NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

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In the Matter of:	
THE INVESTIGATION OF THE U.S. AIR FLIGHT 1016, DOUGLAS DC-9-30	
CHARLOTTE, NORTH CAROLINA JULY 2, 1994	DOCKET NO.: SA-509
(DCA-94-MA-065)	

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Charlotte Marriott Executive
Park Hotel
Charlotte, North Carolina

Wednesday, September 21, 1994

The above-entitled matter came on for hearing pursuant to notice, at 9:00 a.m., before:

Board of Inquiry

John Hammerschmidt, Member, NTSB
Chairman

Ronald Schleede, Chief,
Major Investigations Division, Hearing Officer

Bud Laynor, Deputy Director of
the Office of Aviation Safety

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

Technical Panel

Gregory Feith, Investigator-in-Charge

Renee Mills, Operations Investigator

Barry Strauch, Human Performance Investigator

Hank Hughes, Survival Factors Investigator

Jim Ritter, Aircraft Performance Engineer

Sandy Simpson, Air Traffic Control Investigator

Nora Marshall, Senior Survival Factors Investigator

Larry Roman, Airport Investigator

John DeLisi, Aircraft Systems Engineer

Jack Young, Powerplant Specialist

Greg Salottolo, National Resource Specialist, Meteorology

Staff:

Alan Pollock, Office of Public Affairs

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National Safety Transportation Board

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C O N T E N T S

P R O C E E D I N G S

[Time noted: 9:00 a.m.]

CHAIRMAN HAMMERSCHMIDT: Ladies and gentlemen, let's please come to order again.

Good morning, and welcome to the third day of the National Transportation Safety Board's public hearing concerning the USAir Flight 1016 accident.

If there are no opening comments or questions of a procedural nature, we will proceed with the questioning of the next witness, Mr. David Bowden.

Mr. Bowden, would you please come forward?

Mr. Bowden is employed by the Federal Aviation Administration and he will be questioned by Ms. Renee Mills and Mr. Gregory Feith.

(Witness testimony continues on the next page.)

DAVID BOWDEN, FAA POI, USAir, PIT-FSDO, PITTSBURGH, PENNSYLVANIA

Whereupon,

DAVID BOWDEN,

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

MR. SCHLEEDE: Mr. Bowden, could we have your full name and business address for our record, please.

THE WITNESS: David Bowden, Pittsburgh, PA.

MR. SCHLEEDE: And by whom are you employed?

THE WITNESS: FAA.

MR. SCHLEEDE: In what position?

THE WITNESS: POI.

MR. SCHLEEDE: Okay. Principal Operations Inspector for USAir?

THE WITNESS: That's correct.

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

THE WITNESS: Almost four years now.

MR. SCHLEEDE: Could you briefly explain or describe your experience, training, background that qualifies you for your present position?

THE WITNESS: Yes. In 1968 I graduated from college and joined the Air Force and after pilot training I flew KC-135's for five years. When I got out of the Air Force I went to Spartan School of Aeronautics where I got my CFI and A&P. I then went down to Brazil as a missionary bush pilot with Mission Aviation Fellowship. Flew in the Amazon area for three years supporting the missionaries working with Indian tribes.

When I came back from Brazil I went to a college as a College Administrator for six years and I received my MBA degree at that point. Then I got back in aviation in a corporate setting. I flew Lear's, Aukers, prior to coming into the FAA.

I've been in the FAA for 7-1/2 years, initially as an Assistant POI, then as an APM and now as a POI.

MR. SCHLEEDE: You mentioned some of your ratings. What all FAA ratings do you hold?

THE WITNESS: I have my airframe and power plant mechanic's rating. I have a CFI. I have an ATP and I have type ratings in DC-9, Lear Jet 720 and 707.

MR. SCHLEEDE: Approximately how much total flying time do you have?

THE WITNESS: Four thousand hours.

MR. SCHLEEDE: And approximately how much in a DC-9?

THE WITNESS: Less than 50 hours.

MR. SCHLEEDE: Thank you very much. Ms. Mills will continue.

MS. MILLS: Thank you.

BY MS. MILLS:

MS. MILLS: Good morning, Mr Bowden. Thanks for sharing your aviation background with us.

Will you now, please, describe your duties and responsibilities as a Principal Operations Inspector, please?

THE WITNESS: As a POI, I'm the focal point for USAir interaction between USAir and the FAA in all operational matters. That's pilots, flight attendants and dispatchers. And I approve op specs. I approve training programs and I manage the surveillance program on USAir from the office.

MS. MILLS: Do you feel that the FAA training that you've received is adequate to assume the duties of POI?

THE WITNESS: Yes, I do.

MS. MILLS: And you said you were assigned as POI for the last four years?

THE WITNESS: It will be four years in December.

MS. MILLS: And prior to that, you said that you were an APM. Would you explain that to us, what an Air Crew

Program Manager is, please?

THE WITNESS: I have a technical expert on each piece of equipment that USAir operates. It's an Aircrew Program Manager. So, in that role, the APM goes through all of USAir's training programs right up to and including the check airman training program.

The APM then interacts with the flight manager on that piece of equipment and really take a look at safety and the training program from the inside out.

MS. MILLS: Okay. And you had that assignment prior to becoming POI?

THE WITNESS: That's correct. I was an APM for about a year and a half.

MS. MILLS: Okay. On what piece of equipment, please?

THE WITNESS: A DC-9.

MS. MILLS: Did the previous POI conduct an out-briefing with you when you took over the certificate?

THE WITNESS: Yes, he did.

MS. MILLS: Did he identify any problem areas?

THE WITNESS: No. I had worked very closely with the previous POI. In fact, he is still my supervisor so we have daily contact with each other.

MS. MILLS: Would you describe the organizational structure of the FSDO as it relates to USAir, please?

THE WITNESS: We're what's called a CMU, Certificate Management Unit. My supervisor is the CMU Supervisor. Under him are three principals and I'm the principal for the operations area. I manage two different sections. I have the eight APM's in one section that are my technical experts on each piece of equipment. Then I have an assistant shop made up of three inspectors and they help me deal with all the paperwork aspects, passenger complaints, certificate actions and all the other type paperwork that goes on with this type of management.

In addition to that, our office has a Cabin Safety Specialist. She is not assigned to me, but she spends 80 to 90 percent of her time on USAir.

MS. MILLS: Who bears the -- well, first off, are all of your APM's type rated on the equipment that they are assigned to?

THE WITNESS: That's correct. They're not only type rated. They have all gone through the entire USAir training program.

MS. MILLS: Are they current?

THE WITNESS: That's correct.

MS. MILLS: And who bears the expense of the currency?

THE WITNESS: Their -- it's mixed. Whenever an air carrier gets into a program like this the air carrier takes responsibility for some of the training costs. In the case of the APM's, the majority of their training is covered by USAir. In the case of the assistants, the majority of their training is covered by the FAA.

MS. MILLS: And who is responsible for the oversight of the APM's?

THE WITNESS: I am.

MS. MILLS: And are there any APM's based in Charlotte?

THE WITNESS: No, there are not. Can I explain that maybe a little bit? On the 737-300 and -400, because of the size of the size of the program we have two APM's. One of them I have tasked with the responsibility of the Charlotte operation and one of them with the Pittsburgh operation, so I do have an APM -- in fact, two APM's that spend a large percentage of their time in Charlotte, but they're not based in Charlotte.

MS. MILLS: And what are -- excuse me. You said that.

What is the purpose of a check airman evaluation?

THE WITNESS: You're talking about the new check airman checkout? Is that what you mean?

MS. MILLS: I'm sorry. Yes, as a new check airman. When the company comes to you and wants to designate someone, how is that accomplished?

THE WITNESS: They come to us and say we want to designate this particular individual as a check airman. We then go through a process with them, and it's a step-by-step process.

The first step is a training ride in the simulator where the APM would be there with the check airman watching them conduct their training. The second ride would be a ride in the simulator where the check airman is actually conducting a checkride, and they would observe the check airman conduct that checkride. The third activity would be out on the line doing a line check where the APM would watch the check airman conduct a line check.

MS. MILLS: What would cause an inspector to refuse to designate a check airman?

THE WITNESS: Well, first of all, on the first ride, based upon performance. If the check airman's performance was not up to standards, then further training would be discontinued at that point. Secondly, when they come in to give their check, the APM would watch them do the check, watch them do the debriefing after the checkride and evaluate them based upon that. And they would have to go through that step before they got to the line.

So, it's an evaluation, really, in all three area.

MS. MILLS: Are the APM's responsible to monitor and analyze the in-route inspection program?

THE WITNESS: Yes. They do that on their own piece of equipment. The assistants in the office also go out and to that, as well. And when you look at the total surveillance program on USAir, you'll see that about half of it is done by operations inspectors from the Pittsburgh Office. The other half is done by geographic inspectors across the country. So, it's a combination.

MS. MILLS: Do you or the APM's prepare an annual in-route inspection trend analysis report?

THE WITNESS: Yes. That's prepared on a quarterly basis.

MS. MILLS: Do you provide this report to USAir?

THE WITNESS: Yes. What we do as we get these reports in, these reports are basically inspector opinions. You're familiar with the form that they use. They write their opinions down and sometimes they type them in. Sometimes they're typed by administrative people in the office. Therefore, on occasion, there's a typo or their opinion is not real clear.

I have one of my assistants review every write-up that comes in the office. If they need to call the inspector that made the write-up, then they call the inspector to clarify exactly what went on.

Based upon that, if there's immediate action needed, then we take immediate action with the carrier and follow up on it right away. If it's a valid write-up, though, and it doesn't require immediate action or, say an inspector was out there and debriefed the crew member and said that was adequate, then at that point we would put it in that quarterly report and give it to USAir during our quarterly safety meeting.

MS. MILLS: It sounds like you're speaking of the individual reports, as far as looking at them one by one and addressing the inspector's individual write-up. Do you collect these and look at them together and see if there's any kind of trend?

THE WITNESS: That's correct. What I'm saying is that that's what I deal with. I deal with the trends. I don't deal with the individual activities unless they're very serious. My assistant deals with that.

We get a printout of each area on there and then we take a look at any trend items.

MS. MILLS: Are these reports showing any kind of trend?

THE WITNESS: The number one trend that we see on a report like this -- let me say -- let me backtrack a little bit a say what we're looking for.

There are three main areas that we look for. The first main area that we look for is noncompliance with the FAR's. That's extremely serious. There have been no trends in that area. When there is a situation where there's noncompliance with an FAR, I make a call to USAir and they make corrective action immediately.

So there are no overall trends. It's just here and there we might see something or the carrier itself might see something and let me know through the self-disclosure program. Noncompliance with the regulations just has not been a problem at USAir, not as far as a trend is concerned.

The second area we're concerned about is the training program. Again, as far as this data that's coming in, there have not been trends as far as the training program is concerned. There have been individual events that have come in. When an individual event comes in or even a recommendation comes in that the training program could be improved, then I immediately go to the Director of Training and talk to the Director of Training about this area.

The third area that we look at is complying with

USAir procedures. Now, this is a different type of area. If you would take your NTSB hat off and I were to take my FAA hat off, we could probably spend the rest of the day talking about our flying experiences and areas that we have had problems in and lessons that we've learned form that. USAir is no different from any other carrier. There are examples out there of pilots who have not complied with procedures. We get those in. We did almost 3,000 inspections, surveillance activities on USAir last year. Obviously, on occasion, we see those. That shows up as a trend area. It's an area that I take very seriously. It's an area that I go to the carrier on on a very regular basis.

Now, there's different levels of what we see. In some cases, it's a minor level where an inspector out in the jump seat sees something, debriefs the crew, thinks it's adequate and turns in the PTRS. In other cases it's more substantial and we take additional action. But that's basically the surveillance program that we have in place.

MS. MILLS: Have you shared this trend towards lack of adherence to USAir procedures with USAir?

THE WITNESS: Yes.

MS. MILLS: And what have they done to reverse this trend?

THE WITNESS: Well, we do something that's very unique. I think we're probably the only office that does this within the FAA. We have a program with USAir's Safety Department where we do assessments of USAir. We started this about three years ago.

What I did at that point is I went to the Director of Safety and invited the Director of Safety and his people to come in with us in our office and take two weeks and do an assessment of certain training programs within USAir.

It's compliance through partnership. It works really well. This year when I saw a trend in procedures, I sat down with the Director of Safety, George Snyder, and I said, "George, I think we ought to take a look at this area, because we know we're going to see this. I've called other POI's. I know other POI's see this within their carrier. But if there's any way we can help in this, then we should be doing that." And the Director of Safety agreed.

We had this assessment in May and we looked -- this whole assessment was focused on standardization and compliance with procedures.

Now, you're aware of USAir's Altitude Awareness Program of about three years ago. The Altitude Awareness Program, when we began this program, which was a partnership program with ALPA, the company and the FAA, USAir was having three to four altitude deviations per month. Right now they are under a half a deviation per month. The program was a major success. It was industry, labor and government coming together to solve a problem.

When we went out in May and took a look at compliance with procedures, it was pretty striking what we saw because we saw across the board compliance with Altitude Awareness procedures and we realized how effective that program had been.

We saw other procedures, though, that weren't being complied with and immediately after this assessment, we sat down with ALPA and the company and said, "We know how to fix this. We've already done it through Altitude Awareness." And we've established a program now. It's in process of development. Some aspects of it are already taking place as we speak to use the same principles as we used for Altitude Awareness and deal with overall procedures at USAir.

MS. MILLS: This information has come from your observations and the observations of other FAA inspectors on the jumpseat and in-route inspections. Is that correct?

THE WITNESS: That is correct. That's where the trend came from. Yes.

MS. MILLS: Could you share with us possibly a percentage? You said there was roughly 3,000 in-route inspections or cockpit jumpseat inspections last year. Were briefings one of these procedures that was a matter of question?

THE WITNESS: That's correct.

MS. MILLS: Do you have any idea what percentage of them?

THE WITNESS: No, ma'am.

MS. MILLS: How about sterile cockpit?

THE WITNESS: I don't recall sterile cockpit being one of the areas that we looked at. We looked at standardized procedures as a whole. We looked at checklist procedures as a whole. We looked at altitude awareness and we looked at standardized callouts.

MS. MILLS: If you were to observe or one of your inspectors were to observe a pilot not complying with checklists or performing them the way you would expect during a checkride, would it be a satisfactory checkride?

THE WITNESS: It all depends on what it was. If it was a minor deviation from a procedure, it's probably a debriefing item. If it's not using the checklist at all, obviously it's unsatisfactory.

MS. MILLS: When FAA inspectors conduct in-route inspections, they occupy the cockpit jumpseat, do they not?

THE WITNESS: That's correct.

MS. MILLS: And the pilots should know obviously from that that they're able to see -- the FAA inspector is able to see what they do.

THE WITNESS: That's correct.

MS. MILLS: Why would the pilots not conform to their procedures when an FAA inspector is on the jumpseat?

THE WITNESS: That's a good question. You've been in the FAA. You've seen it yourself. I don't have an answer for you. Obviously we expect and we know the pilots are going to be on their best behavior when we are there, but things happen. In the course of almost 3,000 surveillances in a year, things happen. Events come up. And sometimes in the rush of doing business something minor gets missed.

MS. MILLS: Is it possible this occurs because they're not sufficiently aware of their own procedures?

THE WITNESS: I don't think -- you're asking me for a perception. I don't think that's the case. When I look at the material that's out there as far as procedures and the pilot's handbooks and things like that, I see good solid procedures. I don't think this is a case of pilots being unaware of what those procedures are.

MS. MILLS: Of those 3,000 or so in-route inspections, what percentage of them show some kind of procedural lapse on the part of the pilot?

THE WITNESS: I don't have those numbers with me. And it's not 3,000 in-route inspections. It's a total of almost 3,000 surveillance activities on USAir. Those are spread over several different categories.

MS. MILLS: Okay. So they're not all cockpit in-routes?

THE WITNESS: That's correct.

MS. MILLS: Okay.

THE WITNESS: Cockpit in-routes, 1,640.

MS. MILLS: Okay. Of that number, how many showed procedural lapse?

THE WITNESS: I don't have a number for you.

MS. MILLS: When I interviewed you in Pittsburgh right after the accident, you mentioned that there were different cultures within USAir and that there were variants in DC-9 crew standardization. Have you seen any change in that since we last spoke?

THE WITNESS: I'm not sure I've been out -- except for coming down here yesterday, I'm not sure I've been on an airplane since we spoke, so that -- no, I'm not in a position to comment on that.

MS. MILLS: Would you describe these different cultures for us, please?

THE WITNESS: I can. And maybe culture is the wrong word. As you heard in my opening comments, I spent a lot of time, three years, down in Brazil. I flew into primitive Indian tribes that were right out of the Stone Age. I've seen a lot of cultures. I probably use the word culture more than most people do, just because of my background.

Let me explain it to you in maybe a different way so you can understand what I mean.

USAir has a lot of different training programs. The DC-9 is one of the oldest training programs that USAir has. When you take a look at that program, there's an old philosophy that is incorporated in that program.

Now, when Captain Johnson put together the F-100 program a few years ago, Captain Johnson went down to Washington. He talked to all the experts on ATP. He went to other carriers. He incorporated a whole new philosophy into the F-100 training program. It's a much more highly standardized, if you will, philosophy. It's based upon pilot flying/pilot not flying responsibilities, much more so than the DC-9 is.

If you go out on the line and you fly on an F-100 and then you fly on the DC-9, you're going to see two different ways of doing business. I refer to that as two different cultures.

I have a lot of confidence in Captain Johnson. I'm counting no Captain Johnson. Captain Johnson is perhaps the individual within USAir that is the most knowledgeable in AQP. When I said it's going to take several to bring this all together, AQP is a long-term process. Eventually, though, AQP is going to take these cultures and mold them together so that you will not see this difference between one program and the next.

I'm not trying to say that the DC-9 program is unacceptable. I'm just saying it's different and it looks different and you see differences out on the line than you do with the F-100 program.

MS. MILLS: Well, then, explain what you said about the variance in DC-9 crew standardization.

THE WITNESS: I think that goes right along with the culture. If you have a program and a training program that is more highly standardized than another training program, then I think you're going to see the effect of that out on the line.

MS. MILLS: We interviewed Mr. Pushak, your DC-9 APM and he indicated that briefings were an emphasis item.

THE WITNESS: Briefings were what?

MS. MILLS: An emphasis item for him.

THE WITNESS: That's correct.

MS. MILLS: Why is that?

THE WITNESS: After we did our inspection in -- or our assessment in May and realized that there were some procedural problems out there, then we did an emphasis area in this. In fact, we do a newsletter, geographic newsletter out to the community, FAA community. And in that geographic newsletter we ask the inspectors across the country to look at this area and other areas that we had identified in this assessment, just so that they could follow up with the crews if they saw any problems in these areas.

MS. MILLS: And has this improved?

THE WITNESS: It's hard for me to give you an answer without any specific data in front of me. It's our intention next month to do another assessment on USAir and to do it with FAA inspectors. In fact, what we're going to do is we're going to bring in geographic inspectors from across the country at the different crew bases that USAir operates out of to combine with our office and take another in depth look at USAir.

In the meantime, what I can tell you is I've had APM's come to me after being over in the simulator and tell me that what they're seeing is they're seeing a greater awareness of this area on the part of the check airmen and that the briefings from the check airmen to the crew members are giving greater emphasis on this area.

MS. MILLS: Have you any other method of gaining feedback on this?

THE WITNESS: I'm not sure what you mean. I count on the surveillance of the inspectors across the country for my feedback.

MS. MILLS: Are you referring to, again, the PTRS reports?

THE WITNESS: Yes.

MS. MILLS: In the course of investigating this accident I reviewed the public record with regard to a previous accident. And one of the things that came up was that you participated in a couple of special inspections on USAir, one led by Mr. Laperra and another by a Mr. Dubis. Do you recall those?

THE WITNESS: I don't recall a special inspection by Mr. Laperra is a maintenance inspector. I wouldn't think I would have any inspection from him.

Let me -- after the merger, Mr. Dubis came in. Mr. Dubis is the POI for Delta. And he came in. I was part of that team. That team did an assessment of USAir shortly after the merger, basically, to look at the training program and standardization to make sure there were no standardization problems after the merger.

The year after that, we did another assessment. And I think it was in about the third year, then, that instead of doing a formal assessment like we had been, I was a POI then and that's when I approached USAir and got the Safety Department involved and did it on a less formal basis with a partnership program.

MS. MILLS: When you make or have made either a WPMS entry or PTRS entry, are your initials for that Delta Charlie Bravo?

THE WITNESS: No, they're not.

MS. MILLS: Okay. This inspection that Mr. Dubis conducted, were there any findings with regard to approach briefings?

THE WITNESS: I do not recall.

MS. MILLS: Was the content of USAir's computerized flight crew training records at issue?

THE WITNESS: I would not be surprised, but I cannot recall. You know, that was -- ma'am, that was only five years ago, but USAir is a different carrier now, five years later. I'm not sure that anything in that report has any bearing on USAir today.

MS. MILLS: If I were to conduct an audit of the computerized recordkeeping today, would I find remarks in the remarks section on the pilots?

THE WITNESS: Yes, ma'am.

MS. MILLS: Does the FAA's Air Transportation Inspector's Handbook require a record of what maneuvers are trained to proficiency during a proficiency check?

THE WITNESS: It requires a record. It's my personal opinion it does not require a record in the automated recordkeeping system and I do not believe that most carriers put that kind of information into their automated recordkeeping system.

The purpose of that is from a training program perspective. In other words, if your pilots -- if the carrier's pilots are having problems on a particular area, say any of the approaches, then the purpose of that would be to day, okay, X percent of the pilots are having problems on this approach, maybe 20 percent, but only 2 percent are having problems on this other type approach, so that you can have a fluid training program and change it to take into consideration where the pilot problems are.

MS. MILLS: If you were conducting a training event or a proficiency check on a pilot that had difficulty for let's say executing a V-1 cut -- no, let me rephrase that.

Let's say a rejected takeoff, something that he wouldn't hopefully practice on the line very much, and the inspector or check airman found himself training this captain to proficiency in this area. There's no record of this is what you're saying?

THE WITNESS: It's basically a train to proficiency. The record then would be put directly into USAir's computer system and it would be de-identified.

MS. MILLS: So if this individual comes back in six months and still has difficulty with this, the check airman that sees him the next time has no idea that he had difficulty with it before and there may be some underlying problem?

THE WITNESS: That's correct, ma'am.

MS. MILLS: Would you turn to Exhibit 2-K, please, page 10? And this exhibit is a copy of a portion of the National Safety Inspection Program or NASIP, that was performed in 1993 on USAir.

THE WITNESS: What page, ma'am?

MS. MILLS: 10. Finding 1.4.1 states that a review of the past 90- day source documents revealed that the USAir pilot training record system did not properly document accomplish of recurrent windshear training for 51 pilot crew members.

How did you respond to this?

THE WITNESS: That's not showing up on my page 10.

MS. MILLS: Oh, look down in the lower right-hand corner, those page numbers.

THE WITNESS: Oh, okay.

CHAIRMAN HAMMERSCHMIDT: Let's give the witness time to focus on that, first.

(Pause.)

MS. MILLS: We're at the same place?

THE WITNESS: Yes. I see it now.

MS. MILLS: Okay.

THE WITNESS: As I reviewed this after the team had left, what I realized this was administrative in nature. The form that's being referred to here was designed prior to windshear coming into effect. That form had spaces on it for things like V-1 cuts and the approaches. It did not have windshear listed on the form.

Some of the check airmen would write windshear in on this form. This was not a form that the check airmen took into the simulator with them. It was a form that they filled out after they came out of the simulator.

Personally, I had never told USAir that they had to write windshear on that form because of the way the automated recordkeeping system worked. This form, when the check airman was finished with it, would go directly to a computer inputer. If the top of that form was signed off as complete with an hour indication in there, it was put into the automated recordkeeping system as a complete ride. The computer inputer did not look down through this form to see if windshear or any other thing had been checked off properly.

I viewed this as a standardization problem within the check airman group and that the word hadn't gotten out to them properly. Now, I wasn't in there for any of these 51 rides, so I cannot state whether windshear did or did not occur. But when I reviewed this, that was my perception of what was happening.

MS. MILLS: Did you follow-up and interview any of the check airmen?

THE WITNESS: I asked the team to follow up, and if in fact windshear was not being accomplished, to come back and let me know. And they did not come back and say that their follow-up had indicated that windshear was not being accomplished.

MS. MILLS: The team meaning?

THE WITNESS: The NASIP team.

MS. MILLS: Hadn't the team disbanded?

THE WITNESS: Before this went in writing, the team came to me and talked to me about this area and I asked them at that point to follow up on this and see if in fact windshear was not being accomplished. And as you know, later on in the report somewhere they had an example of one case where it was not accomplished.

MS. MILLS: I believe that's Finding 1.3.6, page 8 of the same --

THE WITNESS: Would you like me to comment on that?

MS. MILLS: Well, what I'm concerned about or curious about was the check airman in question here. Did this check airman appear on any of the 51 entries?

THE WITNESS: I don't believe so, but I'm not sure.

MS. MILLS: But you didn't check?

THE WITNESS: No.

MS. MILLS: Did you follow-up -- probably for the best purposes here, I should read this.

Finding 1.3.6 states: On March 12th, 1993 a team member observed a simulator proficiency training period with two captains receiving training. Only one captain was given windshear training, contrary to FOTM 2-4-112 an FAR's 121.404(b) and 121.427(a)(d)(1). The training was indicated as complete on USAir Form OF32.

And what was the outcome of this finding? How did you address this?

THE WITNESS: The inspector that was there at the SIM session came to me and told what had happened. Basically, this particular check airman had given windshear to one of the captains that was in the SIM and had forgotten to give it to the other one. When the inspector debriefed the check airman on this, the two crew members had already left the building. And the next day, I believe, the inspector went back and checked the records and found out that the check airman had actually changed the form and had signed the pilot off without the pilot coming back and doing windshear.

As soon as I found that out, I called USAir, the Flight Manager, and I told the Flight Manager exactly what the inspector had told me. And the Flight Manager immediately called the check airman in. The check airman confirmed to him what he had done. His check airman status was immediately removed and USAir took the captain that did not have the windshear, kept him from flying the line, brought him back into the simulator and conducted windshear training with the captain.

MS. MILLS: Has this happened since?

THE WITNESS: Ma'am?

MS. MILLS: Has this happened again?

THE WITNESS: No, ma'am. Not to the best of my knowledge anyway.

MS. MILLS: Excuse me a second.

(Pause.)

Did you follow up and check into any of this check airman's previous checkride candidates or students to see that they had gotten the training also?

THE WITNESS: As I talked with the Flight Manager and as the Flight Manager talked to this particular check airman, we were convinced that this was a one-time deal. This was not a bad check airman. This was a check airman that had made a mistake.

The real problem we had with this check airman was after he made the mistake, instead of correcting it properly by getting a hold of this pilot and bringing him back, he went ahead and signed off the training as complete. That is unacceptable.

If this check airman had called the Flight Manager and had called this pilot back, then probably the action that was taken would not have been taken.

MS. MILLS: But you're not sure if this check airman conducted any of the 51 checks noted in Finding 1.4.1?

THE WITNESS: No, ma'am. I was not there for the checkrides and I can't state for certain what happened in the SIM when I'm not there.

MS. MILLS: But in reviewing these 51 checks, there is some kind of identification number that shows who conducted those checkrides. Is that not correct?

THE WITNESS: That's correct.

MS. MILLS: And did you take that identification number and compare it with that of the check airman that was removed to determine whether or not this person fell into this group?

THE WITNESS: No, ma'am.

MS. MILLS: Have you put any procedures in place to ensure that this does not reoccur?

THE WITNESS: I'm not sure how you ensure that. If a check airman -- I think yesterday I heard the USAir pilot group referred to as a professional group. The check airmen are the best of that group. If a check airman chooses to pencil whip something, I'm not sure how we're ever going to find that. The only thing we can do as the FAA is be there and observe the check airmen on a very regular basis.

We, -- in the last year, you heard there are 187 USAir check airmen. We did 384 observations of the check airmen group. So we do much more than is required as far as check airmen observations and we have a pretty good feel for the quality of people that we're dealing with.

This is a quality group. This isn't a group that's out there pencil whipping training.

MS. MILLS: Okay. Let's shift our attention to windshear training. Has the FAA themselves provided you with any windshear training?

THE WITNESS: Has the FAA provided me? Ma'am, I don't get training any more. I'm a supervisor. The FAA position is that due to the constraints on the budget to put the training with the APM's and the others that are using it on a daily basis and I get supervisory training and management training. I wish I got technical training but I do not.

MS. MILLS: But you approve the training programs?

THE WITNESS: My predecessor approved the windshear training program. I do approve all of USAir's training programs. That is correct.

MS. MILLS: The APM's, does the windshear training that they get, is that provided by the FAA or by the carrier?

THE WITNESS: That is provided by the carrier. Maybe I should explain what's happened initially as far as the windshear program is concerned because it's unprecedented what happened.

My predecessor, Jim Rapucci, when this windshear training program came out, went to the FAA Academy at Oklahoma City for four days just on windshear. And at that point, all of the materials, the advisory circular, all of the materials and videos were gone over in detail.

When he came back from that training program he then went to the carrier and shared all this information with the carrier. And then, based upon that, the carrier put together the windshear program, the formal windshear program, even though they had been doing windshear prior to that. And that approval took place, I believe in September of 1990.

MS. MILLS: How does USAir evaluate pilots' knowledge of windshear avoidance?

THE WITNESS: I missed the last part of that question.

MS. MILLS: How does -- one more time. I'm sorry. How does USAir evaluate pilot knowledge of windshear avoidance?

THE WITNESS: Well, if you'd seen some of the test questions, you'd know that they ask questions on that. It's a video presentation. If you really look at the ground school material, it's all the way through the ground school material. If you look in the Flight Crew View, it's from one end of the Flight Crew View to the other. It's 50 pages, I believe, of windshear training that stresses avoidance. So their whole ground school program stresses avoidance.

How do you test that? I don't know. I don't have the answer to that.

MS. MILLS: Does the FAA provide air carriers any guidance to develop simulator scenarios that cause pilots to delay or to divert an avoid a windshear?

THE WITNESS: USAir has a LOFT Committee. One of the APM's from the office I've assigned to be a member of that LOFT Committee. So, as USAir is developing their LOFTs, we are working directly with the carrier in this regard.

MS. MILLS: Are you familiar with terminal Doppler weather radar? TDWR?

THE WITNESS: I've read about it in the newspaper, ma'am. I don't have the in depth level of expertise in that area. No.

MS. MILLS: Has the FAA provided any guidance to the air carriers concerning TDWR?

THE WITNESS: No. I can't say for certain. We get documentation from Washington in our office all the time. One of my assistants keeps track of all the documentation that comes in because a lot of it is marked to go to the carriers, so we keep a complete record in the office of what's sent over to the carriers. But this is -- we send information to the carrier on a very regular basis and I don't keep track of all that.

MS. MILLS: TDWR is up and operational in Denver and Houston and if I'm not mistaken, USAir goes to Denver and Houston?

THE WITNESS: Yes, ma'am.

MS. MILLS: So, TDWR would affect the operation of the aircraft, I would assume?

THE WITNESS: Yes, ma'am.

MS. MILLS: What guidance is provided to the pilots as far as TDWR in those two airports?

THE WITNESS: I would have to go to my technical experts, my APM's and find out from them more on this area.

MS. MILLS: Okay. I think I'm done.

MS. MILLS: I have no further questions. Thank you.

CHAIRMAN HAMMERSCHMIDT: Thank you, Ms. Mills.

Mr. Bowden has offered to go to his technical experts. Is that something we would wish to request for the record to get an answer on that post-hearing?

MS. MILLS: That's acceptable.

CHAIRMAN HAMMERSCHMIDT: Okay. If you could, please.

Mr. Feith?

MR. FEITH: Thank you.

Just a few questions for clarification.

With respect to in-route inspections conducted by geographical inspectors and their reports that are entered into the PTRS, how are you made aware of those in-route inspections?

THE WITNESS: By computer.

MR. FEITH: Do you routinely pull those up?

THE WITNESS: That's correct.

MR. FEITH: How often?

THE WITNESS: I believe they come in pretty much on a daily basis.

MR. FEITH: So, of the 1640 some odd in-route inspections, you have reviewed all of those at one time during the course of the year?

THE WITNESS: My assistant reviewed every PTRS that comes in the office. That is correct.

MR. FEITH: Do you ever have any direct communication with those geographic inspectors that have conducted those in-routes?

THE WITNESS: Absolutely.

MR. FEITH: And any corrective action that may be taken based on a review of those PTRS records and when you have identified a problem and gone to USAir, how do you document it and then how do you follow it up to determine if corrective action has been taken?

THE WITNESS: Well, it all depends on the situation.

MR. FEITH: Given the fact that some of the PTRS information has identified on several occasions that there were improper or unconducted briefings, crew briefings that's been written up. If it's brought to your attention, how would you approach USAir with a situation like that and then follow it up to make sure that they've taken corrective action?

THE WITNESS: What we would do is we would lump this together with all the other areas for the quarterly safety meeting. And when we go to that quarterly safety meeting, not only do we take each individual write-up with us, but we also would take trends with us, as well. And if it's -- you're talking about -- I'm assuming, anyway, you're talking about very minor areas that an inspector would see out on the line that the inspector would then debrief with the crew and would sign it off with no further action required.

These would all be put together and would show the carrier that there may be a trend developing in that area. It would then be up to the carrier to assume the responsibility for correcting that.

MR. FEITH: And you stated that in your May assessment of the carrier you identified problems, briefings and et cetera. Were the problems also identified? Where you able to compare those to the NASIP inspection? Did you see a trend there?

THE WITNESS: I think the NASIP inspection really zeroes in on other areas. The first priority on the NASIP inspection is to look for noncompliance with the regulations. If you look at this report, what you'll find within the report is no cases of noncompliance with the regulations.

Now, most of the write-ups in the NASIP report are examples of possible standardization issues. So if you want to draw a parallel there, you could. But the areas we looked at were really quite different from the areas that the NASIP team looked at.

MR. FEITH: Would you not consider that if there is a trend where briefings are either incomplete or not being conducted that there isn't a standardization problem with that?

THE WITNESS: I would state that any time a pilot does not comply with any procedure that I'm deeply concerned about that.

MR. FEITH: And you made a comment that you intend to do another assessment of USAir next month. What is the motivation? Was that pre-planned or is that based on the fact that the accident involving 1016 occurred?

THE WITNESS: No. That was based upon our assessment of May. Basically, based upon our assessment in May, we have been encouraging the carrier to advance into AQP just as quickly as possible. And also we have informed the carrier that we're going to do more follow-up assessments to review this whole area to make sure that the corrections that we're working on as a partnership approach are in fact taking place.

MR. FEITH: Can you summarize basically how much time you actually spend with the carrier physically, either on the property or in communication with them at any length other than a brief phone call? On a weekly or monthly basis, how much time do you spend with them?

THE WITNESS: That's hard to say. They would probably say they see me too much. Our job is compliance and if something's not in compliance, I'm going to be talking with them and they know that. I will say this. I deal with the Senior Director of Flight Operations. I deal with the Director of Safety. I deal with the Director of Training. I deal with the Vice President of Flying. Basically, I have an open door policy with them.

I go over there for meetings on a regular basis. I'm over there probably two or three times a week. I'm on the phone to them almost every day. In fact, it's a relationship where when they see noncompliance out on the line and there are incidents out on the line that I'm not aware of, they call me and they let me know about it.

So, it's a very open relationship and they are extremely concerned, like I am, with any noncompliance that happens out on the line.

MR. FEITH: Given the fact that this relationship exists, can you just characterize then what their response is or how they respond when you take issues to them that need either immediate or near future corrective action? Are they very responsive or does it take prompting to get change made?

THE WITNESS: Extremely responsive. I have seen USAir pull a line pilot off the line at a remote station just because they want to make sure they stay in compliance.

MR. FEITH: If I remember correctly, you've been the POI for three years?

THE WITNESS: Almost four now.

MR. FEITH: Okay. And in previous testimony, considering the fact that you stated that you've seen a change, "This is a changed airline today than it was five years ago," can you characterize or compare that difference? What was the airline like five years ago versus now?

THE WITNESS: I think maybe I can do it best with an example. After a major merger, and this was a major merger, you would expect to see some standardization problems. For a little while there was a north way of doing business and a south way of doing business. And the Flight Manager and management team at USAir addressed this promptly. We addressed it and we worked on it together.

This Summer I did an in-route inspection and when I got to the jetway I met the crew. It was a 737-300. The captain was based out of Charlotte, was former Piedmont. The first officer was based out of Philly, was former USAir. And this was the first trip that they had had together.

So, with this in mind, I didn't say anything to them but kept my eyes wide open to see what was going to happen in the cockpit. What I saw was a crew that appeared to have been working together for the last five years. Everything they did was 100 percent standardized. There was no Piedmont or USAir. It was just a way of doing business in the cockpit.

After the flight, after I commended them on their performance, we got into a discussion of the merger and what's happening, and I asked them how often they fly with people from other crew bases and it's only a couple of times a year, they said. So I asked them what the standardization was and if they were seeing problems. And they admitted that for a year or two there had been some difference but they stated to me that this has gone. It's one airline now.

MR. FEITH: And going back to a previous comment that you made that your predecessor had approved the windshear program, considering the fact that you are now the POI, it's your responsibility then to approve any new program or any modification to an existing program?

THE WITNESS: That's correct.

MR. FEITH: Given this and your familiarity with the airline, can you just characterize briefly your perceptions of the CRM program at USAir?

THE WITNESS: Yes. It was a well designed program. I did attend the initial stages of this program. I did work with USAir as they put together the recurrent LOFT Program, which I think is an exceptional program.

You heard yesterday how that this is -- this is training that's over and above what the FAA mandates and it's costing the carrier a lot of money. There's no question about that. Bringing in every first officer when they don't have to bring first officers in. So, I'm very pleased with their CRM training program.

MR. FEITH: Just several more questions.

Given your explanation, characterization, of the CRM program, and given the fact that the FAA sets a minimum standard, how would you characterize USAir's compliance with the regulations? Do they comply with the regulations or do they exceed it -- their compliance? Do they go above and beyond?

THE WITNESS: Well, that's kind of a general question. They comply with the regulations and they're very sensitive about the regulations. Any time I talk to any of the operations people about a possibility of noncompliance, they are very concerned and immediate action takes place.

MR. FEITH: As far as the APM's are concerned, do you provide or does the FAA provide standards or guidance with regard to evaluating the effects of training, such as windshear? I mean, how does an APM go in and effectively evaluate that program to see if the training is actually doing what it's intended to do?

THE WITNESS: Well, the APM's are in there on a regular basis. The APM's that I have are a really highly experienced group. One of my APM's has spent 20-some years with Continental Airlines, is well-versed in this whole area. All the APM's are highly trained, highly experienced.

They're in there watching the check airmen. They're watching checkrides on a very regular basis. They see windshear on a very regular basis.

Initially, back in 1990 our role was to go into the simulator and look at each different scenario that USAir operated and evaluate all of them, so that now what they would be doing is they'd be spot checking. Every time they happen to watch a training event that had windshear as part of it, they would do another evaluation of windshear.

Let me say that other than the administrative areas that have been addressed today, I've never had an inspector come to me with any criticism of USAir's windshear program.

MR. FEITH: And one last question. Given the fact of the recent accident at USAir, what changes, if any, have you made in your surveillance of the carrier or guidance provided to your APM's? Have you changed any procedures in the way you look at USAir?

THE WITNESS: That's a hard question to answer. On the one hand, I'm coming here from an office that's under stress. The last week and a half has been tough for us in

Pittsburgh. We are watching USAir.

On the other hand, we're waiting to see what the cause of this accident is. We're also waiting to see what the cause is of the accident in Pittsburgh. Until we have that data, it is very difficult for us to know what direction to go in. But we already have several months ago put a geographic newsletter out to the FAA community on some of these areas and obviously, every time we do surveillance on USAir, we're doing very in depth and high quality surveillance.

MR. FEITH: Thank you, Mr. Bowden.

I have no further questions, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Feith.

We've gone about an hour and 40 minutes since our original time, so to try to eliminate any undue stress, why don't we take about a 10 or 15 minutes break.

Thank you.

(Whereupon, a recess was taken.)

CHAIRMAN HAMMERSCHMIDT: Back on the record.

Let's please come to order.

Mr. David Bowden is still at the witness table. Let me remind you, Mr. Bowden, you are still under oath, and we will proceed with the questioning by the parties.

National Air Traffic Controllers Association, any questions?

MR. PARHAM: Yes, sir, Mr. Chairman. I just have a couple.

Mr. Bowden, do ATC pilot deviations come to you for enforcement action?

THE WITNESS: That's correct.

MR. PARHAM: How many deviations have you had in the last -- well, since you became POI?

THE WITNESS: Gee, I can't tell you a number. As I said before, it's much less now than it used to be.

MR. PARHAM: Have you detected any trends in the nature of these deviations?

THE WITNESS: Well, there's been a substantial downward trend as far as USAir is concerned. I'm trying to think off the top of my head when was the last one that we had to deal with in the office, and as far as I can tell you off the top of my head, it's been several months since we've had to deal with one in our office.

MR. PARHAM: Does your office have any dialogue with the FAA Air Traffic Division in which you discuss procedural problems that may be inherent to the handling of traffic in particularly the large U.S. hub areas?

THE WITNESS: Yes, sir. On our PTRS form that's been referred to there is a section on there for ATC. And obviously, when we go out and do an in-route inspection, I know the pilot perception is we're there to give them a checkride. We're there to do more than that. We're there to look at the system as a whole.

So, therefore, if we see problems as far as ATC is concerned, there is a code that we can use to record that. And then my assistant gets all that information and my assistant would then deal with that.

MR. PARHAM: Do you know if you've detected any major problems?

THE WITNESS: I have not seen anything that would indicate a trend in that area. No.

MR. PARHAM: All right. Earlier you had mentioned the Altitude Awareness Program. Do you know why the program was discontinued or not renewed? And if so, who made that decision?

THE WITNESS: Well, my own opinion is that we worked together and we solved the problem, and once you solve the problem, you move on to new problems. That's my opinion of what's happened.

MR. PARHAM: Do you think the information gained through this program was positive to improve and enhance the pilot in ATC techniques and procedures?

THE WITNESS: Absolutely. Any time you go from three to four altitude deviations per month to less than half a one per month, you have made a substantial improvement and it impacts on safety.

MR. PARHAM: I would agree with that.

Do you think that the FAR's should be modified to allow such a progressive and beneficial program to be instituted with all Part 121 air carriers and 135 computer operations?

THE WITNESS: Well, I think if you look at what's happening, I've personally had meeting with other carriers. Several of the other carriers have adopted not only the Altitude Awareness Program itself but this whole way of doing business.

MR. PARHAM: Thank you, Mr. Bowden.

Mr. Chairman, I have no further questions.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Parham.

Honeywell?

MR. THOMAS: No questions. Thank you.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Thomas.

Airline Pilots Association?

MR. TULLY: Thank you. No questions.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Tully.

USAir?

MR. SHARP: We just have one question, Mr.

Chairman.

MR. SHARP: Mr. Bowden, there has been mention of some differences between the DC-9 and the F-100 training program. Isn't it true that at USAir the DC-9 training program is a fully approved training program and receives exactly the same surveillance that any other program does at USAir?

THE WITNESS: That's correct. In fact, as far as surveillance is concerned, I would say the numbers would indicate it receives more surveillance than some of the other training programs. But that is a correct statement.

MR. SHARP: Okay. That's all we have, Mr. Chairman. Thank you.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Sharp.

Douglas Aircraft Company?

MR. LUND: No questions, Mr. Chairman. Thank you.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Lund.

Pratt and Whitney?

MR. YOUNG: No questions.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Young.

Association of Flight Attendants?

MS. GILMER: Yes. Thank you.

Mr. Bowden, prior to September of last year, flight attendants had the responsibility of taking a head count of passengers in the cabin. That procedures changed. It's a computerized system, of course, except for our 757 and 767's.

Are you satisfied that the passenger count that the pilots receive in the cockpit is accurate with this new change in procedure?

THE WITNESS: I've had some concerns with this new procedure. I've expressed that to the carrier. As you're aware, the pilots for the most part still ask the flight attendants to conduct a count and each captain can do that. Ultimately it's up to the captain to be assured that that count is correct because that impacts weight and balance for the airplane, so most captains are having the flight attendants continue on with the count.

We have done surveillance on this. We have seen an occasional problem in this area but for the most part the counts that we see have been fairly accurate.

MS. GILMER: Okay. Thank you. And FAR 121.693(e) speaks to the carrier's responsibility for having the names of every passenger on board an aircraft on a manifest, not necessarily the flight attendant's manifest, and this includes children under the age of 2. Is it your feeling that USAir is in compliance with this FAR?

THE WITNESS: It's my understanding that the passenger count that the pilots are given deals with weight and balance. It was my perception that the carrier itself through the gate agents was keeping a complete list for a passenger manifest as required under the FAR.

MS. GILMER: Okay. Thank you.

Thank you, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: Thank you, Ms. Gilmer.

International Association of Machinists?

MR. GOGLIA: No questions, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Goglia.

Dispatchers Union?

MR. SCHUETZ: Mr. Chairman, my questions have been answered. Thank you very much.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Schuetz.

National Weather Service?

MR. KUESSNER: No questions.

CHAIRMAN HAMMERSCHMIDT: Okay. Thank you, Mr. Kuessner.

Federal Aviation Administration?

MR. DONNER: Thank you, Mr. Chairman. Just a couple of questions.

Dave, could you give us some information on the magnitude of the training program at USAir?

THE WITNESS: Well, it's really a university. It not only involves the pilots, it involves flight attendants and dispatchers, as well. That is a total of 15,000 employees. All of them receive training on an annual basis, so last time I counted it up, it included a total of somewhere around 130 approved programs. So it is a massive endeavor.

If you look at the magnitude also out on the line, USAir operates 2640 flights a day, almost a million flights a year, and so it's a huge operation.

MR. DONNER: I may have missed this, but how many FAA people do you have that report directly to you?

THE WITNESS: Eleven.

MR. DONNER: Eleven. On a different topic, on the PTRS forms that you talked about and the comment section specifically, typically why kind of information is put into that comment section with respect to limiting it to factual information?

THE WITNESS: Well, I have a real concern over this. The PTRS, initially when it was put out to inspectors, was to be inspector opinions. We were told, as such, they were not releasable outside of the FAA to the press or to any other group.

I rely completely on this information as far as trends are concerned and I'm extremely concerned now because the word is passing very quickly with inspectors that not only is the press requesting access to this information but groups like the NTSB are as well. And if I do not have this kind of information, it's going to be very hard for me to establish any kind of trends. I'm going to have to rely on an inspector picking up the telephone and giving me or my assistant a personal call.

MR. DONNER: What do you think would be the outcome of public release of this opinion information?

THE WITNESS: I think inspectors will stop writing up opinions.

MR. DONNER: Thank you. No further questions.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Donner.

Any other questions from the Technical Panel?

(No response.)

Okay. Mr. Laynor?

MR. LAYNOR: Just one, Mr. Bowden. You referred in your testimony about the information in the Flight Crew View article and it was established here yesterday that this long one on windshear came out ironically just before this accident.

Are you aware how frequent other articles in that publication have referred to the issue of microbursts and windshear?

THE WITNESS: I believe that USAir covers this pretty much on an annual basis. I would have to go back and verify that, but I get a copy of this each time it comes out myself and I'm pretty sure it comes out on an annual basis.

MR. LAYNOR: Perhaps I ought to ask USAir if he could provide any information other than the article that came out in June that might have been in the publication. It would be of interest to us.

MR. SHARP: Yes, sir. We'd be more than happy to make any information available we have to you. Normally, we try to approach those areas on a seasonal basis, like early in the Spring or late in the Winter -- March, those areas. We try to pick subjects that are going to apply to the coming season. But we'd be glad to provide you any information we have on that.

MR. LAYNOR: Okay. Thank you.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Laynor.

Mr. Clark?

MR. CLARK: I have no questions.

CHAIRMAN HAMMERSCHMIDT: Okay. Mr. Schleede?

MR. SCHLEEDE: Yes. A follow-up question about the passenger count. I think one of your answers was your surveillance, I think recent surveillance -- you said something to the effect for the most part the counts have been fairly accurate. Is that a fair characterization of your testimony?

THE WITNESS: That's correct.

MR. SCHLEEDE: Could you elaborate on that? What do you mean? I mean, is it 5 percent of the time the passenger count doesn't match the actual people on board, or --

THE WITNESS: Within the system right now, because the pilot's only concern would be weight and balance, the system would allow the pilot to take off if the passenger count is plus or minus 2. And I believe in the F-28, that's plus or minus one because of the size of the airplane. So, they do not have to have 100 percent accurate count to begin with.

I'm not sure if that answers your question or not.

MR. SCHLEEDE: Well, that answers that question. Did I understand that there had been a procedure by which the captain was required to get a count prior to takeoff and then that was rescinded?

THE WITNESS: No. There's still that procedure in there. The difference is it used to be a flight attendant responsibility to make that count.

MR. SCHLEEDE: And then to report it to the flight deck?

THE WITNESS: Yes. That's correct.

MR. SCHLEEDE: And that's not the case any more?

THE WITNESS: That's correct. The captain has to ask the flight attendants to do that. The procedure right now is for the gate agent to give the captain the count before the gate agent closes the door.

MR. SCHLEEDE: But does the gate agent actually do a head count in the cabin?

THE WITNESS: No. The gate agent does a ticket count.

MR. SCHLEEDE: Did you hear Captain Greenlee's testimony --

THE WITNESS: No. I came --

MR. SCHLEEDE: -- about this subject? I'm sorry.

THE WITNESS: No. I came this morning, during the morning, and I did not hear his testimony.

MR. SCHLEEDE: I believe his testimony was to the effect that he did it on occasion but it wasn't a requirement for him to get that information.

THE WITNESS: That would be correct.

MR. SCHLEEDE: Okay. Do you feel comfortable with that arrangement, that plus or minus 2 passengers aboard the airplane?

THE WITNESS: I feel comfortable with that. I have expressed my opinion to the carrier that I think the head count is a much better way to get the actual count on board the airplane versus counting tickets.

MR. SCHLEEDE: And this may be outside your area of responsibility, but how does this meet with the security regulations, requirements for airplane security?

THE WITNESS: I'm really not sure on that. I'm concerned with the weight and balance issue. And I would be concerned with an airplane that's taking off that is way out of weight and balance. And that would be my concern.

MR. SCHLEEDE: Do you know what the industry standard on this is for verifying passenger counts at other carriers?

THE WITNESS: Yes. When this carrier adopted this procedure, then I made several calls to some of the other POI's to find out what their policy was. In most cases, they allow takeoffs within 2 or 3, depending on the size of the airplane.

MR. SCHLEEDE: What guidance is there in the Air Carrier Inspector's Handbook regarding this, if any, this area of passenger count?

THE WITNESS: Well, I think we're talking about two different issues here. One, we're talking about the weight and balance issue that a captain deals with. The other one, we're talking about a regulation that deals with the passenger manifest. And I don't want to say anything concerning a carrier not having to comply with what the FAR's say concerning a manifest. This is a separate issue from that.

MR. SCHLEEDE: Well, that was the next question. Are you responsible for ensuring that the manifest list is accurate, including names? Is that something that --

THE WITNESS: That's correct. That's an issue that I don't see and I don't deal with on a very regular basis.

MR. SCHLEEDE: Why wouldn't that be under your purview if it's an operating rule?

THE WITNESS: If someone came to me and expressed some kind of a problem with that, I would look into that. But what I see is what happens in the cockpit. That's where our surveillance takes place.

MR. SCHLEEDE: And cabin is not under your area? The regulations pertaining --

THE WITNESS: Well, I'm not saying that. I'm saying as far as the count is concerned. We're dealing in the airplane itself.

Now, the count that you're talking about as far as the passenger manifest is concerned is taking place at the gate, so that is taking place after we depart on the airplane and we don't see that on a regular basis.

MR. SCHLEEDE: Does that count at the gate include lap children, unticketed infants?

THE WITNESS: I would assume that it should. If you believe this is a problem area, I can certainly take that home with me and check that out.

MR. SCHLEEDE: Well, we'll be evaluating it and looking into it further. I just wanted your views on this. I appreciate it.

I'd like to shift to another subject. The term -- I think it's compliance through partnership that you were speaking about?

THE WITNESS: Yes, sir.

MR. SCHLEEDE: I'd like to delve into that a little bit. How can we evaluate -- or this term, compliance through partnership, how can we ensure that this isn't really the FAA being in bed with the carrier?

THE WITNESS: Well, I think the key is not on the partnership but on the compliance. And as long as we stay focused on compliance, then I don't think there's any problems. I think on a national basis when you look at the magnitude of USAir, when you look at a training program that involves 15,000 individuals, when you look at one million flight operations per year, you look at my staff of 11 inspectors. You can see, without compliance through partnership, what kind of task I have on my hands.

I cannot follow up on every noncompliance that we find out there. I have to rely on the carrier to take that responsibility. And so, as far as I'm concerned, compliance through partnership works and we become very innovative in making it work in our office and we've done some very unique things with this.

MR. SCHLEEDE: You said something I'd like to follow up on. I'm a little concerned. You say you can't -- you're unable to follow up on all the compliance issues?

THE WITNESS: If you look at the nitty-gritty aspects that we deal with on a very regular basis, the minor issues that are involved, the trend areas that are involved, you'll see the need for more follow-up than what we can give.

Let me give you an example here. This is a pyramid system. We have designees that we deal with on a regular basis. The APM's work with them. The APM's train them on how to give type rating rides. And USAir has almost 200 check airmen. We work with them on a very regular basis. In addition to this, they have 5500 pilots out there.

We rely -- we focus our surveillance within our office on the APD's first, the check airmen second. Then, our surveillance out on the line is a spot check. We get a picture as we do surveillance out on the line of the whole system, the whole training program, but we do not even make an attempt to follow up with every individual pilot out on the line. That's beyond the scope of what we can do.

MR. SCHLEEDE: Who is responsible for ensuring compliance with the federal regulations, the airline or the FAA?

THE WITNESS: Well, the carrier is responsible for the highest levels of safety and we're responsible to make sure that the carrier is in compliance with the regulations.

MR. SCHLEEDE: How much of your responsibilities is delegated through the APM and designated check airman program?

THE WITNESS: Well, I think if you look at it staff wise, and I guess that's the only way I can break it down data wise, I have eight APM's and I have three administrative people. The three administrative people are those that are dealing with -- mostly with passenger complaints, with the noncompliance with the regulation issues. The APM's are dealing more on a proactive basis with the philosophy of compliance through partnership.

In other words, if you comply through partnership with this APM program, then hopefully you will not have noncompliance in the first place.

MR. SCHLEEDE: How many people -- you may have answered this. How many people do you have directly on the certificate on the operational side?

THE WITNESS: I have 11.

MR. SCHLEEDE: Eleven. Okay.

Sticking with this theme of compliance, I'd like to define this a little closer about what is really compliance or noncompliance. I believe in your testimony regarding Exhibit 2-K, the NASIP March 19th, 1993 National Safety Inspection of USAir, I believe I wrote down that you said there was no cases of noncompliance with the regulations.

Did I hear your statement correctly?

THE WITNESS: That's correct. I can explain that, if you'd like.

MR. SCHLEEDE: I'd like you to.

THE WITNESS: What the NASIP team does when they come in is they have three categories that they list things in, and it doesn't show up on the report. The first category would be noncompliance with the regulations. Then, as I've already explained, there'd be another category that deals with training issues, and there would be a third category that deals with noncompliance with company procedures.

So, when the NASIP team left they did not have any class one findings or findings that they considered to be noncompliance with the regulations.

MR. SCHLEEDE: Okay. Could I refer you to that Exhibit 2-K, please? And the first section would be page 8, lower right corner, or page 13 center.

And we've already discussed the Finding 1.3.6 regarding the two captains that received windshear training. One was signed off that really had not. Now, this Finding says, contrary to the OTM and FAR's -- a couple of FAR's, 121. My humble opinion, this is a violation of the regulations, noncompliance. But could you help me understand why that's not?

THE WITNESS: Okay. Sure. This could very easily have led to a noncompliance of regulations. If this captain had not been brought back and had not received that training, then you would have had a captain out there without this required training.

Now, the training program goes on a monthly schedule and I'm not sure if this captain was in the grace month or not, but the captain would have had until the end of the month or the end of the next month to complete this training requirement before it got into noncompliance with the regulations.

MR. SCHLEEDE: So, the fact that this training was not properly signed off or was in fact improperly signed off was not in violation of the training program and the approved training program?

THE WITNESS: Well, that's what put it down into another category because it dealt with the training program rather than with the noncompliance with the regulations.

MR. SCHLEEDE: But it cites regulations here that it says it's contrary to and I can't see the difference between. It's either in compliance or not in compliance. I don't understand that. Can you help me?

THE WITNESS: Well, I don't have the regulations here in front of me, so I can't -- I don't know what regulations that were used here. All I can tell you is the captain would not have been in noncompliance until the end of the captain's required training was to take place, which would at least have been the end of the month.

In this case, I know this particular captain came back, I believe the next day or at least within two days to complete the windshear training.

MR. SCHLEEDE: Also, to clarify this. I know you said that the initial anomaly was a mistake by the check airman. Then it became more significant when he signed the record off. I think you used the word this was unacceptable. Isn't it really a falsification of a record?

THE WITNESS: If you look at the FAR's when it comes to falsification of records, it's very clear on the maintenance side that that is noncompliance with the regulations. It is not that clear on the ops side that that is noncompliance with the regulations.

MR. SCHLEEDE: Well, I understand if a pilot on his medical certificate makes a false entry, I believe there are civil penalties and possibly other penalties involved. THE WITNESS: That is correct, because there is a specific regulation that deals with that.

MR. SCHLEEDE: But there isn't any specific regulation or anything in the training program itself that addresses -- I hate to use the word -- falsification of records?

THE WITNESS: I would need to do more research, but to the best of my knowledge, there is not.

MR. SCHLEEDE: Thank you. I'd like to move through this just to clarify a couple of other ones here, the same exhibit. Let's take page 11, lower right, or 16 in the center.

And I think I know the answer but Finding 1.4.6, records of eight pilots do not reflect completion of the required number of training hours described in the training manual for requalification training. And it references a couple of -- an FAR. Is this another case where this is still in compliance with the Regulations?

THE WITNESS: Well, the FAR itself does not list a minimum number of hours.

MR. SCHLEEDE: But the program, the approved program does list?

THE WITNESS: The program -- the way the program was written in the FOTM, on one page if you would read it, it would indicate that they needed a certain amount of training. On another page they had a philosophy listed there of "train to proficiency." So, it would in a gray area. And the corrective action on this one way to go ahead and make the corrections to the FOTM, to rewrite it, so that everybody know that it was a train to proficiency philosophy.

MR. SCHLEEDE: Okay. The next page I believe, page 18 in the center and 13 on the lower right, Finding 1.6.1 under the dispatch area. It says dispatcher's competency check expired May '90. Records show the next competency check was July 1990, contrary to another 121 rule. This individual had dispatched numerous flights on the two days.

Again, help me understand how this is not in noncompliance or is in compliance with the applicable rule.

THE WITNESS: We responded to each one of these and I cannot recall what the response was. I'm not sure if someone has that response that we made from the office here at the hearing, but off the top of my head, I'm not sure.

MR. SCHLEEDE: Okay. That's fair.

Page -- well, I think one more here. Page 19, lower center, and 14 on the lower right, at the bottom of the page, Finding 1.7.4. Do you have that?

It's 19 from the center. Yes. Finding 1.7.4. Two flights the crew did not maintain a sterile cockpit, and it references a 121 rule. Is this rule also in a gray area?

THE WITNESS: Oh, I don't think the sterile cockpit rule is a gray area. I think normally, though, when this takes place, and I know it did in these cases, it becomes a debriefing item rather than certificate action on the part of the pilots.

MR. SCHLEEDE: Help me understand how a clear rule such as this one that's not complied with is considered a debriefing item and not a clear violation of the regulations and a sanction issued.

THE WITNESS: Well, it is a clear violation of the regulations. When you have a violation of the regulations it does not mean you have to do a certificate action on it. We have a lot of tools that we can use. And basically the guidance from the FAA is to allow the inspector on the scene to have that discretion to go ahead and make those kind of calls as far as what action is required.

And we deal with things completely differently. There is no one set way that is best to deal with something. It depends upon the situation. It depends upon the severity of the situation.

When there's a deliberate act out there, obviously we're going to take certificate action. When there is a serious safety problem out there, we're going to take certificate action. If there's an inadvertent act, then there are other means we can use to maintain compliance and compliance is what we're looking for.

MR. SCHLEEDE: Well, if compliance is what you're looking for, why would this not be considered noncompliance if someone violates the sterile cockpit rule? I'm still not --

THE WITNESS: The question is what's going to happen next time and that's what we mean when we're talking about compliance.

Can I maybe give a little frustration with what you're talking about, the enforcement program?

MR. SCHLEEDE: Sure.

THE WITNESS: We have done, off the top of my head -- and I'd have to go back and look at the record. We've done three certificate actions this past year on three USAir crews that were very serious violations. That's a tool that we use and it's a tool that can be very effective. However, you are very aware of the NASA form.

If we cannot prove in front of a Law Judge that it was a deliberate act, then the pilot goes to the informal hearing, puts a copy of the NASA form down on the table, and that's the end of it. We have not -- my perception now. It's a very ineffective means of getting compliance in the future with this particular pilot.

In the last case, not only was it a very serious lack of use of the checklist, it also involved lying to ATC about the situation, which could have jeopardized the passengers on the flight. It involved an attempted coverup on the ground after the flight. At that point, not only did we take certificate action but we called for emergency revocation.

This was upheld by a Law Judge and it was the NTSB Board that overruled this and the FAA was forced to give these two pilots back their certificates. I don't consider that an effective means of compliance. What I prefer to do, because most pilots who have problems out on the line are out there trying to do their jobs. They get caught in a bad situation. If one pilot gets caught in a bad situation, probably there are a lot of other pilots out there that are doing the same thing on a regular basis.

My preference is to work with the Safety Department of USAir, to work with ALPA, to bring a pilot in, to sit down in a room with that pilot and find out why it happened. Once we find out why it happened, then the company and ALPA can get that word out to the whole pilot group.

I find that it's like a lightbulb going off inside the pilots' heads. They see what happened. They see the consequences of it and they don't let it happen to themselves again. Then USAir's entire pilot group learns from that experience.

We end up usually in a situation like this doing administration action on the pilots in exchange for them being willing to come in and open up and share with us. I find this a much more effective means of maintaining compliance.

MR. SCHLEEDE: Thank you very much for elaborating on that. In the same area, are you aware whether the pilots' organization for USAir has any kind of a professional standards committee?

THE WITNESS: I'm aware that they do have one. Yes.

MR. SCHLEEDE: Do you work with them at all, with that committee, pilots professional standards?

THE WITNESS: No. I normally work with the safety people in ALPA.

MR. SCHLEEDE: In ALPA. Okay.

THE WITNESS: Yes.

MR. SCHLEEDE: Thank you. I've got just a couple of other areas here.

Is the Director of Training position an approved position under the FAR's? Is it a required position under the FAR's and required qualifications?

THE WITNESS: I believe it is.

MR. SCHLEEDE: Did you approve the recent appointment of the Director of Training?

THE WITNESS: I wouldn't want to say I formally approved that appointment. You have to realize that in a 121 carrier like USAir, whenever you have someone coming out of the Training Department into a position like that, obviously they're going to far exceed the requirements that are set up by the FAA.

MR. SCHLEEDE: Are you aware of any special emphasis surveillance outside your office since this accident by the FAA, either regional or headquarters?

THE WITNESS: As I told you before, we have a -- we put out a geographic newsletter back this Summer requesting surveillance. Not requesting additional surveillance but requesting an emphasis in certain area. Our records indicate what resulted from this was increased surveillance on USAir.

We have a team coming in next month to do an assessment on USAir.

MR. SCHLEEDE: This is a national team?

THE WITNESS: This is a geographic inspectors -- probably five or six geographic inspectors to work with our inspectors to do surveillance on USAir. I have also requested that next Spring that a POI and APM's from a major carrier come on in to do a special assessment on USAir and on us and on me. If there's anything I'm missing, I want to know about that. If there's anything the APM's are missing, they want to know about it.

We're trying to do our jobs. We're trying to do it well. Sometimes, though, you get tunnel vision and we want to see if we can learn from another carrier and if there's anything for them to learn from working with us. So, we're going to do that next Spring.

MR. SCHLEEDE: I appreciate that answer but I was more interested in things that weren't initiated by you or your office that were initiated directly from the region or from headquarters FAA. Have there been any special emphasis teams or efforts unsolicited by you?

THE WITNESS: Not to the best of my knowledge. Now, I have briefed -- been involved in briefings up the chain within the FAA and my perception was they were very happy with the surveillance activities of our office and the directions that we're going to go in the future.

MR. SCHLEEDE: So you're not aware of any special teams that came out of headquarters or like a special team that has been in since July to look at USAir?

THE WITNESS: I'm only aware of the Department of Defense team that came in the Summer.

MR. SCHLEEDE: Okay. Thank you very much for your cooperation.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Schleede.

Mr. Bowden, I have just two brief rather generic questions for you.

CHAIRMAN HAMMERSCHMIDT: Question number 1. From your perspective as having served in the Principal

Operations Inspector role for USAir for, as you mentioned, almost past four years, would you say that the resources that your office has been given to accomplish its mission have been adequate? Not ideal, but adequate?

THE WITNESS: I would say with the philosophy of compliance through partnership, with the relationship that we have been able to maintain with this carrier, those are the reasons why it's adequate. If you take either one of those area away, then I would have to say it would not be adequate.

CHAIRMAN HAMMERSCHMIDT: Okay. Thank you.

Question number 2. Have you ever been advised or ben aware of any information from the public who may live in the vicinity of the Charlotte Airport who have expressed their thought that -- well, in your case it would be USAir flights have continued approaches to the airport and landed during times of obvious thunderstorm activity? That is, during the warm months, late afternoon peak traffic times, have you been aware of any public concern over that having happened or possibly having happened?

THE WITNESS: Here in Charlotte? I do not believe so.

CHAIRMAN HAMMERSCHMIDT: Okay. Thank you very much. And we thank you for your participation in the hearing. We know you're a very busy person these days and you may stand down. And Mr. Bowden, you may be released from the hearing.

THE WITNESS: Thank you.

(Witness excused.)

CHAIRMAN HAMMERSCHMIDT: Let's see. Let's proceed to our next witness, who is Mr. Robert Saffle.

Mr. Saffle, would you please come forward?

Mr. Saffle will be questioned by Mr. Greg Salottolo.

(Witness testimony continues on the next page.)

ROBERT SAFFLE, NWS EXPERT, NEXRAD, SILVER SPRING, MARYLAND

Whereupon,

ROBERT SAFFLE,

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

MR. SCHLEEDE: Mr. Saffle, could you give us your full name and business address for our record?

THE WITNESS: Robert Eugene Saffle, Silver Spring, Maryland.

MR. SCHLEEDE: And by whom are you employed?

THE WITNESS: The National Weather Service.

MR. SCHLEEDE: In what position?

THE WITNESS: I'm a meteorologist in the Advanced Development and Demonstration Laboratory.

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

THE WITNESS: I received a bachelor of science in mathematics in 1963. I spent four years in the U.S. Air Force as a meteorologist/forecaster. I've been employed by the National Weather Service since 1969. I have specialized over most of that period in digitized weather radar systems and the operational use of data from those systems.

MR. SCHLEEDE: Thank you very much.

Mr. Salottolo will proceed with the questioning.

MR. SALOTTOLO: Mr. Saffle, I wonder if you'd briefly describe the WSR-88D Doppler radar. You know, what it is, what it does, and compare it to the conventional radars.

THE WITNESS: Sure. The National Weather Service has operated a system of weather surveillance radars dating back to about 1957. That was the year the contract for the Raytheon systems was signed. In the late 1970's or mid to late '70s, research developments at National Severe Storms

Laboratory and other areas were pointing the way to the operational use of adding Doppler information, which is essentially the ability to measure the motion of precipitation toward and away from the radar to our operational capability.

The NEXRAD program is essentially an outgrowth of that research and development. I've been associated with that particular program since about 1983 and there's several main differences between the conventional radar systems and the NEXRAD or Doppler radar system.

First of all, of course, is the motion detecting capability due to the Doppler principle, but there are other very important differences, though. One is the resolution of the radar beam. The conventional 57 radars have a 2.2 degree beam width. The 88D, WSR-88D, which is the designation for the NEXRAD individual radars, has a beam resolution of .95 degrees and this is very significant to operational use in the ability to determine finer scale structures within thunderstorms.

Another big difference is the sensitivity of the WSR-88D. It's a much higher powered radar. That, combined with the fine resolution beam, gives us the ability to see smaller strength or lesser strength signatures associated with weather, with gust fronts, outflow boundaries, this kind of thing, very light snow or very light rainfall.

Another big difference, final chief difference, is the fact that the WSR-88D is an automated system. It combines a basic radar with very sophisticated computer processing capability and the WSR-57 did not have that capability. With the WSR-88D, we're able to utilize the basic radar data along with scientific algorithms to provide guidance to the forecaster in the form of hydrological and meteorological products.

MR. SALOTTOLO: Thank you. Could you give us an idea of the approximate number 88D radars that are out there right now?

THE WITNESS: We're scheduled to implement about 162. I believe that through August we were up in the 90's. We're currently implementing at the rate of four per month.

MR. SALOTTOLO: And do you have an approximate number of the 88D's that are commissioned?

THE WITNESS: I'm really not real sure. I think it's around eight or 10. We're in somewhat of a pause in commissioning at this point we had run through a commissioning. We're using all the sites that are implemented operationally, but commissioning has a requirement that we have a certain set of spare parts available and we have had recently a problem in obtaining the adequate number of spare parts. That's been resolved, but there will be some time before that spare parts logistics chain is established. And I think we will be back on a pace for commissioning regularly. I believe it's scheduled for January.

MR. SALOTTOLO: Even though the radars may not be commissioned they're being used by the National Weather Service?

THE WITNESS: Absolutely.

MR. SALOTTOLO: Mr. Saffle, I'd like to discuss the accuracy of the presentation on the radar. In the case of Charlotte, the WSR-88D at Columbia is located about 77 nautical miles to the south. What kind of accuracy on the location of an echo, the maps that are used to navigate on the image, what kind of accuracy are we talking about?

THE WITNESS: There's two factors involved. One is the basic accuracy of the radar antenna positioning system and the requirements and the specifications of the WSR-88D require a positioning accuracy both in azimuth and elevation of plus or minus 1/10 of a degree. And at approximately 75 or so miles, we're talking about a mile and a half, 8,000 feet beam width. So a tenth of that would be about 800 feet.

So, we're talking very fine spacial accuracy of the basic antenna positioning system.

The initial map backgrounds that are displayed at the user station, the principal user/processor, are required to be accurate to within the display resolution of a data element. So this is essentially then one degree. So, they aren't required to be as accurate, actually, as the basic radar antenna positioning.

So at the range of Charlotte from Columbia, that would imply a map background accuracy of approximately 3 kilometers.

MR. SALOTTOLO: So, if we were to attribute a number to the accuracy of the weather depiction in the Charlotte area, would you say within a mile, within a couple of thousand feet?

THE WITNESS: I would say that the geopolitical backgrounds, the county lines, rivers and things like that are accurate to about a mile and a half. If you had some kind of overlay information that was placed with a known latitude and longitude, it would be more accurate than that probably.

MR. SALOTTOLO: How about the echo itself, the shape of the echo and the --

THE WITNESS: As I said before, the resolution of the radar beam gives us a very sound picture of the shape or morphology of the echo, the thunderstorm, both in the horizontal and in the vertical. There is no doubt as to the accuracy of that shape of the echo.

MR. SALOTTOLO: So that would be on the order of 1,000 feet, you were saying, as far as --

THE WITNESS: Yes.

MR. SALOTTOLO: Mr. Saffle, could you refer to Exhibit 5-G, please?

THE WITNESS: Which page?

MR. SALOTTOLO: The document itself, have you had a chance to study this document?

THE WITNESS: I reviewed it. I wouldn't say I studied it.

MR. SALOTTOLO: Do the methods and assumptions used in this document to calculate liquid water content and rainfall rate, are they reasonable?

THE WITNESS: Yes. These are consistent with the vertically -- with the liquid water content calculations. They are in use in the 88D system and the rainfall rates that are in use in the 88D system. These are --

MR. SALOTTOLO: And the -- I'm sorry.

THE WITNESS: And the references to the formula and so forth, these are accurate.

MR. SALOTTOLO: And the data that was used was from the WSR-88D at Columbia?

THE WITNESS: Yes.

MR. SALOTTOLO: Now, there's a caution or several cautions in there regarding hail and its effect on reflectivity. Are those appropriate?

THE WITNESS: Yes. When we're receiving the reflected signals from the echoes, in thunderstorms this is typically a combination of actual rainfall and hail. And when we're trying to reduce that to a rainfall rate, we want to mitigate the effects of the hail. And typically for the WSR-88D, it's sort of a default, a threshold of hale. We're using 53 dBZ currently. This could vary with the air mass characteristics, but this is a currently more or less a standard. And when we're estimating rainfall rates then or rainfall accumulation, we cap the rainfall rate at 4.08 inches per hour.

And similar condition then prevails for the vertically integrated liquid water contents. And we also have to -- we're looking for the -- it's some estimate of the actual liquid water and we want to mitigate the effects of hail in that also. And in the historical development of the VIL program, 55 dBZ was used as the cap for that.

MR. SALOTTOLO: Okay. You mentioned dBZ a couple of times. That's just a measure of reflectivity?

THE WITNESS: Yes. The term for the reflected -- the quantification of the reflected energy is Z, which is a measure of the -- well, I don't know how technical you want to get here. It's millimeters to the sixth power. The diameter of the raindrops to the sixth power per cubic meter.

It's simply a measure of how much rain is out there at a given volume space. That number goes from very small to very, very large, so in order to develop a number that's more usable by forecasters and algorithms, we take the logarithm of that number and then multiple that. That gets to decimal numbers between 1 and 6 or 7 and we multiply that by 10 and use whole numbers then.

It's just an artifact to make it make it easy to work with the numbers.

MR. SALOTTOLO: The effects of hail you just alluded to, in what conditions or what circumstances would those effects be minimal?

THE WITNESS: I didn't understand the last part of the question.

MR. SALOTTOLO: In what circumstances would the hail effects be minimal? In other words what type of echoes. Would there not be much of a hail effect and you'd expect mostly liquid in the storm?

THE WITNESS: Well, the more that the thunderstorm growth penetrates the freezing level, the more time for growth of the hailstones. So, in general, the warmer the atmosphere and the lower the storm top, the less chance of hail -- of hail reaching the ground.

MR. SALOTTOLO: So in other words, in a storm where the top was 30,000 feet, there'd be less chance of hail than a storm with a top of 40,000 or 45,000?

THE WITNESS: In a normal or typical summertime warm environment, that's true.

MR. SALOTTOLO: Mr. Saffle, could you turn to Exhibit 5-D?

THE WITNESS: Yes.

MR. SALOTTOLO: What I'd like to do know is -- 5-D contains data from the WSR-88D Doppler radar at Columbia. They are color prints of various products that were generated on the radar. We have an overlay that was developed from a map provided to us from Columbia, South Carolina, and I'd like to go through page by page, if I might, and just --

THE WITNESS: I have one problem here in mine. I don't have the color.

MR. SALOTTOLO: It's not in color? Okay. We need to get a color set to --

THE WITNESS: These are not going to make a whole lot of sense unless they are in color.

MR. SALOTTOLO: I know there's at least 15 out there, so it's --

THE WITNESS: I believe the Board is going to need some color. I need to be referring to colors when I'm talking about it, and I think you need to be seeing those same colors.

CHAIRMAN HAMMERSCHMIDT: Let's see. Would everyone with the NTSB who has the colored copies, those with the color depictions, would you please raise your hand?

Just for Mr. Salottolo? Okay.

Let's proceed and see if we can understand it through Mr. Salottolo's and Mr. Saffle's very good descriptive ability.

MR. SALOTTOLO: Okay. Let me proceed. We're not going to address the color prints just yet. A couple of minutes.

MR. SALOTTOLO: On the -- do you have the transparency that has the polar grid?

THE WITNESS: I actually have a hard copy of the transparency.

MR. SALOTTOLO: So, you need --

THE WITNESS: Yes. I have the transparency.

MR. SALOTTOLO: You have the transparency. Okay.
On the transparency there's a runway icon.

THE WITNESS: Yes.

MR. SALOTTOLO: Could you just kind of describe -- it for Charlotte, for the airport. Could you just kind of describe what that's all about and how it's located?

THE WITNESS: Yes. These are all pictures taken from the principal user processor, the user's workstation. And part of the capability of this workstation is to overlay various map backgrounds on the basic radar data, and one of these map backgrounds is the airports and terminals.

This was generated back in the early period of the program by the Unisys Corporation, the prime contractor, and I understand from talks to the NEXRAD Program Office that these points were taken -- were essentially hand derived from maps -- in latitude and longitude -- was hand derived from those maps.

And this particular symbol is a generic airport symbol. And one of the characteristics of the PUP, principal user processor, for displaying these kinds of symbols is that there's a character space of 9 x 11 pixels and within that character space the actual symbol occupies 7 x 9 pixels. And the latitude and longitude that was used to locate the symbol is actually at the upper left corner of that character space.

So, when you -- it's a little confusing when you're trying to get as detailed a location as we are in proceedings like this, but if you just remember that the latitude and longitude that was used for this airport location on this overlay is a little bit to the upper left of that icon.

MR. SALOTTOLO: Okay. In other words, the location -- you have to view this particular icon in reference to the echo pattern with caution?

THE WITNESS: Exactly.

MR. SALOTTOLO: It can be misleading. I'm sorry.

THE WITNESS: Right. In normal -- in most of operational use of the weather radar data for surveillance and general warning support, warning operations support, we're not concerned with a level of positional accuracy of one or two miles. Those are typically warning for counties or parts of counties or multiple counties. And it's the relative location of the storm with respect to a city that's more important.

MR. SALOTTOLO: Okay. And the X on there is the initial impact point which was located by latitude and longitude, so the accuracy of that would be -- would that be fairly accurate?

THE WITNESS: Yes. I would expect that to be very accurate.

MR. SALOTTOLO: Okay. Do you have the color?

THE WITNESS: Yes.

MR. SALOTTOLO: Okay. Good.

Let's start with 2217 coordinated in universal time, Zulu. All times will be in Zulu. To go from Zulu to local time, Eastern Daylight Time, subtract four hours.

THE WITNESS: That's correct.

MR. SALOTTOLO: Okay. Let's start with the 2217, the point 5 degree elevation scan.

THE WITNESS: Maybe I should explain the format of these products just for a little bit.

MR. SALOTTOLO: Fine.

THE WITNESS: The PUP is designed to be a general purpose user workstation and it has quite a variety of display capabilities. And one type of capability is to take the overall umbrella display of a product and magnify around a particular point and to get a better look at the shape or morphology of the storms in that particular area. And also there's a capability for what you see here, what's called a four panel display. So you can independently look at four different products in these four panels.

Now, for this purpose of this exhibit, we've taken the first four elevation angles which are part of the standard scanning sequence of the 88D and magnified around the Charlotte area for each of those four elevation angles, so you can look at successive heights on one page.

MR. SALOTTOLO: Talking about heights, the point 5 degree elevation angle would be approximately how high? The center of the beam would be how high?

THE WITNESS: The center of the beam in the Charlotte area would be about -- between 7,000 and 8,000 feet. It's not really productive to try to be more precise than that, due to the beam width and propagation effects and so forth, but somewhere around 7,000 or 8,000 feet.

MR. SALOTTOLO: And the 1.5 degrees, do you have that?

THE WITNESS: Yes. The beam width at this distance is about 8,000 feet, so you can go up the 1.5 degree center. It would be approximately 15,000 or 16,000. And the 2.4 degree would be another 8,000, so it would be up around 22,000 or 23,000 and the 3.4 degree would be approximately 30,000, the center of the beam.

MR. SALOTTOLO: Okay. 2217 base reflectivity looking at the top left corner, I wonder if you could just kind of explain what that is showing?

THE WITNESS: All right. This is a very -- it's the same kind of data. It's reflectivity data, as the community is used to, from the conventional radars. It has the advantages of the greater sensitivity and the better resolution of the beam, so that you can see finer detail in the structure of the echoes and you can see dBZ values below what you normally would think of as the level 1 or VIP-1 display, which is around 18 dBZ normally at a conventional site. But other than that, it's still reflectivity.

So, what we're seeing at the point 5 degree elevation angle picture is an echo of level 1 probably only, located a little bit to the southeast of the terminal, and some slightly stronger echoes to the north about 10 miles and to the south about 20 miles going up to about 35 -- possibly in the southern one, 40 dBZ, so up to the VIP-2 or VIP-3 range.

MR. SALOTTOLO: Now each range ring is 10 nautical miles and each tick is one nautical mile. Is that correct?

THE WITNESS: On the overlay. Yes.

MR. SALOTTOLO: And true north is to the top?

THE WITNESS: Yes.

MR. SALOTTOLO: Anything of significance in the higher elevation scans on this?

THE WITNESS: Yes, I think so in discussing the evolution of this storm. When you look at the 1.5 degree panel, you can see that at that elevation angle just to the southwest or south-southwest of the terminal icon, is the beginning of a very light echo return. This is typical with the general thunderstorm or rainshower formation being noted first in the mid levels. So I would say that this and also the 2.4 degree panel indicates that we're actually beginning the formation of a new cell in that location, rather than the movement of the old cell up to that location.

MR. SALOTTOLO: How about the other two elevation angles? Any thing of significance?

THE WITNESS: Not particularly, no.

MR. SALOTTOLO: Page 2, we have --

THE WITNESS: This, again, uses the four panel capability. In this case, rather than looking at four elevation angles of the same product, is to look at four different products for the same magnified area.

MR. SALOTTOLO: Okay.

THE WITNESS: In the upper left or quadrant one, panel one, the title of this stands for composite reflectivity. And if you take a particular geographic point on the display, this is the maximum reflectivity that was observed at any elevation angle above that point.

So, it's a way in one picture to see the maximum reflectivity at any elevation angle for that particular location. And often this will give you an early indication if you're monitoring this product that mid level echoes have started to form in an area that you're not seeing yet in terms of rainfall on the ground.

MR. SALOTTOLO: So what's it telling us in relation to the Charlotte Airport?

THE WITNESS: Well, it's consistent with the individual reflectivity panels shown on page 1. You can see that the two parts or pieces of small echo on the 1.5 degree and the 2.4 degree show up on the composite reflectivity.

And one thing I would like to caution you on the interpretation of the composite reflectivity versus the base reflectivity. The PUP allows the color scales to be individually selected for different products at the PUP, and you'll note that on the base reflectivity product -- that's the 50 dBZ -- that's colored. That's the first red.

Unfortunately, the 50 dBZ color on the composite reflectivity is yellow. So when you're comparing the two products back and forth, you have to refer to the individual color scales and the dBZ value that they represent for a good comparison.

MR. SALOTTOLO: The top right panel base velocity, is that what this is?

THE WITNESS: Yes. That's what that stands for.

It's base velocity. And the term base, when I say base reflectivity or base velocity, this refers to a reflectivity or a velocity display generated from what's called the base data, the polar data received and processed by the radar. The only difference from the four resolution is that it's being quantized into 16 display categories.

And this particular display really doesn't show anything of meteorological significance. Once, again, it's at the point 5 degree, so you don't see any of the early formation of the cell near the airport.

And the gray areas for the area near the town of Charlotte there just indicate very light radial velocity. That means there's very little motion toward or away from the radar. And in an area that's this broad, if there were significant motions in other directions, you should be able to see some of that.

So, I would say very little wind associated with that older echo at this time.

MR. SALOTTOLO: But we're looking at about 8,000 feet up?

THE WITNESS: Right.

MR. SALOTTOLO: The lower left panel?

THE WITNESS: This stands for vertically integrated liquid. This is a product that displays the estimates of the total mass of liquid in a column over a given unit area on the surface. The concept of vertically integrated liquid content was initially presented to the community by Robert Clark and Doug Green in a paper while they were both at Texas A&M University back in 1971.

And essentially, this is a way to try to get at a radar parameter that will let you estimate the updraft strength in a given thunderstorm, the theory being that the more liquid water supported in that storm, then the stronger the updrafts in that storm. And this has proven to be a very robust tool for forecasters using the 88D and earlier versions of computer assisted radar analysis in identifying those storms that are more likely to have severe weather size hail and severe weather strength of winds than other thunderstorms that might be on the scope at the same time.

In this case, all the numbers here are very low. For this time of year, a warm environment, the typical guidance for a threshold VIL that you would worry about for potential severe weather would be at least 50. So we're only talking about down in the noise level.

MR. SALOTTOLO: And in the area of Charlotte, nothing remarkable showing at this time?

THE WITNESS: Nothing that would be significant as far as severe weather size hail and winds would be concerned.

MR. SALOTTOLO: Okay. The lower right panel, the echo tops?

THE WITNESS: This, again, is just a straight representation of the geometry of the observed data. Just take the mid point of the highest elevation angle where you see a return and you calculate the height at that point above the surface and display that as an estimate of the echo top. The only thing to be further aware of there that we use a threshold of 18 dBZ in determining what's echo and what isn't for this purpose.

MR. SALOTTOLO: So the top south of the runway icon, look like there about 20,000 feet or so?

THE WITNESS: Right.

MR. SALOTTOLO: On page 3, all four panels, we have relative velocity map.

THE WITNESS: Right.

MR. SALOTTOLO: Can you summarize what that's telling you?

THE WITNESS: Yes. Once again, this is looking at one kind of product at each of the four basic elevation angles. Relative velocity map refers to a product that's derived from the base velocity product or information, but the motion of individual echoes has been removed from that overall base velocity field.

The attempt here is to get the motion internal to a given thunderstorm. So the attempt normally here is to be able to see signatures such as circulation patterns within a thunderstorm or divergence at the top of a storm, this kind of thing that might be masked if you had a fast moving storm in the base velocity field.

In this particular case, I don't see anything of particular significance at this time on the cells around Charlotte.

MR. SALOTTOLO: Okay. Page 4 is 22:23Z, base reflectivity.

THE WITNESS: Right. You'll notice that this is six minutes later than the time of the previous set of products. I should probably explain that a little bit.

When we're observing significant precipitation, there are two scanning strategies or sets of elevation angles that the forecaster can use for the 88D. And in this case, he's using -- and this is designated in the overall ancillary data as to which VCP number. In this case it's 21. That's means that we're obtaining information from a total of nine separate elevation angles. And the time for this particular scan strategy is six minutes.

And by convention, we've assigned the beginning of that volume scan time as a date time stamp for all the products associated with that volume scan. So, that's accurate for the 0.5 degree product but the higher elevation angles where actually the data were taken somewhat further along in that six minutes.

MR. SALOTTOLO: Mr. Saffle, could you give us kind of an estimate of where point 5 and 1.5, how much further along the six minutes period are we?

THE WITNESS: Yes. The system is designed to rotate very slowly at the 0.5 and the 1.5 angles in order to get the maximum signal-to-noise ratio for accurate velocity estimates. And in fact, we rotate at 1 rpm for the velocity information at those angles and we take a separate antenna sweep to get the reflectivity information at those two angles.

So, for each of those angles the data collection time is about one minute and 10 seconds. And as you go up in the elevation, the antenna typically spins faster. The average throughout the volume scan is about 3 rpm.

MR. SALOTTOLO: So the point 5 is 2223; the 1.5 would be a minute and 20 seconds later?

THE WITNESS: Yes.

MR. SALOTTOLO: And then the 2.4 would be a minute and 20 seconds after that?

THE WITNESS: That's right. And after that, they would be approximately 20 seconds apart.

MR. SALOTTOLO: Could you just summarize what the base reflectivity you're showing in those four panels at that time -- at this time?

THE WITNESS: Right. On panel 1 you can see that the echo to the south-southwest of the airport icon now has somewhere between 5 and 15 dBZ appearing at the 0.5 degree angle. Once again, the center of this beam is about 7,000 or 8,000 feet, so the bottom is about 3,000 feet. So for this very light reflectivity, the precipitation probably isn't reaching the ground yet in a detectable manner, but it does show evidence that the thunderstorm or shower is growing. At this point I would say it's still a shower.

The second panel, you can see that the mid level reflectivity is difficult on this kind of display to distinguish the shade of green, but it's somewhere around 25 or 30 dBZ, which would be a high VIP-1 or perhaps just getting into VIP-2 at that mid level, and similar on the 2.4 degree scan.

And one of the other features here. You can see that at the 2.4 and the 3.4 elevation angles the original echo that goes over the symbol for Charlotte itself doesn't appear any more. This is further indication that that was a dying cell and the cell of interest is really a new cell that's growing. You see a little bit of that new cell now appearing at the 3.4 degree. This probably wouldn't have shown up yet as part of the echo tops calculation because the strength is below 18 dBZ, but you can see that it is beginning to grow up to that height.

MR. SALOTTOLO: Okay. Page 5?

THE WITNESS: Once again, the composite reflectivity essentially is a summary of the information from the individual reflectivity charts. I don't think it adds anything. The base velocity is still not enough organization, I would say, of the cell, to say much of anything about it yet. There's not anything that the forecaster would pay particular attention to at this point in terms of looking for circulation patterns or anything like that.

The VIL is still low and the echo top is indicating somewhere around 20,000 or 25,000 feet. It's hard to tell the shade there.

In the actual operation use of the PUP, the forecaster has the ability to click on one of the categories and cause that category to blink and so forth so that he can -- in actual operations he has a lot more utility with these data than we do.

MR. SALOTTOLO: Okay. Page 6, the relative velocity data.

THE WITNESS: Right. And this is once again at the point 5 degree. We're still not seeing that much of the new echo, but we are starting to see some significant velocity signatures at the 1.5 and 2.4.

This where the color is very, very beneficial when you're interpreting these data. You can see that both at the 1.5 and to a greater extent at the 2.4 in the echo that's near the airport icon, there's an area of orange to the north and green to the south toward the Columbia radar. This indicates that from the center, taking the center of the cell as a reference point, the motion, the precipitation is away from that point in both radial directions.

This is a signature for divergence at the upper levels of this storm, which is common. This is what you get with any growing rain shower or thunderstorm, but it's just confirmation that this storm is still in the growth phase.

MR. SALOTTOLO: Okay. Page 7, 2229, the base reflectivity.

THE WITNESS: All right. Once again, this is six minutes later. This is the start of the next volume scan. In this case the 0.5 degree now has reflectivity up to about 40 dBZ which would be approximately the threshold of VIP-3, south-southeast, I would say, of the center of the airport.

At the mid levels, the reflectivity is increased to 50 dBZ, which is approximately the threshold of VIP-5. And once again, we're seeing continual growth of the overall strength of the echo at the higher elevation angles.

MR. SALOTTOLO: Now, the top right panel, 1.5 degrees, you had indicated VIP-5, approximately VIP-5. And it looks like it's located just southeast of the initial impact point. Is that a significant feature now or is that something that --

THE WITNESS: It shows that this is a -- once again it's a growing -- at this point I think you would start suspecting that it was a thunderstorm, not just a rain shower because of the strength of the echo return. Can't say that absolutely, but it would be considered likely. Probably going to experience heavy rain on the ground at some time out of this storm.

I would say that at this point, looking at the point 5 degree, that there's quite possibly light to moderate rain starting to appear on the ground.

MR. SALOTTOLO: Now, you said it indicates -- the 1.5 degree base reflectivity indicates the possibility of heavy rain beginning on the ground at some time?

THE WITNESS: Yes. You would anticipate that heavy rain would reach the ground fairly soon after this.

MR. SALOTTOLO: But there's no way to put a number to that? In other words, 5 minutes, 2 minutes, 3 minutes?

THE WITNESS: No, not really.

MR. SALOTTOLO: Based on what you see?

THE WITNESS: Within a few minutes.

MR. SALOTTOLO: In a few minutes.

THE WITNESS: We're not talking about 15 or 20 minutes. We're talking probably 5 to 10.

MR. SALOTTOLO: Okay. Page 8.

THE WITNESS: Once again, there's little additional information really over what we've had from these particular products. The VIL is still only around 10 and the echo top is -- looks like it's still only in the 25,000 or 30,000, somewhere between 25,000 and 30,000.

MR. SALOTTOLO: Now, the base velocity, was that anything significant in that page.

THE WITNESS: No.

MR. SALOTTOLO: Page 9.

THE WITNESS: At the lowest elevation angle, we're tending to see outflow or motion away from the -- don't want to classify it as thunderstorm. Outflow, a poor choice of words. But flow away from the radar at the lowest elevation angle. It's probably just the general ambient flow.

The mid levels still low -- and upper level -- still show significant divergence signature, or a clear divergence signature. And now you can even see a divergence signature at the 3.4 degree, indicating this is still a growing storm.

MR. SALOTTOLO: Is there anything unusual in that signature? I think you said it was typical of a developing thunderstorm?

THE WITNESS: No. There's nothing unusual here.

MR. SALOTTOLO: Okay. Page 10, which is 2235.

THE WITNESS: Yes. At this point, at the 0.5 degree we're now observing 50 dBZ or approximately VIP-5 at that lowest elevation angle. I would say it's highly likely that we have at least significant if not heavy rain at the ground at this point. And you can see the growth of the area of the 50 dBZ at the 1.5 degree. That area has expanded. This is a -- I'm not sure too much more what we can say. The storm has still been growing to this point.

MR. SALOTTOLO: Now, is there any significance to this or is this an atypical type of --

THE WITNESS: No. The thing that you might note is that the strongest gradient of the storm is toward the north-northwest part of the storm and you can see that that part of the storm now is -- I would say west. It's off the northwest edge of the runway.

MR. SALOTTOLO: Where in relation to the initial impact point would that be?

THE WITNESS: Well, of course, there's a difference in timing now of several minutes, but my overlay shows the initial impact point being in the center of the 50 dBZ echo area on the 0.5 degree panel.

MR. SALOTTOLO: Now, the base reflectivity presentation, should this -- if someone was sitting in front of the Doppler radar display and he saw this, would this raise an alarm or anything or what would normally be expected?

THE WITNESS: No. Once again, you'll not be looking at just the base reflectivity. You'd be looking at the VIL and the velocity signatures or looking to see if there were velocity signatures and you're be aware of the overall environment. And in this case it would be interpreted as a routine Summer thunderstorm.

MR. SALOTTOLO: Okay.

THE WITNESS: And probably, unless it persisted for longer than it has here, you wouldn't even be concerned about flash flood warning, even though this is heavy rain. You would want to have some indication it was going to persist longer before you'd be starting to be concerned about flooding.

MR. SALOTTOLO: Okay. Let's look on page 11, the other products at 2235.

THE WITNESS: It's hard to get anything that would be significant to a forecaster. Once again he's monitoring the VIL and he sees it's still only up to about 20, so he's not going to have any concern that this storm might have severe weather size hail or winds with it. Echo top is till showing about 30,000 feet.

MR. SALOTTOLO: Now, you mentioned severe weather. That's defined as wind gusts greater than 50 knots and hail of three-quarter inch or greater?

THE WITNESS: That's correct. Or tornadoes.

MR. SALOTTOLO: Or tornadoes.

Now, the relative velocity data, page 12.

THE WITNESS: Yes. There's some significance here in judging the evolution of the storm, where it is in its normal growth and decay cycle. The lower -- the 0.5 degree to me indicates the possibility of some outflow boundary being detected, even though this is pretty high. The bottom of the beam is about 3,000 feet. In the northwest part of the echo you can see the indication of a little motion, a little bit of convergence in that area toward the radar at the northern part and away at the southern.

It's not anything that is going to raise any kind of alarms to a forecaster, but it's hard to interpret exactly what it means. But it's a -- it may just be at this time we're seeing the actual inflow area of the storm. We're seeing the upper part of that with the bottom of the beam.

I think a more significant area on this set of charts is looking at the 3.4 degree. Remember at the previous time, 2229, we were seeing a divergence signature at the top of the storm at the 3.4 degree and now we're not. This is to me an indication that the storm has started into its decay cycle. It's no longer growing.

There's still a strong storm and still got a divergent signature at the 1.5 and 2.5 areas, but I would say that the forecaster would normally be looking to see whether this storm didn't continue to decay over the next volume scan or so.

MR. SALOTTOLO: Now, what are the implications of this decay on the ground as far as weather on the ground?

THE WITNESS: This would be the beginning of the rain-out phase of the storm, the heavy rain period. And as is typical with a decent thunderstorm, decent size thunderstorm, there would be often associated this down drafts.

The possibility of microburst has been mentioned many times in this testimony. There's nothing that we can see with this data that would either confirm or invalidate the idea of a microburst. It certainly would be possible but we just don't have the evidence with this data to say yes or no.

MR. SALOTTOLO: And when you say this data, it's the data contained in this exhibit?

THE WITNESS: Yes.

MR. SALOTTOLO: Okay. Page 13, 2241.

THE WITNESS: Just looking at the four panels as a group, you can see that the storm has indeed begun to lose not the maximum intensity but the area of 50 dBZ, a smaller -- and in general, the reflectivities are the higher elevations are significantly lower than they were in the pervious volume scan. Simply confirming the earlier indications that the storm was beginning its decay phase and is now well into that decay phase.

MR. SALOTTOLO: Looking at the point 5 degree elevation angle, the max reflectivity is just north at 55 dBZ. Would you agree with that?

THE WITNESS: It's hard to say. I can't really tell. I can't really tell the shading here, but it's around -- it's in the red. I can't tell whether it's 50 or 55 on this particular --

MR. SALOTTOLO: Okay. You haven't had a chance to review the data on the -- the level 4 data on the on the PUP -- on a PUP?

THE WITNESS: No. No, I didn't.

MR. SALOTTOLO: Now, you had indicated the high reflectivities have decreased in the higher elevation angles or higher altitudes?

THE WITNESS: Yes.

MR. SALOTTOLO: Is this indicative of a descending reflectivity core, would you say, or how would you characterize that?

THE WITNESS: Potentially or possibly, yes.

MR. SALOTTOLO: And with the descending core would you expect or could you expect some type of outflow on the ground?

THE WITNESS: Definitely. I think the kinds of rainfall rates associated with this storm, you would expect some. It would be hard to quantity or estimate from the radar data what the strength of the outflow would be, but you would expect an outflow boundary or a gust front or whatever out of this thunderstorm on the surface.

MR. SALOTTOLO: And depending on the size of this outflow, it could be classified as a microburst, a down burst, a gust front?

THE WITNESS: Right. We're really getting into scale and degree here.

MR. SALOTTOLO: Okay. But there's no way to quantify the speed of the outflow as far as --

THE WITNESS: Well, not from this data. And we don't have an operational algorithm in the 88D program that attempts to quantify this. I know that research is ongoing to try to come up with quantitative forecasts of this, but I think that to some extent the identification of yes or no with appropriate radar data is getting mature. The strength of that is probably less mature.

MR. SALOTTOLO: Let's look at page 14.

THE WITNESS: Once again, I don't really see anything that a forecaster would pay much attention to on here, other than to continue to corroborate that the VIL is still not threatening in its magnitude.

MR. SALOTTOLO: Now, the base velocity, nothing significant that you can see in that?

THE WITNESS: No.

MR. SALOTTOLO: Now, the radar is located about 77 miles away.

THE WITNESS: Right.

MR. SALOTTOLO: If the radar had been say within

20 miles could there have been some sort of divergent signature picked up on the data?

THE WITNESS: Well, we have observed -- I don't know what we would have seen with this particular storm. But we have observed quite often with operational experience since we've had the 88D's the actual outflow boundaries associated with the down drafts off thunderstorms. And yes, I think it would be quite possible if we were 20 miles away that you could see that from this storm. You could have seen the outflow boundary.

MR. SALOTTOLO: But at 77 miles it's -- the beam is --

THE WITNESS: No. You're too high.

MR. SALOTTOLO: -- 8,000 feet.

THE WITNESS: You're much too high.

MR. SALOTTOLO: At 77 miles, is there any way to calculate a vertical velocity close to the ground?

THE WITNESS: Not really. The indication there is that at range we can identify to a large degree of confidence whether or not it's a thunderstorm and the relative strength of that thunderstorm. And at that point, then, you infer the possibility of significant down drafts and maybe even a microburst just due to the normal nature of thunderstorms and all the thunderstorm theory that supports the possibility of these kinds of wind phenomena. You can't actually measure that phenomena at that surface level and we don't attempt to quantify a forecast of what that would be.

MR. SALOTTOLO: Okay. So it doesn't matter if we were 10 miles away or 20 miles away. Still there's no way to come up with a --

THE WITNESS: We don't attempt to quantify from the data. However, when you're close, you can actually see the outflow with both the reflectivity and the velocity data because the beam is low enough to actually see it.

MR. SALOTTOLO: But you can't see the vertical velocity.

THE WITNESS: We don't have a product for vertical velocity.

MR. SALOTTOLO: Now, 2241, what are the tops?

THE WITNESS: Looks like they're still about 30,000 feet, if I'm interpreting this color shade correctly.

MR. SALOTTOLO: And it looks like that top, the 30,000 top is just east of the initial impact point?

THE WITNESS: Yes.

MR. SALOTTOLO: Page 15. Anything of note?

THE WITNESS: This is just to further corroborate the decaying phase of the storm. Now you don't see a divergent signature at any level. I don't think there's anything else of significance on that page.

MR. SALOTTOLO: Now, subsequent to the accident, 2247, page 16. Just briefly, what we're seeing.

THE WITNESS: Once again the cell is continuing to decrease in intensity in the area of the stronger intensity. I don't think there's much else. You can see there has been some movement through this period of time and the low level and mid level core of the storm is now north-northwest of the runway.

Other than that, there's nothing of significance there.

MR. SALOTTOLO: And on page 17? Anything?

THE WITNESS: The VIL has dropped back down to the 10 level. The echo tops are now perhaps 25,000. They've dropped down a category.

Once again, continuing the decay of this particular cell, the evidence of that decay.

MR. SALOTTOLO: Okay. And page 18?

THE WITNESS: Nothing other than -- the one thing you can see is the motion of the storm that was about 20 miles north of the airport. The edge of it is getting somewhat close to the outer edge of the storm that was over the airport. But that's the only thing. You would start perhaps anticipating some kind of combining of those storms in some manner.

MR. SALOTTOLO: I wonder if you -- you've testified that data was showing divergence aloft at higher levels at 25,000 feet or so --

THE WITNESS: Yes.

MR. SALOTTOLO: -- and then convergence lower at 8,000-9,000 feet? Just kind of a -- does the divergence -- why is that typical, divergence removing the air from the top so you sustain an updraft?

THE WITNESS: Right. At the lower level you've got convergence of air streams and the air has to go somewhere. You have to have a trigger for a thunderstorm and this might be to start to vertical motion. It may be a hill or something or a graphic. It may be surface heating due to the sun, maybe a front coming in providing a surface for the lower level flow to start rising on.

But the bottom line is you have convergence in the lower level. This air rises and when it reaches the top of the conditions, atmospheric conditions in terms of buoyancy and so forth, it spreads out. And that spreading out is called divergence and that's the signature that we could see here. And the strong that is, the higher that is, and the presence of it indicates still a thunderstorm in the growth phase.

MR. SALOTTOLO: In the data, did you see any microburst precursors or can you say?

THE WITNESS: Once again, we don't really have microburst precursor products or data that's specifically oriented to that in the WSR-88D. The WSR-88D is designed as a surveillance radar. That's what the "S" stands for, Weather Surveillance Radar. And it covers a continual scanning pattern nominally to a radius of 230 kilometers or 125 nautical miles.

And the scanning strategy is it takes at least five minutes or six minutes depending on the volume coverage pattern. And it's designed to give sort of equal attention to all area within that umbrella because the Weather Service Forecast Office that's using this radar has a county warning area of responsibility that extends potentially throughout most of this umbrella and both the frequency of the observation of data at a particular point and the height of the beam after a certain range dictate that we don't necessarily see the low level indications of a microburst, per se.

As far as precursors, I think that once again the identification of a thunderstorm or a likely thunderstorm, the strength of that thunderstorm and the morphology, the height and considerations of the environment that that thunderstorm is within, these are the kinds of things that would be pertinent.

However, a Weather Service forecaster is concerned not with predicting microbursts but with predicting severe weather strength; winds, severe weather size hail, tornadoes. The mission is oriented toward -- if they spot, they'll put out low level wind warnings if they see a strong gust front or infer a strong gust front, but the overall use of the WSR-88D is not oriented toward microburst detection, per se.

That's why -- I'm not an expert in the Terminal Doppler Weather Radar Program, but that's why the FAA has established that program for the major airports is to get a radar similar to that WSR-88D that will concentrate a scanning strategy and scientific algorithms on the microburst and low level windshear mission areas.

MR. SALOTTOLO: On your review of the data, did you see anything that would indicate severe weather potential?

THE WITNESS: No. Not in the sense of official severe weather criteria.

MR. SALOTTOLO: Well, how about unofficial?

[Laughter.]

THE WITNESS: Severe is in the eye of the beholder. It's a decent thunderstorm, Summer thunderstorm, with heavy rain.

MR. SALOTTOLO: Is there anything unusual about the fact that the maximum intensity was a VIP-5, level 5 or 6, and the tops were only 30,000 feet or the radar tops were only 30,000 feet?

THE WITNESS: I don't think there's anything of particular significance. It indicates there's a lot of low level moisture in this system and there's a lot of ammunition, so to speak, to -- as soon as you lifted that air containing that moisture to any significant height, it was going to precipitate out. It's more a measure of the warm moist condition at the lower levels than anything else

MR. SALOTTOLO: How many times would you see a level 5 or level 6 thunderstorm in let's say the southeast during the Summer?

THE WITNESS: Well, I think that's probably a little beyond my specific area of expertise and that kind of climatology. I would guess that this is not atypical at all.

MR. SALOTTOLO: I have two other questions here. The major or the primary use of the WSR-88D is public? Is that fair to say?

THE WITNESS: Yes. To support public weather forecasts and warnings.

MR. SALOTTOLO: And one further thing. I'm going to ask the question again because I think it's importance as far as the accuracy.

THE WITNESS: Okay.

MR. SALOTTOLO: Now, the template we used which was derived from the WSR-88D at Columbia, the navigation is accurate to plus or minus 1.5 nautical miles?

THE WITNESS: The radar data itself is accurate. The radar antenna pointing system is accurate to a tenth of a degree, plus or minus a tenth of a degree.

MR. SALOTTOLO: Which was about 1,000 feet?

THE WITNESS: Yes.

MR. SALOTTOLO: Plus or minus 1,000 feet.

THE WITNESS: Yes.

MR. SALOTTOLO: But the actual navigation or the map you put on there is accurate plus or minus 1.5 nautical miles.

THE WITNESS: Approximately. Yes.

MR. SALOTTOLO: Okay.

MR. SALOTTOLO: Thank you, Mr. Saffle. I have no further questions at this time.

CHAIRMAN HAMMERSCHMIDT: Okay. Thank you, Mr. Salottolo.

Federal Aviation Administration, any questions?

MR. DONNER: We have no questions, sir. Thank you.

CHAIRMAN HAMMERSCHMIDT: Thank you.

National Air Traffic Controllers Association?

MR. PARHAM: Yes. Mr. Saffle, I have a couple of questions. Are you familiar with the circumstances involved in the flight of USAir 1016 and the investigation that's going on?

THE WITNESS: In general.

MR. PARHAM: In your opinion, if the Charlotte Air Traffic Control facility had had the Doppler Weather Radar, could it have provided additional information to the flight crew and to the facility to help prevented this accident?

THE WITNESS: Are you referring to the WSR-88D type of Doppler or to the TDWR?

MR. PARHAM: The Doppler weather radar that is being installed at certain Air Traffic facilities around the country?

THE WITNESS: That's the Terminal Doppler Weather Radar. I think you should probably hold that question for the experts that will testify after me in that area. I'm not -- I have some peripheral association with FAA development efforts in this area but I don't consider myself an expert in the TDWR.

MR. PARHAM: Well, more generally, I estimated it took probably 45-50 minutes to explain this development of the storm on the Doppler. How difficult is it, just general Doppler weather radar, for a layman to interpret that information?

THE WITNESS: I think that it's not easy. As was testified to earlier, the National Weather Service and the DOD conduct a four week training course at Norman in interpretation and operation of the WSR-88D. It's not trivial to learn how to interpret the velocity data and reflectivity data in terms of the morphology of the storm and connecting these data to thunderstorm theory.

MR. PARHAM: Does the equipment allow for realtime data display to be immediately retrievable?

THE WITNESS: It's very nearly realtime. The first elevation angle, the 0.5 elevation angle base products, the reflectivity, the velocity, that data is coming down in real time from the radar antenna into the radar products generator and as soon as -- I would say that within a very few second after the complete scan has been accomplished that product is ready for display.

MR. PARHAM: So there's not really a processing delay in it?

THE WITNESS: No. The volumetric products, such as VIL and echo tops and composite reflectivity, they obviously have to wait until the entire volume scan has been acquired. But the base products are available very shortly after that particular elevation scan has been acquired.

MR. PARHAM: All right.

I have no further questions, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: Okay. Thank you, Mr. Parham.

Honeywell?

MR. THOMAS: No questions. Thank you.

CHAIRMAN HAMMERSCHMIDT: Thank you.

Airline Pilots Association?

MR. TULLY: Thank you. Just a few. Mr. Saffle, just to clarify a few things on this WSR-88D radar, please.

You say this is a digital radar; is that correct?

THE WITNESS: Yes.

MR. TULLY: And it works basically in an automatic kind of mode? I mean, it doesn't require any human operator once the thing is going?

THE WITNESS: The scanning strategy, the operation of the antenna, driving it through the scanning strategy is all under program control. The forecaster has some capability dynamically to change parameters. He can choose a different scanning strategy. There's some feature concerning the pulse repetition frequency that he can change.

He can modify the area to attempt to do clutter mitigation, ground clutter mitigation. There's not a whole lot of things, but there are some things he can do dynamically. But all they do is change program parameters. Once -- he changes those parameters and then the programs actually control the antenna.

MR. TULLY: And this information is continually recorded on an optical disk?

THE WITNESS: The products generated at the radar products generator, when a system is commissioned, which hasn't happened yet a Columbia, a standard set of those products will be archived on optical disc and kept at National Climatic Data Center. The PUP, the principal user processor, the separate workstation for display of products, has its own archival capability and this is up to the judgment of the forecasters as to when they want to archive products and when they don't.

MR. TULLY: Does the radar have any type of alarm feature to alert, say someone that might have a monitoring function, to when storms might be reaching certain thresholds?

THE WITNESS: Yes.

MR. TULLY: Can you explain that alarm feature?

THE WITNESS: Part of the system at the principal user processor allows the forecaster to set two different alert areas, and within each alert area, can actually have contiguous or disjoint sectors of the umbrella to be alerted -- to be monitored. And there's a number of different products that he can set. He can choose which threshold to be alerted for.

MR. TULLY: We've seen several products from the WSR-88D here, the base reflectivity -- I think a vertical integration of the liquid water content composite radar picture, et cetera.

THE WITNESS: Yes.

MR. TULLY: How many products is this system capable of generating?

THE WITNESS: Too many, according to some people, but in reality I don't remember the exact number. It's something like -- I think the product identification numbers go into the 80's, but this includes variations of given aerial resolution and so forth. For instance, the reflectivity, base reflectivity, has about six different versions depending on the horizontal range, depending on whether you're one kilometer display resolution or 2. This kind of thing.

In terms of different kinds of data reflectivity, velocity, storm relative velocity, VIL and so forth, there's probably -- I don't know, 40 some odd, probably, 40 to 50.

MR. TULLY: And how many NEXRAD radars are in operation right now? You said that number. I just didn't write it down.

THE WITNESS: Yes. It's in the upper 90's and may be approaching 100 now. We're installing about four per month.

MR. TULLY: Okay. The reason I asked that question -- if you might permit me, Mr. Chairman.

I was reading Flying magazine and there was an advertisement in Flying magazine, a company out of -- I believe it was Saddle Brook, New Jersey was advertising that me, the private individual, with this company's product, could have access to something like information from several dozen NEXRAD sites and something like 17 various products.

THE WITNESS: Absolutely.

MR. TULLY: Okay. Well, I called this company up and I said what's it going to take to get this data? And they said, well, you need to spend about $100 for a modem and about $59 for the software and then we'll give you an

800 number. And for a very reasonable air time fee, you can get this information right into your home computer.

So the reason I was asking those questions, I just wanted to make sure I wasn't going to be bamboozled when I subscribed to this service.

THE WITNESS: I could explain a little of what's behind that, if you wish.

MR. TULLY: Absolutely.

THE WITNESS: The government has chosen to -- for the distribution of NEXRAD products to other than the principal government users, DOD, National Weather Service and so forth -- to have that provided by the private sector. And this is done through a device called the NEXRAD Information Dissemination Service. We've dedicated four communications ports on each RPG and we've allotted contracts to four commercial vendors.

And each one will connect to each WSR-88D at least in the CONUS, Continental United States, Coterminus United States, and they're interested also in the overseas sites. And these vendors in turn sell these products data to wherever they can find customers.

It sounds like you're in touch with a reseller from one of the NIDS vendors.

MR. TULLY: The base reflectivity data looks very similar to me as a pilot, in its color presentation, to what I might see on my radar in the airplane. I mean, it has a color code to indicate various intensities, while the other products seem to be fairly complicated.

I have a degree in meteorology and I look at these products and to tell you the truth, other than the base reflectivity, I can't really say too much about the weather cell from these other products. But the base reflectivity at least looks pretty straightforward. I mean, it looks like you can almost correlate the colors immediately with VIP levels in the storm.

THE WITNESS: Yes, you can.

MR. TULLY: Is the WSR-88D, is that the latest technology? That's the best radar available for painting convective weather right now?

THE WITNESS: Best available? I'd say state-of-the-art.

MR. TULLY: State-of-the-art. Okay.

THE WITNESS: The only thing that -- it gives us all the dynamic range and sensitivity that we feel we need for our meteorological use.

MR. TULLY: Okay. All right. Well, if the base rate reflectivity is pretty -- you know, is fairly easy data to interpret and I can get this information for about 150 bucks into my living room and this data is from the best radar that the Weather Service has available, I guess my question is why can't we get it into FAA control towers?

THE WITNESS: I do not have any knowledge of or association with FAA policy in this area.

MR. TULLY: I'll save that for another witness. No further questions.

CHAIRMAN HAMMERSCHMIDT: Let's call that a rhetorical question.

MR. TULLY: Okay. No further questions.

CHAIRMAN HAMMERSCHMIDT: USAir?

MR. SHARP: Just one question.

Pilots recognize, I think, levels of thunderstorms. The higher the number, the more attention they direct in that area. Most of the comments and the testimony that we've heard thus far have referred to level 3 thunderstorm from ATC people and other weather people.

In the charts that you've just described, we see it reflected as a level 5 thunderstorm.

THE WITNESS: Right.

MR. SHARP: How do we account for the difference between what's seen on other radars and what's on your radar?

THE WITNESS: It goes back mainly to one of the differences that I pointed out earlier between the 88D system and our previous conventional radars, and also perhaps the ASR-9, although I'm not very familiar with that.

It's basically the beam resolution. The approximately one degree beam of the 88D versus the 2.2 of the 57 involves a footprint sample, so to speak, at a given range that's -- off the top of my head, I don't know whether it's a factor of 8 or a factor of 16 in volume footprint, but it's a tremendously smaller section of the storm that you're seeing. And so with the 88D, we're able to detect smaller cores of higher reflectivity and that's why you -- in a given thunderstorm in a given rate, at a consistent range, you'll quite likely see 1 to 2 VIP levels higher on the 88D than you would on the 57.

CHAIRMAN HAMMERSCHMIDT: In shirtsleeve language, would you say that that is just greater resolution?

THE WITNESS: Just greater resolution. Right. Aerial resolution or volumetric resolution.

MR. SHARP: Would that be a general statement then that on the ASR radars as opposed to the Doppler radar you would see two levels of difference between --

THE WITNESS: No. I don't want to characterize this as a general statement. There's a lot of things that come into play. First of all, you have to be talking about comparable ranges from the two radars, and you have to be talking about consistent propagation paths. Given the actual humidity and temperature profiles of the atmosphere determines whether the radar beam projects in an normal pattern or whether below that normal or up above it, has to do with the actual morphology of the storm itself, the strength and distribution of the maximum strength.

If you have beam filling of 50 dBZ in the ASR-9 or the WSR-57 or the 88D, either one, you're going to get 50 dBZ back as your answer.

MR. SHARP: Okay. Thank you very much.

We have nothing further, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Sharp.

Douglas Aircraft Company?

MR. LUND: No questions, Mr. Chairman. Thank you.

CHAIRMAN HAMMERSCHMIDT: Thank you.

Pratt and Whitney?

MR. YOUNG: No questions.

CHAIRMAN HAMMERSCHMIDT: Okay.

Association of Flight Attendants?

MS. GILMER: No questions. Thank you.

CHAIRMAN HAMMERSCHMIDT: Thank you.

International Association of Machinists?

MR. GOGLIA: No questions.

CHAIRMAN HAMMERSCHMIDT: Thank you.

Dispatchers Union?

MR. SCHUETZ: Yes. Mr. Saffle, just one question to clarify. You said you were behind on the installation. Is that because of hardware or it that a money problem from the government agencies?

THE WITNESS: No. I didn't say we were behind on installation. We're on schedule on installation. Our operational use of installed is happening as soon as we accept a system. We've temporarily paused in commissioning, a big difference, only while we catch up on the logistics pipeline for our spare parts.

MR. SCHUETZ: Thank you very much. No further questions.

CHAIRMAN HAMMERSCHMIDT: Okay. Thank you.

National Weather Service?

MR. KUESSNER: Yes. Just a couple of questions, please.

Mr. Saffle, first of all, is it true that virtually all thunderstorms or even heavy rain showers have the potential for producing outflow or gust fronts?

THE WITNESS: Yes.

MR. KUESSNER: And could you please turn to page 10 of Exhibit 5-D. On the upper left-hand corner, I believe that depicts base reflectivity at point 5 degrees?

THE WITNESS: Yes.

MR. KUESSNER: Now, in interpreting this picture, where in relation to the airport would the VIP-5 area be in your estimation?

THE WITNESS: In my estimation almost due west, west-northwest of the center of the airport, based on the presumption that the original latitude and longitude that was used for that airport icon was selected accurately and that that represents the upper left area of that icon character space.

MR. KUESSNER: Now you have an X on the acetate that you're using when you put that overlay. I believe that X was determined by the NTSB meteorologist to be the impact of the accident.

THE WITNESS: That's what I understand. Yes.

MR. KUESSNER: Where is that red area in relation to that X?

THE WITNESS: They are superimposed.

MR. KUESSNER: I believe you said earlier -- I want to make sure I heard this right -- at 2235, from analyzing all the information at 2235, did you testify that you believed it would be raining heavily at the surface?

THE WITNESS: Yes.

MR. KUESSNER: Can I refer you now to the next time frame here. I believe that would be page -- excuse me -- page 13. Sorry.

THE WITNESS: Okay.

MR. KUESSNER: Now, let me ask you the same set of questions. At that time you still had a VIP-5 at the lowest angle?

THE WITNESS: Yes.

MR. KUESSNER: Okay. Now, where in relation to the airport would you estimate that to be at that time?

THE WITNESS: Approximately the same location. It looks like it's a little bit north of where it was in the previous time frame.

MR. KUESSNER: So it's a little bit north now of the X?

THE WITNESS: Yes.

MR. KUESSNER: And at that time you would also say or determine that there was heavy rain at the surface?

THE WITNESS: Yes.

MR. KUESSNER: Could it be described as we've heard in some of the statements as a wall of water?

THE WITNESS: I think that's too subjective.

MR. KUESSNER: Okay. Thank you.

Sorry. No more questions.

CHAIRMAN HAMMERSCHMIDT: Okay. Thank you.

Let's see. I have a quick question. Mr. Salottolo, are the times depicted in this exhibit, are they pretty much synchronized to our CVR time or have we established that as yet?

MR. SALOTTOLO: Yes. We did a time check to make sure the clocks were accurate, and the best we could come up with, they're in the same minute.

CHAIRMAN HAMMERSCHMIDT: Okay.

MR. SALOTTOLO: The witness agrees with that.

THE WITNESS: Yes. I agree with that.

CHAIRMAN HAMMERSCHMIDT: Okay. Thank you.

Mr. Laynor?

MR. LAYNOR:

MR. KUESSNER: You may have answered this, Mr. Saffle, but when will we have nationwide coverage with the Doppler Weather Radar NEXRAD?

THE WITNESS: The tri-agency WSR-88D program, NEXRAD program, is scheduled to finish its implementation in early 1996.

MR. KUESSNER: '96. Okay. And if you've answered this, just tell me also. But you referred in your testimony to official hazardous weather criteria. What is that?

THE WITNESS: Severe. That's hail three-quarters of an inch in diameter or greater; 50 knot winds, recorded winds or significant wind damage; or tornadoes. Those are the criteria that our forecasters are considering when they decide whether to issue a severe thunderstorm or tornado warning.

MR. KUESSNER: Would the wind velocity be based on the Doppler or the radar, or --

THE WITNESS: It's difficult. Since it's a tilted end antenna and we're sampling after a few miles somewhat off the ground, usually above the boundary layer, it's not an easy matter to judge how fast the wind will be at the surface, which is where we warn for, versus what it is at 5,000 or 10,000 or 15,000 feet. That's proven to be a large issue, a large problem in the scientific interpretation of the data.

MR. KUESSNER: And one other question. You referred to algorithms that may be able to convert the reflectivity level and the down draft or downflow with an outflow velocity. Is that work ongoing for the --

THE WITNESS: Well, what I was referring to there are specific briefings that I've attended by FAA TDWR people, mainly from Lincoln Laboratory, that have discussed their algorithm development. And one of the more promising is apply pattern recognition techniques to the radar data from the TDWR to the possibility or probability of microbursts.

MR. LAYNOR: Okay. All right. Thank you very much, sir.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Laynor.

Okay. And let's see. No other questions, I think, from the Board of Inquiry. So, Mr. Saffle, let me thank you for your participation in this hearing and for the expertise you've been able to lend to our efforts. You may stand down.

(Witness excused.)

CHAIRMAN HAMMERSCHMIDT: We'll break now for lunch. Let's try to return at 2:00 p.m.

The next witness -- before we break, let me mention that the next witness will be Dr. Wes Wilson who is an LLWAS expert affiliated with the MIT Lincoln Labs.

The following witness will be Dr. Mark Weber, also with Lincoln Lab, and he will be able to shed some light on the Terminal Doppler Weather Radar Program. And following that witness, we will question Mr. Leslie Brown, who is with the Federal Aviation Administration.

Following Mr. Brown, we will go to Dr. Fred Proctor, who is with NASA. So that would be an indication of the next several witnesses, in that order.

So, we'll break until 2:00 o'clock.

(Whereupon, the luncheon recess was taken at 12:56 p.m.)

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

[Time noted: 2:10 p.m.]

CHAIRMAN HAMMERSCHMIDT: Let's please come to order. Our next witness is Dr. Wes Wilson. He has already been sworn in. He will be questioned by Mr. Greg Salottolo.

WES WILSON, LLWAS EXPERT, MIT LINCOLN LABS,
BOSTON, MASSACHUSETTS

Whereupon,

DR. WES WILSON,

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

MR. SALOTTOLO: Mr. Chairman, Dr. Wilson has a presentation to make. May he use the viewgraph?

CHAIRMAN HAMMERSCHMIDT: Of course. Just proceed accordingly, please.

MR. SCHLEEDE: Before we get started, we need your full name and business address for our record.

THE WITNESS: Okay. May name is Wesly Wilson and I'm with MIT Lincoln Laboratory in Lexington, Massachusetts.

MR. SCHLEEDE: And how long have you held that position, or the position you're in?

THE WITNESS: I've been at Lincoln Laboratory since 1990.

MR. SCHLEEDE: And what is your title of your position?

THE WITNESS: Pardon?

MR. SCHLEEDE: What is the title of your position?

THE WITNESS: Technical staff.

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

THE WITNESS: I was awarded a Ph.D. in mathematics in 1964 by the University of Maryland. I have been working in geophysical fluid -- or geophysical data analysis since sometime in the early '70s. I've been working in meteorological data analysis, specializing with winds in the boundary layer and other measurements in the boundary layer since the late '70s when I started with the Environmental Research Lab, NOAA lab, in Boulder.

I joined the JAWS Project with the National Center for Atmospheric Research in Boulder in 1982, worked with that group through the time of its contributions in microburst detection and technology. I was the source scientist on the redesign of the LLWAS system for the detection of microburst windshear and I wrote the algorithm description for both the LLWAS Phase II and Phase III.

The LLWAS system at Charlotte is a Phase II system.

MR. SCHLEEDE: Thank you, very much.

MR. SALOTTOLO: Dr. Wilson, you may proceed with your presentation.

THE WITNESS: We're going to try -- the mike won't go there, so I'm going to sit here and point.

MR. SALOTTOLO: The presentation is contained in Exhibit 5-J.

(Whereupon, a presentation was made using viewgraphs.)

THE WITNESS: Okay. What I'm going to discuss first of all is what LLWAS is and how it's designed to work, and then we'll follow up with talking about how it actually worked on July 2nd, the day of the crash.

Okay. As far as what it is, there are a couple of issues here. One is the technology. Another is the FAA's procedure for first installing and then upgrading this system. And then I'm going to talk about some details about how you know if the system is doing what it's supposed to do.

LLWAS is a windshear detection system that is based on the detection of windshear by a network of anemometer. An anemometer is sort of a weathervane with a propeller on its nose. The spinning propeller measures the speed of the wind. The direction that the vane is pointed in measures the wind direction. The LLWAS system is typically placed on poles that are tall enough to measure the unobstructed wind at different positions around the airport.

There are three phases. The Phase I is no longer in existence. It was the first LLWAS. We'll say some more about it, but the important thing about it from our viewpoint is that it went out of existence in 1987. Phase II is an improvement on that system and Phase III is just currently being installed around the country.

The Phase I system has six sensors. They were space a little over two miles apart and they extended about a half mile to a mile beyond the ends of the runways at the airport. We'll see a picture of an LLWAS system in a few moments.

This system was not designed for microburst detection and it had a very high false alert rate, a high enough false alert rate that it was actually recommended semi-seriously that the best thing to do to improve the system would be to decommission it. Studies I've done have indicated that this system had a false alert rate perhaps as high as 60 or 70 percent. By that I mean, 60 or 70 percent of the issued alerts should be ignored. Pilots were learning to ignore the system.

Phase II LLWAS was designed to improve on that. Before I tell you about that, I want to talk about the Phase III LLWAS, because Phase II is a consequence of the Phase III technology.

The Phase III system was designed to detect microbursts. It has 15 or more sensors. They are space much more closely together, nominally about 1.2 miles apart, and a well designed system will extend to a full three miles beyond the ends of each runway to give coverage of the full hazard region.

The biggest problem with this system is that the installation of those sensors so far off the airport site is costly and slow. A lot of logistics problems in putting that system in. Because of the fact the FAA recognized that this would not be a technology that they would be likely to have a rapid deployment with, they approached me and asked me if we could modify the existing Phase I system to get some of the benefit more quickly.

We determined an algorithm that uses some of the Phase III algorithm concepts. The intent -- the design goals, if you will, were first of all to reduce the false alert rate to the point where the system would be believable, and then secondly, to see what we could do about detecting microbursts with the system.

It was known when we put the system in or when we planned the upgrade, that because of the big spaces between the sensors, this system would never be an effective microburst detection system. You would have to have the denser sensor spacing in order to have that kind of microburst detection.

These are numbers that describe how well the system works, and I need to say a few words about what these numbers mean. POD is probability of detection. Vertical bar WS means probability of detecting a windshear event. These are typically the weaker events and all of the system, LLWAS, TDWR, any detection system has more trouble when the event is weak. And you notice that we here have a probability detection of windshear on the order of 76 percent.

These numbers are computed using archived recorded data from Denver and Orlando. About five Summers' worth of data went into these computations, so these are fairly reliable numbers.

When the windshear event is a microburst, then we're looking at a number like this. LLWAS in a well designed and installed system, has a detection probability of on the order of 97 percent, very comparable to the TDWR. The Phase II system doesn't do quite so well, and there's two things that happen.

First of all, with windshears, it's quite weak. The detection probability there is on the order of 40 percent. The microburst detection capability is in the order of 60 percent. And unfortunately, these numbers are a little worse than they appear -- I mean, a little better than they appear.

The 60 percent number here assumes that the microburst is within the range of detection network, so that means that this detects 60 percent of the microbursts that are hitting near the airport. Since the network does not go out for the three miles beyond the ends of the runway, it actually doesn't give any coverage out there.

On the other hand, the PFA, the probability that an issued alert is false, this is the measure of the believability of the system. We see that the LLWAS Phase III has a 4 percent chance that an issued alert is false. This system should be believed. But lo and behold, even the quick fix, the LLWAS II, only has a 7 percent chance that an issued alert is false. This system, if it does issue an alert, it should be taken seriously. And from some of the things I've been hearing here recently in the last few days, I'm not sure that that's gotten out to the community enough. I think there's perhaps a training issue here that when you hear an LLWAS alert, you should pay attention.

MR. SALOTTOLO: Dr. Wilson?

THE WITNESS: Yes.

MR. SALOTTOLO: Those numbers were put together looking at the meteorology? They weren't looking at the hazard possibly experienced by an airplane -- an aircraft?

THE WITNESS: Yes. Those numbers were developed at the TDWR test sites. The major instrument that was used to evaluate the meteorology was the Terminal Doppler Weather Radar. We most of the time had a second radar and we were able to do dual Doppler analysis. That's sort of a jargonish thing.

I think the simplest thing to say is that if you use two radars you can fully resolve the wind field. Most meteorologists believe that the most accurate volumetric measure of a wind field you can make is with dual Doppler analysis. We used that to determine where there were microbursts with addition of human experts evaluating the situation, and that was the basis on which we determined the performance of the LLWAS system.

Now, the Phase II, since the Phase III system was so good, when we got ready to do the evaluation of the Phase II, we simply measured how well did it do at issuing the alerts that were being issued by the Phase III. We did not go back to the radars for that.

Okay. This is the enemy. I'm not going to spend a lot of time on this but we've been talking about these suckers for a couple of days. Over here we have a caricature of a microburst and what's happening here is a shaft of cool air is falling. When it hits the ground, it splashes.

LLWAS anemometers that happen to be conveniently located would show the wind blowing out, and across here we would have the characteristic divergence signature of a microburst. The other windshear event that comes along is a gust front. It can occur as an outflow either from a microburst or for a storm. It's sort of a one-sided beast that comes out, and this would represent the signature that that would give. We won't be discussing that today.

This is plan view of what a microburst would look like hitting an LLWAS network. The runways here are from Stapleton in Denver. This is the geometry of the six sensor system that was at Stapleton up until 1977 when the expanded network system was installed for use in the development of the Phase III technology.

Over here was have a 15 -- or I believe it's actually a 16 sensor system that was obtained by adding anemometers. For example, this station here is right here. All of these extra sensors were put in and around the original six. What you should notice here is that when a microburst lands on a very dense -- when a microburst lands on a dense network it gives a very strong signal. You can see the winds flowing out here. It made my job easy when it came time to write or develop an algorithm to detect that signature.

That same microburst falling on this sparse network gives a much more subtle signal. Now, remember, one of our problems was to be quite certain that when we issued a windshear alert that it was believable, and so the issue here in algorithm design is to find a way to correctly issue an alert when that signal is there and is corresponding to a windshear, and not to issue that alert at other times when there's no hazardous windshear present.

We'll come back to that in a little while.

Because the sensor is so weak or the chance of being so badly detected in a Phase II system, we added another component to the Phase II detection, that of detecting a windshear by noticing a very strong or anomalous wind at a single sensor. And so the first issue and the way that most LLWAS alerts, Phase II alerts are issued, is based on having an exceptional wind at a single sensor.

The way we would like to detect a microburst is by measuring a significant divergence between sensors. Unfortunately, in the Phase II system, because of the geometry, that doesn't happen very often. Only about 15 percent of the alerts issued by this system are based on the divergence detection.

Because of the concern with false alerts and the fact that occasionally Ma Nature does something cruel to you as far as squirrely winds, in order to avoid false alerts, we not only insist on getting the signature of a windshear, but we ask that that signature be repeated.

For the LLWAS Phase II system, we require -- and that's what alert persistence is about. We require that we have four consecutive detections by the system before we issue an alert. This puts about a 40 second delay into the detection because of the fact that the winds are re-measured every 10 seconds by this system. This compares, for example, with a nominal 30 second delay that's build into the TDWR system because of the fact that it simply updates the whole surface scan once a minute. So this is fairly characteristic in these systems that there's a little bit of a delay built in through the sensing technology before alerts can be issued.

The Phase III works completely on major divergence. Convergence is simply the negative of divergence. It's the same basic mathematics. And it also has its alerts delayed by a persistence requirement, although it's slightly different.

Looking now at what an ideal situation would be, if I had three LLWAS sensors and a microburst hit right in between them. Then the winds would blow out in three directions. And by doing correct mathematics in this triangle, I could compute the strength of that divergence. It would not only tell me there was a microburst there but would give me a good measure of how strong that microburst is.

If the microburst hits off to one side, then the winds flow out from that microburst and we are still getting a divergence signal, but it's not the pretty symmetric picture that we would like to see from this situation. It turns out that the case that we're going to be considering from July 2nd was more of this type but the signature is still there.

The other thing that comes up is sometime the microbursts aren't necessarily -- you'll notice down this edge here I'm getting a signal just on those two sensors.

If I did the arithmetic just on that edge of the triangle, what I would be interested in is if I take the component of the wind along the edge direction and then the component on this side, what is the net change in headwind if I would experience if I flew an airplane down that edge. If down that edge is reasonably parallel to the runway, then that would be an indication of what would the actual headwind loss that the airplane would experience be if they flew down the edge or down the runway on their approach.

The other part of LLWAS is are we measuring winds that allow us to correctly make those computations. I said in the introduction that I have been studying making measurement in the boundary layer. The boundary layer, to meteorologists, means that portion of the atmosphere that is fairly directly influenced by the interactions with the surface of the earth. When you are near an airport, you frequently could have some buildings, trees -- stuff. As the wind blows across that, two effects can happen that will change your ability to measure the wind field.

The first is that you may simply -- if you tried to put an anemometer down in here behind that tall building you wouldn't be able to get a correct measurement at all. That would be called sheltering. The wind may actually -- and I don't have a three-dimensional picture here, but the wind could actually be distorted around the building and when it gets to the other side, not be moving in the direction of the normal wind behavior but in a local distorted wind field that came from the wind blowing around an obstacle.

There's another feature that's more subtle but just as real when it comes to sensing technology, and that is that the atmosphere has a viscosity, which in a sense means it has a memory. As the wind blows across a rough surface like this, it begins to build up a drag, which is something that happens in addition to the sheltering or channeling that would come from abrupt obstacles. And what that drag does is if the wind speed is really going with a -- maybe we could say an indicated speed of this much at a couple hundred meters, when we get down near the surface, the wind slows down and may only be blowing this fast because of this drag that comes up.

A lot of work has gone into designing the LLWAS system, finding ways to site the poles to minimize these adverse effects from the boundary layer friction and obstructions.

I worked with the FAA and we'll come back to this. I'll call it the siting criteria here. I supervised a project with a group of excellent wind engineers from

Colorado State University. Did about three years of research on this question and wrote a siting criteria which is now an official FAA order, which describe how the maintenance people and the construction people should install an LLWAS system to avoid some of these problems.

Why do we care? Well, there's two things that can happen if you're not measuring the wind correctly. Since the system depends on wind measurements, incorrect measurements are bound to screw it up. It can work both ways. It can either cause false alerts to be issued. That's usually what happens. Or it can cause a missed detection or an underestimation of the intensity of an event.

We've talked about the three critical problems that come up with measuring. We have the roughness issue, the sheltering issue, the channeling issue. They will all come back to haunt us as we go through this discussion.

People working with me at Lincoln Laboratory have developed some automated techniques for analyzing how well a system is working or how well a particular sensor is working. One of the problems you have, again, is knowing what's true. The system is making measurements. It gives you numbers. It always gives you numbers. When are the numbers representative of what we want to know about the wind field?

I think the easiest way to describe that is that the way the atmosphere, the local structure of the atmosphere behaves changes from time to time. Most of the time the wind effect across a region is quite general and consistent across the region. The very tight network of anemometers that we've put together to measure windshear is an over-sampling of the phenomena. Any anemometer will tell you about the same as any other. We've taken advantage of that redundant information and we statistically compare each anemometer against the mean behavior as measured by all the anemometers. That gives us a way of determining how the system is working.

When there's a windshear present, of course, now the local structure of the atmosphere becomes much more diverse and when that is going on we want to detect that diversity. At that time, the windshear algorithms are used.

Finally, there are times -- the National Weather Service has a phrase, "light and variable winds." What that means is that usually it's very light winds, of course. The structure of the wind field has fallen apart so much that what you read at one anemometer is almost totally unrelated to what you read at another anemometer, even if it's only a mile away or even a few hundred yards away.

At that time we don't want the system issuing alerts. What's going on is just the expected chaos in a white wind field. And that's one of the reasons why we've put some of the protective steps into the algorithms that are built in there. We only want to detect significant organized windshear. Significant to us means it's going to hang around long enough that a pilot will care.

Okay. This is the outline again. So far I've tried to explain to you what this part of the story is. Now we're going to move down and talk about the performance of the system.

I'm going to reverse the order and first tell you about the -- and I know there's a lot of concern on this issue -- how well did the system here at Charlotte work on July 2nd. Well, we'll start by talking about how well did each anemometer work.

We took the data from the 14 days previous to the 2nd and we only looked at the wind at those times when we expected a consistent behavior. So we did not look at the -- we did not apply the analysis to the winds from the times when the winds were very light.

Based on the times when the wind was blowing steadily, we compared each of the sensors against the mean wind as measured by all of the sensors. The sensors that are of most interest today are sensor number 1. That's the center field sensor. It's in the airport center right next to the ASR-9 for those of you that know or care. Sensor number 2, this is the northeast sensor and it was one of the ones that gave an early alert. And sensor number 6, this is the northwest sensor.

I've gone out and looked at these sensors and for the life of me I cannot figure out why station 1 is showing high speeds fairly consistently. The sensor is not badly sited. It is not on an exceptionally tall pole. It's about a 20 foot pole. It's sitting there, but it seems to always measure winds -- this band represents plus or minus 20 percent of the mean wind, and it is always up at the top end and frequently as much as 30 percent high.

My supposition is that in fact because of all the trees around here, everything else is low because of excessive drag in the region and in the middle of the airport is the one place where you don't have that kind of drag going on. I don't think that that adversely affected the performance of the system. It's the kind of a thing that you can scratch your head about when you look at these data.

What we've done at these other sensors -- I'm going to talk about sensor 2 first. We looked at all of the winds in each 30 degree sector. So what I've got here is 30 degrees where 360 or zero is north and then we move around the compass. And what we see is that most -- this direction, we didn't have enough wind over two weeks to ever get a measurement on it. We didn't have enough to do the statistics and that's why that one's missing.

All these other ones we had measurements and in almost all of the directions we were within the plus or minus 20 percent. From 300 degrees we fell just a little bit below 80 percent of wind speed. There is some sheltering in that direction. And indeed, when i went out to look at that sensor, there's a quite visible line of trees sitting about 150 feet west of that sensor. Probably what's happening is the wind is hitting that line of trees and deflecting upwards. It's otherwise in an open field and giving a slightly light reading at that sensor.

Station 6 is visibly sitting in an area with a lot of trees. I was called about this sensor. It was suggested it was sitting in a trough. That's not quite true but it does give that visual appearance.

The trees in that area are about 50 feet tall. The sensor is on a pole actually sited at 61 feet, so it is above the trees. It is also the grade from the south. It's going up hill from the south to the sensor. The area has been cleared to the south for the installation of some other equipment, other FAA equipment, and so there's a fairly good exposure of the sensor from the south. From all other directions I think the wind speed is reduced not as much by blockage by the trees. It is sited about 10 or 11 feet higher than the trees in the area. But rather, because those trees go on for a half a mile or more on all directions away from that sensor and they absorb the energy, the roughness is what slows the winds at that sensor.

It is right under the centerline of the runway. Part of me would say put a taller pole there and push it up. I'm not sure how much you're allowed to. But in any event, this sensor is showing statistically winds that are occasionally down in the range from 68 to 80 percent and sometimes below 60 percent of speed. The one good exposure is from the south.

And I guess the FAA was lucky. Maybe the pilots don't feel so lucky, but in fact, the sensor did give good measurements of the wind at this time. And we'll come back and look at that. But in fact, the winds were always from the direction where it had good exposure during this period.

The next thing, the other issue would be, of course, was it getting the direction wrong. And that would be deadly for this system. We have a different statistical test we apply to look for sheltered winds or misdirected winds or channeled winds. We'll come back and talk about that for a minute.

I just want to graphically for a moment describe what we could have seen if we'd read all the numbers on the previous transparency.

This is the Charlotte Airport. North is up. This is the center field sensor and then sensor 2, 3, 4, 5 and 6. I've put a little -- remember we saw that sensor 2 had a little sheltering from 300 degrees and I've put a little single stripe there to indicate that that sensor is below 80 percent wind measuring capability from that direction. Right along in there is where the line of trees was that I mentioned.

Sensor 10, there's a mistake in the handouts. In the transcription, this got drawn over here. It should have been at the bottom. Sensor 10 has some sheltering at the 80 percent level from both the north and the south. That wasn't relevant to this particular incident.

Station 4 is pretty clean. Station 5 has a little bit of sheltering from the south and station 6, which is certainly a pertinent issue for today, has a lot of sheltering. In fact, I've used a double bar here to indicate that it actually is dragging down to in the order of 60 percent of wind measurements from the two sides. From the north it's getting about 80 percent and from the south it's actually doing a fairly good job.

MR. SALOTTOLO: Excuse me, Dr. Wilson.

THE WITNESS: Yes.

MR. SALOTTOLO: I think you mentioned Station 10.

THE WITNESS: Did I? I'm sorry. Station 6.

MR. SALOTTOLO: Well, the one in the southeast --

THE WITNESS: Oh, I'm sorry. No. That 10 is a little thing to say -- it's a legend for arrows. This is station 3.

MR. SALOTTOLO: Okay.

THE WITNESS: I'm sorry. Did I say 10?

MR. SALOTTOLO: I think you did.

THE WITNESS: Oh, okay. I'm sorry. There's only six sensors at Charlotte.

Okay. The other thing we can do is ask when the wind is blowing reasonably strongly is the wind at each sensor directed in the same direction as the wind from the rest of the network. And here we looked at the issue of when are they sort of exactly lined up. And by this we mean actually plus and minus 5 degrees. Minus 10 degrees is where there's an error between minus 5 and minus 15 degrees. Going the other way we could have plus 5 and plus 15 degrees, et cetera.

Well, the first thing we notice is center field our quite unobstructed sensor is doing a wonderful job and we have basically a normal distribution here with a strong clustering of winds pointing in the same direction as the whole network. That sensor is showing no sign of sheltering at all.

The diversity here comes from the fact that as you move across a region -- and remember, all of these sensors are at least a couple of kilometers from each other -- that you will get a natural diversity in the winds at each point and what we're seeing here is a result of the natural diversity.

When we move over to station 2, we see a broader spread. The reason for that is the roughness in the area. That causes local distortions, very temporary, and gustiness as the wind goes around the obstacles or over the rough terrain and that will show up with a broadening of that signature. But notice that the signature is still pretty much centered on the middle.

If we look down here we see that this sensor -- actually, if you do all the arithmetic, has got a bias of about minus 1.5 degrees. This sensor has a bias of plus a half a degree. This sensor, again, the wider spread is plus a half a degree. This one's off by about plus 3 degrees.

This one 3.7. And sensor 6, the one we're really concerned about, is showing a minus 6 degree bias. I don't view that as exceptional at all. I see this all the time when I look at LLWAS data and I've looked at a lot of it. And this one, you can see the slight shear upwards there in the numbers, but this sensor, again, is showing a fairly symmetric pattern except for that slight bias.

Again, this is not a sensor that would be viewed as cause for concern from the viewpoint of direction. So my conclusion on this is that it's not a station that is mis-measuring the wind due to channeling but because of the previous things we've looked at, it has certainly got obstruction problems from the north and to the east and west, -- or roughness problems I think would be a more correct statement.

Okay. I now want to talk about what happened in the few minutes before the crash and what were the wind indications that were available to the system. And what I'm going to do is take you through, first of all, by human inspection. And along the way we'll talk a little bit about when alerts were issued and what their meaning was.

This is a few minutes before. And except for the fact that the center field winds are a little strong than everyone else, which we expect from what we've measured on the system, the winds are generally from the southeast and at nominal speed.

A minute later, this wind has swung over from about this direction down to the 110. And this wind has actually picked up speed a little bit. Normally, that would be accepted as normal fluctuations of a wind field. In retrospect, it turns out that this is a first subtle signature of something to come.

And what we see now is that this is picking up. We are starting to see a divergence down this side and -- well, let's move on to the next one.

At this point the system registered its first windshear alert. I'm only going to the nearest minute here. I don't know the exact time to the second on this. We can retrieve that if anyone wants to know. But there was a windshear alert at center sector issued at this time. And it was based primarily on the fact of the direction is a little different and the speed is quite a bit higher. And that caused the algorithm to say this sensor, this one sensor, is measuring unusual winds. And so there was a center field windshear alert at this time.

MR. SALOTTOLO: Dr. Wilson?

THE WITNESS: Yes.

MR. SALOTTOLO: Let me interrupt you again. Let's get the units straight. It's in knots?

THE WITNESS: I'm sorry. Yes. These are in knots and degrees.

MR. SALOTTOLO: Magnetic?

THE WITNESS: Magnetic. Yes.

MR. SALOTTOLO: Now on page 19, I notice it was corrected in the viewgraph. The exhibit has 120, and that should be --

THE WITNESS: Yes. There's a zero that I was able to erase from this transparency. I think it says 120 on the handouts. That was a typo.

Thank you.

Let's go back to that one, though.

You'll notice because of our sort course on divergence at the beginning of this discussion that this edge is starting to show a divergence. On the next transparency that will become much more obvious. And I've sketched the edge in here so you can see it. You see that this arrow is pointing almost up the edge at 15 knots. This is only pointing down a little bit, but the loss along that edge is now in excess of 15 knots, and that caused the system to issue an alert.

Now, okay. We know we've got a problem but what do we tell the pilot?

What the system is designed to do is to analyze what is the cause. Was it this edge or what part of the network caused the alert and if the cause was there, then what areas might the windshear be in. And I have to emphasize the word might because with a network that it this sparse there are lots of places that a windshear could be that could potentially issue the same signal.

And in this particular case when that edge is above the windshear detection threshold the supposition is that the windshear is somewhere around here. And that caused the system, therefore, to issue an alert for both center field and the northeast sector. This is the alert that a lot of people have been talking about, the northeast sector alert. It's because the system detected a microburst in this region.

Now this was not given to anyone. There was also an alert at this sector at this time. The reason for that is because this triangle was also exhibiting a divergence feature. If that whole triangle is showing divergence you can't be sure if the windshear is to the north or to the south of the center field sensor. With the uncertainty in mind, the system is designed to give the alert to everyone who might possibly need it.

Again, a pilot would probably only be given the alert from the direction that he's coming -- or in the direction he's operating in because the controller knows where the planes are and what the operation is. So he would not tell this pilot that there was a windshear alert in the southeast normally but he would probably tell him about the center field and the northeast alert.

Okay. This is a very touch time. This is probably close to the last time that AT had a chance to talk to this aircraft. And we'll come back and revisit the time on this more closely in a few moments.

This alert is being maintained. And in fact, the detection of that has become even more certain. This alert was not issued. The winds at this sensor have now suddenly surged to 23 knots. The reason that this alert was not issued is because this center field wind is also surging and is surging to the north. And if you measure the loss of headwind down that side, it's a little over 13 knots. Even though that wind is large, this wind is going the same way. The reason this is built into that detection algorithm is you don't want to issue windshear alerts if all the winds are going in the same direction at a high speed.

For example, if you had 20 knot winds from the south everybody would be showing a strong wind to the north, but it would not be a windshear situation. It would be an operational wind situation.

So, this system is designed to make a distinction between operational winds and windshear. And this is not quite. I said it's a little over 13 knots. Fifteen knots is the threshold and it did not trigger an alert at this time.

We'll come back and talk about that on a 10 second by 10 second basis in a moment.

Okay. At this point these winds continued to surge. They're all the way up to 34. It actually went to 35 knots up here. That outflow is so strong now that in fact every single edge on the network was seen to be showing an excessive loss down the edge and the "all sectors" alert went out. So this was the cause at the about approximate time of the "all sectors" alert.

I'm going to look at these now from a different viewpoint. And what I've made is a plot. Down here we can see a caricature of the map of the airport. I've got the center field winds indicated in blue and then they're matched up here in blue. And indeed, over here I have a blue bar which indicates when the center field alert was in effect.

The northeast sector is in green. That, of course, speed trace is here in green and the northeast alert was in effect over this time.

This is the time when the NEXRAD, the nearest surface NEXRAD scan was given. I put 6,000 feet. This morning Bob said maybe 7,000-8,000 feet. The beam is very wide there so we've quibbling over a few details. But in any event, this is the time when the most appropriate NEXRAD scan was effective. And then this time here was the time when the last communication was made with the aircraft when he announced his attention to go around.

You'll notice that I've monkeyed with the numbers here. It's not because I'm incredibly careless and didn't want to make a new transparency. The LLWAS clock had a 10 second slip in it. These are the times -- and some people here have obtained copies of the data. These are the data times that are stamped on a data archive. These are the real times. They're 10 seconds earlier. The clock was 10 minutes fast. So this was the time that was actually going on and this is the aircraft time. I put both numbers on so that you could make that comparison.

Over here I've given you the sort of folksy description of what does wind speed mean. Down below five knots, winds are usually referred to as light; breezy, 5 to 15 knots; and starting to get windy 15 to 25 knots. Above 25-30 knots would be called a gale. That's serious wind.

What we notice is that none of these winds is in what we would think of as being an exceptionally strong state. Down around here you'd probably start grabbing your napkins and paper plates at the picnic. Up here you'd probably rather be inside. But these are not in any sense damaging winds.

What has happened -- oh. And the other thing that happens about these winds is they basically don't change direction during this windshear event. The center field wind started sort of to the north and swung around going mostly west, but it then sort of stabilized at 100-110 degrees. The northwest sensor and the northeast sensor were kicking around between 180-190 degrees consistently throughout the event.

So the only thing that's relevant is how strong is the wind at each of these times. And what we see in strength is that right around minute 40, center field wind showed a fairly substantial surge and that's the surge we saw when we were looking at it. And if you count 1, 2, 3, 4, you discover the alert starts over here and then the alert was sustained.

The northeast sensor -- well, what it that -- about 30 second later started a surged. There's a little plateau and then another surge. The northeast sensor, because of the fact that it was creating a divergence signal in cooperation with the center field sensor, together these two started showing this combination windshear alert, which is the base detection of the signature for a microburst.

By the way, this system does not issue a microburst alert. Unlike TDWR or the LLWAS Phase III which can issue microburst alerts, this system is not capable of issuing the microburst word. When it detects a windshear, regardless of how it was determined in the algorithm, the only message that it can give to AT and hence that can be passed on to the pilot would be the windshear alert. And that's because of the design of the display equipment.

Remember, we were backfitting an old system when we put this together.

Okay. What about the northwest. That's the one we care about. The first thing you notice at all of these winds is that the winds are rather choppy but the northwest wind is a little more choppy. The wind starts to go up about the same time as the northeast sensor. It drops back off and then it ramps up about the time this is showing another little surge. The sucker goes up and then comes back down. And this is where we were 10 second before the last communication with the pilot.

So, the situation is -- even if I as an expert had been sitting there looking at these winds, this is what I would have had to work with and the issue would be should I give this guy a windshear alert, a microburst or no alert.

I put this up this way so you could see where the uncertainty in the system is.

Could we have the next transparency?

Unfortunately, with perfect hindsight, immediately after communication was severed this sucker took off. This is at the time of his last communication and then the 10 second following that there was a surge of wind at this sensor.

There's something else annoying that happened. These three winds here were strong enough to issue a windshear alert on this LLWAS system, this wind here, by about a half a knot drop below the threshold. Remember when we looked at it before, it looked like it was kicking up and then it was dropping off. This dropped down I believe -- the number, I've got it here if anyone really cares. It's about 14.7 knots. We're looking for 15 knots to issue an alert.

I take it back. It's 14.3 knots. It dropped just below the threshold. Because of the requirement of four consecutive alerts or detections before the system issues an alert, it stopped the count and then when it surged again, it started the count again and -- oh, our color code got reversed. Sorry about that.

Over here is when we got the northwest alert and by now the plane is no longer communicating with Air Traffic. So, we had an unfortunate piece of bad luck because the winds went white for one flicker right here. We also had back luck that most of the really significant action here happened right after the communication ceased.

MR. SALOTTOLO: Excuse me, again, Dr. Wilson.

THE WITNESS: Yes.

MR. SALOTTOLO: I'm a little confused. Could we turn back to 24 there?

THE WITNESS: Sure.

MR. SALOTTOLO: You said the color codes got --

THE WITNESS: The color code -- could we go back -- let's go back to 23.

MR. SALOTTOLO: Okay.

THE WITNESS: The color codes are correct except for these alert bars. And when I asked the technical graphsman to change the colors of these curves, she got these guys right but when she changed it, she didn't change the bars on the next transparency.

So what we have is these are correct; these are correct; these bars here are incorrect. This red actually corresponds to the blue up here. The green corresponds to the green and this blue corresponds to the red. She reversed the code on the red and the blue.

MR. SALOTTOLO: Thank you.

THE WITNESS: Okay. Let me go back one more time. I want to go back to 22.

I think one of the things that we have to keep in mind as we're going through this is that this network has only limited capabilities to resolve microburst behavior. I've shown you some pictures of nice round microbursts. When I think of microbursts in my naive state I like to think of nice round microburst. When you generate them by numerical models you see fairly nice round microburst.

When I take pictures of microbursts with dual Doppler radar analysis, I find that microbursts are rarely round. They are all sorts of funny shapes. They'll have fingers of gustiness come out. Sometimes you'll have a superposition of a big microburst and another microburst sort of hitting right on the edge of it. All sorts of curious things can happen in nature.

When I look at this, my eye is drawn to that divergence. I think of a microburst sitting over here slightly offset as my idea picture would indicate, and winds blowing out from that center in these two directions. And then as I look at that, I wonder where did that wind come from.

First of all, if the wind is only that strong there and there, I would not expect the exceptionally strong wind this far away from the microburst center. I'd expect it in more on an arc somewhere in here.

Secondly, I would expect this wind to be blowing straight out from the center of that microburst. So I take this as an indication that maybe this is not a nice round microburst after all but some more complex event. And what I would say from this as one possibility is that a very small microburst has popped in here, so small that it's only being seen by that one sensor.

Another possibility is that there is some sort of a jagged glove like thing with a thumb sticking out in that direction. I don't know what it is. I can't know from these data. And I'm afraid from what we have available from this accident we just can't know those details.

I think what we can see from this is that there is a complexity here which is a hint that maybe we will never know the whole story, except perhaps from one other instrument.

There is one other measurement of the wind out there and I'm sure we'll be discussing that soon. That's the flight data recorder. So, with the caveat that I don't have access to that and that's not my business, but I am trying to analyze the winds. I can guess what might be going on looking at a picture like this, but I cannot know. And the reason I can't know is I don't have enough anemometers out there.

So, based on that, there are two things that could be going on. We could have a nice simple round microburst like we like to draw in the textbooks. What would make us believe? Well, the nice round microburst can move across a region. They definitely can translate. And the fact that we first got a pulse at center field and then in the northeast and then in the northwest might make you think of a nice round microburst footprint that's moving across the region to the northwest hitting sensor after sensor as it goes.

The alternative or the contrary argument on that would be that if you moved the microburst across the region that way, you would see the wind directions swing with time so they would always be pointed away from the microburst center. We didn't see those wind directions move at all. They were always going the same way throughout two or three minute. So that makes me suspicious that I'm not looking at that kind of a simple situation.

The other thing is that no matter what kind of a microburst I put in there, I wouldn't see the winds from the northeast. The northwest sensor is pointing in the same direction. And those winds are essentially pointing due north throughout the time. Again, making me suspicious that this is some kind of an abnormal microburst feature that happened to be undersampled by this LLWAS network.

I am leaning in my own mind -- and I guess we could this, at best, an educated guess -- to the fact that this is some kind of a complex microburst event. I base that on two factors.

First of all, there were different pulse types. If you look at the time traces of the pulses, the pulse that happened at the northwest sensor is decidedly different in its time history from the pulse that happened at the other sensors.

And secondly, it turns out, and we'll see -- I guess Bob Saffle discussed this this morning. We'll see a picture a little bit later of where there might have been this special cell from the NEXRAD. And in fact, it's located up in the direction of that sensor where I think there might have been some kind of a special feature.

The big problem with this, of course, is I don't have enough data to come to a firm conclusion with what we have.

So what have I told you about? I've told you that the LLWAS II is not the perfect windshear detection system. It was installed knowing that it had limitations. The reason it was installed was to improve on an existing system that was issuing too many false alerts and which had no ability at all to detect microbursts.

I think one of the findings from the New Orleans crash, Pan Am 759, was that LLWAS, because of a deficient algorithm, was a contributing factor in the crash. We were correcting that deficiency. But this system was known, because of the sparse network, not to have the capability to be a full microburst detection system.

Most of the inadequacies of this system are traced to the sparse network. In my opinion, the system did what it was supposed to do on July 2nd. It did the correct arithmetic. I've re-checked almost all that arithmetic by hand as well as running it in my own software, my own computer programs. I can confirm that the numbers that are coming out of the system are essentially correct, but in fact the system didn't give alerts as early as we would have liked them to. It's unfortunately designed to do that so it won't give so many false alerts. There's a little conservatism built into it.

And finally, I do believe there is strong evidence that there is a complex microburst event that occurred on this day at about the time that airplane was trying to fly through there.

MR. SALOTTOLO: Thank you, Dr. Wilson. I just have a couple of follow-up questions, just to restate a couple of questions.

MR. SALOTTOLO: In your opinion, analyzing this data, how would you characterize the performance of the system in general at Charlotte?

THE WITNESS: I can tell you how I think it worked and how I wish it had worked. It worked the way it's suppose to. As I said, it cancelled -- stop issuing the alert in the northwest because of a very close call because of a wind speed drop for one ten second pull, but that's the way it's designed to work and that's the way it did work.

MR. SALOTTOLO: I was getting at in general, not the event we're talking about. It's in general operation.

THE WITNESS: Yes. The measurements made by the system when the wind is blowing from the south are believable measurements. We had the wind blowing from the south that day, so the system was correctly measuring the wind field as far as I can tell.

MR. SALOTTOLO: Okay. But the system as it is operating right now --

THE WITNESS: Yes.

MR. SALOTTOLO: -- there's a problem with sheltering?

THE WITNESS: There is a problem with sheltering at the northwest sensor. The interesting thing is that if the thing you're most worried about is microbursts on the airport, whenever there's a microburst on the airport the winds going to that sensor will be from the south and it will detect them. It will not detect other kinds of windshear coming from outside of the airport from the north or the east or the west or it will give a delayed detection, at least.

MR. SALOTTOLO: Now the only sheltered sensor is northwest?

THE WITNESS: The only severely sheltered sensor is the northwest. The map I showed shows partial sheltering at a couple of other sensors. We could put that back up if you want.

MR. SALOTTOLO: That's okay.

THE WITNESS: But there is some sheltering at each of the sensors. It's almost impossible to install an LLWAS system without having some sheltering. I mean, when you're in an airport -- around an airport, you're very likely to have some buildings and you usually have some trees, especially in the southeast.

MR. SALOTTOLO: Okay. But for optimum performance of the system, the site should be as representative as possible and sheltering should be eliminated?

THE WITNESS: Well, -- yes. The FAA would probably have trouble bulldoze the whole area flat. But what they can do, and that's what the siting criteria is for. There is guidance on how to site the anemometers at a high enough position so that the most egregious effects of the sheltering are not impacted on the system.

There are times when you get into awful troubles. Pittsburgh, it turns out, is a place where it's very difficult to put an LLWAS. We actually modeled the whole airport in a wind tunnel to find out how we could put an LLWAS in there that would work.

So, it is possible almost anywhere to install an LLWAS, but you need to be very careful with it.

MR. SALOTTOLO: Okay.

THE WITNESS: By the way, TDWR has the same problem. With TDWR it's called ground clutter. Any sensing system will have its weak points and good engineering will be used to overcome those weak points.

MR. SALOTTOLO: Now, your analysis of the data, LLWAS data, showed that on July 2nd, 1994 during the event, prior to and up through the event, that there was no system degradation or significant system degradation at all?

THE WITNESS: I -- well, of course, I don't know what was really out there. I don't see anything in those data that makes me feel suspicious of the system. It looked like a normal behavior of an LLWAS during a windshear event. The story it tells is believable.

MR. SALOTTOLO: So, in your opinion, sheltering was not a factor, given the prevailing wind at the --

THE WITNESS: That's correct.

MR. SALOTTOLO: -- northwest sensor?

THE WITNESS: That's correct.

MR. SALOTTOLO: Thank you very much, Dr. Wilson. No further questions at this time.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Salottolo.

We'll, begin with the parties. Federal Aviation Administration?

MR. DONNER: Thank you. Just one question.

MR. DONNER: Doctor, in a Phase II system, is a complex microburst event more difficult to detect than your classic event?

THE WITNESS: That's hard to answer. Part of me would say that with the sparse network, almost any detection you get is dump luck. However, I've watched the system work well so often. I just continue to be amazed that it even is getting the 60 percent detection that it's getting. I don't know that I've ever had enough information to know that in a specific way.

Most microbursts -- I mean, there's my microburst when I do computer simulations and there's God's microbursts. And most of God's microbursts are not nice and round and the system seems to detect them. So I guess I'd have to say it does all right, but I don't know why.

MR. DONNER: Okay. Thank you very much.

CHAIRMAN HAMMERSCHMIDT: National Air Traffic Controller Association?

MR. PARHAM: Yes, sir. I have a couple of questions.

MR. PARHAM: Recognizing the system's performance as -- that it did perform as it is designed and you were involved in the design of it, how much input in the design process was from the pilots and controllers that actually have to use it.

THE WITNESS: Okay. Ah --

MR. PARHAM: Could you kind of elaborate on how that was done?

THE WITNESS: Sure. I'd be happy to. In fact, LLWAS was responsible -- a very courageous FAA program manager named Dan Rebnon, who is no longer doing this, went head to head with the Administrator over this and formed the TDWR/LLWAS Windshear Users Group, which was used to design what has ultimately become the Phase III LLWAS and the TDWR operational concept. That user group involved several air traffic controllers, a few line pilots, representatives of ALPA, the people that wrote the windshear training aid. There's a fellow from Douglas, a fellow from Boeing.

We made a very -- several different FAA headquarters people met and we haggled for usually two or three days at a time over what the system should do -- what each of these systems should do. And then we, the scientific group, would go back to the trenches, work for a year and we would reassemble.

The Phase II LLWAS concept came out of the second meeting of that group and it came out because of a plea from the pilot community and the controller community to do something now. They didn't want to wait for a four or five year FAA procurement. And indeed, it was at one of those sessions where somebody said, "What's the best thing we can do to improve LLWAS," and the rhetorical answer was "Pull the plug."

And we came up with this concept. We presented it to that group and that group agreed that this was an appropriate thing that could be done quickly. We were able to do this simply by changing the software in the computer. We didn't have to change a single sensor. We didn't have to touch a piece of hardware. We simply loaded a new tape into the computer and it was running.

MR. PARHAM: You had mentioned the false alarms and the concern of those earlier. Do you have what the occurrence of false alarms are now under the new system?

THE WITNESS: Okay. They were published in that handout. The Phase II LLWAS system, according to the evaluation I did, and that evaluation was based on about five months' data from Stapleton and Orlando. Based on those data analysis and asking the question -- I guess the system was called issuing a false alarm, if it issued an alarm that was not issued by the Phase III system. I just compared LLWAS Phase II against LLWAS Phase III.

On that basis, about 7 percent of the alerts it issues would not be issued by a Phase III system. Now, there is a caveat in that. The Phase III system has an additional wrinkle in it to actually cancel an alert that is in the process of being issued, and that cancellation occurs if the shear is primarily across the runway rather than along the runway.

Another requirement from the user group was that they only wanted to hear of a headwind loss or gain along the runway. Phase III LLWAS and TDWR attempt to only issue alerts when the shear is along the runway. LLWAS Phase II is unable to make that determination, so it issues an alert no matter which direction the shear is coming on.

Other than that, all of these alerts -- only 7 percent of its alerts would not also be issued by a Phase III LLWAS.

MR. PARHAM: Do you have the capability of going to a specific site, say Charlotte, and determining false alarms over a -- say month period? Is there any way to determine that?

THE WITNESS: Oh, boy, that would be touch. I'll tell you one of the big problems with Phase II LLWAS. It was -- it's sort of like a temporary building. It was put in as a quick fix to give people improved performance until TDWR or Phase III LLWAS could be installed at all these airports. And so there was not a lot of -- I mean, the effort that was put in -- and I've also worked substantially on the TDWR windshear detection algorithms.

Most of our scientific time was put on coming up with a very good Phase III LLWAS and a very good TDWR. We were not funded to put a lot of money and time into a perfect Phase II, because the expectation was it would be turned off as soon as all this good stuff came down the line. And the good stuff has been a little too slow.

MR. PARHAM: That kind of brings me to my next question. Was at the time the quick fix was contemplated, a time frame that this was to last until -- you know, when the new system to be here? Was it six months, two years, 10 years?

THE WITNESS: Oh, we started working on this -- I mean, for the FAA, even quick isn't as quick as what we'd like.

MR. PARHAM: I don't mean to start it up. How long was it designed to last?

THE WITNESS: Well, it was in the spirit of '87, I believe, that we decided to do the Phase II concept. I developed the algorithm, tested it with the recorded data, and delivered it to the FAA in about six months. It took them two years to go do a procurement of 21 67A completed tested approved software.

The FAA has to be very careful in the stuff it puts in the field. It doesn't put it in the field and then have me run around and watch it afterwards. It wants it to be right before it turns it on.

So, we started on this concept as early as '87. Most of it got out into the field by '89. i'm not sure, quite frankly. You'd have to ask someone else what was the anticipated date in which all the TDWR's would be in the field and commissioned. And commissioned, of course -- a lot of them are in the field, but they aren't -- only one of them is commissioned, as far as I know.

MR. PARHAM: So, really, basically, you worked on the equipment not knowing how long it was to last, just to get the best you could in the field quickly?

THE WITNESS: Well, we were using the existing hardware. Our charge was to not touch the hardware. To do a software upgrade that would make the system work better. And so we only changed the software.

MR. PARHAM: Can a controller working at an operational position determine if an alarm he receives is false or whether it is a valid alarm?

THE WITNESS: I couldn't if I were working at that position. I don't think so. And I don't think it would be wise to have a system there with people sitting there trying to second-guess it.

We do try to test these systems very thoroughly before we turn them over to the FAA.

MR. PARHAM: You had mentioned that 15 knots was some of the criteria used in the activation of different things. What is the criteria for the activation of the oral alarm in the tower?

THE WITNESS: An oral?

MR. PARHAM: The oral.

THE WITNESS: I've actually never -- I've stood around towers a little bit but I can't answer that. I know there is an oral alarm. I thought it was the same as the windshear alarm. If it's different, I don't know how it's different.

MR. PARHAM: I think you're probably familiar with the previous testimony on the windshear that were received. And I think the controllers basically, or the evidence -- there were two or three alarms that were received.

THE WITNESS: Unfortunately, I was had to arrive late and I did not hear the controller's testimony. But if you'll refresh me, I'd be happy to --

MR. PARHAM: Well, basically the tower personnel only recall two or three alarms during the 4-5 minutes just prior to the accident. What would you account for this, based on the data that it appears that the alarm started and it should have been continuous.

THE WITNESS: Okay. The alarm table that I have and that I used to make these transparencies was the archive from the LLWAS computer and the alerting sector is indicated in the documents. I don't know if these are part of the exhibit here or not.

MR. PARHAM: I think it would be Exhibit Number 5-E. There's two sets of charts in there, but I believe they both are the same, if you want to take a look at them.

THE WITNESS: Okay. Yes. That's 5-E. I have that one.

MR. PARHAM: I guess you can go to page 5. Well, let's use page 12 because it's got asterisks which indicate, I think, the alarms.

(Pause.)

Page 12, 2240 and 37 seconds.

THE WITNESS: Yes. Right.

MR. PARHAM: I think where the asterisk is, is that not the first center field alarm?

THE WITNESS: Yes. 22:40:37 is the first one I see. Now, that's really 22:40:27 because of that 10 second slip.

MR. PARHAM: Okay. But it starts at center field for it appears three alarms, and then you have three sensors and I don't have the --

THE WITNESS: The three there are the northeast and the southeast. That was indicated on you graphic.

MR. PARHAM: Okay. And then they continue all the way to -- on the chart, 22:51 and 47.

THE WITNESS: Yes.

MR. PARHAM: We've got the plus or minute 10 seconds.

THE WITNESS: Right.

MR. PARHAM: But that appears to be, you know, a continuous alarm. And at one point there were five sensors involved.

THE WITNESS: Yes. It went to all sectors for a brief period of time when the big wind surge hit at the northwest sensor.

MR. PARHAM: My question is the controllers and other personnel in the tower say they received three separate alarms. In other words, an alarm and then a period of no alarm and then another alarm and another, three alarms; center field, northeast and northwest. How could you explain that from this data?

THE WITNESS: Okay. I can't. These data were delivered to me and I believe to the NTSB by the FAA Technical Center and the first pages here, pages 2 through 5 or 6 or something. These pages I believe are a direct transcription of the data, the message values and the alerts as archived on the LLWAS computer. If there is a discrepancy, then it would seem to me that there's a discrepancy between what's being archived in the LLWAS computer and what is appearing on the display.

I've never known that to happen, but that's would be where you'd have to go to find that discrepancy. Either that, or the Tech Center unpacked this correctly. I've worked with them several times. I don't -- I would be surprised if they did, because they've done this a lot.

MR. PARHAM: One other question. Is it your opinion that the northeast boundary alert that the controller issued, if you're familiar with that one, was the proper alert for that time?

THE WITNESS: It was an alert that was new on the system. I don't know all of what was going on. And I suppose even though I have opinions -- I've got a very fertile mind. It gets me into a lot of trouble. But sometimes I can control my mouth. I think I'm really not an expert on that. It's really more of a procedures question, so I'm going to duck.

MR. PARHAM: Thank you, sir.

Mr. Chairman, I have no further questions.

CHAIRMAN HAMMERSCHMIDT: Okay. Thank you.

Honeywell?

MR. THOMAS: Yes. We have a couple.

MR. THOMAS: Dr. Wilson, do you believe that the resolution of LLWAS is sufficient to isolate microburst activity to a specific sector? That is, how likely is it that a microburst could in fact have greater coverage over an airport than measured by the LLWAS?

The point of this is, does it make sense to have aircraft land on a runway outside of the sector of the alert given the fact that a microburst may be moving across the field?

THE WITNESS: That's a lot like the question I just ducked, but I'm going to speak to this one. I've been in the windshear business for a long time. I think I said I started working with the JAWS group in 1982. What I've observed through the years is that when microbursts are happening they are very dynamic, both in place and time. New pulses come down. A lot of bad stuff can go on.

I've been personally bothered the last couple of days in hearing some of the strict interpretations that have been made in training issues with regard to microbursts. Sort of in the back of my mind, it seems to me that somebody's telling me there's a bear in the campground and since we don't have a bear expert present, we don't -- we only will agree that it's a bear when we can actually see him in our tent.

I would prefer that people treated microbursts the same way they treat slush on the wings of airplanes. Which is when in doubt, don't move. Don't go there. And it's not just in this group. It's certainly with regard to this airline or this group of pilots. It's in the whole community that people seem to think it's okay until they have rock solid proof that there is a microburst windshear to worry about. And I would prefer that there was a lot stronger education out there about the fact that once you have a microburst somewhere, that the rest of the circumstance should be treated with the utmost caution.

Now, that doesn't directly say the next runway. I think of the detected element, if anything, the current system is a little too generous in spreading the possible threat around. The threat that it's not and if it missed the threat in this case, the threat it missed was that something new might be happening right next door in not very many seconds.

MR. THOMAS: Okay. Thank you. Another one.

Microburst outflows are typically highest about 200 to 300 feet above the ground. How do the LLWAS algorithms account for this phenomenon.

THE WITNESS: I've studied that and I would question your premise. I have seen microburst where the strongest outflow was at a few hundred meters up to almost 1,000 feet off the ground. Those are rare. I've seen microbursts where the strongest winds with good radar coverage, where the LLWAS sensor winds were stronger than the low radar winds and that the outflow was crushed right down to the ground.

I don't thoroughly or completely understand why they are sometimes higher and sometimes lower. I do agree with you that the outflow is typically, in a statistical sense a little higher than the network.

We have not made an effort to artificially or statistically amplify the alert to match what we see above the ground. In careful statistical studies comparing with TDWR, we have found that using TDWR as the measure of how strong the outflow is, that LLWAS is very close to giving unbiased estimates of microburst strength. It's certainly not underestimating by as much as 5 knots, so it 's very close. It might be a few knots low, but it's not a lot low.

MR. THOMAS: Okay. Lastly, the system performance statistics you give on page 6 --

THE WITNESS: Yes.

MR. THOMAS: -- do we understand that those are relative to the Terminal Doppler Weather Radar? Are there any statistics on the accuracy of the Doppler radar?

THE WITNESS: Those statistics are based on a -- the Terminal Doppler Radar is one of the sources of information that went into those statistics. In that sense, they are based on that radar. They are not a direct comparison of LLWAS alerts and Terminal Doppler Weather Radar alerts.

The process that we used was we took the LLWAS as a good sensor system. We took the radar as a good sensor system. And we indeed usually had a second radar available, which we also used. And then by human judgment, we combined those pieces of information and we also looked at the outputs of the algorithms and tried to come up with our best estimate of what the real threat was. And then we scored the algorithms against that human determined threat.

It's a very tedious process but we took a lot of care in that.

MR. THOMAS: Okay. Thank you, Dr. Wilson.

We have no further questions.

CHAIRMAN HAMMERSCHMIDT: Okay. Continuing on that last question concerning the performance statistics on page 6, I believe you said that in the Phase II system in the control tower you would not get a microburst alert.

THE WITNESS: You'd get a windshear alert.

CHAIRMAN HAMMERSCHMIDT: Windshear alert.

Therefore, in your data on page 6, how do you differentiate to come up with your probability of detections between windshear and microburst?

THE WITNESS: Okay. The issue there is when there is a windshear that is not a microburst present, how well does the system do in issuing an alert. That's the POD windshear. And the other question is when there is known to be a microburst there, does the system issue some kind of an alert. That's the POD microburst.

So the 60 percent number is a reflection that in a situation where from our other information we know there's a microburst present, what is the likelihood that the system will give some kind of a warning. And in the case of LLWAS II, it can only be a windshear warning.

CHAIRMAN HAMMERSCHMIDT: Okay.

Airline Pilots Association?

MR. TULLY: Thanks. Just to clarify one issue. The best protection from ground based system occur when a low level windshear Phase III system is integrated with the Terminal Doppler Radar. Is that correct?

THE WITNESS: That's correct. Right.

MR. TULLY: All right. That's my only question. Thank you.

CHAIRMAN HAMMERSCHMIDT: USAir?

MR. SHARP: Just one question, Dr. Wilson. If you'll look back at your charts on 21 and --

THE WITNESS: Let me -- let me -- can I back up just a second? I was a little short on the last.

That answer, yes, about the Terminal Doppler Weather Radar and the LLWAS is based on a study for over two years' worth of data at Orlando. The person who is the lead scientists on that is Rod Cole from Lincoln Laboratory and there was a research paper on that, I believe, in the Aviation Weather Conference from a year ago in Vienna, Virginia.

MR. TULLY: Thank you.

THE WITNESS: Sorry.

MR. SHARP: That's fine.

If you'll look at your charts, the ones you had on page 21 and 22, if you'll look at 21, the wind at sensor number 6 is 180 degrees at 23 knots. If you'll look at page 22, the wind at sensor 6 is showing 170 degrees at 34 knots. That's an increase of 11 knots over a period of a minute, assuming your times are correct.

THE WITNESS: Yes.

MR. SHARP: That 11 knots could possibly been the increasing outflow off the bottom of a microburst?

THE WITNESS: Well, in fact, a better place to look at that, I guess, would be on the time charts on page 24. There was -- let's see. The times we want are 42, 4157, if you will, up to 43. And you see that top graph represents that sensor. And those winds surge very strongly over that minute.

It's not an atypical situation. There was an incident where a Continental aircraft survived a 95 knot microburst in Stapleton and the winds there went up almost that much in a minute. In fact, the winds there at one sensor were increasing about 10 knots every 10 seconds for well over a minute.

These winds can surge very, very quickly in case of a microburst.

MR. SHARP: I believe I recall that incident you're talking about. In this particular case, this could be off the jagged edge you're talking, since it may not be a round microburst?

THE WITNESS: Or a second pulse. I personally think that whatever it looked like from the ground that there was some second pulse, but that's -- I guess they asked me to be an expert and so I'm cautious about fantasizing to much. But it does not look to me like a single evolutionary event. It looks like some kind of a surge.

MR. SHARP: Yes. And I don't want you to speculate. I just wonder about the possibility of that happening.

Could you also make a general statement. We talked about winds at lower levels versus higher levels in the microburst and where the stronger winds were. Could you make a general statement that said as you increased there could possibly be an increase in the winds?

THE WITNESS: Well, the way you posed it, yes, there could. There could also be a decrease. The comparisons we've made with LLWAS derived losses and TDWR losses indicate that they're similar and each sensor will have times when it sees a stronger wind. There's not a clear pattern of one being stronger than the other.

Most of our data in that direction were taken at Orlando where the radar was looking up a couple hundred feet above the airport and the LLWAS, of course, was right down at the airport. Well, the LLWAS there was on tall poles, about 100 foot poles, and probably the radar was up around 300 feet. It's about a 200 foot difference, and yet we could not see a pattern where one sensor system gave stronger measurements than the other.

MR. SHARP: Considering that, the data that you have, is it possible to estimate the winds or predict the winds at a 200 or 300 foot level above the ground in this particular incident?

THE WITNESS: I cannot do that. There will be -- Fred Proctor will be speaking a little bit later. He had done a different kind of analysis and he has the only technique that I would have confidence in for answering your question.

MR. SHARP: Okay. Thank you, sir.

We have nothing further, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: Thank you.

Douglas Aircraft Company?

MR. LUND: Yes. Dr. Wilson, from the time the system thinks it's detecting a shear, is there any time delay from the time it detects the shear until such time as the alarm is sounded in the tower?

THE WITNESS: Yes. There's the persistence condition that's imposed, which requires for it to wait for the shear condition to be detected for four consecutive times. And since the wind data are re-measured every 10 seconds, that means there's a 40 second delay in the issue of the alert.

MR. LUND: What about after the fourth detection, between that time and the sounding of the alarm?

THE WITNESS: It issues the alert on the fourth detection. That means it goes running up through the electronics. The computer algorithm executes in under a second. That's not an issue. The other significant delay in there would be the time for the controller to observe the situation and make the transmission.

MR. LUND: Thank you.

No more questions, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: Thank you.

Pratt and Whitney?

MR. YOUNG: No questions.

CHAIRMAN HAMMERSCHMIDT: Association of Flight Attendants?

MS. GILMER: No questions.

CHAIRMAN HAMMERSCHMIDT: Okay.

International Association of Machinists?

MR. GOGLIA: No questions, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: Dispatchers Union?

MR. SCHUETZ: No questions, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: Thank you.

National Weather Service?

MR. KUESSNER: No questions, sir.

CHAIRMAN HAMMERSCHMIDT: Thank you.

Any more questions form the Technical Panel?

Mr. Feith?

MR. FEITH: Just two questions. One, I guess, my ignorance for windshear and microburst. Is there any way to measure the thickness or depth of that diverging pattern in a microburst shaft when it hits the ground?

THE WITNESS: Not with any of the -- I mean, there certainly is, but not with any of the operational equipment that we've been talking about here.

MR. FEITH: So, if there's moisture in it, could you use Doppler radar to measure the depth of that outflow pattern?

THE WITNESS: Well, no. The Doppler radar is scanning at different stratifications and your ability to resolve a vertical profile is impaired by the granularity of that scan. You could get a few slices, but in fact, I believe with even the TDWR, which is one of the most aggressively sited radars for this particular purpose, you would get about two looks at places in that outflow profile.

MR. FEITH: And one last question. Were you able to determine if the geometric configuration file, the GCF, was correct at Charlotte?

THE WITNESS: Yes. I did check that. It turns out we frequently -- we, and the Tech Center frequently look at data from airports and one of the biggest headaches, of course, is to run a data tape through your programs at home and discover you're getting different answers and wondering why.

We discovered early on that almost always when we got different answers it was because we had the wrong file. So now it is standard practice that when they print the data archive they also print the airport configuration file that was used on that computer at the time the data were taken. And I did ask the Tech Center to check that. They did, and they told me that it is the same file that they have on record.

MR. FEITH: Thank you, sir.

No further questions, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Feith.

Mr. Laynor?

MR. LAYNOR: No questions.

CHAIRMAN HAMMERSCHMIDT: Mr. Clark?

MR. CLARK: Yes. Would it be possible to reduce the amount of time delay if we were to implement some sort of change that could monitor the level of error or the level of warning -- or the level of wind difference?

For example, if we within the 10 second time frame saw a 20 to 30 knot increase, could we forego the full 40 second time delay?

THE WITNESS: We've talked about that. I'm sure there's something that could be done in that direction. Again, this is the system that's supposed to get turned off any day now and for several years now there's been no effort put into really monitoring it or improving it as far as its algorithm. And it's starting to look like it's going to be around for a while, but we keep hoping the other stuff is going to show up.

I don't know what to say beyond the fact that yes, something better probably could be done, but nobody's working on it.

MR. CLARK: Does the system cancel the warning? What's the mechanism to cancel the warning? It there a time delay built into that?

THE WITNESS: Yes. Once the system is issuing a warning, after the last detection, it holds that alert for a period of time. I believe it's 30 seconds.

MR. CLARK: Three hits then roughly?

THE WITNESS: Pardon?

MR. CLARK: Three hits? Or let me ask you. If we lose the warning level and then it reoccurs after two radar hits, will the warning continue or do we have to shut off and wait four more --

THE WITNESS: Go through the four? I really don't know the answer. I did not design this part of the algorithm. The persistence strategy was designed by people at the Tech Center. But I think -- I know the way Phase I LLWAS worked and I believe that this is designed very similarly and that it would hold the alert if it started getting it.

In other words, if it was in the 30 second grace period and then the alert came back, that it would continue the alert.

MR. CLARK: Do you know or have any information on the plans to install Phase III?

THE WITNESS: There is a -- well, one of the interesting things you get into in the FAA is that they buy a system and then they have to talk the local facility into installing it, the so-called commissioning of the system.

I'm sure there'll be more talk about that, but the difference I think is primarily keyed around the fact that the users of FAA equipment, FAA weather equipment, are not meteorologists. They are air traffic controllers primarily and they don't want to have to sit and worry about is it working all right today.

So the stuff is banged on pretty hard by the FAA Technical Center before they agree to turn it loose for operational use. And another issue is that not only does it has to work. It also has to be maintainable. So there's facilities and logistics issues. And the LLWAS right now is still, I believe, being held up on commissioning. It has been delivered. Only nine have been procured, but they are all ready, except for turning them on.

The one that's where the tests are occurring is at Orlando, and that one has been running operationally for a year now in a test status, so they are getting service form it, even though it's not commissioned. I understand the one at Denver will be -- is commissioned and will be turned on whenever they turn the airport on. It's at the new airport.

MR. CLARK: Each one of these sites has to be commissioned. Is that because you're having to write code for each specific site?

THE WITNESS: The commissioning -- and again, I'm not an expert on this at all, but I've observed. There's a first major commissioning, a first article evaluation. And that's very lengthy and carefully done. The subsequent commissionings are basically equipment checkouts. They happen much more quickly.

MR. CLARK: Are there any plans to collocate the Phase III with the TDWR?

THE WITNESS: Some of the sites are collocated sites and they will use the integration algorithm. There will be a couple of them put at other places and I don't know the list right off.

MR. CLARK: Okay. Thank you.

CHAIRMAN HAMMERSCHMIDT: Mr. Schleede?

MR. SCHLEEDE: No questions.

CHAIRMAN HAMMERSCHMIDT: Okay. Dr. Wilson, do you what the -- do you happen to know what the time correlation is between the LLWAS data in Exhibit 5-E and the cockpit voice recorder time would be? Do you have any concept on that?

THE WITNESS: Oh, I have not -- literally, all I know about cockpit voice recorders is what I've read in the newspapers.

CHAIRMAN HAMMERSCHMIDT: Mr. Salottolo, do you have those?

MR. SALOTTOLO: I don't know.

THE WITNESS: With the 10 seconds slip, they should be exact. You should be able to line them up. I just don't have access to the voice recorder data.

CHAIRMAN HAMMERSCHMIDT: Right. I was just noticing that after the LLWAS system showed an alert on the northeast boundary, the tower communicated that alert almost instantaneously. And I was just wondering if we had a way to pin that down.

MR. SALOTTOLO: Mr. Chairman,the only thing that we know is that the LLWAS data was 10 second -- LLWAS clock was 10 seconds fast. We probably certainly could marry it to --

CHAIRMAN HAMMERSCHMIDT: That would explain it.

THE WITNESS: I've stood in a lot of towers and if a controller is talking to an airplane and he gets a windshear alert, he pretty much gives it instantaneously. The delays occur when the plane hasn't checked in yet and he's got a windshear alert and there's nobody out there to talk to.

CHAIRMAN HAMMERSCHMIDT: Right. I simply wanted to point that out for the record.

Mr. Lund?

MR. LUND: I'd add something. One of the controllers testified that the alarm that went off was recorded on the ATC tape. So if you wanted to make a correlation, that would be the way of doing it.

CHAIRMAN HAMMERSCHMIDT: Right. Thank you.

MR. CLARK: I was going to ask how you determined that there was a 10 second offset?

THE WITNESS: Greg told me.

MR. SALOTTOLO: I obtained it from the FAA.

THE WITNESS: I'm suspicious. I've seen enough time slips that before I start a data analysis, I try to find out as much as I can about what the background situation is. And I specifically asked him for that information and he found it out somehow and gave it to me.

MR. CLARK: We were in the process of discussion and I thought you were the man that had said that. So, my apologies.

THE WITNESS: I was repeating the truth.

CHAIRMAN HAMMERSCHMIDT: Well, Dr. Wilson, when we were here during the on scene phase of the investigation, we were asked many questions about how this system operates and I hope that most all those questions were answered today. That was a very good presentation and we appreciate your participation in our public hearing.

Is there anything else you would like to add for our public record?

THE WITNESS: No. I've enjoyed being here. Thank you.

CHAIRMAN HAMMERSCHMIDT: Okay. Thank you, again.

(Witness excused.)

CHAIRMAN HAMMERSCHMIDT: Why don't we take about a 10 minute break and resume with the next witness.

(Whereupon, a recess was taken.)

CHAIRMAN HAMMERSCHMIDT: Back on the record.

Let's please come to order.

Our next witness is Dr. Mark Weber. He will be questioned by Mr. Greg Salottolo and I believe you've already sworn him in, Mr. Schleede?

MR. SCHLEEDE: Yes. The witness has been sworn.

(Witness testimony continues on the next page.)

DR. MARK WEBER, ASR-9 & DOPPLER Wx RADAR, MIT LINCOLN LABORATORIES, BOSTON, MASSACHUSETTS

Whereupon,

DR. MARK WEBER,

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

MR. SCHLEEDE: Dr. Weber, please state your full name and business address for our record?

THE WITNESS: I'm Mark E. Weber. I'm at MIT Lincoln Laboratory in Lexington, Massachusetts.

MR. SCHLEEDE: What position do you hold at Lincoln Laboratories?

THE WITNESS: I'm an associate group leader in our Weather Sensing Group.

MR. SCHLEEDE: Would you briefly describe your experience and education that qualifies you for your present position?

THE WITNESS: I earned my doctoral degree at Rice University doing experimental studies involving thunderstorm dynamic processes and associated electrification, that is, lightning activity. For the last 10 years I've been at Lincoln Laboratory. Our group has had major responsibilities for many of the recent terminal area weather systems, particularly those that employ Doppler radar technology.

MR. SCHLEEDE: Thank you very much.

Mr. Salottolo, proceed.

MR. SALOTTOLO: Thank you, Mr. Schleede.

Dr. Weber, you may proceed with your presentation. It's Exhibit 5-K.

(Whereupon, a presentation was made using viewgraphs.)

THE WITNESS: Well, this just amplifies on my introduction. I just wanted to make the point that over the last 10 years the scientists and engineers in our group have played a key role in I think all of the major terminal area weather systems for the FAA. We were the lead in developing the algorithms and doing the field testing for the FAA's Terminal Doppler Weather Radar system.

My particular focus has been on the weather sensing capabilities of the Airport Surveillance Radar, the ASR-9, both in terms of its six level weather reflectivity channel that is on line today with sort of base line 9 and then in terms of the capability for adding a processing channel that will allow the ASR-9 to provide the same type of functionality as provided by the TDWR at a lower cost for some of the smaller airports.

Wes Wilson, who joined our group five years ago, of course brings in some sense a lot of the FAA's corporation knowledge on the low level windshear alert system. And finally, we're currently heavily involved in an activity to tie together these various sensors in a data fusion system, a so-called Integrated Terminal Weather System which will be coming on line five or six years down the road.

My briefing today will concentrate really on the system I'm expert on that's most germane to the Charlotte accident. That is, the six level weather reflectivity channel that's part of the base line ASR-9. I'll provide some technical background on that system, our experience in terms of technical operational evaluations of that system, and then, using the NEXRAD data that Mr. Saffle discussed this morning, I'll simulate what our best estimate at least of what the ASR-9 should have been painting at Charlotte around the time of the accident.

At the end of my talk I'll briefly summarize I think some of the pertinent technical points relative to the technology that either is currently coming on line or will be coming on line down the road. That is, specifically, the Terminal Doppler Weather Radar windshear process or modification to the ASR-9 and the Integrated Terminal Weather System.

Okay. Well, this is a photograph of an ASR-9 for those of you who haven't seen it. The FAA has procured I believe 130 some odd of these systems. About 88 of them are currently commissioned; that is, providing operational system.

Of course, the primary mission of this radar is to provide aircraft detection and tracking. However, the ASR-9 is the first version of this class of radar that also features a dedicated digital processing channel that provides quantitative information on precipitation reflectivity live to controllers on their displays. So there's an important new functionality coming on line with these radars.

The basic feature of the radar. It operates at 10 centimeter wavelength. Scans in azimuth only 12-1/2 times per minute. Provides coverage out to 60 nautical miles and the weather maps are updated once every 30 seconds.

In terms of the weather surveillance capability this radar is very important to understand the beam coverage and I think this is relevant to what the radar would have been painting here at Charlotte. This radar has so-called co-secant squared, basically a fanned shaped beam, narrow in azimuth, but as shown here, broad in elevation angle. It's about 5 degrees in elevation extend and, in fact, the antenna gain falls off slowly above the half power limit show here in the chart. So, it actually can see up probably somewhat higher than is indicated by this chart.

At any rate, what I'm showing here is the coverage in altitude versus range of the so-called low elevation beam and the high beam. The radar operates basically by processing data from the high beam, the red plot here, out to a range of about 30 kilometers or 15 nautical miles. And then is switches over to the low beam, the green curve, beyond 30 kilometers.

You can see from the chart that at long range the beam essentially intercepts the entire extent of a storm system, so that in some sense the precipitation display being provided to controllers for storms, I'd say beyond 30-40 kilometers, is somewhat equivalent to the composite reflectivity product that Mr. Saffle discussed earlier.

The processor is set up so that at these longer ranges it's essentially trying to paint the highest reflectivity at any altitude within a storm on the two-dimensional display provided to controllers.

Now, at very short ranges, again, I'd say about 20 kilometers or less, because in contrast to conventional weather radars this antenna doesn't scan up and down an elevation angle. You've got a fixed elevation angle. So at short ranges, you may be to some extent looking underneath the highest reflectivity in a storm, at least when that high reflectivity is still up high in the cloud as it typically is during the early stage of a thunderstorm.

The display provided to controllers is quantized into the six National Weather Service so-called VIP levels, ranging from light to extreme intensity. My understanding is that airborne weather radars, the correspondence to airborne weather radars is such that, in general, green would correspond to level 1; yellow on an airborne radar would correspond to level 2; and level 3 and above would show up as red on an airborne system.

Talking to controllers, most air traffic controllers assert that traffic will general deviate around precipitation cells when they're displaying level 3 or higher precipitation.

As I said, the ASR-9 features a separate digital processing channel, and this is a high level block diagram of what goes on there. Very important to painting precipitation that's short range with a radar beam that's also intercepting targets on the ground, buildings and trees is a clutter suppression module, and this is basically controlled by a site specific clear day map that determines the amount of suppression applied in each area of the radar's coverage.

The data are then threshold into the six standard National Weather Service levels and passed on to a smoothing and contouring processor which basically regularizes the contours for display on the controller's scopes and also fills in any sensored cells that had such severe ground clutter that it couldn't make an accurate measurement of the reflectivity in close to the radar.

The controllers then are able to by means of buttons select any two of the six available levels in two display modes, which we've mocked up here. A so-called discrete mode where the two selected levels only are shown, and then a summation mode where the selected levels plus all higher levels are shown with a light and dark intensity modulation.

It's a fairly nice setup, so that I believe, in spite of the fact that you can't see all six levels at one time, it's fairly easy to toggle the controls and get a pretty good understanding of all the data that's coming out of the processor.

MR. SALOTTOLO: Excuse me, Dr. Weber. Could you just explain a little more about the summation feature, exactly what the controller would be looking at at various settings? Say 1 and 3. Could you set like 1 and 3 on there or --

THE WITNESS: Well, let me see if I can illustrate. In this chart we're illustrating at the level 2 and 5 and in the upper panel you can see a level 2 contour with sort of dark green shading, and then there's a black area within the level 2 contour corresponding to levels 3 and 4. And then the level 5 contour shows up. And then here is a level 6 region within the level 5 contour.

So you're seeing displayed there only regions of level 2 and 5 and you're having to infer the presence of levels 3, 4 and 6 within those contours.

Now, the summation mode shows you 2, 3 and 4 with ia dark green color and then 5 and 6 with a bright green color. So essentially the controller has a button that allows him to toggle between discrete and summation display modes.

MR. SALOTTOLO: In the summation mode, how would you know if there was in fact a level 6 in there somewhere. Is there some kind of setup that gives you an indication?

THE WITNESS: There's a panel of lights up on his display that shows the highest available weather level within the radar's field of view. So, for example, if the strongest intensity storm within 60 miles of the airport was showing level 4, this panel would probably have lights 1, 2, 3 and 4 illuminated and lights 5 and 6 would be dark. So that aids the controllers in selecting their display setup.

MR. SALOTTOLO: So, in other words, to find this particular, for example, VIP level 6 cell, you'd have to actually go to discrete 6 and then locate it that way or you'd have to -- there'd be no way to know where it was without manipulating the radar some other way?

THE WITNESS: That's right. The light panel would alert him to the fact that somewhere in the field of view there's a level 6 cell, but he would have to select the appropriate settings to delineate exactly where it was.

MR. SALOTTOLO: Okay.

THE WITNESS: All right. I want to turn briefly to the opportunity we had to work with the FAA during the operational test and evaluation of the ASR-9 in Huntsville, Alabama back in 1987 and 1988.

We were tasked basically to validate the performance of this six level weather channel. This chart shows our setup down in Huntsville. The Westinghouse ASR-9 which was being tested by the FAA was here at the airport. Within a mile of that site we had located both an ASR-8, an earlier airport surveillance radar which has very similar basic radar features and we simply instrumented this radar so we could record all the relevant data and carefully calibrate out what was going on with respect to that system.

Likewise, we also operated a pencil beam meteorological Doppler weather radar similar to NEXRAD, at least in terms of its beam shape and scanning capabilities.

With those two sources of truth, if you will, we could take the actual ASR-9 report and compare them to both the fan beamed ASR-8, which we've emulated the processing algorithm of the ASR-9. It was the same class of radar, so you would certainly expect if the ASR-9 was working properly we should get a similar report.

And likewise with the pencil beam radar, we now had three-dimensional coverage. We were able to understand in detail why these fan beam radars were reporting what they were. And through a simulation process similar to that I'll be discussing a little later in the talk, we were in fact using the pencil beam radar, able to simulate what the ASR-9 should have been reporting.

At any rate, the game plan here was to test the actual ASR-9 reports against what we measured with our truth radar systems. And overall, the results were very positive. We were able to analyze in detail data from 19 precipitating weather situations ranging from air mass thunderstorms, widespread stratiform precipitation, organized squall lines and cold frontal passengers. And on a pixel by pixel basis, there was very good agreement. Eighty percent of the pixels -- by pixel, I mean radar resolution cell. Eighty percent of the levels agreed exactly, and where there was a discrepancy it was generally no larger than one National Weather Service VIP level.

So, we felt that given the difficulty in calibrating a radar better than 2 dB or so and given the slightly different sitings of the two radars -- three radars, actually -- that this was very good agreement.

During that OT&E and subsequent work with the ASR-9, we have identified a couple of issues, and I'll raise those now.

One is ground clutter breakthrough that occurs during unusual temperature or moisture conditions in the atmosphere that causes ducting of radar energy or so-called anomalous propagation. This occurs, for example, at night or early in the morning when you have a temperature inversion near the ground. These are data from I believe the ASR-9 at Dallas-Ft. Worth, showing on a perfectly clear morning the weather channel display. And what you're seeing here are false storm cells caused by ground clutter breakthrough during an anomalous propagation episode.

You can also see this during thunderstorm passages. Here we have a situation where a thunderstorm system has moved across the radar to the west. It's dumped a pool of cool moist air over the radar. And again, that's causing ducting of the radar's beam. So, in fact, these cells down to the south-southeast are not weather. They are ground clutter breakthrough caused by anomalous propagation.

This problem seems to be fairly widespread and it certainly has the effect of reducing to some degree controller confidence in the validity of the 6 level weather channel coming out on their display.

There are solutions to that problem which we discussed with the FAA. This chart simply shows that using Doppler processing, which is something this ASR-9 windshear processor, I mentioned earlier, will do. You can discriminate between actual storm cells, these things east of the radar here, and anomalous propagation induced ground clutter breakthrough out here to the west. Basically, the left panel shows the ASR-9 report if you don't use this Doppler discrimination feature. And then with the Doppler discrimination feature on it's possible to get rid of, to a large extent, the ground clutter breakthrough.

Another observation we made very recently this past Summer has occurred in connection with our ITWS, our Integrated Terminal Weather System, testing down in Orlando. What we're doing there is providing to controllers a display integrating data, as I said, from these various weather sensors. And in particular, the precipitation reflectivity is coming from the ASR-9. This panel on the left is the ITWS operational display. The Doppler products are coming from the TDWR.

We started observing very near the airport instances where we were seeing windshears. Here's a circle indicating a 20 knot windshear with no apparent associated precipitation. And we knew in Florida that dry microburst activity is essentially not something you'd expect, so we went and looked at the raw TDWR data and it turned out, in fact, that TDWR was painting small rain showers. These are level 3 showers, just a few hundred square meters of level 3 weather, but it's not appearing in the ASR-9 data at very close range.

You can see the cell removed from the ASR-9 a little bit further is showing up with reasonable fidelity on the ASR-9 display.

Before you go on, we don't fully understand what's going on here. It's nothing intrinsic to the sensor. The beam shape of the ASR-9 being so broad should allow it to see rain at the surface without problems, so we suspect some kind of either inappropriate site variable parameter setting or a glitch in the software, but we're working with the FAA to better understand that.

One final sort of background comment here. Early on in the deployment cycle of the ASR-9, the GAO flagged the absence really of formal procedures for controllers to pass that six level weather data on to pilots. This is just a cover sheet and an excerpt from the abstract of that report, but basically they flagged that the FAA believes at that time that before implementing formal procedures controllers need to, if you will, better understand the basic changes that the ASR-9 will bring in their capability to detect precipitation. And they stated that a policy question regarding whether to route aircraft around storm using ASR-9 weather data will not be answered until the FAA learns more about precipitation effects on aircraft and workload effects on controllers.

To my knowledge, nothing further has really gone in the area.

Okay. Well, let me turn now to our simulation of what the ASR-9 should have been painting or our best expectation of what it would have been painting around the time of the Charlotte accident.

As I said, we've used the data from the NEXRAD at Columbia that Mr. Saffle discussed earlier. This is the point 5 degree tilt closest in time to the time of the accident. Three small storm cells. This is a 70 and an 80 nautical range ring. The Charlotte Airport is underneath this particular cell.

This chart summarizes the simulation procedure. The first step is to take the NEXRAD data -- as I said, 76 nautical miles away from Charlotte, and construct from it a three-dimensional reflectivity grid on a half nautical mile by half nautical mile resolution. This was done using the beams which, as Mr. Saffle said, is a point 5 degree beam centered 8,000 feet up, extending from about 4,000 feet to 12,000 feet and the similarly three more beams centered 16,000, 23,000 and 31,000 feet up in the air.

It's important to note that the lower edge of the lower beam, as I said, is about 4,000 feet, so in estimating what was going on at the surface, we simply extrapolated down from an altitude of 4,000 feet. We don't have the very low altitude data.

At any rate, given that three-dimensional reflectivity grid, we integrate over elevation angle to simulate the beam pattern of the ASR-9. That is, we weight the data by the ASR-9's beam pattern as a function of elevation angle and integrate, essentially collapse this data down into the planned view provided by the ASR-9. We then convert that integrated reflectivity measurement to the National Weather Service six level scale and finally simulate the spacial and contouring process used in the ASR-9 processor.

I have to acknowledge some significant caveats here to the simulation, one of the largest being the data resolutions of the NEXRAD. As I said, the lowest beam is centered at about 2-1/2 kilometers, 8,000 feet. The vertical resolution, likewise, is about the same, 8,000 feet. And it takes six minute for the NEXRAD to do its thing. So you're integrating in both time and space.

The simulation was performed in a cartesian coordinate system, as I said. The ASR-9 processor actually works in a polar coordinate system. That may make some qualitative differences but I don't think should have any big effect on the outcome here.

What may be more important is that we did not include ground clutter and ASR-9 ground clutter suppression processing because we didn't have knowledge of the ground clutter environment at Charlotte.

Possible effects of the ground clutter and the ground clutter suppression could be sensoring of weather at short range or at least a downwards bias in the reported weather levels in areas where the ground clutter was very heavy.

MR. SALOTTOLO: Excuse me, Dr. Weber. That last bullet, that's an active part of the radar? In other words, each of the ASR-9's has those as other ground clutter and clutter suppression software, whatever?

THE WITNESS: Yes. As I said, that's a very important part of the radar's capability to measure weather at short range. If you remember the old television pictures of old weather radars without any clutter suppression capability, you have this big ring -- you know, 10, 20 miles around the radar where you couldn't see anything because you were blinded by ground clutter. So for the ASR-9 to be able to detect weather on or near the airport it's essential that it have that ground clutter suppression capability.

MR. SALOTTOLO: Is that a selectable parameter or is that -- that's on all the time?

THE WITNESS: It's on all the time, but the degree of ground clutter suppression that's applied is determined really on a resolution cell by cell basis based on the intensity of the ground clutter in each area. So, if you have an area with very little ground clutter, there's no need to use a lot of clutter suppression. And you can see, if you will, lower level weather in such areas than you can in areas where you're forced to use heavy clutter suppression.

MR. SALOTTOLO: Okay. I guess the question is you can't turn it on and off. I mean, it's there.

THE WITNESS: It's there.

MR. SALOTTOLO: Okay.

THE WITNESS: And you want it to be there because you wouldn't see anything without it.

All right. Let me turn to the simulations. We worked with three of the volume scans that Mr. Saffle discussed this morning. The one beginning at 22:29, the next scan beginning at 22:35 and then the scan nearest to the time of the accident at 22:41. Let me see if I can work through the plot format here.

We have four panels. The upper two plots are just slices through the Cartesian grid we formed from the NEXRAD data at heights of 5,000 and 15,000 feet above the surface. These data are in dBZ units, which Mr. Saffle discussed this morning. The meteorological unit would basically -- green, corresponding to level 2; the brown shade corresponding to level 4, I guess; and the reds and above corresponding to level 5.

The airport at Charlotte is sketched here. The north-south runway is the ASR-9 location with the dot. So, at any rate, as Mr. Saffle said, at this time, about 12-13 minutes prior to the accident, the highest reflectivity in this storm, 50 dBZ or greater, was up at altitude 15,000 or above.

In the lower left panel, we've essentially taken a vertical cross-section through our Cartesian grid along this blue line passing through the ASR-9 to show you in some sense what the ASR-9 would have been seeing. Here's our vertical cross-section. We're now in meters -- 5,000 meters, 10,000 meters. Here's the core of reflectivity aloft 5,000 meters up. And the lines here show effectively the coverage of the ASR-9's low and high beams.

So you can see what's going on at this time because the cell is essentially over the radar. The core of high reflectivity is above the beam. Within the beam, the most we have is this yellow 35 dBZ which corresponds to sort of level 2. So our simulation indicates that at this time 12 or 13 minutes prior to the accident, the ASR-9 would have been painting basically a level 1, or at most level 2 cell extending up towards the airport from the south.

Okay. Moving ahead to 22:35, again, as Mr. Saffle indicated this morning, by this time the high reflectivity, the reds and the browns I guess you'd call them, the 45 dBZ's and above, have descended into the lowest NEXRAD beam. We're now picking up significant reflectivity down at 5,000 feet. Our vertical cross-section now along an east-west plane shows this core of red extending down into the ASR-9 beam.

There's a little bit of level 5 getting down to the surface, but because it's small in area, the ASR-9's smoothing and contouring processor would not pass that through. But at least according to our simulation there should have been plenty of level 4 area so that we would have been seeing a level 4 cell that's now moved up more or less over to the west of the airport at this point in time.

And the volume scan beginning at 22:41 just prior to the accident, you continue to have the heavy precipitation falling into the lowest NEXRAD beam. In fact, as Mr. Saffle indicated, this storm seems this be raining out at this time. The high reflectivity aloft is dying. It's all coming down to the ground. And again, according to our simulation at least, the ASR-9 should have been painting a level 4 -- level 3, level 4 cell, more or less centered on the west side of the airport at this point in time.

MR. SALOTTOLO: Excuse me, Dr. Weber, could we back up to 22:29 again? I guess two back, the second one back.

THE WITNESS: One more back.

MR. SALOTTOLO: One more back. On the simulated ASR-9 weather channel, I believe the testimony of the controllers was that the ASR-9 was set up on discrete 1 and 3, 1 and 3 selected. Now if it was 1 and 3 selected, how would that --

THE WITNESS: What they would have seen would have been this light green contour with a black hole in the middle.

MR. SALOTTOLO: Okay. Now you have level 2 there but you just indicated that could be -- it also could be level 1, given the fact of the clutter suppression.

THE WITNESS: And as I said, it's possible that owing to the necessity to suppress ground clutter in close, that could have been biased downward. So I certainly would have no problem if somebody told me all that was showing up at this time was level 1.

MR. SALOTTOLO: So you'd just have one level?

THE WITNESS: In that case you would just have a continuous contour with no hole in the middle.

MR. SALOTTOLO: Okay. The next, page 19, 22:35.

THE WITNESS: Again, assuming discrete level 1 and 3 selection, you would see this light outer green contour. You would have a black hole here. You would have this yellow contour showing up with a darker intensity modulation on their scope and you would have another black hole in the middle.

MR. SALOTTOLO: Okay. And the next one, 22:41.

THE WITNESS: Exactly the same thing here. An outer contour of level 1. A donut of blackness, an inner donut of level 3 and then a hole in the middle right on top of the airport.

MR. SALOTTOLO: Dr. Weber, were you here for the controllers' testimony at all?

THE WITNESS: I did not have the opportunity to get in Monday to hear that.

MR. SALOTTOLO: Okay. The controller or controllers testified, and I'll paraphrase it, that at about the time of the accident, a level 3 popped up on the ASR-9. Now is that consistent with what your simulation is showing for 22:35 and 22:41?

THE WITNESS: If we believe the simulation, we would -- as I said, the basic sequence of events here is reflectivity forming above the beam, dropping into the beam. So I do believe that at some point in time they would have seen a rapid popping up, if you will, of reflectivity from level 1, 2, up to 3 or 4 or whatever. The exact timing of that is a little bit hard to derive from this data because, as I said, we're taking a beam that's centered 8,000 feet up in the air, extends from 4,000 feet to 12,000 and trying to use that to guess what's going on on the surface.

Rain falls 30 feet a second or so, so at 8,000 feet, that would take it some 3-4 minutes to reach the surface. So I think there's an inherent uncertainty in the timing of when they should have seen that rapid intensification of what was being displayed on the ASR-9. And the uncertainty of that timing is probably in the order of, as I said, 2, 3, 4 minutes.

According to our simulation at 22:35 they would have been seeing high intensity at the surface and that's consistent with what Mr. Saffle testified this morning. But I do have to caveat that we're trying to work from data from a very distant radar where the beam is way up in the air; the lowest beam.

MR. SALOTTOLO: The simulation is showing a level 4, but it's entirely possible, as you just mentioned, and as was mentioned before regarding the clutter suppression, that it could have been a level 3, pop up level 3.

THE WITNESS: It could well have been.

MR. SALOTTOLO: We just can't say for sure.

THE WITNESS: We can't say for sure. Yes.

MR. SALOTTOLO: Okay. Now the comment, pop up level 3, does that have anything to do with the cone of silence?

THE WITNESS: Effectively, it's fairly small because the ASR-9 is designed to have a beam to see aircraft up to 20,000 feet. So it's designed to have a very minimal cone of silence. But within a mile or two of the radar, there's very definitely -- you know, we've seen it many times with some of our experimental radars as these microbursts producing reflectivity cores drop into the beam. You see the sudden blossoming of the reflectivity as painted by the ASR-9. It's a very characteristic type of signature.

MR. SALOTTOLO: So this is not unusual, the comment of popping up. Have you heard that before?

THE WITNESS: No, it's not. But we've seen it.

MR. SALOTTOLO: It's not a real technical term.

THE WITNESS: It's actually something with our windshear processor system that we use as a means of detecting microburst, or at least confirming that we're in a microburst situation.

MR. SALOTTOLO: If I might, just getting back to the cone of silence again, how is it defined? Is it a one mile diameter from the antenna or is there a certain distance from the antenna or is it variable?

THE WITNESS: Well, rain at the surface should be detectable right up to the antenna. It's a function of the altitude of the rain. But barring very heavy ground clutter or some kind of problem in the software site variable parameters of the radar, -- you know, I can confirm from data we've collected over many years with tests of that airport surveillance radar system that it's very capable of seeing rain right up to the radar as long as it's reaching the ground. It's when the radar is up at -- excuse me -- the rain is up at 5,000-10,000 feet that there's a cone of silence, if you will.

MR. SALOTTOLO: So in other words, when the rain is reaching the ground, it doesn't matter where it is in relation to the antenna. It should be picking it up.

THE WITNESS: Exactly.

MR. SALOTTOLO: Okay.

THE WITNESS: All right. Well, I want to leave now the ASR-9 and just wrap up with a brief discussion of some of the Doppler based technologies that are either currently coming on line or will be coming on line over the next five or six years.

This is just a chart we put together to illustrate the Terminal Doppler Weather Radar which has been discussed a number of times during these hearings. This is a dedicated pencil beam weather radar. It uses an eight meter parabolic dish to focus the radar energy into a very narrow half degree beam. This antenna then scans back and forth at a breakneck pace to map out the structure of thunderstorm winds and reflectivity in both azimuth and elevation over the airport.

Basically, the scan strategy is such that you will get an update on the near surface wind pattern once per minute. That's the primary means of detecting microbursts. And then it takes about 2-1/2 minutes to perform a full scan up an elevation angle to map out the full three-dimensional structure of the thunderstorm.

The raw data coming out of the radar's Doppler wind channel is illustrated up in this panel. This is a map from the near surface scan showing -- it's hard to see the plot, but basically, this shows the speed and direction of wind as measured by the radar. The blue colors indicate winds with a component towards the radar and the yellow and browns indicate winds blowing away from the radar.

So what you're seeing here inside this circle is the signature of a very strong microburst in this case. The radar, for example, is looking from this position into headwinds across the event into tail winds, so you're seeing greens over here and yellows over here. That's the signature.

Key to the TDWR system is the use of an automatic microburst detection algorithm, which recognizes this type of divergence pattern in the raw data and provides for air traffic controllers' use very simple graphical, as shown here, or runway specific alpha-numeric information on the type of windshear, it's location within one nautical mile and the intensity of the event.

So I think certainly in contrast to the Phase II LLWAS system that Wes Wilson discussed, this system provides much more area specific information on where the windshear is, exactly how intense it is, and the type of windshear, be it microburst, gust front, whatever.

This chart is derived from years of testing sponsored by the FAA of a prototype TDWR. And the point I want to make is that these algorithms for automated detection of windshear are extremely reliable. For strong microburst with those changes in wind speed, differential velocities across the event exceeding 30 knots, the detection probabilities are nearly 100 percent for all these very different environments. The probability of false alarm is likewise very low for this system.

So, I think again, the point is that when it comes on line, I believe this system will provide certainly a qualitative improvement in accuracy of reporting of windshear over what we currently have.

A related system which the FAA is currently planning on bringing on line five or six years down the road involves a processor modification to the ASR-9, sort of an outboard or external processor that will, as with the TDWR, measure the Doppler wind velocity, precipitation, run algorithms to automatically detect the occurrence of microbursts and gust fronts and show those to controllers.

This system is much less expensive than a TDWR, so it will allow the FAA to deploy radar based windshear detection capability at smaller airports that don't qualify for the much more expensive dedicated sensor.

Just an comparative chart of detection performance numbers for this system, based on four years of operational testing in Orlando, Florida and more recently in Albuquerque, New Mexico. Some degradation in performance relative to the TDWR, as you'd expect, since the ASR-9 is not designed as a windshear detection system.

False alarm probabilities probably a factor of 2 or more higher, but still we believe operationally acceptable. Lesser performance at least for the weak microbursts and some degradation of performance in an environment such as Albuquerque where so-called dry, that is, low radar cross-section microbursts, occur with some frequency.

But overall, during operational testing of the system the acceptance by both controllers and pilots has been very high. So the FAA currently intends to by about 35 of those systems to supplement the 45 TDWR's and, as I said, bring them on line sometime in the year 2000 time frame.

A final capability I want to mention is the capability for providing a two or three minute advanced prediction of microburst via this Integrated Terminal Weather System which will use both thermodynamic data, that is, the temperature structure or real time measurement of temperature structure provided from surface stations and information downlinked from aircraft. It will also use the three-dimensional reflectivity data from the TDWR to identify these cores of high reflectivity that form aloft and then descend over time to form microbursts at the surface, such as appears to have been the case here at Charlotte.

At any rate, the algorithm uses this information to provide, as I said, a two or three minute advanced estimate of when the microburst will occur at the surface and make an estimate of the strength of the outflow when it occurs at the surface.

This algorithm has been tested this past Summer at both Memphis and Orlando. The preliminary indications are that it accurately predicts about half of the microbursts that occur and has a very low false alarm rate. So, it doesn't predict all microbursts but, as with the case of Phase II LLWAS, when it does make a prediction it's a reliable one.

All right. Well, let me try to wrap up what I've tried to convey this afternoon. My sort of first topic was an overall look at the ASR-9's six level weather channel. And as I said, our work with the FAA during the operational test and evaluation of serial number 1 of the ASR-9 down at Huntsville indicated that generally the weather reflectivity depiction is quite accurate.

We've identified two significant technical issues in subsequent activities. One is false ground clutter -- excuse me -- false weather indications cause by anomalous propagation conditions. I'd point out that with the implementation of the windshear processor on the ASR-9 and the Integrated Terminal Weather System, this problem will be resolved.

We noted very recently what appears to be inappropriate site variable parameters or some kind of software glitch that appears to be causing some degree of suppression of weather returns at very close range.

And finally, I flagged that there don't appear to be well defined operational procedures for controllers to convey this weather channel information up to pilots.

With respect to the Charlotte simulation, we took three volume scans dating back about 12-13 minutes prior to the accident. Overall, the trend was for the indicated maximum weather level on the ASR-9 to increase from level 2 of this initial volume scan, up to level 4, as the high reflectivity core in this thunderstorm dropped down into the beam.

There was a slow drift of the cell northwards from a position about 3 kilometers south of the airport up towards the airport center. Average speed of drift was something on the order of 8 knots. And clearly this descending reflectivity core is at least consistent with the development of sort of a fairly classic wet microburst scenario on top of the airport.

Finally, I summarized some of the Doppler radar technology coming on line. TDWR deployments are in progress. That will cover 45 or so of the large airports in this country. The windshear processor modification to the ASR-9 is coming along slowly. Deployment is planned for 35 sites around the year 2000. And the Integrated Terminal Weather System likewise will come out into the field around the year 2000 and will provide more timely predictions of microburst prior to their actually reaching the surface.

That's the end.

MR. SALOTTOLO: Thank you, Dr. Weber. I have just a couple of quick questions. Circular polarization, linear polarization. Is there a vertical polarization?

THE WITNESS: No. The ASR-9 operates with either vertical/linear polarization. In other words, the electric field vector is oriented vertically. When the radar detects precipitation returns over approximately 25 percent of its field of view, it switches over to a circularly polarized mode which has the effect of suppressing the intensity of the precipitation returns in the target channel, the aircraft processing channel.

So, that feature allows the radar to see aircraft when they're flying through rain. It turns out that the weather channel uses a different receiving chain during circular polarized operations than it does during linear polarization operations, but if properly configured, there should not be any change in the weather reflectivity display when that transition from circular polarization occurs.

MR. SALOTTOLO: You mentioned properly configured. What is that exactly?

THE WITNESS: Well, I guess I'm referring -- you have two separate receiving chain, that is, radio frequency receivers, analog digital converters, what have you, that are used in either, A, linear polarization transmission mode, or B, circular polarization mode. And it's very important that the people who set up the radar carefully calibrate both of those receiving chains so they have the same effective gain. That there's not some just offset in the gains between the two channels which would cause a sudden change in indicated weather reflectivity when you switch from linear to circular polarization.

MR. SALOTTOLO: Now is that something that is done automatically in the system itself or is it a maintenance type requirement on the system?

THE WITNESS: That's something that's done by the FAA technicians at the time the radar is commissioned. Basically, they go through a full set of tests involving injecting calibrated signals in the front end of the radar and measuring what comes out of the processor to ensure that all the gain factors that are used in that calculation of reflectivity are correctly entered into the system.

MR. SALOTTOLO: Now, can that change over time or you just do it once and that's it?

THE WITNESS: No. It should be stable over time. The radar does have self-test features which do sort of on line keep track of any slow drifts in amplifier gains or what have you, but that should be stable.

MR. SALOTTOLO: As far as you know, there's no controllers or supervisors don't tinker with the -- so to speak, tinker with the ASR-9 as far as calibration or making sure that it's performing properly?

THE WITNESS: No. I don't believe the air traffic people would have access to any of the control knobs, if you will, that would allow them to change the gain. I mean, they can force the transition from linear to circular polarization. The can change a lot of things. But they can't give at the fundamental calibrations of the radar.

MR. SALOTTOLO: Now, the weather channel processor, is that a separate part of the equipment?

THE WITNESS: It's a separate processing cabinet. If you walk into an ASR-9 shelter, there's one cabinet with the transmitter, there's a cabinet with the aircraft processor and there's a cabinet with the six level weather channels. So it's very definitely a dedicated piece of equipment.

MR. SALOTTOLO: Now, does that require periodic maintenance or do you know does it get periodic maintenance?

THE WITNESS: Well, again, there'd be self-test features which periodically go through and ensure that all the digital circuits are up and working. If something breaks there are well established procedures for replacing the broken item.

I probably shouldn't go too far in trying to delineate the FAA's calibration procedures for these radars since I'm not an expert on what the FAA does. I know with our test bed system, our technicians go in on a weekly basis and do a pretty thorough check that all the -- that the thing is still in calibration.

To be frank, I'm probably not qualified to comment in detail for the FAA people.

MR. SALOTTOLO: And if it's out of calibration, of course, the weather echo intensities will be in error?

THE WITNESS: Sure.

MR. SALOTTOLO: Okay. Well, thank you very much, Dr. Weber. I have no further questions.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Salottolo.

Federal Aviation Administration?

MR. DONNER: No. We have no questions. Thank you.

CHAIRMAN HAMMERSCHMIDT: Thank you.

National Air Traffic Controllers Association?

MR. PARHAM: Yes, sir. Dr. Weber, I have a couple of questions. As a center controller, which I am, we have no capability of distinguishing any National Weather Service VIP levels as does most of the other radar approach controls that doesn't employ ASR-9's at this time.

Most of the aircraft that deviate in this environment, air carriers, deviate based on their own airborne weather radar. You made the statement that you had toured around facilities and controllers had told you that most aircraft deviate level 3 and above.

I wanted to kind of clear up was that based on their observations or their vectoring based on level 3?

THE WITNESS: Well, I guess the statement I was trying to make was that anecdotal comments from controllers that we work with in operational evaluations with systems like the TDWR have been that their experience has been that aircraft are to a large extent unwilling to penetrate areas where their ASR-9 scope is showing level 3 or greater precipitation.

MR. PARHAM: I was just wanting to clear up that it was based on their refusal on possibly or more probably their airborne weather radar rather than the controllers actually --

THE WITNESS: Oh, I agree. The decision to deviate, I believe, is based on the airborne weather radar visual cues.

MR. PARHAM: I was wanting to clear that up. I was a little bit unsure of what you meant.

Referring to the anomalous propagation that you mentioned, what is the reliability of the product information that is displayed around or just outside the main bank?

THE WITNESS: Given the anomalous propagation issue, are there concerns at short range? Is that the question?

MR. PARHAM: Well, because normally most of your anomalous propagation occurs around the main bank. In other words, if you turn off the filters, that's where most of it would be. At low altitudes, are there any concerns with the reliability of the product after the filter has been processed?

THE WITNESS: I have to try to distinguish here between two forms of ground clutter. There's what I'll call normal ground clutter which is what you see every day during normal propagation conditions, and that tends to be concentrated around the radar. The radar seeing the ground very well close in and then the beam lifts up off the ground as you go out in range.

During the so-called anomalous propagation conditions, what you get is a duct in the atmosphere, which essentially, the energy goes up and then it comes back down at range and then it may bounce up and come back down at longer range. So, this unusual or anomalous ground clutter, at least in my observations, tends to be something that occurs somewhat removed from the radar. We don't normally see that form of clutter inside 5, 10 nautical miles.

MR. PARHAM: I was referring to like the city around the main bang that's filtered out.

THE WITNESS: The normal ground clutter, the nearby city, the buildings or the airports is very definitely in close to the radar and that's why the ASR-9 has to use fairly aggressive clutter suppression circuitry, if you will, to get rid of that at short range.

MR. PARHAM: And what would be the reduction in reliability of the product because of that?

THE WITNESS: It depends on the intensity of the weather. I mean, it's really -- if you have effectively level 3 ground clutter and level 5 weather, you have no trouble seeing the weather. Conversely, if you have level 4 ground clutter and level 2 weather, you'll have some trouble seeing the weather.

So there's no single answer, but in general, I mean, I concur with you. Your likelihood of having a degradation in the accuracy of the depicted weather increases at short range owing to the need to work in and around that ground clutter.

MR. PARHAM: So would it be safe to say that there's no way it could be 100 percent reliable within the main bang or the area that is in a large city like Charlotte?

THE WITNESS: On a pixel -- on a resolution, cell by cell basis, I think that's true. I think for a cell of significant area will extend, such as the one that appears to have been at issue here. My experience has been that this radar should have no trouble finding enough clutter free areas to extrapolate around and make a pretty good representation of what was going on. But again, without a detailed study of the ground clutter environment here at Charlotte, I couldn't give you 100 percent certainty on that.

MR. PARHAM: Yes, sir. Going back, you had the simulation of the ASR-9, which was real nice, but it was still a simulation. I want to refer now to the cone of silence inside 5 kilometers at Charlotte. Would you agree that it is probable that the weather on the Charlotte Airport was not depicted or not displayed due to equipment limitations?

THE WITNESS: I wouldn't use the word probable. I believe that when it was raining heavily at the surface the ASR-9 should have been painting a pretty accurate depiction of the intensity of that rain at the surface, right up to the radar, unless there's something inappropriate in the site variable parameters for the radar at Charlotte.

MR. PARHAM: Let me change probable to possible then.

THE WITNESS: Possible, I'll accept.

MR. PARHAM: In your opinion, Dr. Weber, could the coupling of the ASR-9 and TDWR and NEXRAD weather products present as accurate a depiction of the weather as airborne weather radar?

THE WITNESS: I'm biased. I think they present a more accurate depiction of the weather, particularly on final approach. A pilot is doing a lot of other things and the airborne radar is likely to be looking down into the ground and he's dealing with heavy ground clutter as well.

Again, I'm biased, but I think when data link, the capability to data link weather products from the ground up to the cockpit becomes widely available, that that's a very attractive solution relative to onboard equipment.

MR. PARHAM: I suppose now I need to ask are you familiar with the circumstances concerning the flight of USAir 1016 and the impact of the weather?

THE WITNESS: To some extent. What I've read in the newspapers and what I've heard here over the last two days.

MR. PARHAM: I'm going to try this question on you since I think you're the expert that the previous one was referring to.

If the Charlotte Air Traffic facility had Doppler weather radar, could it have provided additional information for the flight crew and ATC personnel to base their decision on?

THE WITNESS: The direct answer is possibly. What we don't know given the available data is the timing of this microburst, if it was a microburst. As I showed in my statistics, I believe the TDWR is very reliable for detection, particularly of these microbursts, wet microbursts associated with heavy rain.

So if the microburst was on the ground prior to the time of the accident, in my opinion it's very likely that TDWR would have picked it up. But again, the indication from the flight crew seemed to be that something fell on them from above. And in that case, you might speculate that maybe they just happened to get in the very beginning of this particular event, so maybe it wouldn't have helped.

Impossible to say with the available data. Certainly you would have had a better shot at it.

MR. PARHAM: One other question, Dr. Weber. Going back to the ASR-9, I was trying to keep up with the process of how the radar, the beam, goes up and down in this process and arrives to the controller. What would be the maximum time delay from real time happening until it was displayed on the controller's scope?

THE WITNESS: The weather channel accumulates data over six scans of the antenna, or about 30 seconds, before it constructs it six level map. And then there may be a further delay of 4 or 5 seconds to get that up onto the controller's scope. So, we're talking about a maximum delay of 35 seconds.

MR. PARHAM: Okay. Thank you, sir.

I have no further questions.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Parham. That last question of yours is one that I was going to ask.

Honeywell?

MR. THOMAS: Mr. Chairman, we have no questions.
CHAIRMAN HAMMERSCHMIDT: Thank you.
Airline Pilots Association?
MR. TULLY: Thank you. No questions.
CHAIRMAN HAMMERSCHMIDT: Okay.
USAir?
MR. SHARP: We have no questions, Mr. Chairman.
CHAIRMAN HAMMERSCHMIDT: Thank you.
Douglas Aircraft?
MR. PARHAM: No questions. Thank you, Mr. Chairman.
CHAIRMAN HAMMERSCHMIDT: Pratt and Whitney?
MR. YOUNG: No questions. Thank you.
CHAIRMAN HAMMERSCHMIDT: Okay. Association of Flight Attendants?
MS. GILMER: No questions. Thank you, Mr. Chairman.
CHAIRMAN HAMMERSCHMIDT: Thank you.
International Association of Machinists?
MR. GOGLIA: No questions, Mr. Chairman. Thank you.
CHAIRMAN HAMMERSCHMIDT: Okay.
Dispatchers Union?
MR. SCHUETZ: No questions, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: National Weather Service?

MR. KUESSNER: No questions, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: Well, any more questions from the Technical Panel?

Mr. Laynor?

MR. LAYNOR: Just a couple. First of all, you commented about the ASR-9 going into localities where the TDWR wouldn't be present. Doesn't the remote siting of the TDWR give it a bit of an edge on the ASR-9 weather processor for one airport?

THE WITNESS: Yes. That's an advantage. I mean, as I said, the TDWR is the sensor that's optimized for this problem of detecting low level windshear. In the case of the ASR-9, the system has another primary function and clearly one of the disadvantages is having to find microbursts that land right on top of the radar, which in fact appears to be kind of the case here at Charlotte.

But we have shown that, to the degree I was able to illustrate in those numbers, that you can work around those technical problems and still have, I believe, the capability that is a lot better certainly than what we currently have at these smaller airports.

MR. LAYNOR: Does the work on the ASR-9 weather processor

-- will it lead to an algorithm that will present the same kind of message to the controller that the TDWR presently does?

THE WITNESS: Yes. We have a full up operational prototype of that system which as operational displays and associated procedures that are identical to that of the TDWR. I mean, in fact we tested that back to back with the TDWR prototype down at Orlando for two or three years. And from the controllers' perspective, there was no change in the display format or the procedures when we transitioned from one system to another.

MR. LAYNOR: Another question. You heard Mr. Saffle. Do you think it practical to apply a microburst prediction algorithm to the NEXRAD product?

THE WITNESS: It's problematic with the NEXRAD because of the slower volume scan. As I said, the TDWR completes a three-dimensional scan over the airport in 2-1/2 minutes whereas NEXRAD takes 5 or 6 minutes. So that's one thing going against you. The second thing is the NEXRAD is likely to be further away from the airport, so it won't have the resolution. However, if you had an NEXRAD near an airport it would be better than nothing.

MR. LAYNOR: And I'm not sure you can answer this one, my last question. But in any of the tests that you've been associated with, has there been any studies of the time increment between when the Doppler element of the sensor picks up an outflow and the reflectivity level picks up the rain core?

THE WITNESS: Well, as in my last chart, the early formation stages of at least your classical wet microburst is a core reflectivity that forms at an altitude of 4 or 5 kilometers -- that's 15,000 feet or so up -- and descends over a period of maybe 5 minutes to the surface. So there's roughly kind of a 5 minute difference between the formation of the reflectivity core and the formation of the strong outflow at the surface. That's a very average number.

MR. LAYNOR: I guess I should qualify my questions to say for a beam that's looking at low altitude only. Are you apt to pick up the windshear or outflow before the heavy rain or is there any -- has there been any studies of the time involved there?

THE WITNESS: My sense is that they tend -- on average, tend to be more or less at the same time in your classic event. But I'm not an expert in that area.

MR. LAYNOR: Okay. All right. Thank you very much, Dr. Weber.

CHAIRMAN HAMMERSCHMIDT: Mr. Schleede?

MR. SCHLEEDE: No questions, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: Okay. Thank you. Dr. Weber, you mentioned that it would take approximately 35 seconds from the time the Terminal Doppler Weather Radar you might say spotted a microburst weather phenomenon until the time it would be able to process that into an alert for an air traffic controller. Is that correct?

THE WITNESS: No. I'm sorry. I thought I was replying to a question about the data age or latency of the reflectivity product provided by the ASR-9.

CHAIRMAN HAMMERESCHMIDT: Oh, ASR-9. What is the time factor on the TDWR?

THE WITNESS: The TDWR does, as I said, a surface scan, which is the primary method of detecting microbursts once per minute. The processing time superimposed on that is I believe fairly minimal. I believe the display updates once per minute. So conceivably there could be as much as a -- you know, if you timing was just wrong there it could conceivably be a two minute lag between your first detection of divergence and its display to a controller. But if Mr. Turnbull is here, I'd appreciate his correcting that when he has a chance to testify.

CHAIRMAN HAMMERSCHMIDT: Yes. We'll ask him that same question. But conceivably you could have approximately a two minute window of vulnerability even with the much improved Terminal Doppler Weather Radar?

THE WITNESS: One to two minutes. But the saving grace is that microbursts don't typically appear on the surface at full intensity. At least in our observations, they ramp up over a period of minutes, so that in an normal scenario your first detection would be what we call a windshear with loss, an even in say the 20 knot loss range and a minute later it will ramp up to 25-30 knots.

There's a grace period here at the beginning of the event that --

CHAIRMAN HAMMERSCHMIDT: As it progresses.

THE WITNESS: -- in my opinion makes that type of delay acceptable operationally.

CHAIRMAN HAMMERSCHMIDT: Okay. Dr. Weber, thank you for your excellent testimony, and we appreciate your participation in our hearing.

(Witness excused.)

CHAIRMAN HAMMERSCHMIDT: Let's see. Why don't we go to our next witness now, Mr. Leslie J. Brown. Mr. Brown will be questioned by NTSB investigator Sandy Simpson.

(Witness testimony continues on the next page.)

LESLIE J. BROWN, FAA AIR TRAFFIC, ADVANCED SYSTEMS BRANCH, WASHINGTON, D.C.

Whereupon,

LESLIE J. BROWN,

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

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

THE WITNESS: My name is Leslie J. Brown, Washington, D. C., National Headquarters, FAA.

MR. SCHLEEDE: What position do you hold with the FAA?

THE WITNESS: Presently, Branch Manager of the Advanced Systems Branch which is part of the Training Requirements Program.

MR. SCHLEEDE: Training Requirements for --

THE WITNESS: Training Requirements Program.

MR. SCHLEEDE: For --

THE WITNESS: FAA technical training, controllers.

MR. SCHLEEDE: For the controllers?

THE WITNESS: Yes.

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

THE WITNESS: I have been employed by the FAA for approximately 25 years. Held a number of staff positions in automation and training. Was a training specialist, automation manager and currently hold the position that I told you.

I was an Air Force pilot and hold an associate's degree in aeronautical engineering.

MR. SCHLEEDE: Thank you very much.

Ms. Simpson?

MS. SIMPSON: Good afternoon. I would just like to talk to you regarding FAA procedures for introducing new equipment to air traffic control facilities.

Suppose the FAA has decided to purchase a new piece of equipment like the ASR-9 or the Terminal Doppler Weather Radar which would be used by controllers. What steps does the FAA take to familiarize the controllers with the equipment before it is commissioned and fully operational?

THE WITNESS: That would depend, Ms. Simpson, on the nature of the equipment. The equipment change might be so simple as to be, for example, changing a switch from 1, 2, 3, to low, medium and high, in which case there would be a verbal briefing or it may be necessary to provide extensive residence training. But it would all depend upon the nature of the equipment and the nature of the change.

MS. SIMPSON: Suppose they were going from the ASR-4 to the ASR-9. What training would they be required to have?

THE WITNESS: Well, they would clearly need to be trained ont he differences which are not transparent to the controllers. Very often when there are changes in equipment the changes are transparent to the controllers. Those aspects of the new equipment which change the way the controller does business would have to be trained.

MS. SIMPSON: What about the weather radar portion of the ASR-9 compared with the ASR-4? What training would be given then?

THE WITNESS: Do you want to know what the training was like for the ASR-9? Is that the question? I'm not sure.

MS. SIMPSON: That would be good.

THE WITNESS: Okay. There were individuals at the affected facilities who were trained at cadre instructions. They received an intensive course and then these individuals trained the controllers at their own facility on the use of the ASR-9.

MS. SIMPSON: And what were those controllers taught?

THE WITNESS: What were they taught?

MS. SIMPSON: Yes. Do you have any idea of what they were taught specifically so that they could go back and teach the rest of their facility?

THE WITNESS: Generically, just generally, they were taught the knob-ology, so to speak, the buttons and switches. They were taught that there would be six levels of weather depicted on the radar. They were taught how to select what was going to be displayed on the radar, and so forth.

MS. SIMPSON: Are the controller taught to interpret the levels of radar -- I mean, the levels of weather, precipitation?

THE WITNESS: Absolutely not.

MS. SIMPSON: And are these training given in like a video cassette or are there manuals to read or there's hands-on training?

THE WITNESS: I'm not sure I understand the question. If you're asking me generically about training, it again would depend upon what training was required, whether it was extensive or not extensive. In the case of the ASR-9 there was a videotape. There were slides or transparencies which were part of the course work plus electric.

MS. SIMPSON: And about how long would that training take generically?

THE WITNESS: I believe it was about 40 hours altogether.

MS. SIMPSON: And is that done at the facility or do they go to Oklahoma City for that?

THE WITNESS: At the facility.

MS. SIMPSON: And the Terminal Doppler Weather Radar is new to air traffic controllers. What training is being done now for those controllers who will be using it?

THE WITNESS: Well, the Doppler radar, to the best of my knowledge -- not the TDWR but Doppler radar is a piece of equipment which I believe will be used solely by National Weather Service people and there is no training for controllers for that piece of equipment.

If you are talking about the aspect that Doppler radar which will be included as part of TDWR, the course is currently -- well, it has been developed. It's going to be prototyped I believe next month. And assuming that everything is all right with the course, to the best of my knowledge we're going to begin formal instruction after the first of the year.

MS. SIMPSON: And is that formal instruction at the facility at Oklahoma City?

THE WITNESS: At the facility.

MS. SIMPSON: And since 1989, has the FAA established any formal procedures for issuing ASR-9 weather data from controllers to pilots?

THE WITNESS: I'm sorry, Ms. Simpson. Could you repeat that?

MS. SIMPSON: Since 1989, has the FAA established any formal procedures for issuing ASR-9 weather data from controllers to pilots?

THE WITNESS: I'm not a procedures expert and in answering that question I can only repeat to you what I've read in the handbook. And the handbook does show some phraseology examples which explains the method that controllers should use in providing this information to pilots. But again, that's a procedural question.

MS. SIMPSON: Right. So then is that a requirement since it is in the handbook for the controllers to use?

THE WITNESS: Well, if you're asking me to interpret procedures, it's really not my area of expertise. Basically the handbook is the controller's bible, and I can say generally that that which is required in the handbook is required of controllers. Some things are mandatory; some things are optional. But I might respectfully suggest that you ask that of a procedures person rather than a training program.

MS. SIMPSON: That was going to be my next question. Who develops the procedures and how would they disseminate the procedures?

THE WITNESS: Procedures are developed by others. I believe most of these procedures are developed either within or with the oversight of the Procedures Branch of the FAA, but don't carve that in stone. I don't know.

MS. SIMPSON: I have no further questions.

CHAIRMAN HAMMERSCHMIDT: Thank you, Ms. Simpson.

Let's see. Going to the parties. National Air Traffic Controllers Association, any questions?

MR. PARHAM: Mr. Chairman, I have no questions. Thank you.

CHAIRMAN HAMMERSCHMIDT: Okay. Honeywell?

MR. THOMAS: No questions.

CHAIRMAN HAMMERSCHMIDT: Airline Pilots Association?

MR. TULLY: Thank you. No questions.

CHAIRMAN HAMMERSCHMIDT: USAir, Incorporated?

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

CHAIRMAN HAMMERSCHMIDT: Thank you.

Douglas Aircraft Company?

MR. LUND: No questions. Thank you, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: Thank you. Pratt and Whitney?

MR. YOUNG: No questions.

CHAIRMAN HAMMERSCHMIDT: Association of Flight Attendants?

MS. GILMER: No questions.

CHAIRMAN HAMMERSCHMIDT: Okay. No questions there.

International Association of Machinists?

MR. GOGLIA: No questions, Mr. Chairman. Thank you.

CHAIRMAN HAMMERSCHMIDT: Dispatchers Union?

MR. SCHUETZ: Yes, Mr. Chairman. We have one question.

CHAIRMAN HAMMERSCHMIDT: Okay.

MR. SCHUETZ: Mr. Brown, do you have any recurrent training for controllers?

THE WITNESS: Yes.

MR. SCHUETZ: And may I ask how often do you have it? Do you have it on a yearly basis or anything?

THE WITNESS: Well, the current training, there are numerous or a number of things that are trained recurrently. I believe that there is some training that occurs annually, but I'm not sure. I'd have to check the rules again. I've been away from an operational facility for quite some time and I don't remember, but I believe it's annual.

MR. SCHUETZ: So you don't have any -- you don't know if you have any classroom style recurrent training and how many hours per year or anything like that?

THE WITNESS: No. I couldn't answer that question.

MR. SCHUETZ: Okay. Thank you very much.

No further questions.

CHAIRMAN HAMMERSCHMIDT: Thank you.

National Weather Service?

MR. KUESSNER: No questions.

CHAIRMAN HAMMERSCHMIDT: Any questions from the Tech Panel? Any more questions?

MR. FEITH: Yes. I just have a question as far as the question that Mr. Schuetz asked with regard to recurrent training. Who establishes the recurrent training?

THE WITNESS: There -- you mean, who establishes a need for recurrent training?

MR. FEITH: Yes.

THE WITNESS: Most of this is done on a facility basis by the Assistant Manger for Training. There may be some requirements nationally for some recurrent training. The reason for my vacillation is there have been some changes recently in some of the requirements, such as for -- there were certain types of checks that were given and unfortunately I'm not prepared to tell you exactly what those changes were and I'm sorry I'm unable to give you a definitive answer.

MR. FEITH: Do you determine or do you develop the training programs?

THE WITNESS: Do we at the national level? No, we do not.

MR. FEITH: Who does?

THE WITNESS: We would set the requirements and in most cases this type of training would be set up based upon local facility needs at the facility level.

MR. FEITH: Do you in your office oversee these programs, then?

THE WITNESS: Broadly, yes.

MR. FEITH: I have no further questions.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Feith.

Mr. Laynor?

MR. LAYNOR: Mr. Brown, in referring back to Ms.

Simpson's questions about how new equipment is entered into service, can you discuss a little bit just how people in the engineering and development area of a piece of equipment coordinate the need for training and the development of procedures with the appropriate segments of the FAA?

THE WITNESS: Yes. Sure. There's no -- because there's such a broad variation in what's being introduced, there's no formula.

What happens is if a piece of equipment, for example a new piece of equipment is going to be designed or developed or introduced, the requirements of that equipment are looked at by a number of people, including instructional system designers, training specialists at the FAA Academy, training specialists at headquarters, people with experience, air traffic procedures people. And this consortium, so to speak, will determine what level of training is required for this new piece of equipment, what efforts should be made to develop that training.

And from then, the procedure to develop the training requirements is set up. But each piece of equipment or each new procedure must be looked at independently. There's no formula.

MR. LAYNOR: So, there really isn't a formal process for coordination between the engineering and development people, the training people and the procedures people?

THE WITNESS: Yes. There is a formal process of coordination once it's determined that there are training requirements. There are matrix teams which are developed under the aegis of air traffic and these teams include engineering people, technical people, training people, procedures people, representatives typically of the labor organizations of the workforce, the people who are going to be using the equipment, and then these teams will, as the development of a piece of equipment goes forward, will also include training requirements as part of the matrix and will develop the courseware, oversee it.

MR. LAYNOR: Let me get a little bit more specific. Ms. Simpson asked you about the TDWR, which has already been commissioned and is in operation at at least one site. And I understand other are coming along fairly rapidly.

THE WITNESS: Yes.

MR. LAYNOR: And your response is that there is not a formal training program yet in place for that piece of equipment.

THE WITNESS: At the prototype sites, particularly for TDWR, the contractor provided the training using the course which had been developed and which had been approved by training specialists at the Academy. And that course -- and this is typical. It's a chicken and the egg situation sometimes. You sometimes can't develop the training until the equipment is in the field and you can't get the equipment in the field until you development the training. So very often it's done in this manner.

MR. LAYNOR: To address a subject that's a little remote from this hearing, but was there any training when TCAS was introduced into the airborne system?

THE WITNESS: We did provide a TCAS -- a formal TCAS training, some courseware which included a videotape, an instructor's guide, facilitator's guide, an so forth, which was given to the entire workforce. Yes.

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

CHAIRMAN HAMMERSCHMIDT: Let me ask just a follow-up question on one of Mr. Laynor's questions. Just so I'll have it clear in my mind, when you referred to the prototype installations, would that be a reference to the installation at Houston?

THE WITNESS: I'm not sure where. I believe TDWR has been installed in -- was it Denver and Houston? I believe -- yes.

CHAIRMAN HAMMERSCHMIDT: Right. But that's what you were referring to when you said prototype?

THE WITNESS: Yes. Yes.

CHAIRMAN HAMMERSCHMIDT: Right. Okay.

Mr. Schleede?

MR. SCHLEEDE: Yes, Mr. Brown. I was a little remiss in qualifying you as a witness. What are your duties and responsibilities in your position?

THE WITNESS: As Branch Manager of the Advanced Systems Branch, I manage a group of six training specialists who determine the requirement for training on advanced systems, new systems, and then oversee the development of the lessons plans and courseware.

MR. SCHLEEDE: And you testified earlier -- you were asked questions about procedures and you testified that's not within your area of responsibility?

THE WITNESS: Certainly not to establish procedures, no. Others establish the procedures and when necessary we then teach others or train others in those procedures.

MR. SCHLEEDE: Well, I guess that's where I might direct my question. Regarding your responsibilities in training, could you describe to us what national programs there are for training in the use of procedures that are either spelled out in the handbook for controllers, we're talking about.

THE WITNESS: Well, sir, most of the new procedures -- and I'm speaking now from my experience as an air traffic controller. Most of the new air traffic procedures are trained or briefed by means of briefing guides that come with the establishment of the procedures. For example, 7110.65, when the new version comes out, there will be briefing guides that are distributed to the controllers and we don't get involved in any formal training in that case.

On occasion we are asked to develop formal training for certain procedural changes, and if so, we would use our expertise to do so.

MR. SCHLEEDE: Okay. I just might for the record express my disappointment not at you, sir, but at someone else in the FAA that our intention was to have someone here also to testify on procedures and from a headquarters level. And I guess our grammar wasn't too good in the area that we called you on.

THE WITNESS: Well, sir, I'm sorry.

MR. SCHLEEDE: But thank you for your testimony.

CHAIRMAN HAMMERSCHMIDT: But in that light, you've been a speedy witness and we thank you for your participation.

Is there anything you would like to add for the public record?

THE WITNESS: No, thank you. I just wish for the benefit of this hearing that I was a procedures expert.

CHAIRMAN HAMMERSCHMIDT: Okay. Thank you, sir.

I would like the record to indicate that I have been informed by the FAA spokesman that one or two witnesses were offered to address the issues of controller training and/or procedures for the installation of new equipment. NTSB staff elected to call one witness whose area of expertise was limited to the FAA training program.

(Witness excused.)

CHAIRMAN HAMMERSCHMIDT: Well, the previous witness took one hour and six minutes and this one took 18 minutes, so we're drifting back on schedule.

What is the sense of the room in terms of needing a break at this point, or should we proceed to the next witness?

Keep going is what I see. Okay. Let's proceed to the next witness, Dr. Fred Proctor. Mr. Proctor is with NASA and he will be questioned by Mr. Greg Salottolo.

(Witness testimony continues on the next page.)

DR. FRED PROCTOR, WEATHER EXPERT, NASA, LANGLEY, VIRGINIA

Whereupon,

DR. FRED PROCTOR,

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

MR. SCHLEEDE: Dr. Proctor, could you state your full name and business address for our record?

THE WITNESS: Fred Hayes Proctor, and I'm employed by NASA Langley Research Center in Hampton, Virginia.

MR. SCHLEEDE: What is your title in that position?

THE WITNESS: I am a research meteorologist.

MR. SCHLEEDE: And briefly, what are your duties and responsibilities in that position?

THE WITNESS: My duties and responsibilities are to -- I have developed a computer model which will simulate microbursts and to use that as a tool to study microbursts, determine their characteristics and understand how they form, how they develop. And also to provide data sets from the models for studies in aircraft simulators and for testing windshear sensors, such as look-ahead radar.

MR. SCHLEEDE: Would you briefly describe your education and experience that qualifies you for your present position?

THE WITNESS: I have a Ph.D. in meteorology from Texas A&M University and received that in 1982.

MR. SCHLEEDE: Thank you, Dr. Proctor.

Mr. Salottolo, proceed.

MR. SALOTTOLO: Thank you, Mr. Schleede.

Dr. Proctor, you can proceed with your presentation.

(Whereupon, a presentation was made with viewgraphs.)

THE WITNESS: Okay. What I will --

MR. SALOTTOLO: I'm sorry. Exhibit 5-I.

THE WITNESS: What I will present are briefly the observed characteristics of the microburst event, a brief introduction to the numerical model, computer model, which I will use to simulate this event, and what conditions that I used to initialize the model and I will describe the results from the model and its comparison with the observed data that we have, and end with a brief summary conclusion.

Characteristics of the event that we know of, and this is preliminary, which is summarized from data, most of which has come from NTSB, are that the event had a large velocity change. This came from the data from the flight data recorder. And the wind speeds were on the order -- the velocity change was on the order of about 70 knots, or 35 meters per second.

This wind change occurred over a very small scale of about one kilometer. This then is associated with extremely hazardous windshear with a one kilometer F factor of about point 3. And I'll describe a little bit later what an F factor is and what magnitude of that value means.

It was associated with moderate to heavy rainfall. The precipitation shaft was observed by eyewitnesses as being visually a wall of water. Aircraft radar from aircraft that were on the runways or landing behind the aircraft observed it with a diameter of about 1 to 3 miles. It was generated from a thunderstorm with a top of about 30,000 feet and as far as summarizing one of the bottom lines of the simulation itself, would be that it's the most intense microburst that we have numerically simulated from any case to date.

Now, to give you just a brief introduction to the model, which is called the Terminal Area Simulation System, or we use the acronym TASS for short, it's an atmospheric simulation model or cloud and micro scale phenomena. It has a meteorological framework which includes the microphysics for rain, snow, hail, cloud ice, cloud droplets. Meaning that I can simulate all these different processes that occurs within cloud growth and microburst development.

Ambient conditions, the environmental conditions that were surrounding the storm which produced the microburst, was initialized from vertical profiles of temperature, dew point and wind velocity.

As far as past uses of the model, it's been applied and validated against a wide range of atmospheric phenomena, including super cell hail storms and with many cases applied to actual microburst phenomena. It has a history of FAA acceptance and it has been and is being used in windshear certification for look-ahead sensors.

The model has been used to investigate some of the previous windshear encounters, such as the 1985 DFW microburst accident and a couple of other incidents which are listed below, as well as several cases that we experienced during the NASA/FAA windshear program on our deployments in both Orlando and Denver in 1991 and 1992.

The composite sounding which was used to initialize the test model is shown here. And if you were to ask me, well, if there was anything unusual about the environment around Charlotte on the day or about the time this storm developed, it would be that there was a very steep lapse rate from the surface to about 3 kilometers above the ground. Lapse rate was nearly 80 --

Also, there was a stable layer at around 7 kilometers above the ground which would have limited the development of thunderstorms to around 30,000 feet, which is what occurred. The moisture in the atmosphere was fairly deep and winds were generally light throughout the depth of the atmosphere.

And I guess in summary I would say that this particular sounding certainly would have a high microburst potential.

Now, the first thing we do when we run a simulation is to check it out against the validation to see how well it did and to make sure that we are simulating the event correctly. In this table that I'm showing here, we have compiled a number of parameters in which we have both the observed and the simulated from the TASS model.

The storm top was observed to be about 25,000 to 30,000 feet roughly. The model simulated it to be about 8 kilometers or 25,000 feet. The translation of the storm was about 9 knots toward the northwest and the model simulated it to be about close to that, about 7 to 8 knots in the same direction. The structure of the radar echo both in the simulated and observed were elongated from west-northwest to east-southeast.

The accumulated precipitation was a little bit less in the simulation. Point 33 inches was observed at the National Weather Service at the airport in Charlotte and point 25 inches was the maximum precip that was simulated in the model.

The diameter of the microburst rain shaft -- and again, this comes from accounts of radars that were on in aircraft that were waiting to either takeoff or were coming in for a landing -- were estimated to be about 1 to 3 miles in diameter or 1.5 to 5 kilometers. And in the simulation it was about 2 miles in diameter or 3-1/2 kilometers.

Maximum temperature drop was about minus 6 degrees

C at the National Weather Service and the model simulated minus 7 degrees Centigrade, which is equipment to 12-1/2 degrees Fahrenheit.

The maximum north-south F factor from the flight data recorder was about point 3 and the simulator was point 3.

I guess at this point -- the F factor is a non-dimensional index which characterizes the hazard from the windshear. It is a function of both the horizontal shear along the flight path of the aircraft and the vertical velocity or the downdraft that it will encounter, as well as the air speed of the aircraft.

Values of point 1 are considered hazardous by the FAA. And again, to give you kind of an idea of what these value mean, the F factor associated with the Dallas-Ft. Worth 1985 crash was a point 25.

Also simulated at the ground, the peak low level gust in the simulation was about 27 meters per second, about 55 knots and LLWAS reported 17 meters per second. Civilians estimated the wind speeds to be on the order of -- at least one civilian said it was about 50 to 60 miles an hour and he was near the scene of the accident. He described it as buffeting his car and almost appearing like a mini-hurricane.

The maximum north-south velocity change or the velocity change along any north-south segment at low levels in the model was about 90 knots or 44 meters per second. And from the flight data recorder it was about 40 meters per second or 80 knots.

MR. SALOTTOLO: Excuse me, Dr. Proctor. I wonder if we could just kind of back up a little bit. First of all, I'd like to get kind of a feel for what's going on here as far as the model itself.

Now you say you initialized it with temperature, dew point, winds and pressure or sounding?

THE WITNESS: That's correct.

MR. SALOTTOLO: Okay. So you plugged this in to start the thing going. Now, what happens next? What evolves from that? A cell evolves that produces various meteorological parameters, such as vertical winds, horizontal winds, liquid water content, things of that nature?

THE WITNESS: Yes. We start out with an environment or a sounding that's representative of the ambient environment of the storm; apply an artificial impulse to trigger the event; and then what happens is a cell or cumulus cloud begins to develop and it grows into a storm which could be then either one cell or a number of cells. And these cells may or may not produce downdrafts, strong downdrafts or windshear at the ground. And this is really a function of the ambient environment at which it occurs.

MR. SALOTTOLO: Okay. So on July 2nd, if we had used the sounding let's say near Greensboro, would there have been a -- would that have generated a cell that would have produced a microburst, do you know?

THE WITNESS: The environments throughout the region had the potential for producing intense microbursts, although their characteristics would have differed, such as their size, structure and so forth, once a thunderstorm had developed.

MR. SALOTTOLO: So it could have developed anywhere. In other words, what I'm getting at, you develop a cell but it doesn't tell you particularly where the cell is going to be in a certain geographical area. It could be anywhere.

THE WITNESS: Not from our model. And in order to do that then we'd have to match it with other data and other parameters, which I will show.

MR. SALOTTOLO: Okay. Now F factor you just explained to us. Is F factor aircraft specific? I mean, is there a DC-9 F factor, a DC-10 F factor?

THE WITNESS: No, it's not.

MR. SALOTTOLO: And maybe you can or can't answer this. Can F factor predict whether a windshear is flyable or not just given a value?

THE WITNESS: Can you repeat that question, please?

MR. SALOTTOLO: Can F factor, the number, predict whether a windshear is flyable or not, if it's given an F factor?

THE WITNESS: Well, what it means is that if you have a large positive value of F factor, then an aircraft would be subject to a large energy loss or performance loss. And certainly if it's of large enough value, then it would -- an aircraft would lose significant altitude or air speed.

MR. SALOTTOLO: Okay. So it can't be used as a predictor of whether we can fly through a particular windshear given a particular F factor?

THE WITNESS: It's used to categorize the intensity of the windshear. That's what it's used for.

MR. SALOTTOLO: Okay. Go ahead.

THE WITNESS: Now, the top diagram shows a plot of data along the flight profile from the flight data recorder and a comparison with a similar constructed profile through the TASS model. And the profile would be -- in other words, the aircraft would be going from left to right on the diagram, so in this region here then, it would represent a very strong headwind for the aircraft on the order of 20 meters per second or 40 knots. And you could see then over a distance of about 1 kilometer then this would suddenly change to a strong tailwind of about 20 to 25 meters per second or 40 or so knots in this region.

So what you see here is both in the model simulation and the flight data recorder, there's a very strong wind change and it occurs over a very small distance, which would imply a very strong shear encounter.

From our simulations before that we've done, every once in a while you will see microburst intensities where you have velocity changes of this intensity, but we've an event where you get this velocity change over such a small distance scale.

On the bottom plot is a plot of the cross-track wind and the model simulation shows a little bit stronger on the cross-track wind than the data in the flight data recorder, but they both seem to have the same tendency showing a strong wind from the east. And I'll show you that in another diagram in a few minutes a little bit better.

Now, look at the 1 kilometer average F factor. And this would be a plot of the 1 kilometer average F factor along the flight path. And if you remember, I said that negative values represent performance enhancing areas -- excuse me. I got that backwards. Negative values represent performance enhancing areas while positive value represent performance decreasing areas. And of course, in a performance enhancing area, then you would either gain air speed or altitude.

So, just upon entering the event, then, the aircraft did experience this performance enhancing area and this is due to the increase in the headwind and updraft associated with a vortex ring. Then as it passed into the microburst, then you can see that there was a ramping up of the F factor with a peak value of about point 265 in the model simulation and someone higher of about point 3 in the flight data recorder data.

And then on the bottom plot here, I plotted a couple of variables that aren't currently available from the flight data recorder and you can see a plot of the liquid water content along the flight path and that peaks at about 4-1/2 grams of rain per cubic meter of air. And also plotted is a profile of the vertical velocity along the flight path. And this, again, is from the model simulation, which showed updraft values of about 2 meters per second or 4 knots in the performance enhancing region, and then it quickly shifted to a very strong downdraft on the order of about 7.1 meters per second, 14 knots, which is also equivalent to about 1400 feet per minute and certainly would cause a -- the downdraft itself would certainly cause a significant loss in climb capability.

And then, of course, added to this effect of this very strong downdraft which we saw in the previous slide, there was very strong horizontal shear. And that's the reason why you have such a strong value of F factor.

MR. SALOTTOLO: Dr. Proctor, excuse me, again. You have a liquid water content of 4.5. What's the error in that? Are we talking -- what could it be actually?

THE WITNESS: I would guess that it could be within a factor of 2 of that.

MR. SALOTTOLO: So it could be as much as 9? Okay. And on the downward vertical velocity, 7.1 meters per second, what altitude was that at?

THE WITNESS: That was along the flight path of the aircraft, so that would be whatever that position would be. And certainly at that point where it was large, the aircraft was probably near its highest position.

MR. SALOTTOLO: Okay. Now, your model, as I understand it, doesn't go below 300 feet above the ground, the lowest level?

THE WITNESS: The lowest level -- yes. The lowest level other than the ground level would be about 60 meters, which is about 100-200 --

MR. SALOTTOLO: 60 meters?

THE WITNESS: Yes. 100-200 feet or so.

MR. SALOTTOLO: Okay.

THE WITNESS: Now, this is a plot that was compiled by Dr. Rolland Bowles at NASA-Langley, and it was derived from three field studies where they had measured microbursts with the Terminal Doppler Weather Radar and it shows the probability of exceeding an F factor of a certain value. And you can see, for example, for a point 25 F factor, then, it would involved the microburst. Probably 1 percent of the microburst would have values of F factor greater than that.

For a point 3 F factor, then the probably would be less that point 1 percent. So for this event, we're talking about F factor values that are quite extreme compared to large samples of microburst which have been measured in the past.

Shown here, then, from the model simulation of the radar reflectivity plot in decibels of reflectivity at storm mid levels, which this is about 9,000 or 10,000 feet. And this is about at the time of the accident.

And now, the way we get times and position are that when we -- is by matching up the profile from the model simulation with that of the flight data recorder. Then we can determine where the model's positions correspond to that of the real world.

On here also you can see, as well as several successive plots, would be the profile of the accident aircraft, as well as the runways. The reason I show this particular plot, this is the altitude at which the NEXRAD radar would be looking at since it's located about 135 kilometers away. It's lowest scan would be about 8,000 feet, slightly below this, and it would see an elongated echo and with reflectivities that are quite high near the center.

MR. SALOTTOLO: Excuse me, Dr. Proctor. You mentioned NEXRAD. On the NEXRAD data, it was indicating the maximum was -- looks like west of where you have the maximum in the simulation. It that just the way the simulation went, or is there any explanation for that?

THE WITNESS: That's the way we matched it up from our position. The NEXRAD radar beam is quite wide when it gets there, while this, we would assume that if a radar was looking, it would have an infinite thin beam. So it's not a simulation of what that radar would have seen, which would have been something more smeared probably than what you're seeing here.

Now, to show you the contrast of how this would change, if you'd go to lower elevations, if we were to look at the radar reflectivity just above the ground at 160 meters, you would see a small diameter circular cell and it would have very high reflectivities through most of the echo. And this seems to be in agreement with the observations from the aircraft radars that were either on the runway or were coming in behind the accident aircraft. They reported a wall of water and the radar showed a cell diameter of 1 to 3 miles or up to about 5 kilometers. And the echo was painted almost solid red, which would be greater than 45 dBZ.

And there was a very strong gradient, as you can see here, of radar reflectivity around the cell. Also, the aircraft which penetrated this echo after the accident aircraft, which he was on a go around pattern, reported that he exited the rain shaft at about one-third of the way down the runway, which is certainly similar to what we're seeing in the results here. You can see that the precipitation area extends about one-third of the way down the runway. Also notice that the echo from our positioning of our model simulation is centered somewhat to the east of 18 Right.

Now, I want to caution you as you look at these results from the simulation. We think we've gotten very good results but I wouldn't want you to think that every exact detail replicates the actual event. But from our reconstruction of the event, and this corresponds to about the time that the accident aircraft was in the middle of the microburst, you can see his track relative to the position of the low level wind outflow. These vectors represent the strong outflow with a strong western component and you can see the strong tailwind along the flight path here, as well as he strong headwind along here.

And again, it's located -- just a small echo or small divergence pattern located just off the end of the runway. And by the way, this divergence center, as I'll show a little bit later, is expanding and tracking to the northwest.

If we looked at a plot of the 1 kilometer average F factor, assuming that they're computed along north-south segments, you can see -- and remember, a point 1 is considered a hazardous by FAA. So anything of a yellow, would be consider a hazard, hazardous windshear. And it's extending off the end of the runway and just barely touching 18 Left here. The blue areas represent the performance enhancing areas which the front mechanics.

Additional characteristics of the storm obtained from this simulation is that it was a multi-cellular storm with new cell growth on the western end. I mean, multi-cellular. It just wasn't one cell but there were new cells forming at it grew. The movement of the microburst itself was toward the northwest at about 9 knots. The microburst was most intense during its early stage. And I'll show you a plot of that in a second here.

The peak rainfall rates were on the order of about -- well, were about 4.3 inches per hour. The microburst outflow expanded with time as it moved northwest. And at some time later, embedded microburst developed within this outflow and aided in maintaining the hazardous levels of windshear as it moved further to the northwest.

Now, if we look at a time history of the rainfall rate and F factor as it is matched with the real time, and this is in UTC, so this would be -- if you want to put that in Eastern Daylight Time, this would be 18:42 or 22:42 UTC. The accident time was about 42:25. I think that was about the time of the first touchdown. And you can see, according to this, that the accident time is roughly about the time of the peak rainfall rate and F factor.

If you were to go one minute prior to this event or prior to the first impact time which would be about

41:15, the rainfall rates are about 1-1/4 inch an hour. In other words, significantly less than one minute after, indicating that the penetration of the microbursts occurred at a time when the rainfall at the surface was rapidly ramping up or increasing.

The F factor, which represents again the intensity of the windshear, again is also rapidly ramping up. Also put on this plot is the threshold, hazard threshold. And you can see in this event that it were three times greater than the hazard threshold. And again, it's rapidly vamping up and it stays somewhat hazardous, although this hazard area may not be along the -- in front of the runways. It could have been off to the side as it drifted on toward the northwest.

Again, the F factor is shown on this plot. But also shown is the north-south velocity change through the microburst. And again, you can see a rapid ramping up of the velocity change toward the time of the accident, and at a few seconds afterward, 15 or 30 seconds afterwards, reaching a peak of about 44 meters per second velocity change, or about 90 knots.

Now, to quickly show you several plots of the low level wind vector field, how it evolved with time, first, I'm showing you at roughly about the time of first impact and you can see that the flow is westward. There's a flight path. And if I were to look at it 45 seconds before this event, you could see a much -- there would be a much weaker shear involved here. And certainly most of this outflow from the microburst is toward the west rather than north-south component.

So at this time at this level, the shears were probably -- I think I looked it up and they were just at threshold hazard values but significantly less than what they were 45 seconds earlier. Along 18 Left, the shears are very small.

Now, if we were to go a few minutes after the incident, then you could see how the microburst outflow is expanding outwards. And to try to get this in comparison with some of the LLWAS's were seeing, LLWAS 6 would have been located in this region where you're having -- LLWAS 6 is reporting a strong outflow of about -- toward the north of about 35 knots. LLWAS 2 is located right in this position. And I believe this is in agreement also with the direction of the flow. And the center field LLWAS is located in here. And the center field LLWAS was showing winds that were almost from due east. This has a little bit of a southerly component.

The other LLWAS's were located south of the outflow boundary and would not have been affected.

The microburst did contain several divergent centers or several centers, so it just wasn't an idealized -- didn't have an idealized single downdraft with a symmetric flow field.

In summary and conclusions, we get favorable agreement with our model simulation with the data that we have compared with. The numerical simulation produced an unusually intense microburst that was of very small scale. The microburst is driven by a small diameter rainshaft and it had strong reflectivity gradients near the edge and had radar reflectivities on the order of about 52 dBZ at the surface.

The storm that produced the microburst has a storm top of only about 25,000 feet in the simulation, which is in rough agreement with what we've seen in some of the observations. So I would say as far as storms that produce microbursts, this was of smaller depth than you would usually see.

The 1 kilometer average F factors from the simulation were extremely large and probably represent the top 1 percent or point 1 percent of the intensities that you would see in a large microburst sample. And a point 3 is certainly greater than the other accident investigations, such as DFW.

A scenario constructed from the model simulation indicates that USAir encountered the microburst early in its lifetime and during its period of greatest intensity. Following the accident, the storm moved westward, northwestward.

MR. SALOTTOLO: Thank you, Dr. Proctor. I have several questions.

First of all, you said the lowest level of your model is 60 meters?

THE WITNESS: That's correct.

MR. SALOTTOLO: But you didn't -- you don't -- there's no data. There's no graphic at 60 meters. I see 90 meters here in the data.

THE WITNESS: Yes. In the time we had to plot these up, we plotted that one up. I would believe that the vector field at 60 meters would have been very similar to that at 98.

MR. SALOTTOLO: How about the vector field at the surface? Is there any way to -- you know, it can't go down to the surface.

THE WITNESS: No winds at the surface. There's no slip condition so it's essentially -- the ground can't move.

MR. SALOTTOLO: Okay. So the winds at 60 meters

are essentially what the winds --

THE WITNESS: The lowest level. Yes.

MR. SALOTTOLO: At the surface. Could you turn -- do you have the exhibit in front of you there? It might be easier. Do you have 5 -- what is it? 5-I, page 11.

Okay. I'd just like to go over -- the storm top, the observed storm top -- now, that's from the NEXRAD Doppler data from Columbia, the observed storm top?

THE WITNESS: I looked at several different sources there. Yes. It's about that altitude. Yes.

MR. SALOTTOLO: Okay. The peak radar reflectivity, where is that from, the observed?

THE WITNESS: I looked at a -- I estimated it from a plot that was provided from the NEXRAD radar. Yes.

MR. SALOTTOLO: And where did that plot come from? Did it come from NTSB?

THE WITNESS: NTSB.

MR. SALOTTOLO: Okay. Now you have the diameter of the microburst rainshaft. You might have mentioned where this came from.

THE WITNESS: Where that came from?

MR. SALOTTOLO: Yes.

THE WITNESS: Again, that came from reports provided by NTSB of interviews with the pilots that were in other aircraft associated with the event.

MR. SALOTTOLO: As did the 20-25 meter per second civilian estimates of wind?

THE WITNESS: That's correct.

MR. SALOTTOLO: Now, the max north-south velocity change, the Delta V, 40 meters per second. That came from --

THE WITNESS: That came from the data from the flight data recorder that was analyzed by NTSB.

MR. SALOTTOLO: Okay. The rainfall rate that the model generated, is that also in error -- could be in error by twice, two times?

THE WITNESS: That's true. Yes.

MR. SALOTTOLO: So we'd double that. I believe it was -- what? 4.3 --

THE WITNESS: That's correct.

MR. SALOTTOLO: -- inches. So it could be up to 8.6 inches per hour. Okay.

Now, you feel this is the worst microburst you ever simulated?

THE WITNESS: That's correct.

MR. SALOTTOLO: Now, worse based on F factor or the velocity field or the vertical velocity field or what?

THE WITNESS: Based on F factor.

MR. SALOTTOLO: Based on F factor.

THE WITNESS: Yes. And it could be the worst on Delta V, but I'm not sure, on the velocity change. There's several events that we have simulated that are close to that.

MR. SALOTTOLO: Okay. That's not to say that this is the worse that's ever been -- ever occurred?

THE WITNESS: No. I would not say that.

MR. SALOTTOLO: And you might have answered this during your talk. How much confidence do you have in this particular solution?

THE WITNESS: Again, we're seeing reasonable comparison with the observed data that we have. And I think overall that I would have a very good confidence, although I wouldn't have confidence in every little detail of the structure. In other words, a divergence center being located at such-and-such position off runway 18 or that sort of thing.

MR. SALOTTOLO: Have you had a chance to match up the wind data with the LLWAS information?

THE WITNESS: No, I have not. No, I have not.

MR. SALOTTOLO: Okay. The data you presented today, that's just a small fraction of what's available? In other words, wind fields at basically any altitude up to -- well, up to and above 1 kilometer are available if other work is needed?

THE WITNESS: Right. There are like 63 model levels between the ground and 11 kilometers altitude.

MR. SALOTTOLO: And the data entailed would be horizontal and vertical winds, among other things?

THE WITNESS: Yes. Winds, temperature, pressure, water content, water vapor, rain, snow, graupel, if any.

MR. SALOTTOLO: So one could fly through different altitudes and it would be a unique wind field generated by this particular model that could be used?

THE WITNESS: That's correct.

MR. SALOTTOLO: Thank you, Dr. Proctor. No further questions.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Salottolo.

Federal Aviation Administration?

MR. DONNER: No questions. Thank you.

CHAIRMAN HAMMERSCHMIDT: Thank you.

National Air Traffic Controllers Association?

MR. PARHAM: I have no questions, sir.

CHAIRMAN HAMMERSCHMIDT: Thank you.

Honeywell?

MR. THOMAS: Yes, Mr. Chairman. We have a couple here.

MR. THOMAS: Dr. Proctor, the first one. How would the surface terrain and friction affect the directions and intensities of the simulated winds?

THE WITNESS: The sensitivity, the test that I had done several years ago just looking at the effect of the ground roughness on the outflow is that it would retard or reduce the wind speeds near the ground, very close to the ground, but probably wouldn't have a very large overall effect.

MR. THOMAS: Okay. At the 60 meters or 90 meters?

THE WITNESS: Much less than that.

MR. THOMAS: Okay. The next one. The F factor shown, I take it that's averaged over 1 kilometer. Is that correct?

THE WITNESS: The F factor. Yes.

MR. THOMAS: So it's possible that in the microburst locally there could have been a much higher peak F factor?

THE WITNESS: Local values were much higher. True.

MR. THOMAS: Okay. Lastly, were there vertical winds derived from extrapolating the TASS data below 60 meters?

THE WITNESS: Yes. That is true. There was a linear interpolation between assuming zero vertical velocity at the ground and the velocity at the lowest level.

MR. THOMAS: Okay. Thank you.

We have no further questions.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Thomas.

Airline Pilots Association?

MR. TULLY: Thank you. No questions.

CHAIRMAN HAMMERSCHMIDT: USAir?

MR. SHARP: No questions, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: Thank you.

Douglas?

MR. LUND: Just one question, Mr. Chairman.

Dr. Proctor, there was an aircraft that arrived about two minutes or so ahead of the accident aircraft. I believe it was Faulkner 100. And they reported a smooth ride. Is that consistent with your model?

THE WITNESS: As I showed, one minute prior to the event there was considerably less rainfall occurring and the shear, based on the F factor, was about one-third of what it was before. And one minute before that, it was probably significantly less than that.

We could probably turn to one of the plots and estimate that. If you'll look at 22, and we'll go to about 40 minutes. According to the model simulation, at 40 minutes there was only -- little, if any rain was reaching the ground at that time from the microburst and the peak values of the F factor were above hazard threshold but they were probably located above the ground. These values are going to occur anywhere between the ground and one kilometer above the ground.

But certainly from the wind fields that we've seen there's not much divergence going on at that time.

MR. LUND: Thank you.

No more questions, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: Thank you.

Pratt and Whitney?

MR. YOUNG: No questions. Thank you.

CHAIRMAN HAMMERSCHMIDT: Thank you.

Association of Flight Attendants?

MS. GILMER: No questions. Thank you.

CHAIRMAN HAMMERSCHMIDT: Thank you, Ms. Gilmer.

International Association of Machinists?

MR. GOGLIA: No questions, Mr Chairman.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Goglia.

Dispatchers Union?

MR. SCHUETZ: Mr. Chairman, no questions. Thank you.

CHAIRMAN HAMMERSCHMIDT: Thank you.

National Weather Service?

MR. KUESSNER: No questions.

CHAIRMAN HAMMERSCHMIDT: Any more questions from the Tech Panel?

MR. FEITH: I just have one, Mr. Chairman.

Can you describe for me, Dr. Proctor, how long this event would have lasted in intensity once 1016 traversed it or from the time of the impact, how long did that system maintain that intensity that the aircraft encountered?

THE WITNESS: Again, if you turn back to either 22 or 21, you can see that the aircraft encountered it roughly at about its most intense stage and it was considerably less before and after that time.

MR. FEITH: Okay. So if I look at this correctly, that at the time of the accident, roughly the factors are at their max. And I look one minute after the accident or to a minute and a half after the accident, what would you expect that an airplane following in trail of 1016, what would they have encountered flying into this same system?

THE WITNESS: They would have encountered a hazardous windshear with the primary difference being that it would be of somewhat less magnitude and over a larger scale.

MR. FEITH: Would you have gotten a significant loss of altitude or expected significant loss of altitude or speed bump?

THE WITNESS: Not knowing the performance characteristics of that aircraft, I couldn't say.

MR. FEITH: Is your modeling on Figure -- or page 21, is this path dependent? Is this flying down the runway or does this incorporate the aircraft deviating to the right?

THE WITNESS: No. This is along any north-south segment through the microburst below -- at any point below 1 kilometer. So it may or may not be associated with a runway, nor may it be at just low levels. Although at the time of the -- after the accident time, most of the peak values of F factor were near the lowest model level.

MR. FEITH: And considering the fact that on one of your models that we don't have a copy of in our exhibit that you showed, if I recall correctly, you showed that there was an area right at the threshold of both runway 18 Right and 18 Left that were similar in nature as far as a cell core, for lack of better term? I don't have the picture in front of me.

THE WITNESS: 19? Would 19 do?

MR. FEITH: I'll look at 19.

(Pause.)

It was a picture that was similar to this, except it depicted both runways on it that you had showed as a viewgraph. The one that's right up behind you.

THE WITNESS: Yes.

MR. FEITH: Would you expect that an aircraft approaching the other runway, 18 Left, would have experienced similar conditions as those experienced by 1016?

THE WITNESS: If the model were this -- had precisely computed this correctly, he would have experienced hazardous windshear but probably not of the magnitude as long as he was directly flying north of the flight path. However, if he were slightly to the west of it, then that would have been a very highest region of extreme intensity, equal to that of what the accident aircraft encountered, according to the simulation.

MR. FEITH: We don't have that in our exhibit package, so we'd like to get that to make our exhibit package inclusive.

Would this system as it's depicted have affected any departing aircraft prior to the arrival of 1016? Since that was moving, I presume, in a direction across the airport.

THE WITNESS: Let's see. Although I don't have an F factor plot of the earlier time, I have a wind vector plot of the earlier time which is 25. And you can see that although the microburst divergence center was centered probably closer to the end of runway 18 Left, it was developing at that time and the windshear was significantly less at the earlier time.

MR. FEITH: Then how about aircraft departing on runway 18 Left? Would it have affected any of those aircraft since it was developing at that end?

THE WITNESS: It's developing and there is some shear there, but it's relatively weak at this time.

MR. FEITH: Thank you, Dr. Proctor. No further questions, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: Okay. Thank you, Mr. Feith.

Let me ask you a question, Mr. Feith. Do we have all the viewgraphs that have been shown today at the hearing in our records? I know they're not in this Exhibit 5-I, but do we have those somewhere, such as the last viewgraph we just saw?

MR. FEITH: No. That's the one that we don't have a copy of that we need to make our package inclusive.

CHAIRMAN HAMMERSCHMIDT: Okay. Let's be sure that we have all the viewgraphs that were shown today that we do not have for the record. If those can be provided, please.

CHAIRMAN HAMMERSCHMIDT: And following up on one of Mr. Feith's questions, we make reference in your presentation or your modeling to the microburst lifetime. Do you have a time value on that?

THE WITNESS: Excuse me?

CHAIRMAN HAMMERSCHMIDT: You make reference to the microburst lifetime a couple of times in your presentation. Do you have a time value on that? How many minutes microburst lifetime?

THE WITNESS: I can say in terms of the hazardous shear that it remained hazardous for some time, but I don't know if that hazardous shear was located at the end of the runway. It was probably drifting toward the northwest. But the hazardous shear from these microburst events were maintained because there were additional pulses that occurred later, which created embedded microburst within this broadening outflow.

CHAIRMAN HAMMERSCHMIDT: Okay.

Mr. Laynor?

MR. LAYNOR: Dr. Proctor, can you refer to page 16 in your Exhibit 5-I I guess it is? I just have a couple of questions there to clarify my understanding of what you presented.

You presented an F factor profile derived from the flight data recorder. Did you have to use aircraft performance parameters, thrust, drag and weight and such, in the development of that?

THE WITNESS: No. All that was involved was knowing the air speed of the aircraft and its position or time and the winds along the flight track.

MR. LAYNOR: I'm sorry? The winds along the flight path derived from inertial data rather than performance data? Is that right?

THE WITNESS: The data of the winds that were provided by NTSB.

MR. LAYNOR: Oh, okay. And the plot at the bottom of the page, vertical velocity. I think you answered this, but I'm not sure I understood it. That plot, the magnitude of the vertical velocity was derived completely from the meteorological data, the environmental data of your model and not from any comparison of energy of the airplane. Is that correct?

THE WITNESS: That's correct.

MR. LAYNOR: We heard Dr. Wilson when he was testifying say that there does not appear to be a consistency in the gradient of the outflow winds as a function of altitude for the lower altitude right below 300 feet. Does your model make any assumptions for the gradient of the outflow winds?

THE WITNESS: The peak outflow, because of the resolution of the three-dimensional model that we use here, it usually occurs at the lowest model level. And in some of our higher resolution runs that we've used with a two-dimensional axis symmetric model, the peak outflow occurs roughly between 30 meters to 100 meters or so, depending -- and it's strongly a function of the diameter of the downdraft which produces it. The larger the downdraft, the deeper the outflow.

MR. LAYNOR: I see. The model, as you presented it here, doesn't have the resolution, I guess, that would be needed to put this into an engineering simulation of the airplane as a three-dimensional model, given variations in a flight path through the model. Could it be made so?

THE WITNESS: Yes. Yes, it could. It has been. Not this particular case, but other cases have been.

MR. LAYNOR: Okay. And one last -- a couple more questions.

Dr. Weber indicated that part of the benefit of the TDWR and other detection systems for that matter, seem to depend on a grade period, a two to three minute build up from a detectability level to a hazardous level in detecting and being able to use that information.

Is your model consistent with this?

THE WITNESS: We have run simulations where we have seen that to occur, but it did not occur in this simulation. The strongest event was the first pulse.

MR. LAYNOR: Approximately how long before you reach a level of detectability of the -- maybe it's the F factor of point 1 that you're talking about -- before you reach the hazardous level in this event?

THE WITNESS: I would say at least one minute before. I don't know how far in advance before, but at least one minute before.

MR. LAYNOR: So a system able to detect an outflow at the detectability level where it would present an alert if it were presented -- detected exactly when the outflow occurred and reached that value, you'd have about 1 minute before you reached it?

THE WITNESS: At least. At least. We have done one simulation of what an onboard Doppler -- if the aircraft had had an onboard Doppler radar. And it would have alerted from the data from the simulation.

MR. LAYNOR: I know we're going to have a later witness talk about that, but I just meant from your model, how long before it reaches a detectability level to a level where it has a potential for being a real performance problems for an aircraft.

In your experience and in the models, can you talk about what comes first, the rainshaft or the outflow, or whether they're simultaneous?

THE WITNESS: Rainshaft comes first.

MR. LAYNOR: Rainshaft comes first. So you should be able to pick up some reflectivity before you reach a hazardous wind outflow?

THE WITNESS: Yes. The exceptions might be in some of the cases of the very dry microbursts. There are instances where we've run cases, say of the Denver area, where there was no rain at the ground because of evaporation eliminated most or all of it.

MR. LAYNOR: Okay. Thank you, Dr. Proctor. That's all I have.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Laynor.

Mr. Schleede?

MR. SCHLEEDE: No questions.

CHAIRMAN HAMMERSCHMIDT: Okay. One additional question, Dr. Proctor.

Speaking in terms of the diameter of the microburst rainshaft, how does the diameter in this situation at Charlotte compare with, for instance, the diameter of the microburst rainshafts in the four other comparative examples that you cite on page 4? Do you recall what those other diameters were just offhand?

THE WITNESS: With the exception of the number 3, the Denver, July '89 case, the rainshafts were all larger. And in the Denver '89 case, very little if any precipitation reached the ground.

CHAIRMAN HAMMERSCHMIDT: Okay.

THE WITNESS: As far as quantitatively, I can't give you that, but I can give you, say, the diameter of the outflow for like the 1985 DFW microburst at the time of peak intensity was about 3 kilometers. And that's comparison to just over 1 in this case.

CHAIRMAN HAMMERSCHMIDT: Okay. Any other questions from the Technical Panel?

I see a lot of discussion going on.

MR. FEITH: We were just talking about airplanes behind 1016. We don't have any further questions, sir.

CHAIRMAN HAMMERSCHMIDT: Okay.

Dr. Proctor, thank you very much for your participation in this hearing and for your interesting testimony. You may stand down.

(Witness excused.)

CHAIRMAN HAMMERSCHMIDT: I believe we will take one more witness this evening and then call it a day. But before we question that witness, why don't we take about a 5 minute break, just a very quick comfort break. And Mr. Earl Dunham will be our next witness.

(Whereupon, a brief recess was taken.)

CHAIRMAN HAMMERSCHMIDT: Back on the record.

Please come to order.

The next witness is Mr. Earl Dunham. Please come forward. Mr. Dunham will be questioned by Mr. Jim Ritter.

EARL DUNHAM, PROJECT MANAGER, NASA, LANGLEY, VIRGINIA

Whereupon,

RALPH EARL DUNHAM,

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

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

THE WITNESS: My name is Ralph Earl Dunham, Jr. My business address the NASA-Langley Research Center in Hampton, Virginia.

MR. SCHLEEDE: I'm sorry, sir. By whom are you employed?

THE WITNESS: The National Aeronautics and Space Administration at Langley Research Center, Hampton, Virginia.

MR. SCHLEEDE: And what is your position there?

THE WITNESS: I am currently in the branch of a group of researchers involved in looking at methods of improving the efficiency and safety of flight operations.

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

THE WITNESS: I have a bachelor of science degree in mechanical engineering; a master's of science degree in aeronautical engineering. I've been employed by the Langley Research Center since 1967 as a researcher. I've been involved in a variety of flight research programs, wind tunnel studies, analytical studies, laboratory experiments all aimed at improving aircraft efficiency and operations.

During the time period from 1979 until about 1989, I led a group of researchers that were involved in investigating the effects of heavy rain on the aerodynamic performance of an aircraft. That resulted in some eight or nine technical papers that I authored or co-authored on the subject.

In 1987 I was an invited lecturer on the subject of heavy rain effect at the van Karman Institute for Fluid Dynamics in Brussels.

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

THE WITNESS: No, I do not.

MR. SCHLEEDE: Thank you.

Mr. Ritter?

MR. RITTER: Thank you.

MR. RITTER: Mr. Dunham, I'll be referring to Exhibit 13-D, which contains a report you co-authored, which describes the effects of heavy rain on airfoils. The first question.

Why was this heavy rain research carried out?

THE WITNESS: Well, it was a part of the broad agency and joint FAA program in the study of windshear effects. In the late '70s, several of the windshear accidents that were investigated were known to have heavy rain occurrences at the time of the accident. Some hypothesis was put forward by a Professor Jim Lours at the University of Dayton Research Institute that this rain could effect the aerodynamic performance of the vehicle. And so we set about to determine if that in fact was the case.

We conducted over the 10 year period a large number of wind tunnel entries. We investigated the effects of simulated heavy rain on several wing shapes, both at small scale and we did some outdoor testing at large scale. So it was a part of NASA's research aeronautics program.

MR. RITTER: What kind of aerodynamic penalty would we expect to occur with heavy rain?

THE WITNESS: Well, the results of the investigation through the various tests that were conducted led to a fairly general conclusion that there was a reduction in the maximum left capability of the airfoil in extremely heavy rain. There was some increase in the drag. These penalties predominantly manifest themselves only in the large angles of attack, only in the maximum performance region of the vehicle.

MR. RITTER: So, is there a -- you said there was a decrease in the maximum left. Is there a corresponding decrease in the angle of attack at which maximum occurs?

THE WITNESS: That's correct. There is a corresponding decrease in the angle of attack for maximum lift.

MR. RITTER: You said that you conducted numerous wind tunnel tests and several different airfoil configurations. Could you describe in a little more detail of what types of airfoils you tested?

THE WITNESS: One of them was a rather simple symmetrical airfoil and was not really representative of a current day modern transport. the other two airfoils were representative of current day modern transports and had flaps and slat systems on them, generic flaps and slat systems, to represent current day transports.

MR. RITTER: In the large scale testing that you conducted, could you explain that a little bit better?

THE WITNESS: One of the difficulties in doing wind tunnel testing with heavy rain is the assimilation of the rain itself. Aeronautical engineers have understood for quite some time how to take wind tunnel tests and extrapolate them to a full-scale aircraft, but they had never done the test in this rain environment, so it was necessary to understand if there were any unusual scaling relationships between small wind tunnel tests and large-scale vehicles.

So, we produced a large-scale wing section that was about four times as large as the one that we had in the wind tunnel. We mounted it on a special carriage that was propelled down a track and we built a rain spray system to simulate rainfall rates from heavy rain to extreme rain. And with this, we were able to tell the various parameters that we had scaled down in the wind tunnel and determine any scaling effects.

MR. RITTER: You might have answered this briefly earlier. Have you gotten good correlation between the various testing, the wind tunnel and the full-scale testing?

THE WITNESS: Yes. The effects of scale were very minimal, if at all.

MR. RITTER: I wanted to ask if you've conducted any flight testing?

THE WITNESS: No. We have done no model configuration tests either. They have all been wing sections or wings themselves. There were no flight tests that were done on the effects of rain on the aerodynamic performance.

MR. RITTER: Why is that?

THE WITNESS: Well, in doing a good scientific experiment you like to have some control over the variables that dictate the outcome of the event, and so you would be dependent on nature to produce your rain for a flight environment. You would like to repeat certain conditions. And the ability to come up with the exact same rainfall rate at the exact -- if you'd like -- wind environment that you may be in in a thunderstorm, would be difficult to reproduce.

It would also be a very -- a flight test from a flight test pilot's point of view would be a very demanding task because in performance flight testing we sometimes ask for very precise angles of attack to be maintained for a certain time period. And then the variability of the rain and the wind environment would make it very difficult to conduct a flight test.

MR. RITTER: Thank you. Is any further research underway or planned at this time?

THE WITNESS: No. The work was concluded and it's been summarized in the various reports written.

MR. RITTER: In Exhibit 5-I, the estimated peak rainfall rate for the weather echoes in the vicinity of Flight 1016 is given as 4.3 inches per hour. I believe Mr. Proctor, the previous witness, talked about that briefly.

Let's refer to your report, Exhibit 13-D, page 15, Figures 20 and 21. These graphs show the effect of varying rain rates on aerodynamic lift. How well do you think these graphs apply to a transport category airplane such as the DC-9?

THE WITNESS: Well, I would expect there to be minor variation for given aircraft configurations. Sort of in a generic sense, I would expect these results to apply and I would expect them not to be largely different for various aircraft.

MR. RITTER: If we look at the graphs, what would be the decrease in angle of attack for maximum lift and the loss in maximum lift roughly for a rainfall rate of 4.3 inches per hour?

THE WITNESS: Well, as you know, the tests that we conducted were -- really the lowest was down around 9 inches per hour. So it's an extrapolation back to that point. And it would show a reduction in the angle of attack for maximum lift at the 4.3 or 4.5 of maybe as much as 1 degree. It would show a loss in the maximum lift performance of maybe as much as 2.5 percent.

MR. RITTER: Also, in Exhibit 5-G, page 2, there's a range of estimated rainfall rates for reflectivities that were shown by the Columbia Doppler radar. And the range of rates was between approximately 4 to 11 inches per hour.

If we look at the graphs again, say we went up to 11 inches per hour. What kind of degradation would we expect then?

THE WITNESS: Looks like the angle of attack for maximum lift would be reduced 1-1/2 to 2 degrees. The loss in maximum lift would be maybe 5 percent, 4 to 5 percent.

MR. RITTER: This is a subjective question, but what rainfall rate do you think an observer would consider to be heavy?

THE WITNESS: Well, it is a subjective question and it's difficult to answer in the sense that through my simulations of heavy rain I've had an opportunity to look either in the wind tunnel simulation or in an outdoor facility simulation of heavy rain, and we simulate rain from as low as 10 inches per hour to about half the world record rainfall rate, which is like in the 35 to 40 inches an hour.

Just looking at rain it is very difficult for someone to tell as much as the difference between 10 inches per hour and 20 inches an hour. I could tell when the rain spray system was probably operating in the difference between 40 and 10, but differences of factor of 2 are hard to tell in just an observation.

I expect most people seeing rain in the neighborhood of anywhere from 4 to 5 inches per hour would call it very heavy.

MR. RITTER: Have you done any research to determine if heavy rain has any effect on angle of attack vanes?

THE WITNESS: The agency sponsored a contract with the University of Dayton Research Institute in which we looked at the middle angle of attack vanes and any influence that heavy rain might have on them. And at very high rainfall rates that were used in that simulation, there was very little effect on the angle that the vane read out. Less than a degree.

MR. RITTER: Could we refer to Exhibit 13-C, page 8, if you would.

THE WITNESS: Okay. I have it.

MR. RITTER: This plot contains angle of attack estimates for the accident flight that were calculated by Douglas Aircraft Company. Does the range of angles of attack in the lower curves on the graph -- does the range of angles of attack estimated for the accident flight indicate that heavy rain might have had an effect on the airplane performance?

THE WITNESS: Recalling the data that we had that said the effect was mostly near the maximum or large angles of attack, and for this particular aircraft I would expect that there is very little time based on this plot that is spent at angles of attack much greater than about 12 degrees. There's only a few seconds' worth of time.

Most of the other time is spent at low angles of attack where I would expect to see little or no influence on the rain. So I would interpret that there was probably not a performance decrement effect due to rain if these are in fact the actual angles of the attack that the aircraft experienced.

MR. RITTER: Thank you very much, sir.

I have no further questions, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: Thank you.

Going to the parties, Federal Aviation Administration?

MR. DONNER: No questions. Thank you, sir.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Donner.

National Air Traffic Controllers Association?

MR. PARHAM: I have no questions, sir.

CHAIRMAN HAMMERSCHMIDT: Thank you.

Honeywell?

MR. THOMAS: No questions, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: Thank you.

Airline Pilots Association?

MR. TULLY: No questions, sir.

CHAIRMAN HAMMERSCHMIDT: USAir?

MR. SHARP: No questions, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: Douglas Aircraft Company?

MR. LUND: No questions, Mr. Chairman. Thank you.

CHAIRMAN HAMMERSCHMIDT: Pratt and Whitney?

MR. YOUNG: No questions, Mr. Chairman.

CHAIRMAN HAMMERSCHMIDT: Association of Flight Attendants?

MS. GILMER: No questions. Thank you.

CHAIRMAN HAMMERSCHMIDT: International Association of Machinists?

MR. GOGLIA: This table has no questions.

CHAIRMAN HAMMERSCHMIDT: And that's inclusive of the Dispatchers Union, I take it?

MR. GOGLIA: That's affirmative.

CHAIRMAN HAMMERSCHMIDT: National Weather Service?

MR. KUESSNER: Neither does this table, sir.

CHAIRMAN HAMMERSCHMIDT: Okay.

MR. KUESSNER: No questions.

CHAIRMAN HAMMERSCHMIDT: Mr. Feith?

MR. FEITH: Just one question.

Regarding heavy rain on angle of attack, can you give me an idea, does heavy rain have any effect on vane type angle of attack sensors?

THE WITNESS: As I indicated, we had done under contract -- you did say the vane type?

MR. FEITH: Correct.

THE WITNESS: Under a contract, we had done a study of that looking at the change in the angle of attack with the possibility of the rain impinging on the angle of attack sensor. It turns out that there was very little effect at rainfall rates that were in the neighborhood of 30 and 40 inches an hour, very extreme rainfall rates. Less than 1 degree error in what the sensor was reading.

And basically, that kind of a flow vane sensor is trying to minimize the aerodynamic forces on it, so it's trying to seek a null. And remember that the rain effect that I was looking at is at a maximum lift capability. So it turns out that there was very little or any influence.

MR. FEITH: And that's in all flight regimes, nose high/nose low, right and left?

THE WITNESS: What we did was look at the sensor itself mounted on a body, but not on a full aircraft configuration. But if we were really looking at the -- because the rain comes at a slightly different angle than the free stream wind does. We were really looking at that vertical momentum effect of the rain dropping itself and there was none.

MR. FEITH: And how about with heavy rain and its effect possibly on the pedostatic system of the aircraft?

THE WITNESS: That study also looked at the pedostatic system, but pedosystems are designed to have, if you like, drainholes through them and they were designed with extremely high rain rate ingestion. So there was little or no change in those measurements.

MR. FEITH: Very good. Thank you, sir.

No further questions.

CHAIRMAN HAMMERSCHMIDT: Thank you, Mr. Feith.

Mr. Laynor?

MR. LAYNOR: No questions.

CHAIRMAN HAMMERSCHMIDT: Mr. Schleede?

MR. SCHLEEDE: Just one. Kind of a strange area.

Has NASA ever worked with the aviation experts in the former Soviet Union or Russia on this topic of heavy rain effects?

THE WITNESS: No, we haven't.

MR. SCHLEEDE: Okay. Thank you.

CHAIRMAN HAMMERSCHMIDT: Mr. Dunham, thank you very much for your direct and concise testimony. We appreciate your participation in the hearing.

Is there anything you would like to add that would help us in our efforts here?

THE WITNESS: No.

CHAIRMAN HAMMERSCHMIDT: Okay. Thank you, again.

(Witness excused.)

CHAIRMAN HAMMERSCHMIDT: Mr. Dunham will be our last witness today and the plan for tomorrow is to begin with Mr. Don Turnbull. We will learn more about the Terminal Doppler Weather Radar and we will proceed according to the listing in the witness list from that point.

We will begin in the morning at 8:00 a.m., so we'll see you in the morning.

(Whereupon, the proceedings were adjourned at 7:12 p.m., to be reconvened on Thursday, September 22, 1994 at 8:00 o'clock a.m. in the same place.)

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