAIRMAN HALL: Well, good. Good. Well, we appreciate your assistance. I just wanted to ask, and I believe you heard some suggestions from Mr. McGrew in regards to some additional things we might want to look at in human factors. Are there any other individuals or work in your field that you're aware of that we should seek out in terms of assisting us with this investigation, to be sure that we have looked at all of the aspects that might impact the human in this accident sequence?

THE WITNESS: I can't think of anyone explicitly at the moment. However, I could pull some people at the Human Factors Committee of the Aerospace Medical Association. And I would be happy to do so, and see if there are people who feel that they would like or are capable of contributing to this, if you would like me to.

CHAIRMAN HALL: Well, if you would coordinate with Dr. Brenner, and with the committee, I just want to be sure we have examined everything that we can. And if there's other expertise that's available, reach out for it. So I would appreciate that.

Any other questions of this witness?

(No response.)

CHAIRMAN HALL: If not, sir, we appreciate you coming all the way across the country to testify, and you are excused.

THE WITNESS: Yes, sir.

(Witness excused.)

CHAIRMAN HALL: I have a closing statement, a brief closing statement, that I'm going to read for the record. But prior to that, I would like to -- where's my package of those things? Did you all steal them? Here they are.

Mr. Haueter, do the parties have the action items from Pittsburgh that you provided, or can I provide a copy for them?

MR. HAUETER: I have a copy.

CHAIRMAN HALL: With the dates?

MR. HAUETER: The action items? I have a copy here, sir, I can give it to them.

CHAIRMAN HALL: Okay If you all remember, at the conclusion of the hearing in Pittsburgh, we identified 19 items, and this information was, that we have been following up on to complete. And this, Mr. Haueter will give you a handout that will indicate that all of these items that were identified, I believe all that work has been completed, is that correct, Mr. Haueter?

MR. HAUETER: Yes.

CHAIRMAN HALL: And for that, I want to thank the parties for your assistance in helping the investigation and assisting that all of these items that were identified have been completed. And I would like now for Mr. Haueter to go over the list of issue items that we will now follow up as a result of this public hearing and any other business that you might have.

Mr. Haueter, I will turn it over to you. And it will probably, since it's not that extensive a list, you might want to read the items and go through them and be sure, see if any of the parties have any comments on them. And also if there are any additions.

MR. HAUETER: Okay, thank you, sir.

I passed out a list. I have 13 items on it. The first item is the FAA to report the actions taken as a result of the critical design review team recommendations. I believe those will be ready by the 27th.

CHAIRMAN HALL: Is that correct, Mr. Donner? Mr. McSweeney said we could get those by that date?

MR. DONNER: Yes, sir. And Mr. Zielinski will work on it next week.

CHAIRMAN HALL: Thank you.

MR. HAUETER: Item number 2 is the NASA OV-10 data on the Boeing 727 vortex strength. We believe that can be available to us before the end of the year, somewhat dependent on the furlough status of the NASA personnel.

Number three, copy of the FAA letter to the A6 committee on the formation of the hydraulic fluid contamination study. We've received a copy of that, and that issue is completed now.

Number four is a copy of the A6 committee report to the FAA, which we anticipate in March of 1996.

Number five is an update on the status of the flight data recorder rulemaking action by the FAA. Do you have a date for that?

MR. DONNER: No, I don't have a date to offer at this time.

MR. HAUETER: Okay.

Number six is the status of the U.S. Air program to incorporate the service bulletin on the rudder PCU servo valve. We received that yesterday. I would say they're 75 percent completed and on status to be completed by the end of the year or shortly thereafter. So we have that.

Number seven, examination of the CVR tapes from United 585 and U.S. Air 427 for clicks possibly due to windshield screen wiper lifting and snapping back, and examination of any other unidentified sounds on the CVR. Mr. Cash will be working on that. And --

CHAIRMAN HALL: If we could hop back just one second. Did we get the information on who's serving on these committees, who are the rulemaking committees, or what were those committees with the FAA on the flight data recorders? The ARAC committees. We were going to get those names submitted for the record. And if we could just add that to the --

MR. HAUETER: Numbre four?

CHAIRMAN HALL: Number five.

MR. HAUETER: Number five.

CHAIRMAN HALL: Yes.

MR. HAUETER: Okay. Number eight is completion of the simulation and kinematic studies using data provided by the wake vortex test. NTSB and Boeing. And I would guess from Mr. Kerrigan's testimony, that's going to be about March of 1996.

CHAIRMAN HALL: Let's put that target date down there. Boeing, Mr. Purvis, does that date sound reasonable?

MR. PURVIS: I'm sorry, what was the date proposed?

MR. HAUETER: I believe from Mr. Kerrigan's testimony, he said he thought he would have it done in March of 1996.

MR. PURVIS: End of March.

MR. HAUETER: End of March of 1996.

CHAIRMAN HALL: End of March. We'll put March 30th, 31. Okay.

MR. HAUETER: Okay. That also puts the pressure on Mr. Jacky.

Number nine, asking the ALPA to assist in providing data on interviews with pilots who have experienced wake vortex encounters. Mr. Cox indicated he had done some interviews.

Number 10, systems group of tests, including the use of the surplus 737. Dates have not been determined. We're still developing the test plan. This will include the rudder PCU servo valve contamination silting testing, tests of a standby rudder system, cable cut tests, and dynamic and impulse loads to the rudder system. We'll be working on that.

CHAIRMAN HALL: Yes, Mr. Purvis?

MR. PURVIS: The last three items that he just went through are all things that we had planned on. The silting test is nothing that yet has been planned. Is that an addition?

MR. HAUETER: That was identified this week.

MR. PURVIS: Are you going to set a date on that separately from the rest?

MR. HAUETER: Yes. All the dates here have to be developed.

MR. PURVIS: Okay.

MR. HAUETER: Yes. The systems group plans to get together within the next few weeks and work on that.

CHAIRMAN HALL: What about the other three? Can we put a date on those?

MR. PURVIS: March 31, we'll aim for that.

CHAIRMAN HALL: Okay.

MR. PURVIS: Leave to be determined on the silting test.

CHAIRMAN HALL: Right.

MR. HAUETER: March 31st, except for silting.

Number 11 is the Boeing report on their analysis of the blue water events in the E&E bay.

MR. PURVIS: The end of the year, of this year.

MR. HAUETER: End of the year? Okay. December 31st.

Number 12 is, this should be marked for Boeing also, it is an update to Exhibit 9X-L on the roll team event summary, as they further refine that.

MR. PURVIS: I think we've given you all the current information we have in the form of 9X-L. We'll continue to update you as we go. It's just going to be an ongoing thing.

MR. HAUETER: Okay.

MR. PURVIS: If that's all right with you?

MR. HAUETER: Yes, that's fine.

MR. PURVIS: Because I don't see an end to this yet.

MR. HAUETER: Okay.

Number 13, study the findings of an unusual attitude or advanced maneuver programs offered by the other airlines. Part of the human performance group under Malcolm's control. They are working on that, and probably into February, March, also, I imagine, to complete that effort.

CHAIRMAN HALL: Are there any other items that any of the parties think that we should be pursuing as part of this investigation, we ought to include on this list?

(No response.)

CHAIRMAN HALL: Do you have anything, Mr. Purvis, on the human performance effort, specific, that we should be doing, other than the general recommendation to expand looking at that?

MR. PURVIS: I think there were comments made by both Mr. McGrew and --

CHAIRMAN HALL: Mr. Carriker, we believe.

MR. PURVIS: I think it was Mr. Carriker and yourself, also, about looking in, with the last witness. I think those ought to be added. Expanding that.

CHAIRMAN HALL: Well, why don't we just note that as item 14. I'd rather have 14 items than 13, anyway.

(Laughter.)

MR. HAUETER: Expand?

CHAIRMAN HALL: Just expand that, and put March 31 on that as well. So that will, hopefully that will become an outside date.

MR. HAUETER: I guess the only other issue that I might bring up is, we did take, there was one person aboard the preceding flight from Charlotte to Chicago who heard a noise. We took testimony on that. We believe that that is not an issue. However, if there's any other passengers who may have been on the aircraft that can, heard a noise or something else, we would be anxious to talk to them.

CHAIRMAN HALL: Yes, and if you'd again let me ask the public, through the media, if there are any individuals that were on that U.S. Air flight, was that 427, was that a different flight number, wasn't it.

We'll try and get that information, the U.S. Air flight that, was it Jacksonville, I believe?

MR. HAUETER: It was from Charlotte to Chicago.

CHAIRMAN HALL: Charlotte to Chicago. That has any information in regard to the sounds, we would appreciate them contacting the NTSB as well as the individual who had heard the sounds.

Yes, sir?

GENERAL ARMSTRONG: Mr. Chairman, for the record, that flight number was Flight 1181.

CHAIRMAN HALL: Thank you. For the media, U.S. Air Flight 1181 from Charlotte to Chicago. Anyone that has information on any of the sounds or anything they think might be useful to this investigation, please call Mr. Tom Haueter --

(Laughter.)

CHAIRMAN HALL: September 8th, 1994, Mr. Tom Haueter, it's 202-382-6830.

So any other items? That gives us a total of 15, right, items? Okay, and if you will get that and distribute it to the parties, and Mr. Benson will have it available for the media at the NTSB in case any of the public or press would like to have a copy of that list. And we will follow it.

Anything else, Mr. Haueter?

MR. HAUETER: That's all, sir, thank you.

CHAIRMAN HALL: Okay. Let me state, then, that with the last witness having been heard, this concludes this phase of the Safety Board's investigation.

Before I get into the balance, I would like to thank Mr. Donner, the participation of the officials from the Federal Aviation Administration. General, again, the participation of U.S. Air. Captain, the participation of the Air Line Pilots Association. We had to have, Mr. Weik had to leave from Parker Hannifin. But we appreciate his participation, of Parker Hannifin. Mr. Purvis, we appreciate the participation of Boeing Commercial Airplane Group. Mr. Wurzel, the participation of the International Association of Machinists. And Mr. Jakse, the participation of Monsanto.

I want to emphasize that this investigation will remain open to receive, at any time, new and pertinent information concerning the issues presented. And the Board may, at its discretion, again reopen this hearing in order that such information may be made part of the public record.

The Board welcomes any information or recommendations from the parties or the public which may assist it in its efforts to ensure the safe operation of commercial aircraft. Any such recommendations should be sent to the National Transportation Safety Board, Washington, D.C., 20594, to Mr. Tom Haueter's attention. Normally, they should be received 30 days after the receipt of the transcript of this hearing. However, since there are still investigation activities open in this case, Mr. Haueter will notify the parties when the final submissions are due.

All the evidence developed in this investigation and hearing and all recommendations received within the specified time will be presented and evaluated in the final report on U.S. Air Flight 427, in which the National Transportation Safety Board's statement of probable cause will be, a determination of probable cause, will be stated.

On behalf of the National Transportation Safety Board, I want to again thank the parties for their cooperation, not only during this proceeding, but also throughout the entire investigation of this accident. Also, I want to express sincere appreciation to all those groups, persons, corporations, and agencies who have provided their talents so willingly through this hearing.

And again, I want to acknowledge the presence of the families of the individuals who lost their lives in the accident that we have been discussing today, and assure them, as I have individually on numerous occasions in the past, it is the intent of this Board to pursue this investigation until we hope a satisfactory conclusion, which we hope will include finding the probable cause.

But all of this, the record of this investigation, including the transcript of the hearing and all exhibits entered into the record, will become part of the Safety Board's public document on this accident, and will be available for inspection at the Board's Washington office. Anyone wanting to purchase a transcript, including the parties to the investigation, may contact the court reporter directly.

This investigation will proceed. We will be following these items. And we look forward to a successful conclusion.

I want to thank Mr. Haueter for his work as the investigator in charge, as well as our staff, that have worked so tirelessly on this investigation. I would like to especially acknowledge Mr. Bud Laynor. Mr. Laynor formerly served, is now serving as a technical advisor to the Board. Mr. Laynor was previously the Deputy Director and acting Director of the Office of Aviation Safety. Mr. Laynor, regrettably, will be retiring from the Board at the end of this year. And the public will certainly miss him. His years of service have made an outstanding contribution to the safety of the American public in the area of flight.

So unless there are other comments from the parties, I will now declare this hearing to be in recess indefinitely.

(Whereupon, at 2:45 p.m., the hearing was concluded.)