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National Transportation Safety Board

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P R O C E E D I N G S

8:06 a.m.

ACTING CHAIRMAN CARMODY: Good morning. Please take your seats. I'd like to get started. Thank you.

Good morning. Let's proceed. I see the witnesses are seated. Ms. Ward, would you introduce the witnesses, please?

MS. WARD: We have Mr. Michel Curbillon and Mr. Uwe Kerlin. Please raise your right hand.

Whereupon,

MICHEL CURBILLON

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

Whereupon,

UWE KERLIN

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

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

Mr. Curbillon, could you please state your full name, your current employer, and your business address?

MR. CURBILLON: My name is Michel Curbillon. My employer is Airbus, and the address is (French address) in Toulouse.

MS. WARD: And what's your current position, and how long have you been in that position?

MR. CURBILLON: My current position is Loads and Dynamics Manager in Airbus, and I am in this position since 1995.

MS. WARD: And what are your current duties and responsibilities, and actually, can you please state any education and training that you have received that qualifies you for your current position?

MR. CURBILLON: My current position is a dual position which covers two main subjects. The first one is an overall loads product coordinator within Airbus across all programs, and the second one is to act as technical advisor to Loads Engineering, and my education is I'm a graduate from French Engineer School in General Mechanical Engineering and where I got a degree, and I got an additional degree on Aeronautical Engineering which is equivalent to a Master Degree in the American system.

MS. WARD: Thank you, Mr. Curbillon.

Mr. Kerlin, could you please state your full name, your current employer, and your business address?

MR. KERLIN: My full name is Ewe Ernest Kerlin. I'm employed at Airbus Germany in Hamburg in Germany.

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

MR. KERLIN: Since 2001, the position is the so-called Local Domain Manager for Loads and Aeroelasticity in Germany.

MS. WARD: Could you briefly describe your duties and responsibilities and the education and training that you may have received to qualify you for your current position?

MR. KERLIN: I have a degree which is equivalent to the Master Degree of the University of Brunswick as an Aeronautical Engineer. I started in Airbus in 1987, at that time in a company called MBB. I started as a development engineer for Component Loads Analysis and worked for nearly all Airbus Programs. In 1991, I took more and more responsibility in the coordination of work for Special Airbus Transporter.

Beyond that, I was involved in the certification of that aircraft in 1995, and starting with 1996, I became the head of the Domain of Dynamic Response Analysis where I was mainly responsible for the Gust Loads Analysis carried out at the Germany site, and in 2001, I became the so-called Local Domain Manager as I said before.

MS. WARD: Thank you, Mr. Kerlin.

Madam Chairman, I find these witnesses qualified and I now turn them over to Mr. Brian Murphy for questioning.

ACTING CHAIRMAN CARMODY: Thank you.

Mr. Murphy, please go ahead.

EXAMINATION

MR. MURPHY: Good morning, gentlemen.

I'd like to discuss the following topics with you today: Certification basis for the -600R from a loads point of view only, the design loads for the vertical stabilizer on the -600R, and the AA-587 and AA-903 loads assessments.

Madam Chairman, Mr. Curbillon and Mr. Kerlin have prepared some overview material for us, and if they could present that at this time.

MR. CURBILLON: Thank you, Madame Chairman. Good morning.

So we will start this presentation by an overview on the loads and, generally speaking, on the loads acting on the vertical airplane. For this presentation, we will address several topics which will give you this view on loads, the structural condition, the envelope loads figure, and also short information on rudder usage, and also the FAR/JAR requirements, and also the American Airlines 587 General Analysis, and we'll finish by a loads summary.

Starting with the general information on loads and to try to understand the loads development in flight when an aircraft is subjected to different type of loading. So, the first one is linked with aerodynamic loads which are due to the pressure which developed around the external surfaces.

The second type of loading we have are the initial loads, those which are due to gravity or acceleration which could be applied on the different items of mass which are distributed all along the aircraft.

You have also the propulsion loads coming from the engine thrust and, in some cases, you may have some specific type of loading, like the pressure, for example, in the cabin pressure or cargo, when they are pressurized.

For calculating the loads, we consider all the significant forces which act on the airframe and those loads are calculated for a number of specific conditions. We call those conditions load cases which are defined with reference to the requirements.

As far as the requirements is concerned, the Airbus aircraft are designed and certified against requirement FAR and JAR 25 which are related to transport category airplane. Each load case is defined by two significant parameters. The first one is the conditions, what we call conditions. Is it a maneuver, coming from the pilot or the -- is it also the result of an atmospheric disturbance, a gust? This is a condition. And second, we have also to define the domain, where we apply this condition, in terms of speed, altitude, and for which aircraft weight and center of gravity. In the domain, where the aircraft may or will operate.

As far as the vertical tail loads are concerned, several conditions dictate the establishment of the vertical tail load, and those conditions, the main condition, are the yawing maneuver resulting from a regular displacement condition which are defined in the Requirement 25.351(a), the lateral forces resulting from the aircraft encountering an atmospheric disturbance, like gust, which are defined in the Requirement 25.351(b), the engine failure and loss of thrust with the associated pilot correction, which are defined in 25.367, and also the potential system failure, and we have, of course, main thrust on flying control systems.

As far as the industry domain is concerned, the flight domain. The flight domain is defined -- is defined by the speed of the aircraft and the altitude. So, it means the aircraft may operate at a speed and a given altitude. To run our loads calculation, we first define what we call design speed. We have the minimum control design speed, the maneuvering speed, the speed DB operating in the gust condition, the gust speed, the VC, which is the cruising design speed, and the VG, which is the design dive speed. Those speeds are defined in agreement with the requirement which is at 25.331, and you can see on these graphs the position of the speed, the minimum control speed, the cruising speed which is this blue line, and the diving speed which is above the cruising speed, which is the speed for which we run the calculation for the loads establishment.

The requirement requests us to run our calculation to cover the overall flight domain and the conditions, for example, for the yawing maneuver requests us and we have seen that yesterday with reference to the requirement between VMC and VD for all altitude where the aircraft will operate. So, there are four defined conditions, for example, at this point where we define an altitude and a speed and it is a point of calculation and you can see here a type of mapping we use to run our load calculation to cover the overall domain. For example, for gust calculation request to be performed at VB, VC, and VD, and the calculation expended above the operational domain. For example, for the high speed, the operational domain is limited by the speed of VMO, which is the maximum operating speed. This speed must be below VC, which we cover with our calculation, up to VD.

The second condition which is important for the domain to be investigated is the mass and CG. We have to cover as per requirement all possible combinations of fuel and payload, covering as well the design weights of the aircraft up to the maximum take-off weight which is for this aircraft 375,890 pounds, and we have to cover also the range of center on gravity which could be achieved by the different kind of loading in terms of payload and fuel from forward limits to aft limits, and as an overall view, for one mass condition and we have defined to cover the full range of center of gravity and weight around 30 different mass cases with different payload distribution, different fuel distribution, for each individual mass case, we run the loads calculation for the overall flight domain and repeat after for in this case to run again the loads calculation for the flight domain.

To run this loads calculation, we use a

mathematical model. This mathematical model involves input data like aerodynamic data which are coming from wind tunnel tests or derived from wind tunnel tests, mass distribution for all the items of mass which are distributed along the aircraft, put through all stiffnesses coming from the Structure Department, the engine data in terms of thrust, and the system data, like the RTL system.

All those input data are fit into a loads model and this loads model alert us to calculate the airplane movement and the associated loads. The airplane movement may result from a maneuver, for example, a rudder maneuver, but we have other type of maneuver in longitudinal, or from atmospheric disturbances encountered by the airplane during the flight, and as a result, we calculate the airplane component loads.

This model, this overall model, is supported by several type of tests, ground, like ground vibration tests, flight tests, flight tests with some of the full loads, and shearing and that creates representation of the aircraft area. By using this model, we run the simulation for the conditions which are requested by the JAR requirement. So, we make necessary analyses, and we calculate the movement of the aircraft and the forces which apply on the aircraft and from those forces, we define the loads on the different components of the aircraft, like wing, tail, and for the vertical tail as well as for the wing, for example, those loads are represented by shear. So, it means you have a side force and you can represent the shear total, for example, as bending moment resulting from the side loads with the level harm against the reference for the route here and/or the torsion loads around the reference axis at the different station where we calculate those loads. Those loads are later on used for structural analysis as well design and certification and structural tests.

Now, you have seen that we have several conditions. We have a domain, and for each individual condition, like yawing maneuver or gust, we run the calculation for each individual condition, for all the flight conditions, all the mass condition, and we select through a selecting process the most severe combination of all those parameters which give the various loads, for example, for the yawing maneuver, the engine failure, and the gust, and those individual loads are called envelope loads for the condition gust, yawing maneuver, and after that, we consider each individual case and the highest value of all of these individual cases gives what we call the limit loads. Therefore, the limit loads at the end is the most severe loads condition which results from a very large number of cases as we have already described to you.

What are we doing with those loads? Those loads are used for the structural analysis and the strengths requirement specifically in terms of limit loads, the maximum loads to be expected in service, and we have defined those loads as we have explained before. The ultimate loads, which are the previous limits loads, multiplied by a prescribed factor of safety, generally 1.5, and we lose loads, so we must be able to support the limit loads without permanent detrimental deformation and also to sustain the ultimate loads without failure, so the structure will not collapse, and as a result of all this set of required conditions, it provides an appropriate level of structural strengths and this result is the overall process which show equivalency between usage purposes of transport category aircraft, for example, requirements associated with this type of aircraft, design, test, and the usage.

If now you would like to have the figure on the envelope loads on the vertical tail plane of the A300-600R, as an example, we'll show you the vertical tail bending moment at root. The limit load is obtained by the gust conditions when you use as a reference one. The yawing maneuver gives us a level of load which is .8 limit loads. The ultimate loads are the limit loads multiplied by a factor of 1.5, so we obtain 1.5, and I presented before, it is the strength which is prescribed by the requirement for the structure. As far as the A300-600 is concerned, we have run full-scale static test for structure which has demonstrated a level of strength of 1.93 times the limit loads.

Now, if we come back to the rudder usage, this has been presented early at the beginning of the -- by the first witness, but just to recall that the usage of the rudder, if you deflect the rudder during a flight, it will result to a yawing movement. This yawing movement is the result of the loads coming from the rudder deflection. Those loads are loads which are induced on the vertical fin by the rudder deflection. Those loads create a yawing movement represented by the sideslip which itself induced on the fin a set of lateral forces, and you can see that in this case, the lateral forces are opposite.

The second type of usage of the rudder is to oppose the effect of the engine thrust asymmetry coming from an engine failure, and in that case, the rudder deflection creates induced forces on the vertical tail which oppose to the asymmetry coming from the thrust of only one engine.

Coming back to a very important case, the yawing maneuver, this has been already discussed yesterday with the witness. So, therefore, I will not spend too much time on that, but I will explain again anyway. Starting from a level normal flight condition, the requirement asks us first to have a full abrupt displacement of the rudder to a stop. This is Case Number 1 which is related to the part of the Requirement 25.351(a). At this time, due to the sudden displacement of the rudder, you induced on the vertical tail plane side loads due to the rudder deflection. Due to this rudder deflection and the associated induced loads, the aircraft starts to yaw, it is a red curve, against time. The rudder deflection is maintained, and the -- due to the dynamic nature of the movement, the sideslip develop, goes through a maximum sideslip which is called oversweep, and later on, due to the natural stability of the aircraft, the sideslip develop and achieve a steady sideslip.

During this phase and before we lose the time around maximum sideslip or whatever is the position, the loads which apply on the vertical tail then could be described as follow: still there is a deflection with the loads as at the beginning, but due to the yawing movement of the aircraft and the associated sideslip, there is also induced -- some forces induced on the vertical tail plane due to the sideslip, and those loads case are opposite, and when the sideslip is stabilized, there is a request to return suddenly the rudder to neutral, and at that time, for this third condition which is defined by the Requirement 25.351(a)(3), the rudder is returned to neutral and the resulting forces on the vertical tail plane are only those induced by the sideslip, knowing that the rudder is to neutral.

If we look now on the development of the movement of the aircraft, you recognize the rudder as before, the associated sideslip, and if we look to the development of the loads, the loads induced on the vertical tail by the rudder deflection are the blue one versus time. The loads of the side force induced by the sideslip are here, it is the red curve, and the total side force which results on the vertical tail plane is a green line. At the beginning, as the sideslip has not yet developed, the loads induced by the sideslip are small and we are nearly at the level of the side force induced by the rudder, and as the loads are opposite, you have the green development and at the end again, and if now we consider the -- what we call the loads in terms of bending moment at route, the bending moment development versus time shows this type of evolution and we made the calculation in a partial manner all along the time, and in our searching for sets to get some maximum force and minimums of the loads, we look -- all the loads erupt in terms of time, and we select just one and you can see that this one, this one, and this one are high loads and we select the highest one for this condition. We repeat the condition for normal flight condition, for all the mass condition, and at the end, the highest one is the envelope of the individual case.

Now, going to the American Airline 587 accident, so since this accident, we have concentrated our effort to analyze and to understand the accident, and for this purpose, we, loads community, have concentrated our effort on the last 12 seconds of the flight as indicated on the DFDR, and we have calculated the loads, taking into account the time history of the rudder development and as well from the other parameters derived from the DFDR, like the aircraft movement.

First, the rudder movement. Here you have the time, the rudder deflection during the last 12 seconds of the flight, and you can see that the movement, the rudder movement, is cyclic and rapid with abrupt, full abrupt displacement. There's back-to-back reversal, one, a second one, third, fourth, and fifth. This is the traces you have seen from the previous witnesses.

Now, if we look at loads on the side, the aircraft movement development, the rudder deflection is in blue, the associated movement of the aircraft in terms of sideslip is represented in red. The first view shows that the sideslip value increased with the time, according to the rudder movement. Now, if we look at the side forces induced on the vertical tail plane during the time, you will recognize in blue the lateral forces induced by the rudder movement. In red, the side forces induced by the sideslip which also increased with time, and you will notice that according to the phasing of the movement, you have the sideslip loads and the rudder forces which are additive here. For example, rudder plus sideslip give total forces as well at the last second of the flight, and what happened in terms of loads and we take into account for this purpose the bending moment on the vertical tail plane and its root. Here you have the development of this value against the time.

The green curve is the limit loads on both sides, positive and negative. The green -- sorry. The red curve represents the ultimate loads, 1.5 times the limit one, and you can see the first -- the first input of the rudder, so loads develop and remain below the limit loads. When you have the first reversal, we are at the range of limit loads. We start again a second movement. We are still inside the limit loads, and when we start the first movement, we exceed the limit loads and we are at the level of ultimate, and when we start the movement of the rudder deflection, the loads, the bending moment at route move again in usual direction, across the limit loads, cross the ultimate and achieve a very high level which is in the order of magnitude of 1.93 limit loads. This value is the value we have demonstrated on the fatigue test rupture which will be described more later by the -- the -- the Airbus colleague and it is really -- this value represents the static strengths of the vertical tail plane.

That's the load summary. The A300-600 vertical tail plane has been established in agreement with the special requirement for transport category airplane. We demonstrated that you present structural model about requirement, so the full-scale static test results, and as far as the American Airline 587 loads are concerned, the aircraft's rudder movement during this flight create very, very high loads on the vertical tail plane which exceed the design loads of the vertical tail plane due to the cyclic movement and the shape of the movement and the amplitude of the movement and the timing of the movement. Here, the -- if you -- to support this sentence, recognize here's the movement of the rudder. You have the yawing maneuver. For the most severe case, which is at around 200 knots, knowing that the American Airline flight accident appeared around 214 knots, there is the same deflection, and at 200 knots, that deflection is bigger, and if you compare to the load results in those two calculations, the thin red line represents the loads of the yawing maneuver for the condition. The movement of the loads for the American Airline accident and you can see that the loads exceed again significantly the design loads limit and the ultimate.

This is the end of my presentation and thank you for your attention.

MR. MURPHY: Just two points I wanted to -- to make on that then, Mr. Curbillon.

The sideslip and the rudder deflections for certification actually relieved the net load on the tail?

MR. CURBILLON: Yes.

MR. MURPHY: Okay. And then, during the accident scenario, they were in fact additive from --

MR. CURBILLON: Yes.

MR. MURPHY: -- Points 2 through 5, but at the first input, it would have behaved as it would for the certification maneuver?

MR. CURBILLON: You are -- that's correct.

MR. MURPHY: Okay. Could you briefly describe for us the history or the evolution of the loads development programs from the B2B4 up through the -600R?

MR. CURBILLON: Yes. If you would like to have that in very simple manner? So, the -- these two aircraft, we start with the A300-B2 which was certified in '74. We have a new version called B4 which has been certified in '75. After that, we have developed new aircraft which is the A310 and the first version was called -200. This version was defined and certified in '83. Later on, we have developed the A300-600 which was certified in '84, and there were some -- already some commonality between the two aircraft, and next, we developed the A310-300 which was certified in '85, and we have also developed again the A300-600, called 600R, which has commonality between the two planes, for example, the fin, to achieve the certification date in '88.

What I would like to highlight is that these programs, even there is some industry commonality, even there is some common component. Each individual program, like the 300-600R by itself, has been considered as a unique program as far as loads are concerned, and we have produced a full set of loads analysis and we have produced a full loads certification document which is dedicated to this version. We have done the same thing for an A310-200 and A300-600 and A310-300. Each in the program has been considered individually to run the full loads calculation.

MR. MURPHY: And the -600R maneuvering gust loads, I may have missed it when you just summarized it, but the -600R actually were contained within the 310-300 design envelope?

MR. CURBILLON: Yes. As far as the fin is concerned, yes.

MR. MURPHY: Okay.

MR. CURBILLON: But again, the loads on the fin coming from the two program are, I would say, contain -- the 600 is contained as the 310, but it's not very large difference anyway.

MR. MURPHY: Okay. During these loads calculations, from a loads point of view, and then obviously passed on to the structures community, is the yaw damper on or off for these calculations?

MR. CURBILLON: The -- for the loads calculation on the 600R, the yaw damper is off.

MR. MURPHY: So, no relief through the whole --

MR. CURBILLON: We don't take the yaw damper into account that calculation.

MR. MURPHY: Okay. If we could, there's another exhibit that's -- it's fairly short in length, but I think it would be helpful -- actually, I take that back.

If you could get referred to the design envelope on Exhibit N, Page 5, and just describe that -- that graph and its use?

MR. CURBILLON: Exhibit N?

MR. MURPHY: Exhibit N, Page 5.

MR. CURBILLON: Page 5.

MR. MURPHY: It should be the design envelope.

MR. CURBILLON: 75. Yes, what is your question related to this?

MR. MURPHY: Just -- just for clarification, explain the envelope, its intent, its purpose, what its used for.

MR. CURBILLON: Okay. May I use a previous slide just to explain from where it's come from?

MR. MURPHY: That's fine.

MR. CURBILLON: If you take into account, for example, a yawing maneuver, I would not come back to the rudders or sideslip. This is the time you have the development of the three main loads. In red, the shear. In green, the bending. In blue, the torsion. You can represent those loads versus time.

But we also are able to represent the loads evolution in the two-dimension drag arm where you have the torsion and vertical and the bending. At the beginning of the maneuver, you are there. When you move the rudder to the stop, the bending moves that torsion as well. After that, the sideslip establish, go to the sideslip. You return to the rudder to neutral and the aircraft is coming back to normal situation.

From those cases, this type of representation, we gain one calculation, and we obtain again the torsion versus bending. We obtain here the envelope for the yawing maneuver limit. If you multiply this envelope by 1.5, you obtain the envelope ultimate for the yawing maneuver, and as you can induce maneuver on the right or on the left, you have a statistical aspect, and here, you have the disparate gust results in terms of bending and shear limit condition, and if you multiply by 1.5, you obtain the ultimate loads.

MR. MURPHY: I think you've described very well the factors that lead up to the maneuver. This is just going back to some -- some thoughts from yesterday on the gust condition.

The gust case, that limit load data point there. The turbulent air speed, flight through turbulent air speed, DB, and the lift slope curve, CY Beta there, they're fairly important factors in calculating the gust loads?

MR. KERLIN: Yes, that's right.

MR. MURPHY: Okay. Now, if I were to increase the DB speed by 20 knots and the lift slope curve appreciably, would that change that limit load data point then?

MR. KERLIN: That would change it, yes.

MR. MURPHY: So, it's very dependent on then those two parameters greatly then for any given airframe?

MR. KERLIN: Yes.

MR. MURPHY: Okay. Thank you.

On that figure -- if we can go back to that, please? Could you just for us, on the design envelope, just show us where 351A, B and C would be?

MR. CURBILLON: So, if we show this envelope, the 351A is giving this envelope, 351B gives this point, and if we go to 351A, the .1 is there. It's at the time where you have the maximum deflection at the beginning of the event. The .AB2 is a point in this area, and here is a .B -- sorry -- A3 which is a return to neutral and observed the aircraft with this natural stability which come back to the result sideslip.

MR. MURPHY: Okay. Understanding that these are not certification requirements, the next question, I discussed yesterday with the gentleman from the FAA the effect of returning the rudder at max sideslip and -- and also the effect of performing a doublet at steady state. Could we put that graph back up?

Is it possible, knowing that you don't have calculated figures maybe or maybe you do, can you indicate what that would do to the shape of that design envelope?

MR. KERLIN: Maybe we can come back to the previous slide, which gives a slightly more better impression.

The return from -- from Beta Max, which is reached here at .2, would then go this direction. So, it would lead to a little bit higher loads. That is the condition what we call the Russian, the Russian type of maneuver, because it's contained in the Russian Certification Basis, and on the other side of the tablet, a better stabilized condition would again start at .4. It would go in that direction but not only to this point but farther -- further on in -- in that direction because of the reversal of the rudder and not to stop at zero rudder deflection.

MR. MURPHY: Okay. Thank you very much, Mr. Kerlin.

If you'd go to the next graph, the next slide, please? Could you -- I'm sure you know it probably from the top of your head. Could you indicate the three points that I asked -- we -- the NTSB asked you to analyze for the accident and show where roughly -- approximately where they would fall on that graph?

MR. CURBILLON: The American Airlines accident?

MR. MURPHY: Yes, please.

MR. KERLIN: We have a slide for that.

MR. CURBILLON: We have a slide for that. It will show you just where we -- the accident will be in this area.

MR. MURPHY: Okay. That's fine. Does anybody want to see the actual slide, if they can produce it, or is that sufficient? You would? Okay. Could you find that, Mr. Curbillon?

MR. CURBILLON: Here.

MR. MURPHY: Actually, now that I see where you've gone with that, why don't we -- why don't I just ask you -- I'd prefer then if you would just present the material, the accident loads assessment, in Exhibit P. That would be beneficial.

MR. CURBILLON: Okay.

MR. MURPHY: Thank you.

MR. CURBILLON: So, the analysis of the American Airline 587 loads assessment, to run this loads assessment, we have, I would say, used the two methods which have been presented to you on Tuesday by the first witnesses, and these two methods are the following.

The first one is what we call the simulation methods. In that case, we calculate the aircraft movement knowing the controls time history, and from this movement, we calculate the associated loads. To run this simulation method, we have used, I would say, two analysis. The first one, of course, is Simulation 1. It is done with the flight mechanic module which is the one used by handling quality and which has been presented to you by the first witnesses.

For the Simulation 2, we have used a model which is used in the loads analysis for the conditions which are requested to be handled by the requirement, like the wing maneuver, and in that case, the flight mechanic module which is used is the one used for the loads calculation at time of certification and we use the lateral movement coming from these equations and the longitudinal movement is the same as the first one.

So, therefore, this comparison we have our two models, especially the one we have used from the time of certification, and the second one is the kinetic ny integration methods where the sideslip is coming from the flight mechanic equations without using any models. This is a summary table. The simulation, flight mechanic movement, the aircraft movement is calculated by the flight mechanic module for landing quality, using the controls movement coming from the DFDR in the post-treatment, like the rudder. It calculates the movement of the aircraft and the sideslip, and with the sideslip and the rudder movement, using loads module, you are able to calculate your loads on the component like the rudder.

The second simulation is using the flight mechanic module from the loads calculation aspect and the same loads module for the loads, and we -- this is called full load simulation. It's called -- this process is called also bypass because in this process, we bypass the flight mechanic module from the loads and the one coming from the handling quality. The kinetic continuation methods. The sideslip is calculated by the kinetic approach and the rudder deflection is the same as the other one. The same loads module to calculate the loads. So, in fact, we have three curves.

The result is as follows. This is the time axis. The black curve is the rudder movement. The red curve is the kinetic NY integration research which was presented to you yesterday. The blue and green curve are the results of the two simulations using the bypass, I mean the handling quality model for the flight mechanics, and the green one is using the loads flight mechanic module, and you can see that these two simulations give very good fit, as well as to the kinetic integration method in terms of aircraft movement.

In terms of loads, the blue and green curve, which are very close, represents the simulations research. This is versus time and the upper part of the rudder bending, and there's a second part, the torsion. Development of the bending against time. Up to this point, we have a good fit between the three calculations and at that time, which is around the time of the vertical tail separation, when you have the simulation, the movement of the aircraft is obtained with the fin still fitted on the aircraft. The loads are also calculated with the fin on the aircraft. With the kinetic integration methods, the movement of the aircraft is already the movement of the aircraft in terms of time with or without fin, and the loads are calculated with an aircraft fitted with a fin because we are not able to do that the other way. So, those loads are if the fin is on the plane. So, up to this point, we have a good fit and here you see a discrepancy, meaning that something had happened, is the reason we can say the fin separation up here most probably in this period of time.

MR. MURPHY: Mr. Curbillon, would you just go back one slide there for a second? It looks like your scale -- it just was noted to me, your scale dropped off your torsion graph. Do you have an idea of what those values --

MR. CURBILLON: Here?

MR. MURPHY: No. Your -- your left-hand scale for your -- for the value of your torque is dropped off.

MR. CURBILLON: Oh, sorry. You will see the value on the next charts.

MR. MURPHY: Okay.

MR. CURBILLON: So here is the movement. The definition in torsion and bending. You start from zero at this point, the first deflection, second deflection, third movement. Here we are at the end of -- at the end of this time. The fourth deflection. We move to the end of the deflection. We go to that direction. The loads move that direction, and when you are at that time, you have the kinetic equation moving like that and the loads increase again for the reason that I explained to you before, and for the simulation due to the movement of the aircraft with the fin in, you have this movement.

To answer to your question, this area of the torsion is around 8 -- 6 -- 6 to 7,000 Meter-Decanewtons. The -- you will answer that real value to that later on, and here, we have some differences into this. To have a quick area for the load case selection at the time of rupture, we have defined several conditions. It's not easy to have -- to detect when the fin may have leaved the -- the -- the aircraft. The first one is here, we represent again the time, the lateral-acceleration. The lateral-acceleration, and when you are at that time, you have an abrupt change in the acceleration, and these loads of acceleration looks like the movement coming loose of the fin. So, we take a quick area, which is the maximum acceleration at that time, and if I tried to put this time in line with the Performance Report, it corresponds to the time 9:15:58.42. So, I can give you the values later on. And if we take into account the change in slope which happened in terms of the torsion bending curve, we have a slightly different time which is corresponding to the NTSB Performance Report, 9:15:58.3.

For the simulation, we take into account the maximum value of the bending moment at root. As a result, you have the kinetic equation. The loads -- the change of rupture or what we call the corner bending torsion, which is the case which is named V371, and the second case at the NY, lateral-acceleration maximum, which is called V375, and here we have the results of this simulation using the flight mechanic movement which gives us this maximum value of bending, a case which is called K376. Those numbers are the reference for the loads case we have given to the Stress people.

So, with those results, we have, I would say, a range of results coming from different methods, different models, which give us an order of magnitude of, I would say, loads which have been seen by the fin at all those times, and here, you observe values. The bending moment from this point is 158,300 cells in Meter-Decanewtons and so on up to this value which is 182,500 Meter Decanewtons with the associated torsion.

In order to have, I would say, in this bubble of -- I would say which represented bounding of the loads and from a minimum value to a upper value and if we take into account all these four cases, you can define a mean kinetic value which gives you a value of around -- not around, a value of 169,325 Meter-Decanewtons. So, it gives -- it's a bounding of the cases, knowing that for the kinetic equation which do not use any loads, any model for establishing the sideslip, we have, I would say, these two values which are the 172-182,000 Meter-Decanewtons.

So, this gives us the information we have obtained from the loads analysis which have been given to the Structure people for stress and strength analysis.

MR. MURPHY: And your numbers, one of those methods obviously corresponds with Mr. O'Callaghan's analysis?

MR. CURBILLON: Yes.

MR. MURPHY: Okay. Which? Do you know offhand? Is it the NY integration that most --

MR. CURBILLON: So, if I -- if I look at the -- the -- Mr. O'Callaghan's report, and if I also look for the -- what is called the loads at bounding, in the report of Mr. O'Callaghan, I can read value of around 170,000 Meter-Decanewtons.

MR. MURPHY: Okay.

MR. CURBILLON: Which is fully in line with the results we presented to you here.

MR. MURPHY: Of your four criteria then, which leads to my next question, which one would be at the bang of the four methods chosen?

MR. CURBILLON: The one which is at the bang is the one which most probably corresponds to the NY -- maximum NY. So, it means the case which is the highest value.

MR. MURPHY: Okay. Are these the most current values? Are there going to be any more changes fed to you from the Systems Group, from the simulation, or have all the biases and -- to the best of your knowledge, I understand it's not your area, but are you expecting any more revisions or tweaks to these numbers?

MR. CURBILLON: As it has been said, we are continuing some activities to try to refine a little bit more the present results, but in terms of loads, the impact of this refinement will be most probably some very small adjustments and they will not change at all, if we can.

MR. MURPHY: Okay. I can see what the four methods we get -- probably the four methods probably answer my next question, but have you ever -- have you done any other independent sensitivity studies, say, of the effect of sideslip or -- or rudder on -- on the net loads? I mean, when you look at these four, you can see the differences, the scatter that's available.

MR. CURBILLON: This was one part of the - one of your -- one part of your answer, that it shows that with this approach, you have already a sensitivity to the different cases because the sideslip, for example, slides but not a lot. You can see the sensitivity of the loads analysis, but on top of that, there was, of course, some sensitivity made. Maybe you can comment.

MR. KERLIN: But I've made a very short study about the sensitivity of pattern and delta combinations, and more or less this is -- this is confirmed. So, this gives already the answer here.

MR. MURPHY: Okay. For 587, going back to the comment, the comment -- the question and then the comment by Mr. Howford regarding static loading or an impulse-type loading, would you agree with Mr. Howford's opinion that it be a static loading for 587?

MR. CURBILLON: I agree.

MR. MURPHY: And then, I could infer that you feel the structure developed the loads completely?

MR. KERLIN: Yes.

MR. CURBILLON: Yes.

MR. MURPHY: Is there -- along this line of questioning, -- no. That's okay.

Have you gone to any other methods, say gone back to your wind tunnel test data or maybe possibly used any of your CFD available to try and just go back and say that we're getting a commonality using some other techniques rather than using our original loads programs?

MR. CURBILLON: We have done something, and we may comment.

MR. MURPHY: Okay.

MR. KERLIN: We have done something, based on the CFD calculations, where we have used the parameter out of these exercise and we have put up several stages of models, and in general, the results of the CFD with the full developed model and some considerations concerning flexibility and -- and so on confirms our -- loads results.

MR. MURPHY: Okay.

MR. KERLIN: We are -- maybe I made -- it's something -- the results differed for the last point about four percent.

MR. MURPHY: Okay. Back to the discussion that we've been having regarding Dutch roll, do you feel the response of the aircraft, say, in -- in sideslip is -- is comparable to what would happen during a Dutch roll event?

MR. KERLIN: In any case, the Dutch roll is excited here clearly.

MR. MURPHY: The Dutch roll is excited here. Okay. Moving on to 903, if you could, please, 903 is summarized in Exhibit R, if you could just for me just summarize the material contained in that exhibit regarding the loads computations for 903?

MR. CURBILLON: Would you like to have the slides or not?

MR. MURPHY: I --

MR. CURBILLON: So, the --

MR. MURPHY: You could use the -- what -- what slides you feel are pertinent to answer the question.

MR. CURBILLON: I would start with – to summarize what we have done. So, this event up here, in May '97, was a stall and with several controls movement, and we have high loads vertical factor and also high loads in the stall factor. During this event, we have some difficulty to get all the necessary information, even if we have, I would say, a DFDR which provide us a lot of parameters coming from the flight. Unfortunately, we have, I would say, a slice of time where we have not recorded all the information due to a unit issue and two additional slices of time where we have no recording at all.

But up to the time, we have all the necessary information and all the parameters which are recorded on the DFDR, we can make a loads assessment. To do this load assessment, we used the kinetic schematic approach which is to derive the sideslip by the kinetic equation without any simulation. Here, you can see the versus time as the event is a speed evolution during this event. With this slice of time I was talking about, one, we have not all the information, but still the NY lateral-acceleration recorded. No recording, no recording.

This is the vertical G which moved from minus .45 to 8, and this was recorded during this slice of time. The bank angle from minus 75 to 80 degrees. The lateral G loads recorded during this time from minus .75 to minus .2+.5. The rudder deflection during this event with where it is not recorded at all, and when we run the -- the kinetic equations, as it is an integration method, up to the time you have all the information, you are in the range of the assumption which are linked. When you lose some information like geographic altitude, you cannot do the calculation directly. So, what we have done is to simply interpolate by spring curve, so link-link, which links the starting point and the end point, but just for interpolation, and in that case, you lose some information and the quality of your analysis is more -- is more and more doubtful, and when you have no parameter at all, you really can question the validity of your results.

As a result of the analysis, up to this time here, we have all the necessary information to run the calculation and we have within the assumption the method, and the maximum bending loads is that we have exceeded the ultimate loads at the value which is 1.53. After that, you have some other loads development, here it is higher, but once again, here it is doubtful. What we can do here is more doubtful as well, but for information, it is what we can derive. But really, the quality is really inaccurate, and if we run into the torsion bending, you will recognize the previous design limit and the ultimate envelope for yawing maneuver. The discreet gust limit, the discreet gust limit, and the full-scale test rupture.

The development of the loads during the 903 event, start from that, here we are at .5 limit loads. We exceed the limit loads here, came back again. Here, we are outside, slightly outside of the ultimate limit loads at 1.53 up to this time. After that, the loads calculation are slightly doubtful because we have not all the information and we continue with this type of movement and we can come back again to that direction later on.

MR. MURPHY: For this event then, were the sideslip -- the loads due to sideslip and the loads due to rudder additive as in 587?

MR. CURBILLON: Yes.

MR. MURPHY: Okay.

MR. CURBILLON: But in this event on top of that, we have very large displacement, and we have taken into account some non-linearities versus sideslip and rudder deflection.

MR. MURPHY: Okay. I think Mr. O'Callaghan may touch on those. That's included in your -- the loads module then?

MR. CURBILLON: Yes.

MR. MURPHY: Okay. The in-service events that are described in Exhibit Q, Pages 5 and 6, when -- when were these values calculated?

MR. CURBILLON: The values calculated in this -- in this table use the same approach as the kinetic NY integration approach, using the DFD data -- DFDR data which are -- which have been made available -- which were available within Airbus.

MR. MURPHY: Okay. For the '97 event, had you done loads evaluation?

MR. CURBILLON: For the?

MR. MURPHY: '97 event. Prior to the 587 accident, prior to the 587.

MR. CURBILLON: At the time of the event, we have made, I would say, not a real calculation but we have made -- based on the different traces, we have made an assessment of the loads level using engineering judgment, taking into account the movement of the aircraft, taking into account the rudder deflections, and it was what we have done at that time.

MR. MURPHY: Okay. That's sufficient. Just two final questions then. 587 and 903, did they experience certificated maneuvers?

MR. CURBILLON: No.

MR. MURPHY: Okay. And then, the loads for 587, were they within the design envelope?

MR. CURBILLON: No. They are outside.

MR. MURPHY: Okay. Madam Chairman, I'd like to allow Mr. O'Callaghan to question the witnesses.

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

Good morning, gentlemen. I just have one question or one area of questioning and that has to do with the validation of the loads module. Yesterday, Mr. Offerman testified that, you know, the FAA -- the regulation authorities go through some pains to have the applicants demonstrate that the methods that they used to calculate loads in fact reflect the performance of the airplane or the loads experienced in flight, and Brian asked -- Mr. Murphy asked a question about -- about the CFD that confirms some of your results, and in a slide in your presentation, you had pointed out that the loads module and the calculations come from wind tunnel tests and are validated by other kinds of tests.

I was just wondering if you could go into a little bit more detail or -- or just briefly describe the kind of other tests that validate the loads modules and the wind tunnel tests and if any of this data is still available.

Thank you.

MR. CURBILLON: So, first of all, the basic data for aerodynamic model are coming from wind tunnel. So, therefore, we use wind tunnel test data which is a good support to establish the data to be used for the loads calculation as well in terms of aircraft derivative, component derivatives, and distribution as well, and those distributions have been established from wind tunnel tests pressure measurements and which give us distribution of unit loads or distribution of loads on the vertical tail as a function of the span, the distribution across the cord, and these distributions are used for the loads calculation.

Later on, based on that which is, I would say, the basis for experimental data, we also perform some different type of tests and we have performed, for example, to validate the model, the ground vibration test, which validate the dynamic behavior of the aircraft for the discreet wind gust calculation continues to be unsteady.

We have also, and this has been made by structure checks, the flexibility of the fin when they are doing their static loading, and later on, in terms of development of the aircraft, we have performed some flight tests to validate the models we use for the loads calculation, and this is the basic which was at the time of certification, and in the frame of the energies of the 587, there was the CFD calculation which has been mentioned by Mr. Kerlin.

So, if you want more information on this case, you can ask Mr. Kerlin to explain to you.

MR. O'CALLAGHAN: Okay.

MR. KERLIN: I would like to make one further sentence, that the considerations for the accident itself is a further confirmation because we couldn't confirm the behavior of the aircraft during this accident very well.

MR. O'CALLAGHAN: Okay. Thank you.

And the wind tunnel, the ground vibration test and the flight test data that you mentioned, is that still in the archives or available?

MR. KERLIN: The results of that are available. Unfortunately, the raw source of the wind tunnel data is -- is no longer available.

MR. O'CALLAGHAN: And for the other tests as well, the flight test and the ground vibration tests?

MR. CURBILLON: The ground vibration tests are available as were some of the flight tests.

MR. O'CALLAGHAN: Okay. So, there is some flight tests available, test data available?

MR. KERLIN: Yeah.

MR. O'CALLAGHAN: Okay. Thank you.

Thank you, both, and thank you, Madam Chairman. I have no further questions.

ACTING CHAIRMAN CARMODY: Thank you.

Is there anything further from the Technical Panel for the witnesses?

(No response)

ACTING CHAIRMAN CARMODY: All right. Then I will move to the Parties. I propose the order of FAA, American Air Line Pilots and finishing with Airbus. So, beginning with the FAA, Mr. Donner, any questions?

MR. DONNER: Thank you, Madam Chairman. We have no questions.

ACTING CHAIRMAN CARMODY: All right. American, Mr. Ahearn, any questions for the witnesses?

MR. AHEARN: Yes, Madam Chairman. Thank you, and just a couple topics I'll touch on.

Good morning, gentlemen.

MR. CURBILLON: Good morning.

MR. KERLIN: Good morning.

MR. AHEARN: I'm going to start off with some reference to Exhibit 7Q, specifically Page 6.

MEMBER BLACK: Is someone going to put that up for us or have we got to find it?

MR. AHEARN: I'm going to reference you to --

MEMBER BLACK: You spoiled us yesterday.

MR. AHEARN: I'm going to reference you to the February 1991 event involving the A310 with a composite tail. This was referred to in testimony yesterday as the Interflug German Airline event involving loss of control. Were you in the audience yesterday?

MR. CURBILLON: Yeah.

MR. AHEARN: Okay. And -- and in reviewing that event, did you perform loads calculation on the vertical stabilizer at the time of the 1991 event in order to determine, as Exhibit 7Q shows, that the tail exceeded ultimate loads?

MR. CURBILLON: I -- I cannot answer because I do not remember exactly what was done at that time.

MR. AHEARN: And Mr. Kerlin?

MR. KERLIN: I'm also not -- not sure whether we have done that at the time.

MR. AHEARN: The calculations on that exhibit, when were they done?

MR. CURBILLON: They have been done in early 2002.

MR. AHEARN: So, -- so, none of those calculations were done until 2002?

MR. CURBILLON: There was probably something done at the time of the event, but I was not personally involved at that time.

MR. AHEARN: Do you know who would have been involved at that time, and any subsequent witnesses that will come forward, would they have been involved at that time?

MR. CURBILLON: I don't know.

MR. AHEARN: With the inspection being conducted or the review of the load calculation in 2002, did Airbus recommend that this carrier replace the vertical stabilizer since it had been exposed to exceeding ultimate loads?

MR. CURBILLON: So, we -- we, as far as that is concerned, we have made the loads analysis and we have provided our results here, and you can see that the level of loads we have achieved is 1.5, a little bit above the ultimate loads, and this plane today is, I would say, the handling of this plane, in fact, there is replacement or not of the fin is not in the domain of the loads analysis. So, therefore, we have -- we provided the information, but I cannot tell you more detail in terms of how this activity is handled in terms of fin or not replacement.

MR. AHEARN: Okay. And -- and so, you don't know if it's been recommended to be replaced. Do you know if any of the subsequent witnesses will know?

MR. CURBILLON: Maybe the Structure people.

MR. AHEARN: Okay. Thank you.

I'm going to refer to the same Exhibit 7Q, Page 5. In 1997, there was another event, this time involving the A300-600, and we're referring to that in this hearing as Flight 903, American Flight 903, in which the tail exceeded ultimate load.

During the NTSB investigation of Flight 903, did Airbus ever inform the NTSB that it knew of at least one other incident in which an operator introduced large rudder movements in an attempt to recover from loss of control?

MR. CURBILLON: Could you repeat your question, please?

MR. AHEARN: With the data that this is at least the second event where an airplane exceeded the ultimate load of the -- the aircraft, during the investigation, did Airbus ever advise the NTSB or for that the parties that they knew of at least one other incident in which the operator introduced large rudder movements in an attempt to recover from loss of control?

MR. CURBILLON: So, we have -- as far as loads are concerned for the 903, we have informed the internal organization of the loads we have achieved in '97, but we are not involved directly into the -- as far as this was concerned into the NTSB investigation.

MR. AHEARN: So, your answer is you don't know if -- if it was --

MR. CURBILLON: Yes.

MR. AHEARN: Okay. It's my understanding that you twice calculated the loads incurred in 903. Were the results in the 2002 loads calculation different from the 1997 loads calculation?

MR. KERLIN: First of all, in 1997, there has been loads assessment, no direct loads calculation, but already this assessment shows or says we have most probably reached loads level which is above ultimate, and this was confirmed by the 2002 calculation.

MR. AHEARN: Okay. And can you explain with an airplane exceeding ultimate loads or an assessment of an airplane exceeding ultimate loads why a loads calculation was not conducted at the time?

MR. CURBILLON: We can answer to that. At the time when we have made this assessment, which was based on the information available, we have informed the, I would say, internal information of Airbus that we were aware of the ultimate loads, and the appropriate actions in terms of inspection have been launched within the Airbus organization. So, it means we, Loads Department, we have the appropriate information for both parties to run an inspection because we have achieved very high loads, and these inspections have been launched, and later on, when we have the results which was stated and explained that there was no significant findings, especially on the fin. At that time, the loads activity was, I would say, internal.

MR. AHEARN: So, at the time -- once again, even though you had knowledge that an airplane exceeded ultimate loads, you only conducted an assessment and you didn't think it was appropriate to complete an analysis?

MR. CURBILLON: That's not exactly what I said. I said we have warned that we have a level of ultimate loads which has been achieved and this has been known and the companion was also informed to everybody, and if you came back to the command of learning, the calculation which has been performed in 2002 does not change the conclusion of what we have said in 2000 in '97, and you have to remember, also, that in the DFDR, we have in bracket some missing information in the recording of the data which cannot alone to perform a loads calculation in very, very detailed form for an overall set of the event, but any -- what we have done in 2002 confirm the assessment of '97. We learned -- have obtained more results if we have had more detailed calculation at that time.

MR. AHEARN: Okay. And then, I'm going to refer you back to the 1991 event. Did you have the same problem with the DFDR data in the -- off of the 1991 airplane as well?

MR. CURBILLON: No.

MR. AHEARN: And can you tell me why there's a difference?

MR. CURBILLON: On what?

MR. AHEARN: The DF -- so, the DFDR data on the 1991 airplane is not filtered?

MR. CURBILLON: It's not a question of filtering. You know, in the '97 event, there was some time for the recording, and in some slice of time, for example, we have no recording at all.

MR. AHEARN: Okay. So, it's the blanking issue that occurred?

MR. CURBILLON: Yes.

MR. AHEARN: Okay. Okay. I'm -- I'm with you. Thank you.

I'm going to refer you to an Exhibit 7LL, and if you need to bring it up, that's okay. You can. I'm going to read it to you. It's Pages 3 and Pages 4, and then this -- it is a document that reads, in the second sentence, "They have clear concerns on the overall rear part of the aircraft, which could have encountered loads higher than the design limit loads."

On Page 4, in the paragraph that stars with "Meanwhile, the study confirms high load factors, both longitudinal and lateral aspects." It appears in the following sentence that for some areas of the airplane, limit design loads have been exceeded and for some others, such as the rear fuselage fin and empennage, and I know you already testified that you handed this off as an internal document to Airbus, but do you know why this information was never given to the NTSB nor the parties at the time of the event?

MR. CURBILLON: So, first of all, I cannot agree with you on one thing. Myself, I was not directly involved into the NTSB investigation at that time, but those information were known internally, and I cannot agree on the fact that you say they have never been. Maybe this took pure document as maybe not provided, but I don't know, but the information that we have achieved, the high level of loads, was known.

MR. AHEARN: Okay. Well, this information, frankly, as a party to that event, sir, this information was just discovered this year. So, I don't know that anybody -- that this information was ever discovered, but I'll move on.

MR. CURBILLON: But this information showed one thing, that we have reviewed the -- the facts.

MR. AHEARN: Yes. You -- you reviewed the facts. I don't know that it was shared, but I'll move on to my other questions.

Let me just refer to again by 1997, given the fact that the A310 operator, A300 or A310 operator may have exceeded ultimate loads based upon rudder reversals, passing that information on, did you pass that on to the appropriate flight department so that this information could be disseminated to all operators via technical publication?

MR. CURBILLON: The -- after the event of 903, there was communication on the rudder movement.

I'm sure you know that. The first time, there was the recommendation which was given by the common letter from the foreign manufacturers and the FAA. There was also the submission letter from Airbus, and I would like maybe to add something.

All those events are events where the aircraft have been in very unusual conditions, and Airbus as well as also under different actions to minimize the risk to be again in this type of situation and including information like the one I have described to you before.

MR. AHEARN: Okay. I would -- I won't get into the letter issue because I think we've already been through that a number of times.

MR. CURBILLON: Yes, it has been already discussed.

MR. AHEARN: But that -- that did not refer to the 903 event, and in fact, again it did not result in a formal publication, such as a change to the --

MR. CURBILLON: There was some formal presentation. The -- I cannot agree with that. There was some formal information. The letter which was sent to -- to you was a formal information. The submission was a formal information.

MR. AHEARN: Okay.

MR. CURBILLON: Just a fact. Factually, it is the case.

MR. AHEARN: I'm -- I'm not going to go on that line of questioning, Madam Chairman, because I think that we've already resolved that issue, that --

MR. CURBILLON: Okay.

MR. AHEARN: -- there was no formal FCOM, that we have plenty of letters back and forth, but I'll move on to other questions.

I'm referring to 7Q once again, and I'll note that on Page 2, there are a number of high load events involving crew rudder inputs. Do you know in how many of these cases you see the crew taking the rudder to the stops? I'm sorry. Page 5 and 6. It's Exhibit 7Q, Page 5 and 6.

MR. CURBILLON: At minimum, the two event where the aircraft has experienced extreme conditions following the stall and during the recovery, but for the other, I do not from memory see a real -- such severe movement than on the two events we are talking about.

MR. AHEARN: Okay. If you -- if you had that -- have that data on all these events, if you could provide that to the parties, that would be appreciated.

MR. CURBILLON: I see no problem with that.

MR. AHEARN: Okay. Thank you.

Moving on, I'm going to refer back to some questions that we talked earlier in the -- in the hearing on, and I'll ask you regarding the -- the A300. If the A300 rudder was hinge moment, if it had hinge moment limiter, would this reduce the sideslip and the loads on the fin?

MR. CURBILLON: By -- by definition, yes. If you limit the rudder deflection, you will reduce the loads on the fin.

MR. AHEARN: Okay. And then, a follow-on question to that. If -- if the directional control system had been designed so that the yaw damper inputs opposed the rudder inputs or opposite the rudder inputs, excuse me, could not have been overridden by additional pilot pedal input, would this not have also reduced the sideslip and/or the loads on the fin?

MR. CURBILLON: In fact, the evidence is that way. We have run the calculation without preparing calculations. So, therefore, we have taken this kind of conservative way to do our calculations.

MR. AHEARN: I'm not certain I understand the answer to your question. Let me -- let me repeat the question again to see if --

MR. CURBILLON: That would be the case, yes.

MR. AHEARN: Okay.

MR. CURBILLON: Thank you.

MR. AHEARN: If the directional control system had been designed so that the yaw damper inputs opposite pilot inputs could not have been overridden by additional pilot pedal input, would this not have in fact reduced the sideslip and therefore reduce the load on the fin?

In other words, if you have a yaw damper that can't be overridden, won't that reduce the load?

MR. CURBILLON: As far as the loads, the design loads is concerned, my answer is the same as previously. We have run the calculation without, so we do not take any benefit for the number, and we in fact -- it is a form of conservatism to the loads calculation for the design, and in any case, when we are doing the loads calculation, we use the system as it is normal.

MR. AHEARN: Okay. I'll just try it one more time because you're answering the question as it refers to the 587 calculation, and I'm not asking about the 587 calculation. I'm sorry. Your -- your -- I think what you're doing is you're answering the question about certification and what I'm asking is about the 587 calculations that you did.

MR. CURBILLON: In that case, it's speculation, you know, and we run the calculation for the 587 as it was.

MR. AHEARN: Okay. Let me move on then. How many different load calculations did you do on the 587 -- on Flight 587?

MR. CURBILLON: How many type of calculation?

MR. AHEARN: Yeah. Yes.

MR. CURBILLON: In fact, the calculation is different what we put behind the types. If I understand types as which kind of calculation we have performed, it is one we have presented to you. In fact, we have four calculations. For these four calculations, we have two types of approach. One is simulation, one is kinetic NY integration. For the simulation, we used two different models, and for the kinetic equations, we used two criterias; one at the time of discontinuity of the bending and torsion, the second, at the maximum lateral acceleration, which represent to us, I would say, a set of different approaches, a set of different criteria, which give us continuance and bound the level of loads we have obtained from our calculations.

MR. AHEARN: Okay. And -- and all four calculations have been provided to the parties, sir?

MR. CURBILLON: Yes. It is as they are in the exhibits I have presented before.

MR. AHEARN: Okay. Thank you.

I want to move on to a different topic for a moment. You talked about the 310 versus the 600, but I'm going to take you back a little bit further in the evolution of the airplane.

Can you tell me if the B2B4 or the 600 had a higher load limit? Which -- which design had a higher load limit?

MR. CURBILLON: So, it depends of the -- of the -- in terms of which parameter, because, you know, there is a lot of parameter on the aircraft. In terms of which -- which component?

MR. AHEARN: The vertical. I'm sorry. The vertical stabilizer.

MR. CURBILLON: So, straight answer, the highest load is A310-300 but slightly above the A300-600.

MR. AHEARN: And how about the B2B4?

MR. CURBILLON: B2B4 is difficult to answer because the B2B4 was a different aircraft with different design weights with different lengths as well and different engine as well. So, therefore, some time or so, the requirements are not exactly the same. Even for the B2B4, it was the same as the 600, more or less.

But again, the -- the fin which is common on both planes is the one which is fitted on the 310-300 and the A300-600R, and the 310 loads are slightly higher than the 600R. From memory, I cannot refer about loads on the B2B4, but they were probably lower, but for different -- because the aircraft are different in terms of weight, CG and inertia.

MR. AHEARN: Okay. But -- but you -- I don't expect you to answer the question from memory, but you would have that data. Would you provide that data to the parties as well?

MR. CURBILLON: Yes, without any problem.

MR. AHEARN: Very good. Thank you.

One final topic, Madam Chairman, and I'll move on. The design of the vertical stabilizer apparently focuses the loads predominantly on the aft lug. Can you discuss the -- the design loads on the vertical stabilizer specifically as it relates -- obviously in your area of expertise with regard to loads?

MR. CURBILLON: So, for this purpose, we produce the overall all loads, what we call external loads. So, it means the shear, bending and torque along the span for different sections of the fin. We are not looking in detail because we cannot accept, if we have the criteria selection, the particular loads on the attachment because if they are internal loads and those loads are calculated by the Structure people using their own model. So, we produce the external loads. They calculate internal loads.

MR. AHEARN: Okay. Maybe that's a better question for Mr. Winkler and I'll defer that question till later.

Madam Chairman, that's all the questions I have. Thank you.

ACTING CHAIRMAN CARMODY: Thank you.

Moving now to Allied Pilots, Captain Pitts, please.

CAPT. PITTS: Good morning, Madam Chairman. Good morning, gentlemen.

MR. CURBILLON: Good morning.

CAPT. PITTS: In your loads review, has Airbus looked at aircraft types, other than the A310, the A300-600, for instances in which the aircraft was exposed to loads that exceeded limit or ultimate limit?

MR. CURBILLON: I'm not sure I understood your question.

CAPT. PITTS: Your research on -- you -- you shared with us that you conducted a loads review. My question is, is in that review, has Airbus as a company taken a look at other aircraft types, other than the A310 or the A300-600, where the aircraft was exposed to loads that exceeded limit or ultimate limit loads?

MR. CURBILLON: In this particular story, we looked basically on the A300 and the A310, but we are also looking for the other aircraft as well.

CAPT. PITTS: Were there any found? Any other aircraft designs found that -- that had experiences that exceeded load limit or ultimate limit as they were designed to?

MR. CURBILLON: Maybe one.

CAPT. PITTS: Could you share that model with us?

MR. CURBILLON: No. It's because it's part of the discussion we have.

CAPT. PITTS: I see. All right, sir. I'm going to refer to Exhibit 2-N, Page 6, if you want to bring that up, and I'll go ahead and ask the question because the question doesn't require that it be present.

My question, gentlemen --

MR. CURBILLON: What was the page?

CAPT. PITTS: Page 6.

MR. KERLIN: What -- what was the reference?

2-N?

CAPT. PITTS: Exhibit 2-N, Page 6.

MR. CLARK: That's not on one of their -- it's not on their list of exhibits.

CAPT. PITTS: Okay. As I said, it's not necessary for them to answer the question. I just thought it might help them.

Do Airbus load engineers review all of the flight crew operating manual procedures before they are given to the operators?

MR. CURBILLON: We were not directly -- I was not directly involved into the FCOM.

CAPT. PITTS: So, if -- if a procedure that may impose a load on the aircraft by the operator, by his operating technique, were developed in the training or the Flight Department, it would not be moved through the Engineering Department and reviewed for loads?

MR. CURBILLON: In case of, it could be.

CAPT. PITTS: Okay, sir.

MR. CURBILLON: It's part of the internal organization of the -- of the company.

CAPT. PITTS: In reference to the procedure that directs operators to use alternating sideslips that was referenced in 2-N, Page 6, did the Airbus Loads Group calculate the loads that that maneuver would place on the vertical stabilizer if performed at B Max?

MR. KERLIN: As far as I know, not.

MR. CURBILLON: We have answered.

CAPT. PITTS: I'm sorry. I didn't hear your answer, sir.

MR. CURBILLON: Same answer.

CAPT. PITTS: Same answer. Very well. Since it was not reviewed, you may not be able to answer this question. I'm just curious. What assumptions regarding rate and amount of rudder input might have been assumed in that operator's instruction?

MR. CURBILLON: Once again, we are not the experts to talk about the FCOM and to provide you the information you asked to us.

MR. KERLIN: But I think one former witness said that it is more or less a stabilized condition. This stabilized condition is covered by the certification requirement calculation.

CAPT. PITTS: Okay.

MR. CURBILLON: The reason why this -- this action was, I would say, handled like that.

CAPT. PITTS: All right. Well, you moved me into an area I was going to get to later, but I'll do it now. In your presentation, you referred to FAR

25.351, and I believe your Slide 22 in your presentation speaks to yaw maneuvers as covered in the certification. Do you want to bring that up or you want to just refer to it from memory?

MR. CURBILLON: This one?

CAPT. PITTS: Yes, sir, that one'll do.

MR. CURBILLON: Okay.

CAPT. PITTS: Now, the FAR speaks to the rudder input as suddenly displaced, and it sounds as if from your description that we might be stumbling over the definition of suddenly. In the testimony from the test pilots, we heard them speak to it being slow and controlled and you mentioned stabilized.

Can you help us understand what philosophy is used or what interpretation is used in reference to this FAR requirement and the need to be able to be suddenly displaced with reference to your design?

MR. CURBILLON: I'm not sure I understand completely your question.

CAPT. PITTS: Well, what is the rate of rudder deflection input on that -- on that top graph, sir?

MR. CURBILLON: The rate -- the rate for the -- for the design calculation uses maximum rate as it has been described by the witness on the first day.

So, it means we use a maximum performance of the control surface which is something like 16 degrees per second.

CAPT. PITTS: You use a full --

MR. CURBILLON: We -- we have to know that for the design, we use, as it has been also explained yesterday by the FAA witnesses, we use, I would say, conditions which are defined, and we use those conditions and sometimes it's difficult to relate, strictly speaking, those conditions to the operational instruction.

CAPT. PITTS: So, in relating those conditions to this operational instruction given to pilots, what rate would have been considered appropriate there?

MR. CURBILLON: So, I -- I repeat again. For the design conditions, we use, what I would say, conditions which are -- I would not say are in the book, which are conditions that are defined by the requirements. So, we use these design requirements as a maximum rate, and we design for that.

CAPT. PITTS: Would it be reasonable then to expect Airbus to calculate this maneuver as described in the operating manual to have been reviewed at different rates and inputs?

MR. CURBILLON: You can -- you can make any calculation you -- which is needed, but again, the -- as far as loads is concerned, when we design the aircraft, we design for a set of conditions which are envelope, and we are doing it that way.

MR. KERLIN: And I mean, the application of the rudder in this sense is the most severe one. If you push the rudder very, very slowly, you will directly enter into the steady sideslip which has no over swing as we see it here in these pictures.

CAPT. PITTS: All right, sir. I think you answered the question.

Did Airbus consider that a pilot responding to an engine out may apply rudder in the wrong direction followed by a corrective input in the proper direction when you reviewed the design for loads?

MR. CURBILLON: In review the design for loads, we -- we followed also as well the type which is in the requirements.

CAPT. PITTS: I'm sorry, sir. I didn't catch your first part of your answer. Was it that you just -- just met the design to the requirements? All right, Sir.

MR. CURBILLON: Not just. We made the requirements.

CAPT. PITTS: Yes, sir. Referring to your

Slide 17, just a little bit further explanation, if you would, please, and I'll wait for that to come up.

ACTING CHAIRMAN CARMODY: Is that 17 from his presentation?

CAPT. PITTS: Yes, ma'am.

ACTING CHAIRMAN CARMODY: All right. Thanks.

CAPT. PITTS: In terms of gust during the yaw maneuver, is it additive? Would the yaw maneuver and you have a load limit with a gust value of 1.0, would the yawing maneuver be additive to that or is it exclusive of that requirement?

MR. CURBILLON: It's not additive for the simple reason, the requirement asks us to run the calculation for serious condition for each individual type of conditions. So, we run the gust calculation with a high severity of the level of the intensity of the gust. We run the yawing maneuver, but we are not combining them.

CAPT. PITTS: Are you gentlemen aware of any provision of the FARs or the JARs that prohibit anyone from performing the rudder reversal at max sideslip and incorporating that into their design?

MR. CURBILLON: No. Because we follow the requirement as well.

CAPT. PITTS: One final question. Now that we have several load cases that have been brought to our attention which exceeded the ultimate load design of the aircraft, one of which was catastrophic, and then the conditions also including such things -- such phenomena as Dutch roll, doublets, sideslip with control, reversal inputs, are there any other loads issues that we, the operators, should be aware of that we could possibly infringe upon in -- in the operation of this aircraft?

MR. CURBILLON: Not to my knowledge.

CAPT. PITTS: Thank you, sir.

I have no further questions.

ACTING CHAIRMAN CARMODY: Thank you, Captain Pitts.

Before we go on to Airbus, Mr. Ahearn, in your questioning, you asked the witness for a number of documents which he agreed to furnish. Could we have a list of those just to be sure they get properly introduced into the process at your convenience?

MR. AHEARN: Yes, ma'am.

ACTING CHAIRMAN CARMODY: All right. Thank you.

Moving to Airbus, Dr. Lauber.

DR. LAUBER: Thank you, Madam Chairman.

Mr. Curbillon, you were asked a couple of questions regarding the Interflug airplane which was one of the high-load cases identified subsequent to 587. Do yo know if, in the inspections, the ultrasonic inspections that were done as a result of the review, were there any findings from those inspections?

MR. KERLIN: There was -- following the inspection of this aircraft, from my knowledge, there was no finding at all.

DR. LAUBER: Okay. Thank you.

Mr. Ahearn asked you a couple of questions with regard to Exhibit 7LL, specifically Page 4. He read to you from Paragraph 3. Could you -- could you describe for us what Paragraph 1 and Paragraph 3 says in general terms? Just summarize what's indicated there.

MR. CURBILLON: So, the first one says as the aircraft has experienced severe case, especially as he has exceeded the criteria which are described in the AMM chapter given there, there was, I would say, an automatic triggering of the necessary inspection, necessary action, whatever they are, when you exceed this -- these values, and for example, in the AMM, you have a minimum and then you have the case for the vertical loads factor, much as in accidents, of such value. You have to run some inspections in any case.

DR. LAUBER: So, both paragraphs are basically recommending inspections, --

MR. CURBILLON: Yes, and --

MR. DONNER: -- based on those findings?

MR. CURBILLON: Yes. The second one highlight again this fact, but the first one was a warning and we have to inspect in any case. The second one is to reinforce the request for inspection according to the engineering and the investigation made at that time in terms of type of maneuver performed, in terms of loads estimated and assessed.

DR. LAUBER: Okay. And this was an internal e-mail that was sent to Jean Daney. Who is Jean Daney?

MR. CURBILLON: Jean Daney is the one people working in the Flight Safety organization.

DR. LAUBER: And in the upper right-hand corner, what's the date and time indicated on this e-mail?

MR. CURBILLON: The date is the 19th of June '97.

DR. LAUBER: Would you turn to Page 17 of the same exhibit, please?

MR. CURBILLON: 17.

DR. LAUBER: Yes, that's the one. Would you, first of all, note the time and date in the upper right-hand corner?

MR. CURBILLON: The time and date is June 19th, 1997, at 8:29 p.m.

DR. LAUBER: About two hours after the one --

MR. CURBILLON: Yes.

DR. LAUBER: -- we just looked at, and this is an e-mail to whom?

MR. CURBILLON: It is an e-mail from the Product report to Mr. Zepf, Airframe Systems, which is American Airlines.

DR. LAUBER: It went directly to Mr. Zepf, who is at Tulsa for American Airlines?

MR. CURBILLON: I think so.

DR. LAUBER: And what does the e-mail say?

MR. CURBILLON: The e-mail says that, first of all, to the analysis of the DFDR. "The Airbus industry confirms that summary of the aircraft had sustained very high loads in particular of the aft part of the aircraft, and these loads require the aircraft to be deeply inspected after the event."

DR. LAUBER: Okay. Thank you, Mr. Curbillon.

The dates on these were 19 June. The event happened on the 12th of May.

MR. CURBILLON: Yes.

DR. LAUBER: Do you know why it was so long between the time of the event and the -- the notification or the analysis?

MR. CURBILLON: From my knowledge, we had been informed first of the event and which was considered an event in turbulence, and we were not able -- so, and based on that, which was only accelerations and description by word, we have run the first loads, preliminary advanced information, and we had expected high loads and therefore we have requested to have the more information to substantiate and to support, even if it is an assessment, to get more information to support our loads view, and for that, we needed at minimum some information on the DFDR, even if it is only traces, we need that to better indicate because when you encounter turbulence, you have seen this type of acceleration, can one use what you may have seen high loads, but to have a little bit more information to support the need for inspection of complementary inspection on the basic one. You will need more information at minimum of the DFDR.

DR. LAUBER: Would you turn to Page 5, please, of the same exhibit?

MR. CURBILLON: Which is on the 15 of May '97.

DR. LAUBER: Three days after the event, and it is what? A letter from or an e-mail from whom?

MR. CURBILLON: It is an e-mail from our representative in Tulsa to Mr. Yves Benoist, who is in charge of the Site Safety Airbus industry.

DR. LAUBER: And would you read, please, the first two paragraphs of this?

MR. CURBILLON: And this -- the first paragraph says, "American Airlines Flight Safety has informed me that they will not give me the DFDR from the subject incident. Further, American Airlines Flight Safety informed me that they will probably never again release a DFDR to Airbus."

The second paragraph, "The reason is apparently Airbus and American Airlines are involved in a lawsuit over a previous turbulence incident. Apparently the Airbus lawyers are using the data from the DFDR from the previous incident against American Airlines. Therefore, American Airlines will not subject themselves to possible incrimination again."

DR. LAUBER: Now, just one more thing from this. Would you read the second-from-last paragraph, please?

MR. CURBILLON: The last one?

DR. LAUBER: Second from last, beginning "Further, at this time".

MR. CURBILLON: "Further, at this time, no one within American Airlines will ever discuss the incident with me. American Airlines Flight Safety will not even return my calls regarding the incident."

DR. LAUBER: Okay. Thank you.

Mr. Curbillon, would you put on from your testimony Slide 26? That's the one that shows the dynamic build-up of loads and sideslip.

Just actually a couple of questions on this. If you'd take any point in -- if you take the Beta build-up, the upper chart, the upper plot on this, take any point in there and tell us from a loads point of view what would have been different had at that given point the pilot simply released the rudder pedals to neutral?

MR. CURBILLON: If the pilot released the pedal to neutral, he will let the aircraft to come back to its zero sideslip condition due to the natural stability of the aircraft, and in that case, it will, as it has been explained earlier during the presentation and following a question from Mr. Murphy, the loads will be lower, and there would be a slight -- they would be lower.

DR. LAUBER: Would they reach ultimate or limit loads? It depends on when, I guess.

MR. CURBILLON: It depends on when. If, for example, you release the loads, for example, at the last case here up to zero, most probably the loads will not achieve the levels they have achieved taking into account the fifth reversal and probably remain but not at the level which has been achieved.

DR. LAUBER: And I'm sorry, I missed it. Which -- which point were you talking about hypothetical release or return?

MR. CURBILLON: In particular, if instead to have this full fifth reversal, we stop the -- the release at zero at that time. The loads at that time would most probably be lower of the ultimate.

DR. LAUBER: Okay. All right. Let's -- let's assume a little bit different situation. Let's assume that the fin did not separate from the airplane when it did. What would have happened to the build-up of Beta and subsequent loads, assuming that it stayed intact?

MR. CURBILLON: If we continue like that and we made a 6-1, we will significantly again increase the aircraft movement and the sideslip will continue to increase and the loads will continue to increase and again significantly above the level you have achieved at the fifth return to the 6-1, significant increase again.

DR. LAUBER: One final question, Mr. Curbillon. Mr. Ahearn asked you a couple of questions about limiting devices, such as hinge moment limiters and different yaw damper design, and asked about the effects on loads from those devices.

Would any of those devices have made any difference with regard to the dynamic build-up of Beta due to cyclic rudder input that excites the Dutch roll of the airplane?

MR. CURBILLON: If -- if you have rudder movement like that, it would not react differently.

DR. LAUBER: It would continue to build?

MR. CURBILLON: Yeah. It will continue to build in any case because for the simple reason, if you excite, so you have a cyclic movement and this cyclic movement on top of the reversal is also at a frequency which is close to the Dutch roll, you have -- even though the Dutch roll is stable, you have a large increase of the response of the system, and if you lose the time here for the last rudder movement here, you have a time which is extremely close to the time of Dutch roll case which is from between, for example, this type of douslet this one. You have a frequency which is very close to the frequency of the Dutch roll.

DR. LAUBER: Okay. Thank you, Mr. Curbillon, and just one final thing. Are you aware that as a result of the submission that Airbus made to the NTSB during the 903 investigation, that the loads issues were discussed in that submission? Do you know if they were or not?

MR. CURBILLON: The submission? I think that there is a part where there was some information related, but I'm sure there are paragraphs which is the loads part is part of that.

DR. LAUBER: Thank you.

No further questions, Madam Chairman.

ACTING CHAIRMAN CARMODY: Thank you.

Moving on to the Board, I had one question, and I may have misunderstood your answer earlier when Captain Pitts was questioning you. I think he asked if you had done any load calculations with respect to opposite rudder inputs from the pilot, and I didn't quite hear what you said, if that was the question.

MR. CURBILLON: At the time of certificate, when we -- when we designed the aircraft, we do not do it, but in terms of internal policy, we sometimes check the specific case if we have which kind of level we can achieve.

ACTING CHAIRMAN CARMODY: When you're

designing the aircraft, the tests you -- the evaluations then are based on rudder input in one direction and return to --

MR. CURBILLON: Neutral.

ACTING CHAIRMAN CARMODY: -- neutral?

MR. CURBILLON: Yeah.

ACTING CHAIRMAN CARMODY: So, this is --

MR. CURBILLON: We design -- we design against your requirements.

ACTING CHAIRMAN CARMODY: Hm-hmm. Member Hammerschmidt, any questions?

MEMBER HAMMERSCHMIDT: I would like to thank these two witnesses for their very informative presentations this morning, and I have no questions loaded or otherwise.

ACTING CHAIRMAN CARMODY: How about Member Goglia for loaded questions? Member Black?

MEMBER BLACK: Just a comment. I looked through this material that was in -- that ultimately became 7LL in preparation for this and was somewhat concerned about the flow of information back and forth, both immediately after 903 and then after we started to look at it again after 587, and I would encourage staff to try to ultimately look at a chronology, so that this can be somehow absorbed in the final report, so that --

I guess it's sort of what did you know and when did you know it, and I think it's important to the Board and to all of the parties to have that documented accurately in the process of this investigation.

I have no questions.

MR. CLARK: We agree, and we've already started that. It does raise one issue that Captain Ahearn's raised about the recommendation for inspections.

Captain Ahearn, do you know if those inspections were accomplished?

MR. AHEARN: Mr. Clark, yes. I appreciate the promotion to captain, but I don't know --

MR. CLARK: Oh, sorry. Mr. Ahearn.

MR. AHEARN: My colleagues might take issue with that, but yes, those inspections were accomplished, and in fact, the results were given to -- to Airbus and the parties, sir.

MR. CLARK: Have they been provided to us?

MEMBER BLACK: John, they're in LL.

MR. CLARK: The results of those?

MEMBER BLACK: They went through the items in the maintenance manual about what they did, and I think Airbus then responded back once with some other things they wanted them to look at, and they apparently did it. Unfortunately, this occurred considerably after the accident, and I believe the airplane was flying the entire time, was it not?

MR. AHEARN: It was, sir. It flew for five years.

ACTING CHAIRMAN CARMODY: You can see we have a board member that reads everything, Member Black. I agree that it's important to get the information on what and when. I don't want this hearing to become the forum for finding out who knew what when because we -- we need to move forward, but I think that's an important point.

Are there anything else from the Technical Panel?

(No response)

ACTING CHAIRMAN CARMODY: Any of the parties? Mr. Ahearn?

MR. AHEARN: Two points. One is from a clarification. I noted when Dr. Lauber was raising the issue about the data, it referred to high loads, and I don't know that people would interpret in the industry or even somebody reading these documents would understand the difference between high loads and exceeding design loads which was part of -- or ultimate loads which was part of the original documentation, and as you look for that exchange of information, I would encourage the Board to look and see if in fact there was any documentation regarding excedance of ultimate loads.

One other item. It -- Mr. Lauber read into some documents that relate to DFDR data from American. Frankly, I have a hard time understanding how it's relevant to this investigation, but since it's in, I'd like to introduce an exhibit. It's an internal document from Airbus that directly addresses some of those concerns, and it reads in part, --

ACTING CHAIRMAN CARMODY: Well, let's have a look at it and then we can make an evaluation. You say it's not currently an exhibit?

MR. AHEARN: No, it's not, ma'am.

ACTING CHAIRMAN CARMODY: Yeah. I'd like to have -- yeah. Let everybody see it. Maybe the parties should have a copy and we'll have a copy.

MR. AHEARN: Very good, ma'am.

ACTING CHAIRMAN CARMODY: Thank you.

Member Black, you had one more question or another --

MEMBER BLACK: Just from a standpoint of the people who are trying to follow what's going on here outside, I guess, John, maybe I don't want to question staff, but for informational standpoint, was not this airplane inspected again after 587, John?

MR. CLARK: Yes, it was.

MEMBER BLACK: And do you feel comfortable on relating anything that was found?

MR. CLARK: You're talking about 903?

MEMBER BLACK: Yeah. Yeah. On 903.

MR. CLARK: We're going to cover that later.

MEMBER BLACK: We are? Okay.

MR. CLARK: Yes. That's -- that's the one airplane that had the one finding around the lug, but Brian's going to cover that later.

MEMBER BLACK: Okay. Thanks. I thought that was it.

ACTING CHAIRMAN CARMODY: Is there anything else from any of the parties?

CAPT. PITTS: Madam Chairman, one final question from us, if you would, please.

ACTING CHAIRMAN CARMODY: Yes.

CAPT. PITTS: Dr. Lauber brought up a letter that referred to a recommendation referencing deep inspection. Was that per the maintenance manuals? I'm not familiar with what that would exactly entail. Can you tell us?

MR. CURBILLON: I'm not really familiar as well because I'm Loads people, not Structure people. But what I know, there was the standdown inspection but also other complementary inspections. But not only the standdown one but there was specific inspection requested at that time.

CAPT. PITTS: And so, you think that there were specific items outlined in -- in follow-on communications?

MR. CURBILLON: I would say simply, to answer your question, yes. What I would like to highlight is due to the facts on loads, the inspections, the standard inspection plan of GMM is one thing and there were also additional requests coming from Airbus, taking into account the severity of the event.

CAPT. PITTS: Thank you.

ACTING CHAIRMAN CARMODY: Any other questions from the parties?

(No response)

ACTING CHAIRMAN CARMODY: Well, then thanks. My thanks to the witnesses. You've been very, very kind with your time and your information.

Why don't we take a 15-minute break and come back and we'll resume? Mr. Ahearn, let's look at that exhibit.

MR. AHEARN: Thank you.

(Whereupon, a recess was taken.)

ACTING CHAIRMAN CARMODY: First, I'll address the request I had at the end of the last session from American to include some additional e-mails or an additional e-mail as an exhibit, and I'm going to not allow that. The Exhibit 7LL from which Dr. Lauber was reading was put in originally at the request of American, and I think this is a subject between the two parties which is a difficult one, and I'm aware of the -- of the feelings running high and I think it's time not to escalate by having one more exhibit on the subject.

Let me just say from the Board's point of view, we're not unaware of -- of the -- of the episode of Flight 903. It's going to be part of our investigation, and there's information we'll be gathering on that, but this is not the forum for back and forth about who knew what and which e-mails went where. Most -- many of them are in the record, and I'm going to leave it as it stands now.

So, Ms. Ward, I'd like to move forward with the next witnesses. Would you identify them, please?

MS. WARD: Yes, I'd like to call Mr. Bernd Rackers. Please raise your right hand.

Whereupon,

BERND RACKERS

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

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

Mr. Rackers, could you please state your full name, your current employer, and your business address?

MR. RACKERS: My name is Bernd Rackers. My employer is Airbus, and my business address is (German address).

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

MR. RACKERS: My current position is I am Senior Manager for Composite Technology in the field of Materials and Processes, and I am in this position since middle of last year.

MS. WARD: And could you please briefly describe your duties and responsibilities and any education and training that you may have received to qualify you for your current position?

MR. RACKERS: Yes. My duties and responsibilities are material selection, material qualification, process development and introduction into the serious production. So, I'm responsible for manufacturing specifications and all the items which are related to that. I got a Master's Degree in

Aeronautical Engineering in '84 at the Technical University of Acken. I joined a carbon manufacturer for four years, and in '88, I joined Airbus, and I always was in the field of materials and processes and developed in this field into my current position.

MS. WARD: Thank you.

Madam Chairman, I find this witness qualified and now pass it over to Dr. Matthew Fox.

ACTING CHAIRMAN CARMODY: Yes, Dr. Fox, please proceed.

DR. FOX: Thank you.

EXAMINATION

DR. FOX: Good morning, Mr. Rackers.

MR. RACKERS: Good morning.

DR. FOX: I would like to discuss composites manufacturing at Airbus this morning, and I understand that you have a presentation regarding this topic.

MR. RACKERS: Yes, Mr. Fox. Thank you.

I've prepared a brief presentation to introduce you into the subject of composites, and I would like to cover the various items of that, like a brief introduction, what is the reason for composites for us to introduce them, what is our experience with them. I will focus on the materials qualification approach, on the manufacturing principles. So, I've prepared a small review to show how a fin box is manufactured. I will focus on quality assurance processes, and I will present some factual results we gained in this investigation on behalf of NTSB.

Let me first introduce what this composite is about. It's, as I said, it's composed of two major elements. It's fiber, carbon fiber or fiberglass, but I would like to focus on carbon fiber as we have used this material on the fin box, and we have a second constituent that's the matrix, as we call it. I refer always in this presentation to carbon epoxy in this to make it clear that we're using more advanced materials than you may know from homework or do-it-yourself work.

These two forms, there is a second step where the raw material is made in an industrial process where the fiber and the matrix are joined in a process we call pre-impregnation. So, we impregnate at a certain supplier to the form of pre-preg, pre-impregnated. It's an industry standard for aerospace engineering manufacturing with these materials to get a material which provides good mix of resin and fiber and which allows us to use it under our standard.

So, we are making parts out of this pre-preg which is in itself not a material because it's weak, it's not cured. So, we do not have any properties we can use. That's why we make the material in the process and we have to be very careful with this process.

The reason why we are using it, we have some fundamental differences to metallic structures. We have effectively no sensitivity to fatigue for aircraft structures. We have superior properties which offer significant gains which you can use for performance increases of the aircraft, and we don't have any corrosion for this kind of material. So, we have some operating advantages.

The introduction of composites, and I would stress this a little bit more in the next slide, it was made after carefully evaluating the informal performance and we started the secondary structure, like fairings. We checked the worldwide environmental conditions and I will explain later why we checked the environmental conditions, because there were some effects of it on the behavior of composites, and we did extensive lead-fleet programs to follow the first part which we introduced.

When we look back to 1972 when the actual unit was introduced, we had some glass fiber or fiberglass reinforced fairings. So, secondary structure, like the leading edges of the vertical stabilizer. We -- excuse me. We used also the first spoilers made in carbon fiber reinforced composite. We did an in-service flight on the A300 B2B4 and effectively was A300-200. There was a first serious applications of carbon epoxy parts, like spoilers, air brakes and to rudder in the same configuration as we have it today.

With the A310-300 in '85, as you have heard before, we introduced the first carbon epoxy primary structure on a civil transport aircraft, the vertical tail plane, what is referred to here as fin. At the same time, there were major NASA programs also on the potential application of carbon epoxy for horizontal tail planes and for vertical tail planes of civil transport. So, we were at the same knowledge base as the industry was worldwide.

Following that introduction of primary structure in A310-300 and A300-600R, we introduced more primary structure in the A320 family which was done in '88, '87-88. So, we added the horizontal tail plane and the flaps in carbon epoxy. The A340 saw some further development. We got the first vent structure. What does that mean? We have a tank made from carbon epoxy. The HTP in this aircraft is a trim tank, so it's fueled, and it was the first vent structure.

In our latest aircraft, we have the bulkhead and the QV made of carbon epoxy that was introduced this year into service. It's the A340-60 and for the A380, we are planning and it's currently in the manufacturing to add the center wing box in carbon epoxy. So, we are on a step-wise approach to introduce more and more composites in order to get these operational advantages, and we used this step-wise approach in order to get experience, in order to get information and, of course, to be always on safe ground with this introduction of new materials.

Up to now, with our fleet of A320 family, A300, and A310 family and A330, A340 family, we get more than 40 million flight hours with primary structure in carbon epoxy.

I would now like to talk about material qualification approach and how we performed when we introduced that and we used the building block approach or perimeter testing which you can see here and I will focus my presentation on the generic part of this perimeter testing which was the lower end, containing the coupons, small test samples that we derived, generic data for the material, and some element testing. The rest of the building block approach was covered by the structure, our stress colleagues, and we will see the same parameter of testing of the building block approach in the presentation of Mr. Winkler.

So, we used all these data which have been generated in the process for the certification of the aircraft. That doesn't mean we tested approximately 1,500 samples on this lower coupon level in order to get a good database and in order to take into account all the effects which may affect the performance of this material, like moisture, temperature, which I will explain in the next slides, and aggressive mid-year effects in a way that we don't have any detrimental effect by, for example, hydraulic fluid which is kind of aggressive to all kind of materials.

We did a statistical evaluation of all this data. The allowables, and I will find it out later on again, were based on MIL Handbook 17, and I will give more information later. What is essentially listed is all our design loads taken for the worst case for carbon epoxy and that's a wetted structure, where the structure or the specimen gained moisture, and I will explain in my next slides about this moisture gain of composites.

There's one slide and this is used also as a -- this test is also used in the investigation. So, I will refer later on as well to this kind of testing that's what we call DMA test. It's a dynamic mechanical analysis. It shows, in easy words, reduction of stiffness of a small specimen with the temperature, and as you see here on this graph, excuse me, we have in the area of the aircraft, only nearly no effect of the temperature, and we will have a kind of weakening, and I say weakening or softening because it's an industry term. It does not weaken the structure because we are way beyond our service temperatures which is up to 80 centigrade or, in American terms, 175 F for the fin box, and you see here the effect of moisture. When moisture gets into the composite, it reduces the thermal capability of this material. So, there's a reduction of the softening temperature to higher -- to lower temperatures, but all of that happens well beyond the service envelope of the material and of the -- sorry -- of the aircraft.

These figures here show -- this graph is for the dry specimen, for the dry structure. This one, 1, 4 and 2 percent material, refers to a moisture conditioning of a specimen which has been done at -- with a moisture of 70 percent relative humidity. So, the level of moisture in the environment can -- responsible for the moisture gain and also for the head of the gain, and we have 1.6 for 85 percent relative humidity. So, you see there is an effect of moisture of the environment on the moisture gain.

These figures are relevant for the specific material we used, and you can see here in this slide that it was this material, 913, which has been used on the accident aircraft. So, these are original data.

I'm going to talk about moisture gain. We have to be aware about the fact that the moisture gain comes to equilibrium at the end, and we have also to take into account that we can dry the specimen completely, and in the term of the investigation, I will show that the material regains its original performance when it's dried again. So, we don't have any, what we call, aging effects. So, it's fully reversible. So, we can moisturize the specimen and we can dry it again and then we have the same performance and that is also part of the presentation I will give to you today later on.

You may ask how we come to the conclusion that 85 percent relative humidity has a correlation to the service of the aircraft that was done by an extensive Lead Fleet investigation. We did them on spoilers flying worldwide, Indonesia and to other countries where we have hot and wet environment, in order to cover the most severe effects on the structure, and we also based our assumptions on simulation based on worldwide weather data, and we checked for the extreme conditions and we came out that 85 percent relative humidity which we do for specimen saturation, for specimen conditioning and for structure conditioning, covers or is conservative in terms of the worst case conditions we may have worldwide, and we never found a structure which had more moisture in it. So, that was driven by a conservative approach.

Let me now talk a little bit about the allowables we determined for the coupon test results. As I said, it was based on approximately 1,500 specimens, and we established B-values. Those are minimum values which are required to do the loads calculation and the stress calculations of the parts. We applied method at that time, request by FAA. There was no MIL Handbook 17 available at that time. It was in discussion. So, what we used the method in discussion with FAA and later on, these methods were included in the MIL Handbook 17 draft. So, we borrowed the industry standard and this Handbook 17, although it's a handbook, it's relevant for our composite for our generation.

The MIL Handbook 17 was established in '88-89 as its first version and including a computer program which is called Stat 17, which we applied since then, also for alternative material qualifications we performed afterwards.

As I said before, this composite material, and when we get it to our manufacturing shop, the -- it is not a material. It's a raw material which has no properties in itself, no mechanical strengths. So, we make the material in this process. It does mean we have to carefully evaluate all the processes when we make the parts and we call it cure cycle because we cure -- cure the material at elevated temperature of 250 F, for example, and we have to be sure that we do it correctly and we have to ensure also that possible forces deviations by the tolerance of the measuring devices and equipment we use. That we analyze them and define a process which covers this potential tolerances in the manufacturing and we have to ensure that we check the material for this processing tolerances we have in manufacturing. So, it's time, it's temperature, it's the heat up in the autoclave where we cure the parts, it's the pressure, and, of course, we check for the combination to establish a safe processing window for the material.

Let me go now to the manufacturing. I would like to present -- excuse me -- a small video because it's very difficult to show on slides how this fin box is manufactured, and I would like to show you how we do it in our manufacturing side.

Video -- "The fin or vertical stabilizer is in foil located at the rear of the fuselage which gives the aircraft directional stability. The fin is composed of different parts, including the leading and trailing edges and the rudder. The main component is the fin box which is built of composite material that has been in use in the aircraft industry for the last 20 years.

Airbus has been manufacturing the fin box in the same way and using the same type of material since the structure was first certified in 1985. The type of composite used to build the fin box in the A300-600 is a carbon fiber reinforced plastic, known as carbon pre-preg, made of 60 percent carbon fiber pre-impregnated with 40 percent resin. Airbus purchases the raw material from approved suppliers who conduct their own quality checks and who are regularly audited by Airbus.

From the moment the material arrives at the factory and is placed in cold storage, only specialized technicians who have undergone a three-year apprenticeship are authorized to handle it. On arrival at the factory, each new batch of pre-preg is examined by Airbus quality inspectors to ensure compliance with the supplier's certificate. Samples are tested by specialist technicians using approved procedures. For every five hours of production time, one hour is dedicated to quality testing.

Mechanical testing shows the strength advantage of the material. Here, pre-test calculations are being verified by loading a narrow strip with a weight of more than 8,000 pounds. Carbon fiber as well as being strong can be modeled and shaped to maximize strength in particular areas.

The carbon fiber is cut using a computer-controlled high-precision cutting tool. The tool also labels each section for later use. Here, a technician is preparing various layers to form a lug, a section that connects the fin box to the fuselage. He carefully positions each pre-assigned section, documenting every new layer he adds. This superimposition of layers of carbon fiber creates a contoured shape that uses the direction of the fibers to give the part its required strength. Each lug has its own individual logbook in which every action, inspection and check is recorded as it occurs throughout all stages of the manufacturing process.

The part is then pressurized and cured in an autoclave to bind the layers together. To ensure there are no flaws inside the lugs at this stage, each one is scanned individually using ultrasonic equipment. The part is dipped in water and images are relayed to a monitor to check for defects. The different colors on the monitor indicate the differences in thickness of the part.

The fin box is the main component of the fin, measuring about 26 feet high and 10 feet wide at its broadest. It is this component that provides the core inner strength of the fin which must withstand the loads imposed on it during flight. To ensure the strength and reliability of the fin box, a modular production method is used to manufacture an integrated structure. The documented lengths of carbon fiber are manually laid over light alloy molds by technicians who are regularly evaluated to ensure they maintain the highest level of skill. These modules are then placed in position according to a precise design pattern that maximizes the strength of the component. They are secured laterally and longitudinally by a system of flanges and reinforcement layers. The resulting structure forms one half of a fin box shell.

The pre-cured lugs can now be manually integrated into the fin box shell. There are six lugs on each aircraft, each composed of an inner and outer part. The corresponding inner and outer parts of each lug are subsequently bonded together with the skin to form powerful attachments between the base of the fin and the fuselage. Before integration, the lugs are again thoroughly inspected and documented to ensure they meet the required standards.

Once all the lugs have been integrated, the skin of the fin box shell is carefully laid by hand over the outer surface. A foil bag is placed over the skin inside which a vacuum is produced to compact the assembly and ensure it is entirely smooth. After the foil has been removed and the skin checked, the module assembly is turned through 180 degrees to allow for final preparation before curing.

Additional strips of carbon fiber are laid longitudinally between the modules to further reinforce the strength of the fin box in this direction. The fin box is then vacuum bagged again to apply pressure throughout the curing process. To attain its ultimate resilience, the completed half section of the fin box is heated in an autoclave to a temperature of 250 degrees Fahrenheit and subjected to a pressure of around 100 pounds per square inch for at least 10 hours. Curing is performed in a single cycle to ensure uniform strength of the final structure.

Once the section leaves the autoclave, the outer vacuum foil is removed and a demolding process is performed. Special tools are used to retrieve the light alloy molds from the carbon fiber frame. The structure is then cleaned and machined to the required shape. To verify the quality of the part after curing, it is tested with ultrasonic equipment. This ensures there are no air bubbles or separations between layers or wrinkling of the outer layers. Areas with complex geometry, such as around the lugs, are double checked and scanned by hand to ensure the part meets quality standards. The two half sections of the fin box and the central framework that holds it in place are now brought together for assembly. A special jig locks the parts firmly in position while they are riveted together. Holes are then drilled through the lugs and a part known as a bushing is fitted through the hole. Large bolts will be passed through these bushings during final assembly of the aircraft to join the fin to the fuselage. The rudder and all other component parts of the fin are added at this stage before a thorough systems check.

Here, a test is being performed to check the rudder systems. A detailed manual inspection of the fin is then performed. The rudder and fin are disassembled after checks, carefully crated in custom-built jigs and loaded aboard Airbus's transport aircraft for delivery to the final assembly line where they are checked again at the point of installation on the aircraft."

Let me strengthen some points on the quality assurance process. You have seen elements of that in the video, but additionally, it's necessary that we have at least three major steps in the quality assurance process we apply on the manufacturing of the parts.

The one which is before the production start is that we certify and verify all the materials we have, the processes, the tools, and also the materials which are necessary to manufacture these parts and we perform batch tests and incoming inspections of all of these parts. That's the first step.

The second step is careful process control and monitoring. Again, as I said, the material gets its performance in the process, so we have to monitor and to control all the processes we apply, and at the end, we do a final inspection which is, as you have seen, an NDI inspection, for example, but also we do thickness measurements, visual inspection, whether we find some anomalies or not.

The requirements we have in place in our manufacturing side are specifications for materials, for batch release testing. We have manufacturing specifications in a general part and we have also a part-specific manufacturing specification and we have and I will show you an example later, a quality requirement sheet where we fix the quality requirements for the individual components of parts.

You see here this picture of the NDI process, but again this NDI process is only one part of the whole quality assurance process, and you see here this so-called squirter technique where the ultrasonic sound is accompanied by a waterjet to the structure. You have seen it also in the film.

Then we go to the quality requirement sheets. We specify the material for the workers. So, the quality requirement sheet is a part of the drawing which the worker has in hand when he makes the part. We check for the material. We check for the process specification, that he applies the correct ones and is aware of what he has to do, and we have also specific requirements in terms of quality, for example, for porosity and that sheet is part of the drawing which comes along when he manufactures the part.

I would like now to show some results of the testing we performed on behalf of NTSB and the investigation and on behalf of BEA, which is the French equivalent of the NTSB. We did the tests in our Materials and Processes Lab in Bremen, Germany. All the tests were witnessed, were part of the NTSB investigation, fully in line with the procedures we have agreed on.

We have chosen the DMA testing which I have explained earlier on in my presentation because we have established in '85 this specific method to check the thermal behavior of the material. We have all the reference data available, and we can check by this DMA whether the material performs to specification in terms of its behavior, its thermal behavior, and whether the curing process was done right with this component when it was manufactured. So, again, as I said, it checks the material performance and it checks whether it was correctly manufactured in terms of the curing process. All tests were performed in our lab and witnessed by the BEA on behalf of NTSB.

The first thing we did when we got the specimens which were extracted from part of the fin and in this case extracted from the fin box in the upper part, so we checked for the actual moisture content at the time when we got the specimen. So, this moisture content has no relation to the moisture content at the time of the accident. It's just a check that we can verify our data. We did in the past in '85 with different moisture content. So, you see the drying curve and we established a moisture content of .6 percent.

Then we compared that to the data we gained in the qualification in '85 with exactly the same material. You can see here that we have got results from 144 Centigrade, I must admit there's no Fahrenheit available for that, and you see the reduction with increasing moisture content. The actual moisture content -- sorry. This figure is for the moisture content of 1.2 and this is the moisture content of 1.6 which is equivalent to the service condition we have established. So, the maximum service moisture we can get as a reference point.

We checked for the .6 percent moisture content and we got it with 134 Centigrade which is 273 F which is above the estimation of the -- of the curve and we did also redrying of the specimen. So, we got the moisture out and we came exactly to the same results we had in '85. So, we got a moisture -- a DMA temperature of 149 or 300 F which is in the schedule of the tests we performed in '85. So, we had to -- at which a mean value of 144, standard deviation of 5, and it was based on 33 specimens. So, we have proven that first the material performed as it should perform. We also can show that the moisture gain and the performance shows a reversible behavior, that we can regain the performance with this kind of material, and we have proven that in this term of the accident investigation.

Let me summarize my presentation. The material was qualified according to the certification standards. We did a statistical evaluation in accordance with MIL Handbook 17. We used the industry standard building block approach. We checked the processing window for the manufacturing process. We have a reliable manufacturing technique verified and approved quality procedures for the manufacturing.

In terms of our contribution to the excellent investigation and with the methods we applied, that we can say in terms of DMA tests, that the material was found to be within the specification and also with reference to the curing process we applied at that time, we can say that the fin box was manufactured to the specification.

Thank you very much.

DR. FOX: Thank you. I guess, thank you for that very comprehensive presentation.

In -- in that, you had mentioned you had done numerous coupon tests, and you mentioned that you had done -- studied environmental effects, among other things. Were -- was also -- were there studies of impact damage or the effects of impact damage or delaminations or, you know, how was that addressed in -- in the -- at the coupon level?

MR. RACKERS: Yes, it was addressed at the coupon level. There is tests called compression after impact. So, we subject the specimen of 4X6 inches to impact energy level of approximately 30 to 50 Joules, but this is done to check the behavior of the material in order to classify the material between different kinds of materials in order to select an impact-resistant material.

DR. FOX: Did you also do open hole tests in tension?

MR. RACKERS: Open hole tests and also filled hole test in compression were part of the element tests and that was mainly done in the Structures -- in the Stress Department at that period of time.

DR. FOX: Okay.

MR. RACKERS: Specific to the part and

specific to the lab.

DR. FOX: Moving on to some of the NDI inspections during manufacturing, what types of defects would you expect to be able to detect using the non-destructive examination?

MR. RACKERS: By the ultrasonic NDI, we can detect porosity and we can detect separation, whether they occurred by non-proper application of pressure in the process or by the finished parts. So, we can detect separation and we can detect what's porosity.

DR. FOX: When -- in terms of the porosity, what's the -- the -- or -- or -- or separations, what's the maximum size, defect size, that's permitted?

MR. RACKERS: The maximum defect size depends on the location of the structures. So, we have -- the smallest one is 75 square millimeters and the biggest one is 250 square millimeters. It depends very much on the location. So, we have tougher requirements for the lower parts where we have the highest loads.

DR. FOX: Okay. Does -- does the size depend at all upon the geometry of the defect or -- or position within the thickness?

MR. RACKERS: No.

DR. FOX: What -- what types of anomalies or defects would be present that could affect strength or stiffness of the material that may not be detected by non-destructive inspection?

MR. RACKERS: We guarantee that we affect -- that we detect all the defects which reduces the strength by this process and by loads calculations. So, we verify also what kind of defect has to be detected and we can detect with the equipment which you have seen 36 millimeters squared.

DR. FOX: So, essentially, through your materials qualification and coupon testing and -- and that whole process defines what type of defects you need to detect and then you use the -- the correct method to find those types of defects?

MR. RACKERS: Yes.

DR. FOX: As far as, you know, looking at fiber volume fraction and the overall richness of -- of resin within the composite, how -- how does -- do an overall resin-rich or resin-poor material have -- what effects does that have on the strength of the material, the stiffness?

MR. RACKERS: Well, there is an effect, of course, and there's a severe effect if the fiber volume content is too high. So, we have to keep, as we say, the resin in the component, in the process, and we have established a limit. First, when we started, we have established a limit of 64 percent fiber volume fraction. What we found in some areas, a higher fiber volume fraction, and we justified that also this higher fiber volume fraction is okay, but as soon as it is higher than 70 percent, then we have a limitation from structures point of view and we can identify the fiber volume content by thickness measurement. That's also non-destructive testing.

DR. FOX: So, -- so, what -- what range do you target for fiber volume fraction? You mentioned 70 percent being the upper --

MR. RACKERS: Yes, but 66 is quite okay.

DR. FOX: And at the lower end?

MR. RACKERS: At the lower end, -- sorry. I forgot to answer this part of the question. On the lower end, we have more resin in the component, but there's no effect on the structural strength of the component.

DR. FOX: Okay.

MR. RACKERS: So, we manufacture, as you have seen with a lot of aluminum blocks, and it's not very easy to seal them carefully, so that we prevent the resin from going out. So, we manufacture with excess resin, and the excess resin may build up in certain areas of the part and we check that there is no effect on the structural strength of it.

DR. FOX: Okay. I guess one -- one more item within non-destructive testing and defects. Would you be able to detect stacked delamination using NDI, the ultrasound?

MR. RACKERS: Could you please explain what -- what you mean by stacked delamination?

DR. FOX: Well, often referred to as multiple delaminations within one area through the thickness.

MR. RACKERS: Through the thickness in several plys.

DR. FOX: Yes.

MR. RACKERS: We can locate, if we have an indication, we can exactly locate which ply the indication is. So, we can detect that.

DR. FOX: Okay.

MR. RACKERS: The standard procedure is to (1) the stress material, see if there's an indication, then we check manually again whether there's a defect and what the exact size and location is in order to verify whether the defect is critical or not.

DR. FOX: So, then there is -- that gives you an overall size and location of the defect but doesn't -- I guess it doesn't really tell you how many, you know, how many layers are affected?

MR. RACKERS: By manual inspection, we can also detect the location of the defect, and we can also --

DR. FOX: Sure.

MR. RACKERS: -- detect whether we have several delaminations.

DR. FOX: Okay. So, you check it from both sides, then, at this stage?

MR. RACKERS: Yes.

DR. FOX: I guess you have a number of checks during -- during manufacturing to, you know, ensure that you have a good cure cycle, temperature cycle on your cure. How -- how did -- what -- what -- what methods do you use to verify the cure during manufacturing?

MR. RACKERS: Well, we monitor the cure cycle. We have established temperature thermal couples in order to monitor the temperature, and we know exactly which temperature of the various ones is critical. So, we have a philosophy of following the slowest thermal couple we have, as we say, because we have to guarantee that each individual part of the resin gets at least the temperature and time which it needs to cure correctly and that's why we established the slowest cure thermal couple philosophy, and the thermal couple location is selected in such a way that we are able to determine that. So, for example, we go for thick areas where we have the slow response of the material to the temperature increase and we check for the thick areas and that determines normally the slowest thermal couple.

DR. FOX: Okay. And did -- in the development of the -- the manufacturing process, did you include travelers or -- or any kind of other material along with the parts being manufactured?

MR. RACKERS: Yes, that's also part of the quality assurance process. So, we have travelers to check whether the processing conditions in the autoclave are okay. So, we check for the temperature and time exposure of the traveler specimen.

DR. FOX: And would there have been a traveler specimen at the time the accident fin was manufactured?

MR. RACKERS: Yes, there was a traveler specimen, and this traveler specimen after the process was tested by the short-term shear test, which was referred to as ILS test.

DR. FOX: Okay. I guess another item involving the cure, what's the role of curing agents in the process?

MR. RACKERS: Well, epoxy resins consist of basic epoxy resins and curing agents to build up the linkage in the epoxy resins and there are curing agents or hardeners, and there's also in this specific material a curing agent which speeds up the curing process.

DR. FOX: And when is that added to the material or included in the material?

MR. RACKERS: It is added when the resin is mixed prior to the pre-impregnation process and that is done at the manufacturer which -- who supplies us the material.

DR. FOX: And then, is there a check when that material comes in as to the content --

MR. RACKERS: Yes.

DR. FOX: -- of the --

MR. RACKERS: We establish later on in the process the chemical analysis of the resin system which you do in-house. At that time, we had checks at the manufacturer that we corrected there and the correct amount is in there.

DR. FOX: Okay. Let's see. I guess moving towards porosity and -- and within the material, what -- what are the void concentration limits permitted?

MR. RACKERS: Well, at that time, period of time, there was no direct correlation to the void content, but we checked on the reduction of the signal strength of the NDI signal of the ultrasonic and it was a reduction of minus 6 decibels which was in thick areas to conservative.

DR. FOX: Okay. I guess in the -- that's how you detect it within -- with the NDI during manufacturing. What -- what are -- what are your target limits for porosity or void content?

MR. RACKERS: In terms of content?

DR. FOX: Yes, and volume content.

MR. RACKERS: Well, as I said, at that time, there was no definite definition for that, but later on, we established that we have at least 2.5 percent maximum level.

DR. FOX: Okay. Then in the -- in the layout as -- during the manufacturing process, you -- you -- you take great care to ensure that -- that layers are placed, and I guess in the final process, you -- you check the thickness to ensure that the -- the -- that -- is that the only check to ensure that you have the correct layup and the correct number of layers?

MR. RACKERS: Well, that's the final check.

DR. FOX: The final check.

MR. RACKERS: When it's too late, normally if something is missing. So, we have a laydown book. When each individual layer is laid down, it's checked that it's in place and it's correctly in place and you may have seen that on the film, that the guy made some remarks that it is put in place.

DR. FOX: And then, if -- if there is the -- a problem in the final check with the thickness measurement, then what -- what is done at that point?

MR. RACKERS: Well, at first, you make a calculation whether the fiber volume content is okay. So, as I said, it's critical to have at least correct fiber volume content and not to have -- go to a higher fiber volume. If there is an indication, then we check locally at this area, and if we come to the conclusion that there is something wrong, we make a core drill in order to analyze the exact number of plys and also the exact fiber volume content that can be done by a microsection analysis of the picture.

DR. FOX: Okay. And then, with -- during the -- in the standard process, there are cores drilled out in the lugs themselves. What type of tests do you do on -- on those cores?

MR. RACKERS: I'm not aware of this test at the moment. So, it's possible to take it. If there is any question on that, so we can check, for example, for

DSC, if we have a concern on the curing. We can check also for the exact number of layers and so on.

DR. FOX: Okay.

MR. RACKERS: But I'm not aware of a routine check for this.

DR. FOX: It's not done on a routine basis?

MR. RACKERS: No.

DR. FOX: I guess in -- when doing the lugs, you -- you use pre-cured halves. Could you talk a little bit about why that is done?

MR. RACKERS: Well, the reason is quite simple. We have approximately 200 plys in this area in the -- in the bigger -- bigger lugs and as soon as we have to manufacture big parts, we have to be careful. That's one point.

The second point is that the geometry is very complex in this area, so that we have to ensure a good quality and that led to the decision to separate the lugs into an inner and an outer one and to manufacture them before, so that we established a good quality in the lugs themselves, and you have seen the precautions which we've taken so these lugs are cured in matter frames in order to achieve the exact geometry and to achieve a good quality. So, quality is the answer.

DR. FOX: And then, what -- what sort of

surface preparation techniques are done as those are -- are co-bonded in -- in the final assembly?

MR. RACKERS: Well, as I said, we do a co-bonding process. That means one part is already cured and we mate it to a non-cured part, and we do two steps of surface preparation for this bonding, and the first step is that we apply a peter ply before curing and we remove the peter ply after curing and, additionally, we do sanding.

DR. FOX: And then, what sort of cleaning or other operations do you do to ensure that you avoid contamination?

MR. RACKERS: We do some -- just some water cleaning. That's sufficient. And we take care, of course, that we have only freshly-cleaned and fresh parts where the peter ply has been removed shortly prior to the following operations. So, if these parts have to be stored, then the rule is that the peter plys has to be on to protect it.

DR. FOX: Okay. So, I guess moving to -- on to the accident vertical stabilizer, and I think you pretty well covered the work that you had done on our behalf, and I guess to summarize, did you -- you did not find any evidence of in-service damage or degradation in those tests?

MR. RACKERS: No, not from our tests. For the rest of the tests we are responsible.

DR. FOX: Okay. And then, I guess the final -- final topic was regarding fractographic examinations. In -- in support of the structures, structural testing, did -- did your -- your group do any fractographic support in those tests?

MR. RACKERS: Fractographic. Depends on the wording, but we did analysis of the internal -- the inner quality, as we say, of the part which was tested in the full-scale test in order to establish a picture how the inner quality is, whether we have deviations and whether these deviations have any consequence. So, there is a full report available on it, and I think I provided that to -- to the Structures Group and we did the investigation.

DR. FOX: Okay. But as far as examining fracture surfaces or anything of that nature, no?

MR. RACKERS: No, not -- we did not do it.

DR. FOX: Okay. That's all the questions I have. Thank you.

ACTING CHAIRMAN CARMODY: Thank you, Dr. Fox.

Are there other questions from the Technical Panel? Yes, Dr. Kushner.

DR. KUSHNER: Yes. Hi.

MR. RACKERS: Good morning.

DR. KUSHNER: Just like to follow up. In response to Dr. Fox's question about how you characterized defects that are found ultrasonically, you said basically that you just do it by the area.

MR. RACKERS: Yes.

DR. KUSHNER: The delamination. So, does that mean that basically a circular delamination would be considered equivalent to an elliptical delamination with a 10:1 aspect ratio, if they have the same area?

MR. RACKERS: Yes.

DR. KUSHNER: Okay. And also then in terms of where they sit through the thickness, the same delamination between a zero degree tape and a plus or minus 45 fabric, it would be considered the same severity, as the same size defect, between a zero degree tape and a plus or minus 90 -- 090 fabric?

MR. RACKERS: Yes.

DR. KUSHNER: Okay.

MR. RACKERS: Can I make a remark on that?

DR. KUSHNER: Sure.

MR. RACKERS: Okay. These limits were established covering the full strength capability of the structure, and this represents the lower limits and, of course, we introduced, when we did the full scale test, for example, much bigger delaminations in various sequences of the testing. So, again we have a conservative approach on that. So, that's the reason why we do not care what location the size. So, the structure is able to carry the full strength with even much higher delaminations. That is part of the witnessing of Mr. Winkler.

DR. KUSHNER: Okay. Thank you.

One other thing now. When you do the thickness check, what is the resolution? You know, how closely spaced are the points that you do that at?

MR. RACKERS: Well, the thickness test is done with conventional thickness measuring -- measurement tools, and we do have, of course, some limitations as soon as we get to very thin parts of the structure, but if you have concern, then we do an analysis which is -- goes more into the detail and we do these core drills.

DR. KUSHNER: I'm sorry. I guess I didn't express it clearly. I meant, points that you sample the thickness at on the surface of the part, how often do you do that?

MR. RACKERS: Oh, we have a test plan for the sampling, and I don't know by heart exactly what it is. I believe more than 100 points on the structure.

DR. KUSHNER: Okay. And in the lug area -- in the lug area, --

MR. RACKERS: Pick a number here.

DR. KUSHNER: Okay. Is that concentrated heavily towards the lug area and the transitions between the lug and the skin?

MR. RACKERS: I think we have some more measuring points in the lug areas, and it's more randomly distributed than the rest of the fin box.

DR. KUSHNER: Thank you. Okay. That's it. Thank you very much.

ACTING CHAIRMAN CARMODY: All right. Thank you, Dr. Kushner.

Moving then to the parties, I'll begin with the FAA, Mr. Donner?

MR. DONNER: Once again, we have no questions. Thank you.

ACTING CHAIRMAN CARMODY: American, Mr. Ahearn?

MR. AHEARN: Thank you, Madam Chairman.

Just a few. Mr. Rackers, little did I know that we would meet again when we said good-bye in the elevator this morning.

MR. RACKERS: Yes, that's correct.

MR. AHEARN: Good to see you again.

MR. RACKERS: Yes.

MR. AHEARN: Just a few topics I'd like to discuss with you.

From your film, I believe it indicated that there have been no changes to the fin box since its initial certification in 1995, is that correct? I'm sorry. 1985.

MR. RACKERS: That's correct, as far as A300-60 is concerned, and we are still using this type of fin box, this type of manufacturing technique for SC40, for example, but with some adjustments to the loads. But the concept is the same.

MR. AHEARN: Okay. And from a certification standpoint, that -- there's no recertification?

MR. RACKERS: Not as far as I'm aware of.

MR. AHEARN: Okay. Also, I believe I heard that the fin when it was designed was designed to be interchangeable with the B2B4.

MR. RACKERS: I am not aware of interchangeability between B2B4 but definitely between A300-600R and A310.

MR. AHEARN: Okay. So that, it was designed --

MR. RACKERS: But the lugs are designed in the same way. So, we have the same layout of the lugs, so of the connections on the fuselage.

MR. AHEARN: So, --

MR. RACKERS: So, I'm not aware whether we can change from 300-600R composite fin to a B2B4 metal fin.

MR. AHEARN: So, from an evolution standpoint then, the lug size was designed to fit into the pre-existing empennage starting from the B2B4 to the 310 to the 300-600R?

MR. RACKERS: As far as the geometry is concerned, I believe so, yes.

MR. AHEARN: Okay. Could you have designed a stronger composite lug without the limitation of trying to fit into a pre-existing empennage?

MR. RACKERS: Of course, we could have designed the stronger fin box with no problem, but we have exceeded 1.93 limit loads. So.

MR. AHEARN: Okay. Specifically talking about the lug from a design standpoint, can you discuss not from a specific load standpoint but from -- from a composite standpoint as to how you overlay the composite material? Can you describe how the loads -- really what I'm looking at is -- is the design of how you do your overlays. Are there ways to increase the strength by overlaying the composite material, particularly as it relates to the lugs, at different angles, at different -- or use a different process when it's connected to the -- obviously the metal clevis?

MR. RACKERS: What do you mean by overlaying?

MR. AHEARN: Well, when you -- the material is overlaid at different angles as it's being built.

MR. RACKERS: Yes.

MR. AHEARN: Okay. In designing that, what kind of testing have you done to look at different overlays to increase the strength of the lug?

MR. RACKERS: Well, it's more a question to the Stress because Stress is responsible for the design and to get the correct layout sequence and the correct layout, but as you have seen on the video, there was highly-contoured part and carefully-adjusted layers with different angles, and as far as I know, it is optimized in terms of strength.

MR. AHEARN: Okay. So, you wouldn't have anything to do with the strength --

MR. RACKERS: No.

MR. AHEARN: -- of the lug?

MR. RACKERS: No.

MR. AHEARN: Maybe Mr. Winkler can help us in that regard.

MR. RACKERS: Yes.

MR. AHEARN: Okay. Thank you, sir.

Just a couple more topics. On the composite lug, do you have any sense that -- maybe this is Mr. Winkler's question as well, but I'll -- I'll ask it. Do you know what the effect of the size of the hull is relative to the edge distance on -- on the strength of the lug?

MR. RACKERS: That is his question as well.

MR. AHEARN: Okay. Then two follow-on questions to your video. It appears, and it may have been because of the angle that I was seeing it, but when -- in the video, when you showed the development of the lug, the lug actually appeared to be quite smaller than actually the 300. It may have been a 320 lug in there but it also may have been the angle that I've been looking at it.

Could you tell me how does the design and geometry of the other aircraft in the Airbus family differ from the -- the 600, and -- and specifically what I'm talking about is in the -- in the lug area?

MR. RACKERS: Well, of course, the 320 is a smaller aircraft with smaller lugs. So, what you have -- what you have seen on the video is actually an A300-600 lug. So, for A340 we have a thickness increase due to the loads of this aircraft. So, we have a different load for each aircraft and, of course, we adjust the lug thickness to the load.

MR. AHEARN: And -- and to your knowledge, there's no certification difference?

MR. RACKERS: What do you mean by certification difference?

MR. AHEARN: Certification of the construction of the fin.

MR. RACKERS: Not as far as I know.

MR. AHEARN: Okay. Do you know if the -- the -- the damper or the hull side that the bushing and then the clevis pin goes through, do you know if they are different on any of your other fleets?

MR. RACKERS: I'm not exactly aware of that.

MR. AHEARN: Okay. Maybe that's a question for Mr. Winkler as well.

MR. RACKERS: Yes.

MR. AHEARN: Madam Chairman, that ends my questioning. Thank you very much.

ACTING CHAIRMAN CARMODY: Thank you.

Allied Pilots, Captain Pitts?

CAPT. PITTS: Thank you, ma'am.

Good morning.

MR. RACKERS: Good morning.

CAPT. PITTS: On the A300-600 vertical

stabilizer, is it -- is it correct that the -- that the attachment to the fuselage is by means of the all-composite lug that is essentially just an extension of the -- of the composite side skin?

MR. RACKERS: Yes.

CAPT. PITTS: And when a hole is cut through that composite to form the lug, the fibers that run in each ply, I think, are interrupted. I think you showed that in your video, and therefore the loads normally carried by those fibers are redistributed. Are they then through the resin and the adjoining fabric pieces? Can you go back into that a little bit, how that -- how that -- that works for us because of the -- of the hole that's been placed in there?

MR. RACKERS: Well, that's standard procedure to carry loads from a skin size, skin type of design, into a point, and it was fully certified this way. Of course, you may argue that the fibers are cut, but that is not of any concern.

CAPT. PITTS: Okay. Do any other manufacturers using composites in the vertical stabilizer build attach points to the stabilizer fuselage relationship in this same fashion?

MR. RACKERS: I'm not aware of that, no.

CAPT. PITTS: You mentioned that if the

structure reached 1.93 of the limit load, the limit load again is the highest loads expected to be seen in service?

MR. RACKERS: Yes, that is per definition I've seen before in this investigation and in the course of this hearing.

CAPT. PITTS: We saw higher loads in those in this flight?

MR. RACKERS: Pardon?

CAPT. PITTS: And we saw higher loads than that limit load in this flight?

MR. RACKERS: In which flight?

CAPT. PITTS: In the Flight 587.

MR. RACKERS: We saw at least loads in the same order of magnitude as the original statement of one of the other witnesses.

CAPT. PITTS: And we've seen limit -- and we've seen that limit load exceeded in other flights as well?

MR. RACKERS: As far as the statement of the other witnesses are concerned, yes.

CAPT. PITTS: In your opinion, would you want to go back and revisit that load value used for the design of this composite structure?

MR. RACKERS: As I said, per the other

witnesses, we fully complied with the certification requirements, and we established a limit load, and I think that is sufficient.

CAPT. PITTS: Okay. What other Airbus commercial airliners use the same attached design and composite materials for attaching either the vertical stabilizer elevators as used in the A300-600 aircraft?

MR. RACKERS: As far as the attachment design is concerned, all of our current flying aircraft have exactly that same design, having six attachments by fins. For the smaller attachments, but for other loads.

CAPT. PITTS: Okay. Thank you.

I noticed the reference to the quality control, and I just wanted to clear up something. Do Airbus employees in the Composite Section perform their own quality assurance functions or is an independent quality assurance department used there?

MR. RACKERS: Our Manufacturing side are qualified to Standards 9000, and we do the quality testing by all, of course.

CAPT. PITTS: Okay. Can you speak to the repair on the aircraft in question, 053?

MR. RACKERS: No. Because Stress has to analyze in terms of deviations from the manufacturing.

They have to analyze the consequence of that and have to fix that.

CAPT. PITTS: Do you -- well, then do you know if there was ever -- was this ever the -- was this the first-ever kind of repair on a lug?

MR. RACKERS: No.

CAPT. PITTS: As a -- as a composite expert, have you seen this kind of repair in -- in other applications?

MR. RACKERS: Yes, I've seen some other and they were certified and tested by the Stress.

CAPT. PITTS: Do you know at what point in the testing or in the manufacturing process that -- that defect occurred in that lug?

MR. RACKERS: No.

CAPT. PITTS: Do you know what might cause a discontinuity in the -- in the -- in the structure?

MR. RACKERS: Sorry. I didn't get the word.

CAPT. PITTS: Discontinuity. Do you know what might have caused the discontinuity that caused the concern in that lug?

MR. RACKERS: No, I'm not aware especially of that.

CAPT. PITTS: All right, sir. I have no further questions.

ACTING CHAIRMAN CARMODY: All right.

And Airbus, Dr. Lauber?

DR. LAUBER: Just a couple of quick questions for clarification.

Mr. Rackers, you -- you used the term "traveler specimen" in some of your testimony. It might be helpful for some people if you'd explain what a traveler specimen is.

MR. RACKERS: A traveler is composite material which is put into the autoclave parallel to the structure but the traveler does not form the same -- from exactly the same batch of material, and it's just used to verify whether the curing process is okay.

DR. LAUBER: Okay. Thank you.

MR. RACKERS: It is not a cut-out of the structure.

DR. LAUBER: Thank you.

You also testified with regard to testing done on the cores that are from the drilling process. Aren't there torsional strength tests done on those cores?

MR. RACKERS: Yes, it's possible.

DR. LAUBER: Okay. One other question. After the grinding process of -- of the pre-trimmed lugs is completed, what kind of quality test is performed on the part at that point?

MR. RACKERS: Well, there's an additional quality test to check for surface resistance because one reason for the grinding is that part of our lightening strike -- lightening strike protection concept is that we have connectivity between the skin plys and the lug plys in order to transfer electricity. So, we do internal connectivity that we at least have access to the fibers which conduct electricity.

DR. LAUBER: Okay. Thank you.

No further questions, Madam Chairman.

ACTING CHAIRMAN CARMODY: Thank you.

I know a number of the board members have been to Hamburg to see that process of the manufacturing. It's quite impressive.

Member Hammerschmidt, any questions from you?

MEMBER HAMMERSCHMIDT: No questions. I'm one of those that have had the opportunity to witness the manufacturing process firsthand and I certainly appreciated that -- that accommodation.

I would just like to say that was a very nice presentation this morning, --

MR. RACKERS: Thank you.

MEMBER HAMMERSCHMIDT: -- and I would like, if you could, to have a copy of -- a hard copy of the slides of the Bremen testing part of your presentation at some point.

MR. RACKERS: Which one?

MEMBER HAMMERSCHMIDT: The -- the -- the testing at Bremen.

MR. RACKERS: Okay. Yes, it's in the exhibit.

MEMBER HAMMERSCHMIDT: Yes, but just an additional copy.

MR. RACKERS: Yes, of course.

MEMBER HAMMERSCHMIDT: Just that one part of your presentation. Thank you. That's all I have.

ACTING CHAIRMAN CARMODY: Member Goglia?

MEMBER GOGLIA: No questions.

ACTING CHAIRMAN CARMODY: Well, anything further from the Technical Panel?

(No response)

ACTING CHAIRMAN CARMODY: Anything further from any of the parties?

(No response)

ACTING CHAIRMAN CARMODY: Why don't we come back at 1 and start with the next witness? Thank you.

(Whereupon, at 11:53 a.m., the meeting was recessed for lunch, to reconvene this same day, Thursday, October 31st, 2002, at 1:00 p.m.)

AFTERNOON SESSION

1:08 p.m.

ACTING CHAIRMAN CARMODY: Ms. Ward, would you proceed with the next witnesses? Let's see. Mr. Ilcewicz.

MS. WARD: Next witness will be Dr. Larry Ilcewicz. Please raise your right hand.

Whereupon,

DR. LARRY ILCEWICZ

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

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

Dr. Ilcewicz, could you please state your full name, your current employer, and your business address?

DR. ILCEWICZ: My name is Larry Burt Ilcewicz. My current employer is Federal Aviation Administration, 1601 Lind Avenue SW, that's in Renton, Washington 98055.

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

DR. ILCEWICZ: I'm the Chief Scientific and Technical Advisor in the area of Composites. I began in 1998.

MS. WARD: Could you please state your duties and responsibilities and any education and training that you may have received to qualify you for your current position?

DR. ILCEWICZ: In this position, I support Airworthiness Assessments, Certification for Composite Structures. Based on the experience associated with that in areas, such as Materials and Processes, Design, Analysis, Manufacturing, Maintenance, Substantiation as related to Certification, I develop education, both within the FAA and for industry, and I also take those experiences to apply and help direct what research is done by the FAA in Composites.

MS. WARD: And what's your educational background?

DR. ILCEWICZ: In 1980, I started off at the Boeing Company. I had a Master's Degree and a Bachelor's of Science at that point in time, worked under their Advanced Composite Developmental Program for roughly two years. At that point in time, I was able to get an educational leave of absence. I had funding from the National Science Foundation and Boeing also gave me a contract where I went to get my Ph.D. at Oregon State University. I returned to the Boeing Company in 1984, worked on a number of programs, got experience supporting 737, 757, 767 service problems as related to composite materials in the early days.

Towards the end of the '80s, I got involved in developing design methods allowables that would consider environmental effects damage tolerance, helped establish design requirements and objectives in the composite world. This was all prior to the 777 going to a composite empennage.

Through the '90s, I was involved in a large NASA program to help develop composite fuselage structure for transport aircraft. I was the principal investigator for that, and the last assignment I had at Boeing before coming to the FAA was with 757-300 program on wing structures.

MS. WARD: Thank you, Dr. Ilcewicz.

Madam Chairman, I find this witness qualified and now pass it over to Mr. Brian Murphy for questioning.

EXAMINATION

MR. MURPHY: Good afternoon, Dr. Ilcewicz.

I'd like to discuss the following topics with you today: certification of composite structure, the requirements for static and damage tolerance, static strength and damage tolerance, and then, finally, NDI and visual examination of composite structure.

Before I begin addressing the main topics, would you tell us what's been required of you during this investigation?

DR. ILCEWICZ: I was on NTSB Structures Team which has been very thorough in this area of composites. We've looked at many different possible failure scenarios for the vertical fin, developed a fault tree to help guide our efforts in all different areas. So, I would say that just about all of my experiences were brought to bear, including my knowledge of certification, manufacturing and maintenance over the years, as well as going back to being able to apply basic stress analysis principles, laboratory techniques and effectively reverse engineer the failures that we have observed in the accident to the extent that we would be able to support the other working groups and confirm that the loads were as predicted.

MR. MURPHY: Okay. Let's move on into certification of composite structure then.

Based on your review of the materials and your work with the Structures Group to date, have all the areas -- all the key areas been addressed in the certification of the Airbus -600R vertical tail?

DR. ILCEWICZ: They have. They followed a traditional building block approach that started late

'70s/early '80s, pretty extensive effort. They used all of the available guidance materials, and they also used whatever engineering standards existed in the composite world at that point in time.

MR. MURPHY: In general, are there any -- possibly maybe from a historical perspective, in general, are there any differences in the approaches used to certify the -600R composite structure versus your knowledge of other transport category composite structure?

DR. ILCEWICZ: Well, my exposure up until coming to the FAA was primarily with the Boeing Company, and in the late '70s/early '80s, there was many military programs. I was always in Commercial Division, but many of the people from my group ended up going to the military, and the NASA organization had also contracted Boeing, Lockheed and McDonnell-Douglas to look into the feasibility of using composite structures on commercial aircraft.

We started very much parallel to the types of efforts that Bernd talked about from the Airbus side with the development of secondary structures to see how the materials would react in the environment, and then as we gained confidence and insight, we started to move the primary structures, and the first primary structures, there was in the early '80s, these NASA prototype tail structures. The one I was most familiar with was the five ship sets of horizontal stabilizers on 737 aircraft that flew an entire life on those aircraft, but that particular exercise didn't lead to production implementation of -- of composite empennage. That did not occur until the 777 did that in the early '90s.

But from a historical perspective, the collective insights gained from military exposures as well as these early NASA prototype programs led to Advisory Material 2107-A which was developed in the mid-'80s, and at that point in time, the European authorities came together with the U.S. authorities, including experts from all major industry groups and even military support, to help define the guidance that exists in 2107-A.

MR. MURPHY: Thank you.

Could you give a basic description of some of the key areas that are addressed during the certification of composite aircraft structure?

DR. ILCEWICZ: Well, Bernd started off with an area that is very important. It forms the basis of the development and certification that you have established proper material in manufacturing fabrication controls because much unlike what goes on in the metal side, you are effectively advancing the material to a final state in your factory, and you have to understand what happens as that occurs at all scales that you're using to help substantiate the structure, and as you go up the building block ladder of the manufacturing and design, I like to say that they're integrating their efforts. They're understanding how the specific details that ends up on drawings can be manufactured and reproduced, and in the end, you want to make sure that whatever you develop in a database to support certification is something that you can count on; i.e., the manufacturing will carry on with the quality assurance procedures, such that you will always reproduce that same type design. So, that becomes the initial very critical area.

You develop data, statistically significant data that represents the lowest levels of the building block that oftentimes start with basic material properties but also include things such as joints and elements that can be tested in large quantities and you get confidence that you understand the variation of the material and then, as you move up the building block, what you're doing oftentimes is substantiating that what you had developed as a basis is correct and you learn from each level of testing what the load paths are versus what you expect to have from your structures analysis, and all of that comes together and culminates in a full-scale evaluation which we refer to sometimes as static strengths substantiation.

At a full scale, you're also concerned with evaluating fatigue as it is done in the metals world, and you are also concerned with evaluating damage tolerance which will balance your static strength requirements. Finally, you're concerned throughout this process with what happens once that structure is put in service. So, you're establishing databases and guidance for what should be done in maintenance and repair, and all of that collectively is the main key areas of relevance to our discussion today.

MR. MURPHY: Is it possible that you could maybe just summarize which -- some of the safety issues and structural details that would drive the design of a composite structure?

DR. ILCEWICZ: Yes. Some of them began to be discussed earlier before the lunch break. In composites, it's recognized that details, such as access holes or bolted joints or lug holes, other details, such as stringer runouts, attachments to ribs and so on, that those become some of the critical structural detail that will drive static strength.

Also as related to composite materials, there has been, as directed from the early experiences with 2107-A, a need to consider non-detectable damage that could come with in-service from accidental events, such as a foreign object impact, and so that becomes another critical part of static strength substantiation. Environmental effects are also important to that. To balance that off, you consider the issues associated with damage tolerance where you're moving to much more serious damage and you're using maintenance to help you in that regard together with your database and understanding of the structure to be able to tolerate that more severe damage and also realizing that it's damage that maintenance can find reliably.

MR. MURPHY: All right. Let's move on into static strength and damage tolerance then.

Mr. Goldberg, could you put up the Exhibit 7W, please, Page 2? Once that's up there, Dr. Ilcewicz, referring to that exhibit, could you explain to us then, you know, the difference between ultimate limit load levels as they would be related to composite structure design considerations and, say, the loads that would normally occur in each flight?

DR. ILCEWICZ: I don't have a very good view of -- of this graph. I believe it's the exhibit that I've submitted. It's -- it's not in -- in color. So, I'm going to have to help highlight some things that are there that you can't see.

Okay. There should be a line that is invisible because of the color that was used right in this neighborhood or somewhere in that -- it's not drawn very well to scale. Did it show me doing that when I was doing this?

MR. MURPHY: I'm going to try and give him a color one to put under the visualizer, Dr. Ilcewicz. I've got one. They're trying to -- he's manipulating the one we currently have.

DR. ILCEWICZ: Okay. Now, the yellow line shows the limit load. Now, within the regulations, there are regulations that will define what is needed for ultimate load, and those considerations are -- would be driven in design by the design details that I described with access holes and bolted joints and so on.

Also, for ultimate load per what's recommended within the Advisory Circular and it's been practiced within the composite world, is you also have to be good for damage that can't be found by the maintenance program, and in addition to that, you have to have a lifetime worth of operating loads. It's essentially a coupling of fatigue substantiation with ultimate load and the worst case environment. So, those become some of the things that are considered in sizing for static strength.

Limit load is not taking advantage of the fact that damages that could degrade the strength below ultimate but are detectable using current maintenance practices or scheduled maintenance practices are things that would have a limit load requirement. In addition to that, there are a number of other things that will fall under considerations for fail safety and some of the rogue manufacturing defects that are often considered for composites, such as weak bonds, and we define the structure to still be able to have those massive or gross defects and still be able to carry limit load, knowing that they can be detected.

If you look at the curve and try to go below limit load and consider operating load levels that the aircraft sees, it's going to be different for every structure. If it's a fuselage, the operating loads every cycle are fairly close to limit load. In the case of air foil structures, they can be significantly below limit load.

So, this is a diagram that I think was shown before by the FAA without the composite substantiation information on it.

MR. MURPHY: You may have answered this when you were describing that ultimate load there, the description, but what composite design details and damage considerations are important for the static strength and ultimate load requirements?

DR. ILCEWICZ: Well, it again would depend on each structure. If it's a structure that's dominated by compression loads, then oftentimes impact damage can be a primary source. In the neighborhood of joints, you oftentimes will have the considerations for the bolt that joints as a driver.

When you dial in the fact that you want to be able to apply a mechanical fastened repair throughout the structure, you effectively move the joints away from where they're normally located to all kinds of other locations wherever repair's allowed of that character, and so those tend to drive you in -- in design of considerations for static strength.

MR. MURPHY: How are the effects of repeated loads evaluated for composite aircraft structures?

DR. ILCEWICZ: Well, this is unique for composite structures because it's understood at the design screen levels that they work at, that most manufacturers try to demonstrate a no-growth approach to fatigue, and so oftentimes static strength and fatigue substantiation will be coupled, and in doing that, you're effectively demonstrating that in a number of ways, that there is no growth occurring at the repeated loads that are characteristic of that particular structure being studied.

MR. MURPHY: Okay. Since we've -- since we've mentioned it, what -- what load levels would typically be required or needed for fatigue damage propagation to become a problem with composite structure?

DR. ILCEWICZ: It would vary with the specific detail or damage being considered. It'd be on the average of from 60 to 80 percent of the critical strength that is being -- the critical detail that's being applied to the -- the cyclic loads. So, if it was a bolted joint, for example, it may fall somewhere in the middle of that. If it was a more serious damage, the SM curves or the fatigue cyclic curves tend to get even flatter and they might approach more of an 80-percent number from the data that I've seen in that area.

MR. MURPHY: What was done during the certification of the -600R to substantiate the static strength and fatigue resistance of the structure?

DR. ILCEWICZ: As I mentioned, they -- they tended to follow what a lot of the other composite programs since then have retained as standard, but this was also done within the scope of the early NASA programs, and that is, that prior to demonstrating static strength capability to ultimate load, a lifetime worth of loads with a statistical significance applied to it, i.e., in the composite world, that means that you increase the repeated loads by some value, apply those fatigue loads for enough cycles, such that you can represent what a lifetime is equivalent to, and then you apply static load requirements for ultimate load to that.

Now, they went through that as the first substantiation of static strength and fatigue insensitivity.

MR. MURPHY: All right. What design details and damage considerations are important for now when we get to the damage tolerance and requirements and damage tolerance and limit load requirements?

DR. ILCEWICZ: Well, now you're moving into rarer damages, damages that don't occur so often to the structure, but you're also, because of what you've done in design, you're usually moving to damage levels that are detected visually with an inspection that would be applied in maintenance.

Now, not all designs will follow that path. Other manufacturers, other designs may push to different means of inspection, but let's say that you've used a visual cut-off for what you will use for maintenance in your inspection procedures, and anything that falls on the other side of that, i.e., is non-detectable at that visible threshold, then that would be subjected to the static strength requirement. Damages that are detectable by visual means are -- are going to be more severe damage and those would be subjected to damage tolerance requirements.

Now, beyond that, oftentimes, depending on what structure you're looking at and how it's constructed, whether bonding's used in the structure, there will be a certain amount of fail safety that will also be developed which is a traditional damage tolerance concept that you can lose a significant portion of the structure and still maintain limit loads with that structure missing.

In addition, in damage tolerance, there's a Part E that relates to discreet source damages, such as very large bird strikes in the case of a tail, as well as the possibility of rotor blades and other things, depending on what systems are in the proximity, and oftentimes the loads that would be applied for that requirement would be lower than limit load because when that event occurs, it's known to the crew and they have specific instructions they follow.

MR. MURPHY: Okay. Following the same line that I did with the ultimate strength then, could you tell me what was done during the certification of the 600R to substantiate the damage tolerance requirements?

DR. ILCEWICZ: Well, as well as I understand it, they -- they realized as they went how tolerant their structure was to damage. So, after they had taken one of the articles through a lifetime's worth of fatigue and demonstrated ultimate load, they put more serious damages that would be detected in -- in maintenance inspection, everything short of what I referred to as fail-safe damages, and they carried those damages for another lifetime equivalent with the load enhancement factors for fatigue and then went back and demonstrated ultimate load a second time and that was with damage that would normally fall under 571 considerations.

The more serious damages that take us all the way to lost sections of structure and taking out elements, that was a limit load requirement was applied to substantiate fail safety on those articles.

MR. MURPHY: Why is impact damage so important in composite structure design?

DR. ILCEWICZ: Well, unlike metals, impact can -- can have an important effect on compression and shear or other "matrix-dominated" properties in composite structure, and so if you were to impact a composite, what'll happen is in the source of the impact, over what area that impact covers. Oftentimes you'll cause some localized fiber failure that are very local to the impact -- impactor itself.

Standing out from that zone can be a myriad of matrix cracks and delaminations that can become much larger than the impactor itself, and these matrix cracks and delaminations are -- are fairly complicated in terms of how they interconnect and form through the thickness of the laminate. I think the terminology "stack delaminations" was described this morning. In trying to understand the physics of impact damage, the terminology "sublaminates" is often used, that a given repeated stacking sequence of laminate will have a characteristic damage state associated with impact events, that oftentimes the matrix cracks and delaminations will form in a characteristic pattern which, if you understand for your specific design detail, you can define these sublaminates through the thickness.

Now, getting back to the issue of compression and composites, they are sensitive to holes and discontinuities in compression. If you load the composite with the impact damage present, then the individual sublaminates can buckle at some load level, and they won't carry any more than the load that caused them to buckle. They may have some post-buckling response and pick up a little more load, but a conservative assumption would be that when they start to buckle, that the only load that goes through the impact damage is the load that caused it to buckle, and now the rest of the load that would ordinarily come through that load path has to go around it and you form a stress concentration and the stress concentrations are both in plane and out of plane. The out-of-plane stress concentrations could tend to grow the delaminations, if the matrix was brittle enough. The in-plane stress concentration tends to act as a partially-filled hole and can cause compressive failure at the edge of the impact, and so these all have to be accounted for when you design and substantiate composite structure.

I gave you a relatively simple description of impact relative to what happens in -- in real structure that has stiffening elements bonded and so on.

MR. MURPHY: This is really a two-part question, the next one, but I've seen it depicted in graphs several times, I believe it was once at the Airbus conference, by both yourself and -- and Airbus.

How does the impact damage affect the residual strength of the -- of the structure, and in particular, how's it accounted for in the certification analysis and testing of the structure?

DR. ILCEWICZ: Well, the -- the harder you impact it, the more strength reduction you will get. I think the curves that you're referring to indicate that initially, as you start to increase damage size, which can occur by increasing impact energy, you start to drop down a relatively steep curve.

Now, as you impact it further and this is characteristic of not just impact but other geometry of -- of discontinuities in composites, whether it's holes or rotor blade penetrations, such I studied in the fuselage program at Boeing, you eventually hit asymptote in that curve, and the -- the description of that -- I don't have a graphic with me. I could draw a graphic, if --

MR. MURPHY: That'd be fine.

DR. ILCEWICZ: -- you desire. The curve I'm going to draw -- the curve I'm going to draw is often referred to, whether it's in metals or composites, as a residual strength curve, and what it -- what it's illustrating is it's illustrating how damages of increasing size affect the strength of the structure and -- and that strength we refer to as a residual strength.

Now, the -- the absolute geometry of -- of these curves can vary, depending on the specific layup and materials and so on. In the compression world, they tend to be relatively steep at the start and they flatten out. The tension world has far more dependence on laminate layups, but the tension curves tend to be significantly above the compression curves. So, they only become drivers in -- in structures such as fuselage, sort of pressurized.

Okay. So, if you look at that curve, as I mentioned, close to the far left side, damage size is approaching zero. You have a relatively high strength, and then as you start to apply damage to the structure of increasing extent and size, the curve starts to bring down the strength and then eventually hits close to asymptotic behavior, and so you reach a certain damage size where you can't get much worse.

MR. MURPHY: I think -- I think you just covered it with the other one. That one says the same thing, I think. But --

DR. ILCEWICZ: Take me a bit longer to draw it.

MR. MURPHY: Mr. Rackers covered some of this material during his presentation, but what would be some of the typical material variabilities and processing defects that would be encountered in the use of composites during their manufacture?

DR. ILCEWICZ: Well, because of the geometry of the structure and bringing complicated geometries together, you can expect that you'll see local wrinkling, porosity, variations in the fiber resin distribution, delaminations, things of that nature. Occasionally, there's small inclusions of things of that character.

MR. MURPHY: How would these -- these types of problems be controlled -- I'm sorry. Let me rephrase this.

How would these be dealt with in the manufacturing of composite structure and such?

DR. ILCEWICZ: Well, what would be normally done is at the time of certification, a certain database is developed, oftentimes in the industry we refer to it as effects of defects, but that usually isn't the end of that activity because oftentimes through the course of manufacturing, additional things are -- over, you know, a long production run, a lot more is going to be understood and found out, so that database continues to increase over time, and those defects by and large oftentimes because they're left -- if -- if it's written up in factory documentation in the hands of the factory personnel, a conservative assumption will be applied, such that they are allowed only if they're at sizes that are given as acceptable from a structures group.

You can get some more serious defects which each time that occurs, a structures analyst would have to get involved with the production engineers to decide with where it's located and what type of defect it is, whether or not it's acceptable or a repair has to be applied.

MR. MURPHY: Back -- back to that issue then, if we were going to be at the material level where Mr. Rackers was discussing, the coupons and the samples where you'd want to address these things, where you can have issues with clamping it in the fixture, cutting the coupon in the saw, what's used at that level to try and account for that variability in those coupons that are going to be used as the foundation for your building block?

DR. ILCEWICZ: Well, the -- the specific level that you're describing becomes one more of material control, that we want to ensure that the material that's being received and applied to the product is invariant over time and is what we expect it to be. So, there's a need for a material specification and requirements within that specification that help control and ensure that the material received is applicable and can be applied to the product.

More important data is developed at levels above that that consider the details that are going to drive the static strength and damage tolerance design sides of things, and a bolted joints database, for example, would be needed for attachments and -- and joints within the structure to cover that.

The relative magnitude of the two effects, there can be manufacturing defects that are as serious as bolted joints and -- and other design details within the structure, but oftentimes they are not as lowering in the strength of the structure as other things that -- that have to be considered anyways.

MR. MURPHY: Are the design strain levels for the -600R composite structure characteristic of that used in other transport category aircraft?

DR. ILCEWICZ: Well, I'm not intimately familiar with all areas of that aircraft, but from what I've seen in the certification documentation, the design strain levels that they are working their structure to is conservatively on the low end of what future Airbus and other aircraft that I'm aware of went to.

MR. MURPHY: I was going to ask you to summarize the static strength and damage tolerance for continued airworthiness, but I think you covered that in your opening questions -- questioning.

Let's -- how about -- are metal structures subjected to the same type of testing that you previously described from a static and fatigue test point of view?

DR. ILCEWICZ: In metals world, because they're not attempting to -- to demonstrate no growth and they would have to go to very low design strain levels to hope of being able to demonstrate that, it is not traditional for a metal structure to go through a fatigue substantiation and then follow that with a static strength demonstration.

The reason why that has become a standard in the composites world is because as we've gone through fatigue substantiation, we would monitor the damage that's present and we would realize that that damage is not growing and so that was one measure of no growth, but an additional measure of no growth is proving that that structure can still handle the static strength requirements and so that's why that is often done.

Now, that aspect of things and static strength is crucial. It's something that we all drive for with the 1.5 factor of safety as required by the regulations, but it is not complete in terms of structural substantiation. That's why we push for damage tolerance demonstrations as well, and we rely and work closely with what we demonstrate there with an understanding of what's possible in service and also a link with the maintenance organizations, so that they make sure that they find any damage that would degrade the strength below ultimate before that degradation could lead to below limit.

Now, traditionally in the metals world, damage tolerance evaluations involve crack growth, multiple site considerations, and I did quite a bit of that at the Boeing Company. Each company has different ways of dealing with it. The -- the ability to predict and the databases that support metals damage tolerance gives us the confidence that we can establish a relationship with defects that grow in -- in service loads with the maintenance organizations and make sure that that damage is found before a limit load is compromised and -- and so, composites are also subjected to the more serious damages for damage tolerance substantiation, and in most cases, composites also elect to apply a no-growth approach there, such that the same residual strength, even though below ultimate, can be retained even after cyclic loads through the course of an inspection interval.

MR. MURPHY: Okay. Let's move on into the area of non-destructive inspection. Where is NDI used for composite structures in the aviation industry?

DR. ILCEWICZ: Non-destructive inspections, such as ultrasonic techniques and -- and other methods that are appropriate for composite materials, are used in production. I think Bernd gave an example of how it's used in production with A300-600 aircraft.

It's also used in scheduled maintenance. If there is an aircraft structure that relies on NDI to detect the damage and work with the maintenance department, such that that type of technique is selected in the inspection scheme, then it could be applied for scheduled maintenance in that way.

It's also applied in scheduled maintenance for those that use visual inspection schemes, such that once the damage is first detected visually, the full extent of the damage is mapped out and understood using NDI, and then finally, NDI is also used in service for unscheduled maintenance, and there's several examples I can think of of unscheduled maintenance where some anomalous event that occurs to the aircraft outside of its design envelope. We've had incidences where an aircraft is too close to the end of a runway and there's some loose runway concrete, you know, sometimes very sizeable concrete that the engines rev up and send it into the tail section, and now even though there's visual indications of the damage, because of the nature of that loading and -- and that specific type of scenario not being considered as a design criteria or consideration for the structure, then you have to go beyond the visual indications of damage and look at what that type of loading might have done to cause damage in other parts of the structure that may not be visible, and so moving away from what's considered realistic threats in terms of what's applied for design, it's classified as what I referred to as an anomalous event that would be covered by unscheduled maintenance. Another example would be an overload outside the design envelope.

MR. MURPHY: Do you think that this factory NDI is capable of detecting all serious manufacturing defects?

DR. ILCEWICZ: Factory NDI on its own is not a foolproof scheme of catching all serious manufacturing defects and this is recognized within the composite industry. We rely on NDI as a means to confirm that things were cured properly or bonded properly but that cannot be the only technique applied. You have to have other rigorous quality controls. The best example I can think of relates to bonded structure. Because if some contamination had gotten into the bond line, years of experience has proven to us that NDI is not a reliable indication of whether or not there's a weak bond as we would refer to it, and so you have to have other quality controls in place that ensure, based on measurements within the factory and control of all the materials that come in contact with the structure as it's being fabricated, that the contamination did not get into the structure.

Now, as an added fail safety, an approach used for all bonded structure, and I'm distinguishing bonded from cured structure in that you have an element of the composite that has previously been cured out and now it's being brought into an assembly possibly to cure it with another piece of composite structure or bonded to another piece of composite structure that is either in a green state or an already-cured state, and now those bonded surfaces, you have to rely on there being no contamination at the location that that bond is formed.

If there is contamination, then you can get loss of bond strength over time. Now, what we've done in the composite industry for bonded joints is we have made them fail-safe, that we've desired and we've designed in oftentimes referred to as "chicken fasteners" or other design detail that would ensure that even if somehow contamination got into that bonded joint, the structure would still be able to carry limit loads and you would have been able to catch the problem through maintenance.

MR. MURPHY: Okay. What factors lead to the selection of a particular inspection scheme for maintenance of composite structures?

DR. ILCEWICZ: Well, it -- the particular inspection scheme selected by the manufacturer is often done in cooperation with the airlines. There's oftentimes a manufacturer -- excuse me -- a maintenance review board, and even before then, throughout the course of development, the manufacturer works with airlines and the inspection scheme is defined based on their experiences with structures that are similar or if they don't have a previous composite structure of that type, it's understood that the types of damages that come to the metal structure in the form of dents and so on could prove to be significant in a composite structure, and so there's a cooperation put forth, such that when the design is developed, the design is developed recognizing the desired inspection scheme, and if someone were to want to use a visual inspection scheme, which is characteristic of a lot of the damage threats and what's done within the industry, then you have to pay a penalty in terms of what design strain levels you can work to.

If you were to want to apply an NDI inspection scheme, you could get more aggressive in how much weight you could save, but there would be more of a maintenance burden on the airlines or maintenance depots to maintain NDI inspection of the structure.

MR. MURPHY: So, I'm going to try and summarize that for you, but if I say it wrong, please correct me.

For the same given structure, then what you're saying -- the same given structure, -- I'm going to stay away from that.

How does the selection of the inspection scheme for metals, metal structure differ from composite structure?

DR. ILCEWICZ: Fundamentally, they're essentially the same. There are decisions to be made in terms of what inspection scheme you're going to apply. You also have to have knowledge of what different types of defects will do in degrading the strength, and with those two pieces of information, you can make a judgment to make the structure more robust and enable inspection schemes that can range from visual into more complicated NDI, if you desire to try to move to higher stressor strain levels, and so that aspect is -- is very similar, but the types of damages you're concerned about in the metals world versus the composites world are uniquely different, not only in terms of threat but also in terms of the characteristics of the damage. In the composites world, as we described before, impact damage, there is no metals equivalent of that in terms of something that could degrade a compressive strength or a shear strength.

In the metal side, you're primarily concerned with a fatigue crack growth phenomena, and you define your inspection procedures knowing the growth characteristics of cracks, and in the composites world, you understand the thresholds of detectability and the damage stress from service, and you define your inspection procedures accordingly.

MR. MURPHY: It would be fair to say then if you -- if you choose to -- to push the -- push the envelope with your design and achieve the maximum out of the given material system for this composite structure, you know, the maximum capability from it, you'd be forced into an NDI, whereas if you stay away and work in a much lower level, you could use the visual inspections. I think that's what I've heard you say through the course of this questioning.

DR. ILCEWICZ: Well, I think it's -- it's not as simple as that in that NDI, as I had mentioned, is still used in scheduled and unscheduled maintenance, regardless of what's first used to detect damage, but in principle, it's -- it's very close to the way you've described it.

The one thing that I would like to add is -- I don't know if it's better to go back and try to illustrate it on that curve. I don't think Airbus has something -- while I'm drawing, I can talk. What I'm going to draw in this curve is I'm going to draw what -- what damage may be considered for a design that is using visual means to detect things, such as impact damage, and what would be the threshold of detectability for that, and I'm going to label that line something that would be forced to be applied as the appropriate strength parameter for an ultimate load level in the structure, and then I'm going to try to show the -- the 1.5 difference from that and associated for limit, and then I'm going to try to demonstrate or show a range of -- of damage sizes that are -- are possible as accidental damage events in real service.

Now, for -- for static strength requirement, you're looking at a need to consider and understand what damages bring you to this ultimate load level and make sure that all of that is covered in your static strength substantiation. Now, I've put here the full gamut of threats and this is an increasing damage size. So, obviously these are more likely to occur and these may become extremely rare.

Oftentimes this could be improperly-designed composite structure on -- on the order of a massive hole, you know, maybe 10 to 15 inches in -- in diameter or greater, but you're starting to approach the asymptote of the curve and even though those events are extremely rare, we have found that to occur in service and so you're making sure that damage that, you know, obviously can be found probably even in a walk-around without problems is still able to meet the requirement of limit load which is the highest load expected in service.

Now, if you were to become aggressive in this and try to apply an NDI approach, then, you know, sure, you could raise the level at which you would apply your ultimate load requirement for that. We'll call that ultimate with an advanced NDI scheme, but at the same time you've shifted that, you've also shifted that, you've also shifted your limit, and now your limit, you know, is conceivably going here, and under those circumstances, you don't have the same ability to maintain the highest load expected in service if you've now applied an NDI scheme and you've tried to increase the design strains you're going to work the structure to.

So, you -- you've to take this whole thing collectively in trying to make decisions as to which inspection scheme is the proper one to apply, and you have to realize and work with the airlines and operators on, you know, what has been found in service and through my course of time at the Boeing Company, anything that would degrade strength of this level and composites is, you know, a once-in-10-year-type event, but nevertheless, you still have to be concerned that those are possible and be damage tolerant in case they ever occur.

MR. MURPHY: I want to ask you about the -- the first AD that came out after 587. The FAA asked for a visual inspection and then immediately -- not immediately but then soon after that changed from -- from a visual inspection immediately following the accident to NDI in this past Spring.

Can you summarize why that -- why that change happened from one type to the other?

DR. ILCEWICZ: The -- the course of events immediately following the accident, it was not a whole lot of facts and data as we've shared throughout the course of this investigation available obviously at that time, and the first activity performed by the FAA was close communication with Airbus and whatever quick and dirty sizing or numbers we could run ourselves to try to understand what level of damage would be necessary before you would reach loads that are as high as expected in service and to the level where potentially a catastrophic event, such as the accident, would occur.

It was determined at that time because Airbus shared with us that they had designed their structure to be fail-safe in the lug attachments, i.e., they could completely eliminate one of the lug attachments and still carry limit load and there was other data available to them as well as our rough calculations, that we realized that a visual inspection was appropriate because it could be done very quickly. That was one piece of information that led to the visual inspections.

The other piece of information was the realization that a repair was performed on that aircraft and not knowing the full history of that repair, whether it was done in the factory or done in the field, we wanted to make sure that a repair of that magnitude was not characteristic of all airplanes in service and in the event that that was a possible contributor, and so the original advisory or airworthiness directive went out to -- to quickly inspect the fleet.

MR. MURPHY: We've talked about 90 -- Flight 903 throughout the hearing. Now, based on the Exhibit 7Q, that was the only aircraft after the inspections that -- that led up to the second AD had any findings and then that fin was not returned to service.

Could you tell me why that fin was not returned to service from the FAA's point of view?

DR. ILCEWICZ: Well, through the course of these meetings, there's been a number of testimonies describing the loads associated with 903 and other aircraft that we were aware of that were either in limit or higher, and what we had determined in the case of 903 and we had close coordination with American Airlines and Airbus throughout this, we had determined that that aircraft had seen above ultimate loads, but it had seen above ultimate loads to an unknown level, and I think this morning, you saw what was shown, that it was only a guesstimate as to how high the loads had gotten.

Now, if you go back to the incident in 1991 which is the only other aircraft in these group of aircraft that have been discussed and studied and supporting that AD, that particular aircraft saw just about ultimate load. The Interflug incident. Now, the difference between the two in terms of one being considered acceptable for airworthiness and the other one not is in the case of the Interflug accident, we had two pieces of information. One was that the highest load seen on that aircraft was just very slightly above ultimate. The other was that there was no NDI indication of damage.

Now, if you would go into Airbus's

certification databases, they had demonstrated that an aircraft could take the equivalent of two lifetimes, including load enhancement factor and double sequence of ultimate load, one after the first lifetime, take it for another lifetime and still be able to carry ultimate load. That gave us confidence that that tail could survive an ultimate incident in 1991 and fill out its entire life.

In the case of the accident in 1997, because we had an unknown load level that, as a conservative approximation could have been within one percent of failure. The decision was made that we do not have a database where that tail had been loaded to within one percent of failure and then taken for a lifetime's worth of load, and so the decision was made to remove it from service.

From what I understand, it's still available to us in the investigation and we can further study the effects of whatever was created in the 903 incident on retained residual strength and cyclic loads or whatever we desire.

MR. MURPHY: There's another series of ADs and the NDI inspections were required on the 319 and the 320 and the 321 aircraft as well as the 330 aircraft in this past year.

Could you give me the history behind the reason for that NDI and those ADs?

DR. ILCEWICZ: Those ADs come back to this phenomena that I referred to as weak bond previously. What had happened was there was mistakes made within the Airbus factories in -- in the materials used to manufacture the fin boxes on those aircraft and the -- the particular material in question was a peel ply which had release agent with it and that brought contamination to those bond lines.

The whole problem, as I had stated before, is not something that you can rely on factory NDI to catch. It's a contamination that we have put or relied in the composite industry on rigorous quality controls of the materials that are used and if somehow a problem still occurs, as it did in this case, there's a fail safety designed into the aircraft, such that it could accept large disbonds with those contaminated surfaces and still maintain limit load.

Those ADs were initiated by service bulletins by Airbus because their quality assurance did catch the problem, although the catching of the problem occurred after airplanes were put in service, and so they immediately sent out service bulletins stating the concern and a need to take all surfaces in question to a bolted repair within a stated amount of time and right on the heels of those service bulletins came Airworthiness Directive equivalents from the French side and then the U.S. side.

As far as this problem goes, the FAA's been very active in -- in long-term solutions to deal with a potential for "peel ply materials" to make it into the production and be used improperly as in this case, and since the time of -- of this occurrence and other known events with other airplane manufacturers, we've done research ourselves to work with the material suppliers, get their product labels changed and make sure that those types of materials aren't used in production or -- or ever allowed to get to production.

MR. MURPHY: Okay. Had you said that they'd all already been repaired?

DR. ILCEWICZ: Those aircraft have all been repaired at this point in time, I think, as of, oh, half to three-quarters of a year ago. So, the ADs themselves are obsolete. Within the ADs, it called out a need to perform NDI and -- and in a given amount of time go all the way to these bolted repairs, and so both were expected. The airlines and most airlines looked at that and said we're going to bypass the need for the NDI and avoid the cost of that and move directly to the bolted repair.

MR. MURPHY: One last question. It was only -- it was really only added because of the last exhibit that was added at the pre-hearing conference from American. So, what's being done with industry, government and government groups to -- to standardize maintenance procedures for composite aircraft structures in the areas of inspection and repair?

DR. ILCEWICZ: In roughly 1990, composites had been in -- in use for on the order of 10-15 years and there had already been accumulated a significant understanding of where issues and concerns were in terms of standardization and use of common materials between the major manufacturers and, you know, things that were of concern to all the airlines that they wanted to try to standardize and so the FAA initiated an activity together with OAMs and all the major airlines and it's an open activity through SAE. It's referred to as the Commercial Aircraft Composite Repair Committee, and in that organization, for the last 10 to 12 years, there's been very close coordination on a number of working groups and things that need to be standardized, and we support that to -- to a large extent with our -- our workforce coming to the meetings and making sure that there's a regulatory voice in the directions that they go in their standards, and in -- in addition to that, there's another organization that I am co-chairman for, called MIL Handbook 17, that was referred to earlier, and again that's an international organization.

It has a supportability side to it that's coupled with the CACRC activities, and what the goals of both those organizations is to -- to move to common practices and be in position for these increased applications of composites that appear on the horizon.

MR. MURPHY: Thank you very much, Dr. Ilcewicz.

Madam Chairman, that concludes my questions.

ACTING CHAIRMAN CARMODY: Thank you.

Are there other questions from the Technical Panel for the witness?

(No response)

ACTING CHAIRMAN CARMODY: All right. Moving then to the parties, I will start with the Airbus. Oh, I'm sorry. One more question from the Technical Panel, Dr. Kushner.

DR. KUSHNER: Yeah. Hi. Thank you.

Are composites typically stronger in tension or compression?

DR. ILCEWICZ: Composites are traditionally known to be stronger in tension than compression, although you can find examples where that's not always true, depending on specific design detail and design considerations.

DR. KUSHNER: Okay. And from a certification perspective, you talked about the building block approach. What are the things that you looked at as you move up each level to show consistency with what was learned at the lower levels?

DR. ILCEWICZ: It's not a highly complicated activity. The programs that are most successful have a very close association between what goes on in the factory and what goes on in structural substantiation, such that those two groups are -- are coordinated very closely how it all comes together.

At the lowest stage, you're wanting to ensure that you've got proper material controls because those are usually the types of tests that you use to prove variance with the material coming into your house for production.

At the next highest levels, there is design details that are common of a lot of the acreage areas. Most areas have to have allowances for repair, have some form of bolted joints. There's a lot of stiffening elements that will look at crippling and other modes of failure, and so there's quite a bit populated at that level, and usually what would be done is, you know, some portion of that would form an additional statistical basis for design values, and anything that's done at higher levels where it's not practical to generate a whole lot of repetitive testing, you will normally take a conservative approach based off of whatever's generated at lower levels that has the closest failure mechanism to what's being observed at the higher levels.

DR. KUSHNER: Thank you.

ACTING CHAIRMAN CARMODY: All right. Moving then to Airbus, Dr. Lauber?

DR. LAUBER: Madam Chairman, Airbus has no questions for Dr. Ilcewicz.

ACTING CHAIRMAN CARMODY: All right. American, Mr. Ahearn?

MR. AHEARN: Thank you, Madam Chairman.

Just a couple, Dr. Ilcewicz. Prior to the 587 accident, had you ever seen a composite lug joint of this size in an aircraft application?

DR. ILCEWICZ: Not -- not in the detail that I have since. I was aware that these existed on Airbus aircraft and so I was aware just from being in the industry.

MR. AHEARN: Do you have any sense of, with your experience, as to how you would describe the application?

DR. ILCEWICZ: The application, from what I understand, was something that was done over a long period of time with careful judgment by all parties involved on, you know, what is the right way to design a structure of that character and it's every bit as comprehensive as what you would find for lugs in metal structure, plus some additional conservatism.

MR. AHEARN: Okay. Let me -- let me draw upon some experience that you've had in your previous life at Boeing, if you will. You've seen single point or single load points as you see in the Airbus and you've seen the fastener patterns used with smaller fasteners or small lugs.

In your estimation, which do you believe are more -- or which efficiently more distribute load?

DR. ILCEWICZ: We get into a design philosophy, especially going into my past experiences with the Boeing Company. I'm not allowed to get into that type of a discussion. I hope you would understand that my past background at Boeing is --

MR. AHEARN: Certainly.

DR. ILCEWICZ: -- supposed to have been left behind.

MR. AHEARN: Okay. Let's move on. You've -- I believe you were here earlier for the previous witness testimony, Mr. Rackers, and you've heard testimony about the design of the lugs to match the pre-existing attached clevises. You also heard him state from a designer's perspective, you could build it stronger.

Do you believe there's an advantage or disadvantage when you design to a pre-existing attachment clevis design scheme as they did with the B2B4 to the 310-300?

DR. ILCEWICZ: I think if you were to look into the details of that and the next witness is going to be the best one to answer that specific question, you may realize that if they were to change the design, it may even go in the other direction in terms of what they had to do in order to make sure that it still had the same geometry and ended up leading to margins that were quite substantial in the case of that lug.

MR. AHEARN: Okay. Well, then I'll -- we'll defer that question for Dr. Winkler.

Those are all the questions I have, Madam Chairman.

ACTING CHAIRMAN CARMODY: Allied Pilots,

Captain Pitts?

CAPT. PITTS: Yes, ma'am. Thank you.

Good afternoon, sir. Earlier, you made the statement, Airbus is on the conservative low end of the composite standards. I didn't understand what you meant by that. Could you expand on that?

DR. ILCEWICZ: I believe the question related to what design strain levels is the structure being worked to, and usually when you use that kind of terminology, you're talking about the structure away from concentrated attachment points or access holes. You're talking about structure that's the acreage-type structure and that structure usually gets driven by compression and -- and oftentimes that compression shear interaction because there's a torque on a torque box together with the fully reversed loads on either side of the fin can be tension or compression, and so a design strain level to deal with impact damage on different panels usually becomes one of the design drivers for an aircraft structure and the strain level that they were applying in their case is -- is quite low relative to other that I'm sure they have pursued over time as well as any other structure that we're seeing out in service.

CAPT. PITTS: Then does that relate to an overall lower capability to --

DR. ILCEWICZ: No. That's what I was hoping that -- lower design strain levels mean, you know, again let's -- let's go back to a curve of, you know, what -- what strength you're expecting out of this structure. If you make the strain level that you apply for design ultimate load, let's say a 0035 or something like that or 0032 or whatever, then the limit strain level's going to be, you know, a 1.5 division off of that. If you were to apply a higher design strain level for ultimate, let's say a 004 or 005, then the strain level that you would be working the structure at at limit load would be higher still and everything tends to go up, including the strain levels. You're working fatigue loads on the structure,too.

CAPT. PITTS: Okay. Thank you for clarifying that.

I'd like to talk about this limit load value just a little bit.

DR. ILCEWICZ: Sure.

CAPT. PITTS: And I understand that you're a materials and structure expert, not necessarily a regulatory expert, but you do speak for the FAA. Now, the FAA takes a systems safety approach to design of equipment, and I'd kind of like to frame the question in that light.

Now, just for the edification of all, in a systems safety approach, we're going to consider the design concept, the design itself, the operation. It's cradle to grave. Is that your understanding?

DR. ILCEWICZ: Correct.

CAPT. PITTS: We look at it in operation. So, we've heard a lot about this limit load and that it has -- was designed to a value and it met the standard. Now, in reviewing that, it speaks to when designing an aircraft, it is necessary to determine the highest load that can be expected in normal operation under various operational situations.

Now, you have a design in operation and now you become aware of the fact that in your normal operation -- operational conditions, you're exceeding limit load, and it's not one of your examples, but I think you probably -- one of your exhibits, but I think you probably saw the -- the citations in -- in 7Q, I believe it is, where there's seven examples of this design exceeding limit load.

Now, once we are aware of that in an operational end use in-service sort of perspective, where are we relative to the -- to the FARs and meeting the regulatory spirit and intent? In other words, we are exceeding limit load in normal operations or under various conditions. What's supposed to happen?

DR. ILCEWICZ: Well, I'm going to have to take the -- the discussion back to my world of expertise which is going to be safety and relationships in the composite world. Much of your question is -- is focused on loads, and so I'm going to leave that behind, but nevertheless, one of the reasons why we designed structure to be good to limit times 1.5 is because we realize that there can be anomalous events that would take us both limit load. That's one of the reasons. There are many other reasons.

Brian has asked me a series of questions as to why we do ultimate static strength substantiation, why we also do damage tolerance. Those two tend to balance things, and if I ever try to explain what I'm doing to my children, what -- what I'll sometimes try to do, you know, in that analogy is I look at ultimate load as an extremely essentially near-impossible load level, you know, per the way that the structure has been designed because it's a 1.5 factor off of the highest load expected.

Now, for that, I want to be good for damages that are possible in service because I'm getting safety out of this factor of safety. Now, in the case of --

of limit load, we know that there are anomalous events or -- or damage states that can occur which is why we inspect airplanes in general that can degrade the strength occasionally below ultimate, so that that full factor safety is not achieved on, you know, individual case-by-case rare events, but we still want to maintain a limit load capability or a certain amount of fail safety, you know, going back to old language, for those rare damages that may degrade strength to that level because that is closer to what is expected in service.

CAPT. PITTS: Right.

DR. ILCEWICZ: And so, those two tend to be a balance. In both cases, you're getting safety out of still being good for extremely rare events.

CAPT. PITTS: I followed your discussion in terms of damage, but in an undamaged structure, operationally in use, service record shows that the value used to determine the limit load is being exceeded. What would be the intent of the regulation at that point?

DR. ILCEWICZ: The -- the definition of limit has been changed from a structures analyst perspective, and we have not designed the structure to accommodate for that, and so it's hard for me to answer your question without going into an area that -- that I am not a specialist in.

CAPT. PITTS: I understand. Well, since the expectation of the limit load is the highest load factor that we expect to see and we do in fact then begin to see it in operational service, as a structures expert, would that not cause you to begin to reconsider whether that load, that load limit value is accurate?

DR. ILCEWICZ: Again, you're asking me to -- to try to influence things that are out of my control and expertise, and I don't care to comment on that.

CAPT. PITTS: And so, from your review of it with your structural perspective, if field service information came to you that -- that highlighted exceeding limit load, you would consider that outside of your expertise to comment on in relationship to ensuring the airworthiness of a structure?

DR. ILCEWICZ: Well, from what I know and what we do in composite structure, I have confidence that a large majority of the composite structure out there maintained properly would still be in good shape. We don't have known fatigue damage growth mechanisms for the strain levels we operate at. So, that becomes something that gives me a certain amount of confidence. However, it's still something that being outside the design envelope is something that, as a stress analyst, it makes me uncomfortable, and I would like to see the investigation move in the directions such that we solve that problem and we don't have that occurring to aircraft.

CAPT. PITTS: All right, sir. How many times have you seen load limit exceeded in an aircraft structure?

DR. ILCEWICZ: Well, I believe looking at the issues of limit load through my experiences in the industry, occasionally that can be exceeded and it's usually an event that has brought attention to the operations people, the crew, and they will react to that and it will be reported and dealt with accordingly.

CAPT. PITTS: Would that include such things as identifying a prohibited maneuver or a system operating limitation, that sort of thing?

DR. ILCEWICZ: I would not be able to answer that from my background.

CAPT. PITTS: All right, sir. I'm going to shift the questions. I have two final questions.

In high load conditions, do loads redistribute in the metal assembly like they do in a composite assembly? You may have already answered that, but I -- I didn't -- didn't stay sharply focused there.

DR. ILCEWICZ: When -- when you look at the way in which metals fail and composites fail, a fundamental difference exists in that metals will start to yield and move towards a strain hardening phenomena, whereas in composites, they start to fail and they move towards the strain softening behavior, and I realize that different words are often used for that, but fibers will start to break, the weakest fibers. Delaminations and matrix cracking will occur and that effectively softens the zone immediately adjacent to where the high stress is coming from. That softening is something that behaves somewhat in the same characteristic as a yield zone in metals, although the characteristics are -- are uniquely different in composite, not sensitivity, can be distinctly different than metal.

So, for example, in metals, they're more concerned with the sharpness of the defect in a crack, whereas in a composite, if it's a hole or a crack, there doesn't tend to be much difference because the softening tends to create much the same redistribution and behavior.

CAPT. PITTS: All right, sir. Thank you.

And this final question, calling upon your entire experience in the aviation industry, not specific to any employer. In your experience, how common is it for a vertical stabilizer to exceed the ultimate loads in operation?

DR. ILCEWICZ: Before this accident, I was unaware of that ever occurring.

CAPT. PITTS: So, when choosing ultimate in the future, should it be higher -- a higher standard for composites, in your opinion?

DR. ILCEWICZ: I don't believe that has any association. Composite is -- is not the function that relates to higher loads.

CAPT. PITTS: It's -- the concern would be the -- the loads of the composites were designed to -- to meet?

DR. ILCEWICZ: Right.

CAPT. PITTS: All right, sir.

DR. ILCEWICZ: If you -- if you take metal or composite well above limit loads, you -- depending on your design, you're moving outside the design envelope in both cases, regardless of what the material is.

CAPT. PITTS: All right. Thank you very much, sir.

Thank you, ma'am. I have no further questions.

ACTING CHAIRMAN CARMODY: The FAA, Mr. Donner?

MR. DONNER: Thank you, ma'am. Once again, no questions.

ACTING CHAIRMAN CARMODY: Yours have all been asked, I believe.

Anything from the Board? Member Hammerschmidt, questions?

MEMBER HAMMERSCHMIDT: No questions.

ACTING CHAIRMAN CARMODY: Member Goglia?

MEMBER GOGLIA: I just have one question.

I'm curious. Have you ever seen -- I'll use the term that we -- we would use on the ramp all the time -- wrinkled skin on the airplane?

DR. ILCEWICZ: Yes.

MEMBER GOGLIA: Are you familiar with that term?

DR. ILCEWICZ: Yes.

MEMBER GOGLIA: And in my past, I've seen airplane fuselages with severe wrinkled skin. Where do you think that would fit on this load -- in these loads categories we're talking about, design load, limit load, ultimate load? Was it approaching ultimate load?

DR. ILCEWICZ: Conceivably, it's -- it's above limit and approaching ultimate, right. The regulations require that the structure can accept limit load and not permanently deform. In the composites world, we don't want to see matrix cracking occurring at that level or any permanent set occurring.

MEMBER GOGLIA: Okay. Thank you.

ACTING CHAIRMAN CARMODY: And Member Black?

MEMBER BLACK: Just a quick one. As a B-52 maintenance officer, believe me, I've seen wrinkled skin.

The -- I guess this question might not -- might be out of your area since you're primarily, it sounds like, a design person, but do you believe we have adequate tools and technology to conduct periodic maintenance and inspection after events on composite materials in the industry in the United States?

DR. ILCEWICZ: Yes, I believe we do. One of my job functions is as the world of composites continues to evolve and it will, there's -- there's little doubt of that from where I sit, I've got plenty of work on my plate, that I have to continue to stay on top of new technology in the manufacturing and materials world and ensure that I understand for these advances what are the most critical defects and how can they be detected in service, and the way that I've approached that, together with the FAA Composite Team of people that I work with closely, is to make sure that we're in close cooperation with airlines and operators and be in a position where everything and anything that is found is brought to our attention and it's recognized, such that we can apply that to the new technologies and make sure that it isn't an Achilles heel. It's not being considered in design.

MEMBER BLACK: Thank you.

ACTING CHAIRMAN CARMODY: Mr. Goglia?

MEMBER GOGLIA: I'd like to go back to follow on to that. I have -- I have a concern in my own mind. When I put myself back in the ramp and I think about the American Airlines 903 airplane, we now know, we now realize this airplane exceeded -- moved out into territory that was unknown.

How are we supposed to -- we, the maintainers, we, the engineering department, how are we supposed to know in composites that we've moved off into this area? I touched on it just a little bit. The wrinkled skin is always a good clue in conventional airplanes that you've done something that you shouldn't have done.

DR. ILCEWICZ: Right.

MEMBER GOGLIA: You know, how are we going to maintain airworthiness in the fleet, you know? Mr.

Charbert, you and I have in different roles, we have the job of ensuring airworthiness.

How are we going to ensure airworthiness when we can have damages to composites or other new materials that remain unseen and we don't have the ability to determine if they've gone over a certain threshold?

DR. ILCEWICZ: Well, John, I think that the best way for that and usually when you get to the "wrinkled skin condition" or the gravel example of the large concrete, there's at least some visual indications of something occurring, but in the case of 903, that went to very, very high load levels without, you know, a visual bend or deformation, and in that particular incident, there was an accident. In fact, a passenger was seriously injured, and what we know today in terms of extreme lateral loads, I've got extreme confidence that an event like that would never occur again without there being a thorough inspection before that airplane is put back in service.

Similarly, the other case of getting such high loads, the Interflug incident was a very severe ride. I've seen the simulations of it and it was intense in terms of what the passengers went through. So, we knew that happened from an operations standpoint, but there has to be the communication and the realization that, all right, I have exceeded my design envelope and now I'm out of the world of scheduled maintenance and I'm into the world of unscheduled maintenance, and the only way that comes is through close communication like we're doing in the CACRC with the maintenance people but also the operations people, so that if somebody drives a service truck into the side of a composite aircraft and gets out and, you know, realizes he hit it pretty good, that he's not in a position where he just turns around and walks away without letting people know that that has happened and so that it can be dealt with accordingly.

MEMBER GOGLIA: You kicked over a can of worms with that one. Given -- given the state of airline management today, actually because of their discipline policies, they actually encourage what you just said. Somebody, especially a baggage -- ramp service man, third party provider for services, would take a look at the airplane and say, well, yeah, I hit it but it's not damaged, and I'm not turning myself in and take the punishment.

DR. ILCEWICZ: Well, that's -- that -- that is why in our "threat assessment", we hammer on these things until visibility is evident, but in -- in the case of something such as that, we also install what we refer to as fail safety which, once you got into a more detailed inspection, even if they want to believe that it's not there, we still have fail safety and we still have sufficient damage tolerance to survive those types of events and still carry the loads.

MEMBER GOGLIA: What has changed today that would make the 903 event rise to the surface before the airplane was returned to service? Are we -- are we going to pull the flight data recorder after every report of turbulence event and wait until it's analyzed at some distant location before we return it to service?

DR. ILCEWICZ: Well, in the case of those specific airplanes, there's an airworthiness directive that's been active since March and this whole purpose of that was not only to catch things of the magnitude of 903 but things conservatively less than that, and in all of the inspection that was performed to support that activity, we understood that that was a conservative lower limit that we've put into that airworthiness directive.

MEMBER GOGLIA: And in that, I have not seen the AD.

DR. ILCEWICZ: It's one of the exhibits.

It's called "Extreme Lateral Loading".

MEMBER GOGLIA: Okay. I have seen the heading.

ACTING CHAIRMAN CARMODY: Is there another question or are we having a conversation?

MEMBER BLACK: I would look at it carefully. Are we doing that on all composite tail airplanes or just the Airbus 300-600?

DR. ILCEWICZ: The AD is directed at the A300-600 because of the history that was uncovered in our investigation with Airbus.

MEMBER BLACK: So, that means if we had a 777 that was involved in some sort of a lateral event or a yaw event, we wouldn't look at it?

DR. ILCEWICZ: I don't believe that's the case. I believe the 777 is also familiar with this accident or any of the events surrounding this accident and it is understood within the aviation community. The key is that when you've taken things outside of the design envelope, that that falls under descriptions that relate to unscheduled maintenance and that type of -- of loading event is something that maintenance manuals will acknowledge and bring forth an investigation and communication with the OEMs on it.

ACTING CHAIRMAN CARMODY: Thank you for your response.

Is there anything else from the Tech Panel? Any questions of this witness?

(No response)

ACTING CHAIRMAN CARMODY: How about the parties? Any questions from any of the parties of this witness?

(No response)

ACTING CHAIRMAN CARMODY: Well, then our thanks, Dr. Ilcewicz. I'm sorry for mispronouncing your name. Thank you for your testimony. It was excellent and you made things very clear for us.

(Whereupon, the witness was excused.)

ACTING CHAIRMAN CARMODY: Why don't we just take a short break, maybe 10 minutes, and then we'll have Mr. Winkler next.

Thank you.

(Whereupon, a recess was taken.)

ACTING CHAIRMAN CARMODY: Ms. Ward, would you proceed with the next witness, please?

MS. WARD: I'd like to call Mr. Erhard Winkler and to assist him with translation will be Mr. Rackers. Please raise your right hand.

Whereupon,

ERHARD WINKLER

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

MS. WARD: Thank you.

Mr. Winkler, could you please state your full name, your present employer, and your business address?

MR. WINKLER: Yes. My name is Erhard Winkler. I am employed at Airbus Hamburg, Airbus Germany in Hamburg.

MS. WARD: And what is your present position, and how long have you been in that position?

MR. WINKLER: My current position is Composite Specialist, and I am in this position since middle of last year.

MS. WARD: Could you briefly describe your duties and responsibilities and any education and training that you have received to qualify you for this position?

MR. WINKLER: Yes. My duty is -- is technical advisory to Composite Development in Germany for Airbus, and I started working for Airbus in 1976 as a stress engineer, and I was directly in composite research. In 1978, I became a member of the Development Team of the A310 and A300-600 composite tail development up to 1985. I was during this time responsible for the finite element analysis and also for the test principles, including the full-scale test.

From 1985 up to 1995, I was responsible for analysis method for composite materials and also involved in the development for the vertical tail for the A320 and A340. In 1995, I became a team leader for the development of the new fin for the A330-200 and my responsibility was the full justification of the structure, including the certification.

In 1998, I became a team leader -- sorry. Department leader for the rear fuselage and fin, and in this position, I was responsible for the development of the rear fuselage, including the rear pressure bulkhead from composite materials and the fin for the A340-500 and 600.

MS. WARD: Could you also state your education?

MR. WINKLER: Pardon?

MS. WARD: Your education?

MR. WINKLER: My education is I have a Master's Degree in Aeronautical Engineering from Technical University in Braunschweig, Germany.

MS. WARD: Thank you, Mr. Winkler.

Madam Chairman, I find this witness qualified and now pass it over to Mr. Brian Murphy for questioning.

EXAMINATION

MR. MURPHY: Still good afternoon. I don't have to say evening.

Good afternoon, Mr. Winkler. I'd like to discuss the -- is this -- can you hear me? The following topics with you. The design and construction of the -600R vertical stabilizer and rudder, the certification of the vertical stabilizer and rudder, NDI and visual examinations, the 587 and 903 structural assessments, and then Dr. Fox would like to speak to you about the fracture features of the accident lugs and some -- some test lugs, I believe.

I also -- Madam Chairman, Mr. Winkler has also prepared some overview material and he'd like to present that for us at this time.

ACTING CHAIRMAN CARMODY: Yes, please.

MR. WINKLER: I would like to -- like just to present an overview on the vertical tail design, the certification approach, inspection procedures, then something about the participation of the investigation of the accident concerning structure, and will finish with a structure overview and a general summary.

The most important thing for an aircraft structure is that it is strong enough to resist all load conditions as required by the FAR-25. Because the vertical stabilizer is fabricated from composite material, compliance has to be provided according to the guidance material AC-20107-A which is related to the application of composite materials for primary aircraft structures.

The structural design and the sizing process depends on the load conditions. The loads analysis provides loads envelopes for lateral maneuver and gust at certain sections along the span of the vertical tail in terms of shear force, bending moment and torsion moment. The figure shows the envelope and peaks over Mz at the root of the fin. For selected conditions, the Loads Department provides then the aerodynamic pressure and the inertial loads distribution in chord and span-wise direction which is then used on the finite element model to calculate the interior loads.

The response to these external loads which are -- sorry -- which are composed from aerodynamic loads and inertial loads are applied to the -- to the fin box and is causing interior loads in terms of contention and compression loads on the skin panels, including shear, and on the other side, an example is shown for -- including the spar caps.

At the bottom of the fin, these interior loads are reacted to the fuselage. This is shown on the left-hand side, bottom left-hand side in terms of the lateral load Fy and two components, normal to -- to in direction of the flight direction, Fx, and normal to the plane which is given by Fx and Fy in direction of Fz, and additional two moments of around the Xz and the X.

The fin and rudder design. The fin -- the vertical tail is composed from the rudder and the fin box. The fin box is the major part which transmits the loads from the rudder via the box to the fuselage. The fin box itself is a monolithic structure assembled from two skin panels, 18 ribs, and three spars. The skin panels are composed of skin panel of -- of laminate which is reinforced for bending stiffness by 24 stringers of double-T section.

At the lower end of the skin panels on each side are six attachment -- on each side are three attachment fittings and some six arranged to be attached to the fuselage. The rudder is a sandwich construction which is assembled from a left-hand side and the right-hand side flat skin panel and the front spar which builds up a triangular section which is closed on top and bottom by ribs. It has a leading edge, an additional tip, and seven hinge fittings from aluminum alloy.

Concerning the design, the structure, the skin has no unusual features, and from -- therefore, it represents the state of the art concept. The fuselage attachment fittings at the lower end of each skin panels are composed from an interlock and an outerlock which is bonded together by the wet skin during the autoclave process. These fittings provide the necessary strengths for the attachment of the fin to the fuselage and fabricated from more than 200 plys each. They provided smooth transition of the attachment loads to the reinforced skin.

The certification basis of the structure is FAR-25 for the rudder up to Amendment 41, including the Amendment 45, for the Damage Tolerance Paragraph 571 and the Advisory Circular from the FAA, AC-20107 in the first edition from 1978. For the fin box, the FAR requirements are up to Amendment 44, and for related to composite material, we have to apply the STPA Note, Technique 1804, Edition 2, which is the European equivalent at that time for the FAA Advisory Circular 20107-A from the first revision from 1984.

The design of the fin box and the rudder of the A300-600 meets or exceeds all certification standards in both -- in the United States and Europe.

After the harmonization of the certification standards in 1981, subsequent type certifications through joint U.S. and European processes has been done since this period.

The certification of the composite structure has been validated by over 40 million flight hours of experience by Airbus aircraft. The certification is mainly supported by the structural testing. We have seen this testing pyramid before in the presentation of Bernd Rackers. The upper part is related to non-generic specimens which are directly linked with the design of the A300-600 vertical stabilizer. The detailed tests and subcomponent tests are used to generate design allowables and also to validate finite element calculations which are compared with the measurements during the subcomponent testing.

The proof of structure is based mainly on design criteria which are locked to assure the structure -- that the structure will withstand all critical environmental conditions, and we have chosen loads design strain level in order to minimize the impact damage effects. The static proof of structure has been done by demonstrating ultimate loads, taking into account the most adverse environmental conditions. The ultimate loads have been tested after fatigue loading and the test article includes impact damage up to the visibility threshold and it has been shown that the structural strength has not been degraded below limit -- ultimate load requirement.

The proof of structure fatigue damage tolerance has been done -- has been demonstrated through testing with artificially-damaged structure, including manufacturing anomalies and in-service damage. Permitted manufacturing anomalies and accidental in-service damage do not propagate in fatigue and this called the no-growth concept.

The full-scale test is divided into two sections, the fatigue justification and the damage tolerance justification. Both sections were done by cycling of a wet structure in an environmental chamber. The first what has been applied were tolerability defects at artificially-damaged and repaired solutions to the test article. After doing this, a pre-test to 80-percent limit load has been performed and the cycling after 49,600 flights which was finished with the stiffness check to compare with the finite element calculations. Then we have further cycling up to 67,600 cycles which was conducted under hot wet conditions and finished by an ultimate load test.

The next step was the introduction of very large damage for the damage tolerance justification. After the introduction of these large damage, visible damages, we conducted a limit load test, and after this, up to 120,000 cycles, the fatigue and damage tolerance justification for this damage and also to validate the no-growth concept.

At the end of this phase, we conducted an ultimate load test under hot wet conditions. The structure sustained these loads without damage and after these tests, the discreet source demonstration has been performed by introducing large damage caused by auto burst. For this demonstration, we used 40 percent limit load for the gust condition and 70 percent for the lateral maneuver condition. This test -- after these tests, the structure was repaired only at the auto-burst damage, and the rupture test was then conducted under hot wet conditions up to a level of 1.3 times limit load for corresponding to the loads from A300-600R.

So, in summary, we have conducted two times ultimate load test on the structure and several times lower test for stiffness check and finally the rupture test up to a level of 1.93 times limit load.

Concerning the discreet source damages, we have two scenarios justified. The first one is the single lug failure. This has been done by analysis and by conducting supporting center lug test. For the other conditions concerning the attachments, this has been done by analysis and by using the achieved stress level form of the full-scale test at 1.93 times limit load.

For the APU auto burst scenario, an artificial cut of about 14-inch length has been applied at the upper center area designated with the .2. There's a skin panel and a rear spar cap. The structure's initial quality control is performed during the manufacturing process until the delivery status of the structure to assure that all parts have no unacceptable internal anomalies. The in-service inspection is -- takes only non-destructive testing inspection into account for -- to assess any visible damage or in case of the certificate loads are exceeded.

The contribution Airbus did to the structural investigation is mainly done by finite element analysis. We are using this model, what is shown here. It's a very detailed model which is able also to address failure scenarios to the rudder because we are able to predict attachment bolt loads on the fittings which are attached at the rear spar and the spar of the rudder itself. It is -- has 95,000 degrees of freedom and is used to calculate the encountered load levels which are provided by the Loads Department. We had seen this picture in the morning from Mr. Curbillon. We have certain scatter pattern of loads in which the load level is -- has been calculated, and the four conditions which have been analyzed are shown here by the external loads, the bending moment, torsion moment and the shear load, and for these four load cases, also the resultant load, which is applied on the tail rear right-hand center, the right-hand lug, on -- on the accident aircraft is shown on -- in the lower -- lower line, starting with 82 tons and ending up with nearly 95 tons. We can say that the computed loads from AA-587 are at rupture level compared to the full-scale test result.

I want now to finish with the structure overview. The vertical stabilizer and rudder comply with the requirements of FAR-25. We have shown, demonstrated that non-visible damage will not call for the operational life. We have also demonstrated that visual inspection is appropriate because the structure is designed with a very low design strain level, and the outcome of the analysis concerning the accident is that strains and forces calculated for AA-587 loads are at the level of the rupture where you obtain from full-scale test.

Concerning the other domains which participated in the investigation, we have concerning materials, there is no evidence up till now of material deficiencies in the AA-587 fin. There is no evidence of a system failure during the flight, and the fin has tested up to a 193 percent of limit load which is well in excess of the requirement, and the Flight 857 was subjected to loads at rupture level.

Thank you very much.

MR. MURPHY: Thank you, Mr. Winkler.

Regarding the presentation, you mentioned that you did the fail-safe analysis on the right rear lug. Assuming the right rear lug failed and then followed up with a subcomponent test on the center lug, analytically, did you consider each lug failed individually and worked through the fail safety analysis?

MR. WINKLER: Yes. Yes, that was done. The most critical situation for the failure of -- of the rear lug.

MR. MURPHY: Okay. Thank you. That was the decision for the choice. Thank you.

The slide that shows the four -- the four load conditions that -- that were -- where loads had been developed, have you had a chance to analyze all of those conditions to date?

MR. WINKLER: Yes.

MR. MURPHY: Okay.

MR. WINKLER: We -- we applied this load on our finite element load or do you -- do you reflect to a special lug analysis?

MR. MURPHY: No. Just have you had a chance to look at them with the finite element analysis?

MR. WINKLER: Yeah.

MR. MURPHY: Okay.

MR. WINKLER: The result of -- the resultant load is the outcome of the finite element analysis.

MR. MURPHY: The resultant loads, yes.

MR. WINKLER: Yes.

MR. MURPHY: Okay. You haven't then -- what I'm -- what I'm driving at is, it was stated earlier that the Condition B-375 corresponds most closely to the bang heard on the CVR according to Mr. Curbillon and Mr. Kerlin, and what I was interested in is you haven't done the detailed solid -- the exhibit is 7BB, I believe, is your solid model, your solid detail.

MR. WINKLER: Yes.

MR. MURPHY: Have you had a chance to analyze other load cases than those shown in the exhibit to date?

MR. WINKLER: No. Up to now, not.

MR. MURPHY: No. Okay. And I'm correct in assuming then that what your -- the plan will be to analyze that at a future date and use that detailed finite element analysis to correlate with the existing subcomponent and full-scale tests that are available? Data that is available? Okay.

You will use that model with the additional load cases that have not been analyzed to date --

MR. WINKLER: Yes.

MR. MURPHY: -- to go back and compare with your full-scale and subcomponent databases?

MR. WINKLER: That -- that is what we intend to do with this model.

MR. MURPHY: Okay.

MR. WINKLER: We want to correlate. I think the model is -- is so -- is capable to -- to -- to analyze the -- the failure sequence of this lug, and we want to compare the component test with the full-scale test and also with the failure scenario on the 587 to -- to -- to validate the -- the -- the load level is -- is at rupture.

MR. MURPHY: Okay. Regarding the design and construction of the -- of the stabilizer and rudder, there's been some discussion about the -- what the -600R, 310-300, vertical fin was intended to be used for. Was it ever intended to be used on the B2B4 aircraft?

MR. WINKLER: No.

MR. MURPHY: No. Okay. Got that cleared up. Are the VTP and -- and -- I'm sorry -- the vertical stabilizer and the rudder common to the -600R only?

MR. WINKLER: No. It's -- it's on the A310-300 and on some other aircraft which were built after -- after the certification of -- of the A300-310-300. Because we stopped at a certain point, we stopped the fabrication of metal fins, so there are some other 600-type aircraft and 200 -- 310-200 aircraft which are fitted with -- with these stabilizers.

MR. MURPHY: Okay. So, never for the B2B4 and maybe -- I believe it's all of the -600Rs have the tail and then --

MR. WINKLER: Yes.

MR. MURPHY: -- all of the 310-300s --

MR. WINKLER: If you want to know the exact, I have --

MR. MURPHY: Yes. If you have that, because it's been a topic of discussion several times here today.

MR. WINKLER: These are the aircraft which -- which differ from -- from the A310-300 and -- and A300-600 which are fitted with -- with composite vertical stabilizers.

MR. MURPHY: Really, it looks like nine plus five, real quick. So, only 14 aircraft outside of the 300 fleet and the 600R fleet have -- have a composite tail?

MR. WINKLER: Yeah. That's right.

MR. MURPHY: Okay. Could you provide a more detailed description of the VTP, the fuselage-attached structure?

MR. WINKLER: Yes, I can. I have some -- some slides, if it's --

MR. MURPHY: Whatever makes it easier.

MR. WINKLER: On this figure, you can see the lower end of an A310-300 or maybe it's the same -- the same fin also as applied on the 300-600, where you can see the bottom closure rip and the lugs, the lugs which are extending below this lower rip on both sides. That is the front lug, center lug and the rear lugs, and also the -- the lugs are -- the lateral shear lugs are visible from the front spar, rear spar and center spar.

You see here a sketch of the rear lug. It's

-- you see it cross -- the cross section below that is -- is a cut directly to -- through the skin and you see the transition of -- of the outer and the inner pre-cured lugs to -- to the skin. The main lugs are built from two pre-cured multilayer composite parts which are joined by a co-bonding process with a skin laminate between and the stringer run out on the inside during the autoclave processing of the integrated skin panels.

The shear fittings are built by reinforcing the basic spar rep laminate with the variety of layers. Each fitting has spherical bearings accommodate -- which accommodate the lateral yokes. The counterpart in the fuselage is a forged aluminum alloy fork-headed fitting which accepts the main lugs. The connection between the fin and fuselage, main fittings is provided by an expanded tapered bolt sleeve which is coated by a bond layer. You can see on the bottom part of the figure the components and on the top the assembled bolt which is secured by castellated nut and the cotterpin.

The purpose of the fin to fuselage attachment is to provide a reaction for the aerodynamic and inertial and mass loads resulting from lateral gust and maneuver inputs. The main lug also are transmitting the loads equivalent to the bending moment, the torsional moment, the skin panel shear flow and the portion of the lateral shear. The lateral shear fittings are transferring the majority of lateral shear to the fuselage. The fin to fuselage attachment is vertical over the determinate and therefore it provides damage tolerance by load redistribution capability. The structure accepts a single main lug failure up to limit load level as defined for the intact condition.

MR. MURPHY: All right. You had described the purpose of the lugs overall in reacting. The global loads on the structure. If we get down to the load -- the lugs themselves, what would be the components of loads at each individual lug that would be reacted?

MR. WINKLER: The main lugs are reacting mainly the bending moment by -- by the load in that direction, and in the shear, it's -- the torsional moment is reacted by loads in -- in each direction, in flight direction, and this builds up the resultant load, and also some -- some small amount of bending moment and torsional moment are reacted at the main lug.

The shear lugs are transferring only tension and compression loads via the link of the lateral yokes which provides the connection between the spherical bearings to the fuselage attachment.

MR. MURPHY: And in the analysis that you're doing to date, you're trying -- you're -- you're incorporating all of those loads? You're making sure that you try to account for those in the most accurate manner?

MR. WINKLER: Yes.

MR. MURPHY: Okay. During the design phase, what other types of failure modes were -- what type of -- what are the types of failure modes that were considered for the lugs themselves? The first one is usually bearing, and then what other failures did you consider?

MR. WINKLER: Mainly the tension failure because then you have a separation from -- from -- from the bolt. In the compression scenario, you have certain capability of transmitting compression loads.

MR. MURPHY: Okay. Can you -- could you estimate possibly what -- what the repeated load level would have to be to initiate fatigue damage propagation in -- in the fin structure?

MR. WINKLER: Concerning a lug?

MR. MURPHY: A lug. We'll focus on the lugs, yes.

MR. WINKLER: Yeah. You need about 70 percent of the failure load for getting fatigue damage, but that is related to -- to a one-step spectrum, not to real -- real-life spectrum. You have to apply 70 percent of -- of failure load and then make the cycling with this load. Then you will have onset of fatigue damage maybe when you have cycled up to one million load cycles.

MR. MURPHY: Okay. Now, you -- have you done testing on other aircraft to demonstrate that with your lugs?

MR. WINKLER: Yes, we do it with all our --

MR. MURPHY: Okay.

MR. WINKLER: -- designs.

MR. CLARK: Let me ask a quick question. When you say it's 70 percent of the failure load, in this case, that 1.9 number we've been hearing about, is that the failure load or -- that's the load that --

MR. WINKLER: Yes, it is. 90 tons is the failure load, and if you apply -- if you apply 70 percent of this and make a cycling with this load level, we would maybe initiate fatigue damage in the range of one million load cycles.

MR. CLARK: Okay. So, you would have -- 70 percent of this 1.9 or 2 is about 1.3 or 1.4 --

MR. WINKLER: Yes.

MR. CLARK: -- load. So, you would have to cycle almost at ultimate with a million times before you're going to start -- you may start fatigue?

MR. WINKLER: Exactly.

MR. CLARK: Okay.

MR. MURPHY: And if it's -- the next question really doesn't matter then because if you're at 70 percent of limit, it really doesn't compare to normal operating loads. I'm sorry. 70 percent of the failure load.

What were the critical design conditions for the rudder, the rudder structure itself?

MR. WINKLER: It is a rudder hinge moment, maximum rudder hinge moment.

MR. MURPHY: Could you describe for us the -- the two full-scale tests that -- that were performed for the -600 -- well, actually the 310-300?

MR. WINKLER: Yes, I can. Initially, we had planned to use only one, one full-scale test, but by accidental damage due to a malfunction of -- of the test, we have to use a second one. The intent was to use one test article for -- to demonstrate the static strength and also the fatigue damage tolerance, and what we actually did is that with the first test article, we demonstrated the static strength and with the second one, we made the fatigue and damage tolerance justification.

MR. MURPHY: You may have mentioned it in the opening presentation, but did you put -- you put an enhancement factor on the fatigue loads?

MR. WINKLER: Yes, 15 percent.

MR. MURPHY: 15 percent. In the beginning of that -- that slide that showed the whole demonstration, you mentioned there were small damages before the initial -- the first fatigue test and then there were large damages for the damage tolerance test.

What were the small damages? What were the big damages? What were -- what's the --

MR. WINKLER: The small damages are those which -- for which static strength has to be demonstrated which are in general non-visible damages or up to the ability threshold, that were delaminations done by -- by -- either by -- by applying teflon foil or by impact damages up to certain level of energy, and the bigger damages which have been applied for the damage tolerance phase are delaminations up to -- on -- on one skin panel side, up to 43 square inches.

MR. MURPHY: Okay. And -- and just for clarification, what -- was not the -600R loads used during the static and fatigue testing, it was a lower set of loads -- a higher set of loads?

MR. WINKLER: It was the load level for A310-300 was slightly higher than the loads for the -600.

MR. MURPHY: Okay. In Exhibit 7GG on Page 9, there's a mention of achieving a goal of 20-percent margin above ultimate, above the 1.5 number. What was the intent or why were -- why were you incorporating that 20 percent above the requirements?

MR. WINKLER: That's -- this was used for demonstration, the effect of -- including the effect of -- of non-visible impact damage. So, you have to -- to have a higher static strength to -- to cover these damages.

MR. MURPHY: It's almost in a sense -- I guess you could liken it to a special factor almost, like would the forging factors?

MR. WINKLER: Well, I -- I would not say that it's a special factor because special factors are for other purposes, but this is necessary. If you -- if we -- if you have to -- to demonstrate non-visible damages, which is linked with -- with the strength degradation, you will have to -- to have a higher initial strength to -- to meet the ultimate load requirement for these damages.

MR. MURPHY: Okay. How often were the damages inspected during the fatigue testing and damage tolerance phases?

MR. WINKLER: We -- when we applied these very large damages, we have an initial inspection to -- to -- to demonstrate the size of the damage. Then we apply -- have applied limit load and after this limit load, we have made an additional measurement. Then there was a measurement, a third measurement at 80,000 flights and then after finishing the cycling at a 120,000 flights, and during these measurements, no growth was detected for these damages.

MR. MURPHY: No growth was detected. What techniques did you use for those?

MR. WINKLER: This has been done by -- by ultrasonics.

MR. MURPHY: Ultrasonics. Okay.

MR. WINKLER: Yes.

MR. MURPHY: What other types of subcomponent testing were done during the development phases?

MR. WINKLER: We did a lot of tests. I can -- I have -- I have a picture from -- from 1985 which I want to have the whole picture visible. The shaded areas are definitely test articles. We can start at the lower end. We have front spar box built and tested extensively in -- in fatigue with including manufacturing defects and -- and all damage sizes which are required for the damage tolerance justification. We have center lug test with surrounding structure and we have several tests for the rear main lug, and we have an area between Rib 5 and Rib -- Rib 8 where we have tested extensively skin panels with including impact damage up to 6,500 square millimeters. Then the lug area adjacent to the rear spar that was a test including the activators to the rudder and the upper end was additional testing with skin panels with the thinner skin panels which -- which are relevant for this area of the structure.

In addition, we performed also a test with rips and for the rudder where we made several tests for the area where the actuator fittings are attached, the connection between the metal fittings and the skin panels made from -- from -- from honeycomb with -- with tested in fatigue instead of static.

MR. MURPHY: For the rudder itself. Did -- did the subcomponent tests correlate well with -- with your large-scale tests as far as seeing failures? Basically, initiating the failure where you wanted the failure to initiate in the full-scale test? Okay.

MR. WINKLER: Depends on the -- the purpose. Most of the tests were to derive design criteria or failure criteria, and the correlation was the finite element analysis, stiffness and deformation and so on, and concerning the -- the attachment lugs, this correlates very well with the finite element results.

MR. MURPHY: Okay. Exhibit 7CC is -- it's entitled "Calculation of the Load Levels Experienced by the Vertical Stabilizer and the Rudder During the Accident". I'm not going to ask you to go through that entire report, but if you could, could you -- could you summarize the results of that report for us?

MR. WINKLER: Certainly. Which -- which exhibit?

MR. MURPHY: 7CC.

MR. WINKLER: Yeah. We analyzed the structure concerning the load level experienced on the -- on all lugs with these three large peaks of the accident flight, and also we investigated the load level experienced by -- by the rudder and the rudder hinge line, and in the summary, you can see that for the first -- for the first peak, which was the name 238, the load level at the rear right-hand lug was significantly below limit load requirement. The second case, K316, was at ultimate level, and in the last peak, Y376, we encountered 1.88 times limit load and this exceeds ultimate load requirement by 26 percent.

Concerning the rudder, the assessment was done in relation to the static load case demonstrated for certification, and for this case, the hinge moment from Load Case Y376 was only 24.5 percent. The answer from -- from -- is that the damage or the assumption is that the damage at the rudder hinge line and the sandwich structure itself could not be caused by the loads acting on the rudder due to the interface loads between vertical stabilizer and rudder from deformation prior to the accident, and we also assessed the maximum strain level in the skin panels. These exceeded limit load level by a factor of 2.15 at the peak point.

MR. MURPHY: Okay. Has -- has the Structures Group identified any pre-existing damage in the -- in the rudder to date? We haven't really addressed that.

MR. WINKLER: I -- I have no knowledge about this.

MR. MURPHY: Okay. Additionally, your slide in your presentation again showed two other load cases, 371 -- B371 and B375. They're not the loads that were used in this analysis. It was -- was the lower load level was used in this analysis?

MR. WINKLER: Yes.

MR. MURPHY: Okay.

MR. WINKLER: So, you can scale up these values with -- with these load results for the two load cases you -- which you just mentioned.

MR. MURPHY: Okay. And then, another report, the next report is Exhibit 7DD. It's the "Analysis of the Rupture Sequence of the Vertical Stabilizer During the Accident". Now, understanding that certification only requires you to -- to be good for one failure up to limit load, could you describe or summarize the results, the conclusions in this report for us? 7DD.

Actually, Mr. Winkler, it's not necessary for you to summarize what's in that exhibit. It's --

MR. WINKLER: What we have done is that we have made the initial calculation and then looked at which point or at which lug we exceed the strength of the -- of this lug, and then we made a failure analysis in removing this connection from our finite element model and this was done until the fittings on -- on the right-hand side have failed completely, and the situation is that we have the first failure on the right rear lugs and we have yoke failure on -- on the shear fittings and subsequently the loads on the center lug is extremely exceeded, exceeded the strength value and this fails next, and we have one -- one picture, 264, 264.

On -- on -- on this figure, you can see the outcome of this subsequent failure analysis. We have the first failure at the main attachment on the right-hand side. Then we have on the left-hand side transverse fittings. The next failure sends a main fitting right-hand side. The transverse load fitting on the right-hand side, Number 4, sends a main attached fitting right-hand side, Number 5, and then the rest is failure on -- on the -- on the left-hand side.

With the sequence as evaluated by comparing the -- with the strength of these lugs or these fittings which are involved in the connection between the fin and the fuselage.

MR. MURPHY: You used the load levels then that either came from a subcomponent test or actually the load levels achieved in the full-scale test at the time of failure?

MR. WINKLER: Yes. We used -- we used the results from the full-scale test and the load levels which were achieved during the load levels for some other lugs.

MR. MURPHY: Okay. Exhibit 7KK attempts to explain a possible scenario for the damage shown to the rudder structure. The only thing I want to find out or note in there is I want to -- are there actuator loads that are expressed in there based on the test results that you performed in Hamburg? Are they achievable during the 587 event or even achievable in service in order to produce --

MR. WINKLER: No. No.

MR. MURPHY: Okay. And that --

MR. WINKLER: Hydraulic pressure is not high enough to achieve these loads, but the -- if the rudder is loaded, then this load is reacted by -- by these actuators and the actuators are capable -- can resist this load because as the hydraulic fluid does not -- cannot escape in a -- in a -- in -- during this time. This is locked. The actuators are locked and so the -- they can react in this manner which is assumed in this assumption -- in this report.

MR. MURPHY: In a dynamic sense of that, --

MR. WINKLER: Yeah.

MR. MURPHY: -- in an instantaneous moment, the actuators, the fluid --

MR. WINKLER: Considered as reaction, not as -- as acting and to provide this moment.

MR. MURPHY: Okay. Understanding that your -- your -- your finite element model contained in Exhibit 7BB is -- is work in progress and you're continuing to refine it, can you -- can you explain or just describe what the intended use of that model is for the investigation for -- for us?

MR. WINKLER: In terms of the investigation, we -- we have additional test planned with -- with the rear lug to -- to verify the failure loads seen on -- on AA-587 and also to replicate these results which we have from the full-scale test, and for this reason, we want to be sure that the test or the test or how the test will be conducted is done in the correct manner. So, we want to -- to provide the correct boundary conditions for this test by -- by making the first analysis and then to -- to be able to -- to apply the moments and -- and forces on these lugs in the correct manner.

MR. MURPHY: Okay. You have another Exhibit 7EE. You don't have to go to it, but it -- you go through the same analysis for the -- the 903 aircraft. Do you agree with Dr. Ilcewicz's reasons, his explanation for not returning it to service or does Airbus have another point of view on this?

MR. WINKLER: It's the same reason. It's already described by Dr. Larry Ilcewicz.

MR. MURPHY: Let's just move on to NDI then. How are the manufacturing and in-service allowable damage limits established? Mr. Rackers had indicated that some of this is driven by the Stress Department.

MR. WINKLER: Yes. That is done by -- by

test. We perform all -- all component tests, include artificial damages, and this -- these damages are then used to -- to define allowable or permitted damages for -- for the production.

We actually do the damages for the -- for testing bigger and then go to a lower level which is allowed for -- for -- for production.

MR. MURPHY: And the visual inspections then are driven by the no-growth concept and as depicted by Dr. Ilcewicz with the residual strength curves and it's all the same?

MR. WINKLER: Yes.

MR. MURPHY: Mostly, I'm not going to keep -- did you do any -- I'm not even -- given the knowledge of the Airbus composite structures databases, when is the NDI needed for maintenance inspection of composite structures on the 600R vertical fin?

MR. WINKLER: NDI has to be applied in maintenance, if we have a visible impact damage or visual damage and for -- for the conditions where we have high loads encountered.

MR. MURPHY: Madam Chairman, that -- that's going to conclude my questions. Mostly, it was covered in the presentation and -- and the follow-on presentation -- the previous presentations.

So, Dr. Fox?

DR. FOX: Thank you, Mr. Murphy.

As Mr. Murphy indicated earlier, I have a few questions regarding fracture features in -- in tested lugs. I'd like to discuss the detail tests first. I guess, first looking at the rear lug that was tested in tension, could you describe the visual appearance of that fracture, where the fracture was located?

MR. WINKLER: For the component test?

DR. FOX: For -- for the -- yeah. The detail.

MR. WINKLER: I have a photograph. You can see how it fails. I think there, it says similarity to -- to the AA-5 -- 587 lug failure.

DR. FOX: Could you indicate which direction is the forward direction in that?

MR. WINKLER: You see there the load resultance is in this direction, and we have three failure -- failure areas. This failure is nearly equivalent to the 587 and also this -- and this is a failure which is caused by -- by the rupture mode by -- by pulling out these -- these are pushed out.

DR. FOX: So, -- so, essentially, what you're saying is that on the aft side or on the right side of the picture, that -- that is a secondary fracture as a result of the test?

MR. WINKLER: Yes, sir. Yes.

MEMBER BLACK: Could we have some forward, aft, left, right direction on that photograph? Which way is forward?

MR. MURPHY: Forward to the left. Would forward be to the left and essentially maybe slightly up?

MR. WINKLER: Forward is to the left.

MR. MURPHY: Forward is to the left, aft is to the right, and where he had his pen the first time was the resultant load vector.

DR. FOX: Okay. Let's see. I guess in -- in the rear lug tested in compression, what was -- what was the failure mode? Where -- where was the failure located in -- in that case?

MR. WINKLER: It was in compression, the forward lug failed above rip one in the -- unfortunately, I've no figure for this, but the fracture is visible on -- on the inside and outside surface by -- by compression failure.

DR. FOX: Okay. And that's still within the -- the transition region between where -- where you still have the -- the pre-cured halves transitioning into the --

MR. WINKLER: Yes. The fracture happens inside. The inner lug half is larger than the outer one, and the fracture is -- is in -- in the inner lug.

DR. FOX: Okay. And above --

MR. WINKLER: It's not --

DR. FOX: Above the --

MR. WINKLER: -- directly supported, but it's in -- in --

DR. FOX: Near the border?

MR. WINKLER: In the -- no. It's more close to rip one.

DR. FOX: Okay. Was -- is -- is the -- the compression fracture, was it oriented approximately perpendicular to the fiber direction or -- or what was the approximate orientation of -- of the compression fracture?

MR. WINKLER: It's like in the elliptic shape of -- of fracture.

DR. FOX: Okay. I guess next, going to the detailed test on the center lug in -- in tension, what did the fracture appearance -- where was the location of that fracture?

MR. WINKLER: It was also above rip one.

DR. FOX: Okay. Similar elliptical shape?

MR. WINKLER: Yes, yes.

DR. FOX: Okay. Did -- did it have an appearance similar to the right center lug in the accident?

MR. WINKLER: Yes. It's nearly the same line of fracture visible on -- on the part.

DR. FOX: Okay. And it's my understanding in compression, there was no center lug tested to failure in compression, is -- or was -- was -- what --

MR. WINKLER: No.

DR. FOX: No. Okay. And then, looking at the -- the front detail tests, the front lug, what was the location of the fracture for that lug in tension?

MR. WINKLER: In tension, it's in that section failure, and in compression, the same. It's above rip one failure, compression failure, and the delaminator of rip one.

DR. FOX: Okay.

MR. WINKLER: We have never bearing failure for -- for those types of lugs.

DR. FOX: Okay. No bearing failures. Okay. And then, the location on the front lug in compression, was it a similar elliptical shape? The location of the fracture?

MR. WINKLER: Yeah. It's -- okay. It's -- you can -- you can say it's like an elliptical, but it sets on the front spar and then it goes down to probably to one stringer to rip one.

DR. FOX: Okay. Okay. Then moving to the full-scale test, what lugs failed or lug or lugs failed in that test?

MR. WINKLER: On the full-scale test, only the right-hand side lug, rear right-hand side lug failed.

DR. FOX: And that -- that lug was in tension?

MR. WINKLER: It was in tension.

DR. FOX: Okay. And we have a picture. And do you have a picture of that failure?

MR. WINKLER: No, unfortunately, not.

DR. FOX: Okay. And what -- what was the failure appearance and location of that fracture?

MR. WINKLER: It looks very similar to -- to the detail test, to the component test.

DR. FOX: Okay. That's all the questions that I have. Thank you.

ACTING CHAIRMAN CARMODY: Yes. FAA, any questions of the witness? Oh, I'm sorry. Mr. Benzon, I missed you. One more question on the Technical Panel. Please go ahead.

MR. BENZON: Yes, ma'am. Thank you.

Herr Winkler, I'm interested in the bolts that attach the fin to the fuselage. They're obviously installed, tightened and then cotterpinned. If they rotate or are found rotated upon a maintenance inspection perhaps, what does this mean?

MR. WINKLER: It has no -- no -- no impact on -- on -- on -- on safety.

MR. BENZON: Thank you.

ACTING CHAIRMAN CARMODY: Dr. Kushner?

DR. KUSHNER: Yes. When you did the detail tests that you were talking about in response to Dr. Fox, was the load -- failure loads and tension higher than in compression or the other way around?

MR. WINKLER: The rear lug was tested by two specimens, one in tension and one in compression after rupture, and both failure loads were very close. One was a 103 tons and the other was -- was about 101 tons. So, the strength is similar but the failure mode is, of course, different.

DR. KUSHNER: Okay. Well, in your reports, you reported a tension failure of about a 150, 1-0-5-0, and 1-0-0-3 for compression. Is that incorrect?

MR. WINKLER: No. I cannot remember such a value.

DR. KUSHNER: Okay. Dr. Ilcewicz mentioned that typically composites fail in compression at lower stress levels than in tension and yet on these components, we're seeing tension failures. Is there something associated with the nature of the way you designed that causes that?

MR. WINKLER: Oh, I think the -- the statement, what was done by Dr. Ilcewicz is concerned to the plain laminate, not -- not to the lug structure where we have much more complicated geometry. We have glide drops and so on. We have transitioned to -- to -- to the skin with -- with stringers and so on.

DR. FOX: Okay. Going back, how did you validate the accuracy of your finite element calculations during the design and certification phase?

MR. WINKLER: You mean the analysis for the complete fin?

DR. KUSHNER: Yes.

MR. WINKLER: Yeah. We have applied an amount of strain gauges on our vertical stabilizer, if we scale test, and also performed deflection measurements and this has been correlated to the finite element results, and they were in accordance.

DR. KUSHNER: Okay. And did you have strain gauges on the attachment lugs during those tests that you compared with the finite element calculations?

MR. WINKLER: Directly around the bushing, I don't -- I don't think so. There were no --

DR. KUSHNER: Okay.

MR. WINKLER: But above rip one where we have access to -- to -- to -- to -- we -- we have some.

DR. KUSHNER: Okay. But the lug loads that you determined for failure in your full-scale test come from the finite element calculations, is that correct?

MR. WINKLER: No. They are measured.

DR. KUSHNER: They are measured?

MR. WINKLER: Measured, yes.

DR. KUSHNER: And --

MR. WINKLER: We have the -- I can't picture how the full-scale test has been performed. The reaction forces which simulates the fuselage are provided by -- also by hydraulic cylinders and all loads which are introduced to the structure are measured by load cells. So, we know exactly -- we know exactly which load is introduced to -- to -- to the lugs.

DR. KUSHNER: Well, --

MR. WINKLER: There is a picture of the fin. It's lying on the -- on the rear spar and the big beams which are three beams that are the supporting structure representing the fuselage. We have two -- two fixed points on the one by -- by what's -- what -- by -- by two rods. Also including load cells and all other direction activity by -- by hydraulic cylinders which -- which are in close tolerance with the requirements from -- from our finite element calculation, and so the -- the rupture load is directly linked to -- to the load introduction of these cylinders and by the geometry of these beams on which the fin box is mounted during the test.

DR. KUSHNER: Thank you.

ACTING CHAIRMAN CARMODY: Mr. Clark?

MR. CLARK: Just a quick follow-up. Mr. Benzon asked about a rotated pin and you commented that it wasn't significant in the strength of the -- why not? Why is it not critical?

MR. WINKLER: It has no influence on load transfer. The operation is -- is safe, and the movements it makes are only very small rotations due to the flexibility of the aircraft, and we have also seen these movements during full-scale testing, and there's only maybe a concern of wear. That is all.

MR. CLARK: Okay. In the -- if the -- my understanding, it's a comb-type bolt that wedges in, --

MR. WINKLER: Yeah.

MR. CLARK: -- and if that's loose enough that we get the slight rotation, I guess, the -- the -- what it would appear then -- let me ask it this way. Is -- I guess the torque of that, it may not be critical at all then in the overall strength for a short period of time.

MR. WINKLER: Please repeat your question.

MR. CLARK: Okay. My understanding is, is that, the -- the comb bolt is torqued, the comb and the bolt, to a proper level, and will that bolt rotate if the torque is proper?

MR. WINKLER: Yes.

MR. CLARK: Okay. Thank you.

MR. WINKLER: It depends on -- on -- on the load level which is applied on the fin. I think on low load levels, nothing happens, and if there is some peaks in there, maybe a slight rotation.

MR. CLARK: Okay. So, what I'm after is the -- I guess that I understand, is that I don't have to loosen the bolt then to get rotation in normal service? I can get normal -- I can get rotation with a properly-torqued bolt?

MR. WINKLER: Yes.

MR. CLARK: Okay.

ACTING CHAIRMAN CARMODY: All right. Moving to the parties, FAA, Mr. Donner?

MR. DONNER: Yes, I do have one question, and it's a multiple choice question.

So, the aft right lug failure on the accident aircraft. Would you say that that aft right lug failed due to (1) a shear-out mode, (2) a net section stress concentration, or (3) a combination of the two under the accident loading?

MR. WINKLER: It's not a net section failure. It's -- I think it's a shear-out.

MR. DONNER: Okay. Thank you very much.

ACTING CHAIRMAN CARMODY: Thank you.

American, Mr. Ahearn, any questions?

MR. AHEARN: Yes, Madam Chairman. Thank you.

Gentlemen, it's still afternoon, so good afternoon. Just a few topics I'd like to touch upon.

Exhibit 7AA refers that Airbus determined lateral gusts to be the critical loading condition for the rear lug. Were the loading conditions to which Airbus designed the composite vertical stabilizer any different than the loading condition for the metal tail from B2B4?

MR. WINKLER: The metal tail has exactly the same design conditions, also the lateral gust.

MR. AHEARN: So, then, the -- I presume that the rear lug on the metal tail would also be the critical component?

MR. WINKLER: No.

MR. AHEARN: What --

THE WITNESS: The load is different on metal structure.

MR. AHEARN: What -- do you know what the critical components were on the metal tail?

MR. WINKLER: Yes. The compression failure of the skin panel.

MR. AHEARN: So, with that, would it have broken higher than the lug? High above -- higher above the fuselage --

MR. WINKLER: No, not very high. The maximum load level is just above the lug, and there, the margins are low in compression. We have buckling and then the margins are very low.

MR. AHEARN: Do you know if there would be enough left to have any control of the aircraft?

MR. WINKLER: I do not know how many fin box is necessary for -- for control of the aircraft. I don't think that -- it may be one meter above the attachment will -- that would be the failure.

MR. AHEARN: Okay. Let me just move on to a different question similar to this damage. Given the restraints of the existing fuselage structure, we talked a little bit about that, could the aft lug have been designed for a higher load capacity, and again, with the expectation that this lug, the rear lug, would fail first?

MR. WINKLER: I consider that the load level we have fatigued is enough concerning to the -- related to the requirements, and so there is no necessary to -- to have a higher strain lug.

MR. AHEARN: So, it meets -- in other words, it meets the FARs?

MR. WINKLER: Yes, of course, and exceeds the FARs. Requirement is 1.5 times limit load and we have reached 1.9 times limit load.

MR. AHEARN: If -- do you know if you have the attachment lugs made of metal instead of composite, would the lugs have failed differently?

MR. WINKLER: That is speculation. I cannot answer to this question.

MR. AHEARN: Okay, okay. I'm just seeing if you have any knowledge of it.

Mr. Winkler, you're familiar with the term "balanced joint", are you not?

MR. WINKLER: With what, please?

MR. AHEARN: The term "balanced joint" or "balanced connection"? What I'm referring to is where the composite lug joins with the clevis pin to the empennage or -- or to the tail structure.

MR. WINKLER: I'm --

MR. AHEARN: Let me bring up a picture. Maybe I can help you with it. Could you bring up Exhibit 7B as in Baker, Pages 33 and 34?

ACTING CHAIRMAN CARMODY: Is that 7B as in Baker?

MR. AHEARN: 7B as in Bravo.

ACTING CHAIRMAN CARMODY: Yeah. That's not an exhibit that this witness was responsible for.

MR. AHEARN: I just want to use it as an illustration, ma'am.

ACTING CHAIRMAN CARMODY: Does the witness object? Have we brought it up? I don't see it on here yet.

MR. WINKLER: Picture from the -- from the wreckage?

MR. AHEARN: Yes, sir.

MR. WINKLER: Okay.

MR. AHEARN: It is? Okay. If you can see it, I just want to take a quick peak at it. Maybe it will help what I'm trying to describe as a balanced joint to you.

ACTING CHAIRMAN CARMODY: What page of the exhibit?

MR. AHEARN: Page 33 and 34. That's one. If you could, 51, and then if you could bring up Page 34, I believe it's Figure 54 -- well, 54 on the bottom. The next figure, please. That's it.

If you look at these pictures, sir, it appears that the loads were not distributed between all of the objects that were joined. It appears that the failure was strictly at the lug, and let me see if I can give you kind of a human illustration of what I mean from a balanced joint standpoint.

If I have three 18-year olds of equal size pulling on each other, they're probably going to stay pretty stable, but if I have a five-year old pulling on one arm and an 18-year old pulling on my other arm, I'm going to be off balance. So, that's what I'm trying to refer to as a balanced joint.

ACTING CHAIRMAN CARMODY: Mr. Winkler, if this is -- is this a question you can answer? Because I find it a little confusing.

MR. AHEARN: Well, let me ask the question and see if you can answer it.

ACTING CHAIRMAN CARMODY: Try and clarify because this is not an exhibit the witness has.

MR. WINKLER: You mean the comparing the

center lug with the rear lug?

MR. AHEARN: No. What I'm trying to say in the one joint, what were the relative strengths of the composite tail lug, the metal fuselage clevis and the connecting pin? Were they balanced?

MR. WINKLER: The metal fuselage lug is -- has a different design condition. It is made for fatigue damage. So, --

MR. AHEARN: So, it's stronger?

MR. WINKLER: Yes. It has to -- to -- to test to -- to fatigue requirements and so that is a different design condition.

MR. AHEARN: Right. And -- and unfortunately, we don't have another picture here, but it appears that none of the clevises on the fuselage yielded at all, --

MR. WINKLER: Hm-hmm. That's correct.

MR. AHEARN: -- and -- and -- and yet the lugs, all the lugs yielded, and what I'm looking to see is if you have a knowledge of the distribution of -- of the loads on the -- the joint itself from the tail to the fuselage or from the fuselage to the tail because it appears that all the loads were on the tail and that there wasn't anything on the -- the joint on the fuselage.

MR. WINKLER: The metal lugs are designed by -- by fatigue conditions, and so they are -- if there is no fatigue damage, they have to be stronger, of course.

MR. AHEARN: Okay. Thank you.

Let's move on to another subject. It's my understanding that you did work on the transition from the B2B4 to the 310 composite tail, is that correct?

MR. WINKLER: No.

MR. AHEARN: No? Do you have any knowledge of the strength or the robustness of those tails?

MR. WINKLER: The metallic one.

MR. AHEARN: Yes. Do you know if --

MR. WINKLER: I know -- I know the reserve factors, yes.

MR. AHEARN: Do you know if one's more robust than the other?

MR. WINKLER: I think they have equal level.

MR. AHEARN: Okay. Thank you.

Just a couple more topics for you, sir. We have heard testimony about changes in design of the lugs in subsequent models following the 600, airplanes that followed in -- in development from the 600. As a result, do you still expect the aft lug to rupture first in full-scale testing on the other models?

MR. WINKLER: Which other models do you mean?

MR. AHEARN: The 310, the -- I'm sorry, not the 310. The 320, the 330, the 340? Is the aft rear lug still the lug that will rupture on the -- on -- on the models that came after the 300?

MR. WINKLER: The -- for the 320 and 340, the same lugs are -- have -- are the highest loaded and so they are -- would be failed for us, yes.

MR. AHEARN: And the 330?

THE WITNESS: We have two Model 330-200 and 300. So, the 300 is -- has the same design principle as the -- from the principle as the 340-300 and so it applies the same statement what I made, and the 330-200 has failed in a different mode.

MR. AHEARN: And -- and --

MR. WINKLER: Because it is -- historically, it is because we -- when we designed this fin box, we have the A340-600 in mind, and we have made the -- the attachments to -- to cover the load levels for the 340-600 so they are stronger.

MR. AHEARN: Okay. And -- and again just to clarify, you would expect that to happen in your full-scale testing? That's what you saw in your full-scale -- in your full-scale testing?

MR. WINKLER: For -- for -- for the -- for the 320, 340, basic -- the basic 340, we have made such tests and it is the same -- the same failure mode.

MR. AHEARN: Okay. Now, just one final topic. You had highlighted in your presentation that the airplane had been certified in the United States and Europe. Has the 300 ever been declined certification in any country?

MR. WINKLER: I'm not familiar with this.

MR. AHEARN: Okay. Thank you, sir.

Madam Chairman, that's all my questions.

ACTING CHAIRMAN CARMODY: Thank you.

Allied Pilots, Captain Pitts?

CAPT. PITTS: Thank you, ma'am.

Good afternoon, sir.

MR. WINKLER: Good afternoon.

CAPT. PITTS: For certification purposes, did Airbus consider any rudder maneuver cases not directly required by FAR.351 for structural substantiation of the A300-600?

MR. WINKLER: That's not my expertise to answer to this question. Sorry.

CAPT. PITTS: I'm sorry. I thought -- I thought I saw certification of the -- of the structure in there. Would you have been consulted on that?

MR. WINKLER: On what?

CAPT. PITTS: On meeting certification criteria in terms of the structure?

MR. WINKLER: Yes, of course.

CAPT. PITTS: And such --

MR. WINKLER: But for -- for the requirements, which are written down in FAR-25, and for these maneuvers, we cover all requirements.

CAPT. PITTS: Are you -- are you aware of anything beyond those requirements that were -- were considered in the design?

MR. WINKLER: No.

CAPT. PITTS: Okay, sir. Any new designs? Do the -- you mentioned the new design.

MR. WINKLER: All -- all our aircraft comply to -- to the latest requirements from JAR or FAR.

CAPT. PITTS: All right, sir. And -- and consider no further requirements, other than those specified in the regulations? In other words, it wouldn't take a look at additional rudder movements, maybe a rapid rudder from neutral and over-swing, maybe a full reversal?

MR. WINKLER: That may be. There may be studies by -- by the Loads Departments or by the Flight -- Flight Departments, but I am a stress man and I use the load input which I get for certification from the

Loads Department. So, I'm not familiar --

CAPT. PITTS: All right.

MR. WINKLER: -- with studies which are made somewhere else.

CAPT. PITTS: All right, sir. Very well. You mentioned in your presentation, I think, and others, we've heard the same thing, that the aft lugs failed first, is that correct?

MR. WINKLER: During the accident.

CAPT. PITTS: In the --

MR. WINKLER: In my opinion, yes.

CAPT. PITTS: Yes, sir. Are the -- the aft lugs designed to the same criteria as the others? Are they -- or are they weaker?

MR. WINKLER: The aft lug is designed for the failure condition when center lug fails. It's the same scenario which we have described in the beginning of my -- my witnessing and -- but this -- for the rear lug, the condition, the failure condition is nearly equal to the normal condition when all lugs are intact. So, we comply with ultimate load, load requirement for the rear lug and we comply with the fail-safe condition at the rear lug when -- when the center lug fails.

For the other lugs, the situation is -- is different. The center lug has to be much stronger to cover the failure scenario on the rear lug. So, that is why it's stronger and the strength is -- is -- is higher than necessary for -- for the normal condition when all lugs are intact.

CAPT. PITTS: Now, did I understand the presentation correct that as the loads build up on the structure, they tend to shift in favor of the aft structure, the aft lugs?

MR. WINKLER: No.

CAPT. PITTS: That's not correct?

MR. WINKLER: That's the wrong interpretation. Yeah.

CAPT. PITTS: All right. Okay. From a systems safety design perspective, wouldn't it be better for the vertical stabilizer to have some of its most critical components some place other than at the lugs?

MR. WINKLER: Please, once more.

CAPT. PITTS: Yes, sir. From a systems safety design perspective, --

MR. WINKLER: Systems?

CAPT. PITTS: Systems safety.

MR. WINKLER: I'm -- I'm not responsible for structure, not for system.

CAPT. PITTS: All right, sir. From a -- from a design safety perspective of the structure, wouldn't it be far better for the vertical stabilizer to have its most critical component some place other than at the lugs?

MR. WINKLER: I do not understand your question.

CAPT. PITTS: All right, sir. I'll see if I can rephrase it.

MR. WINKLER: Hm-hmm.

CAPT. PITTS: The most critical component in the structure is where it attaches, is that correct? Not further up --

MR. WINKLER: Yes.

CAPT. PITTS: -- in -- into the -- into the --

MR. WINKLER: Concerning -- concerning the gust load condition or the load condition, which we have had in the accident.

CAPT. PITTS: All right, sir. And -- and is that -- is that same philosophy in other vertical stabilizers that have been designed by Airbus?

MR. WINKLER: That is no philosophy. We -- we -- in -- in our opinion, the load level of the strength or the strength level which we have built in this pin significantly exceeds the requirements and so there is no concern about this.

CAPT. PITTS: All right. I referenced the critical point on the vertical stabilizer. So, subsequent aircraft models and designs of vertical stabilizers have this same sort of design concept?

MR. WINKLER: That is not a design concept.

CAPT. PITTS: All right. Very well. I'll move on to another area.

Did you participate in the investigation of the Flight 903 event that took place in May of 1997?

MR. WINKLER: I was not aware in '97, but of course, I -- I'm aware since the investigation of -- of the load exceedances.

CAPT. PITTS: So, you did not participate in the investigation or any of the loads analysis or structures reviews?

MR. WINKLER: No, no.

CAPT. PITTS: All right, sir. Would that also be the same case for the investigation of the previously-referenced Interflug flight?

MR. WINKLER: Yes, it is the same.

CAPT. PITTS: Since you didn't participate in the investigation, can you tell me when you or when the company, Airbus, became first aware of the -- of the fact that the vertical tail on Flight 903 exceeded ultimate load?

MR. WINKLER: I think that has been answered several times during this hearing. This question has been answered several times during the hearing.

CAPT. PITTS: Can you refresh my memory? I don't know the answer to it.

MR. WINKLER: In '97, the -- with an assessment which reveals that ultimate load has probably been achieved or encountered by this aircraft.

CAPT. PITTS: All right. So, the answer is 1997?

MR. WINKLER: Yes, the answer is 1997.

CAPT. PITTS: All right. And when did you notify either the National Transportation Safety Board or the operators of the aircraft that the -- the ultimate load had been exceeded?

MR. WINKLER: That's not in my responsibility to make notifications to NTSB.

CAPT. PITTS: All right, sir. Did -- did the fact that it was in fact exceeded, that it -- that it did in fact exceed the ultimate limit, is that in your area of concern as far as your responsibilities within the company and reviewing the system and its robustness?

MR. WINKLER: The structure, only the

structure.

CAPT. PITTS: And you reviewed that -- that --

MR. WINKLER: Yes.

CAPT. PITTS: Those -- those values and -- and --

MR. WINKLER: In 2000 -- this year.

CAPT. PITTS: All right, sir. Were there any analytical tools or methods not available to Airbus in 1997 to ascertain the overloads that are available today and that were used by Airbus in support of the calculations for the review on the data of 903?

MR. WINKLER: I think this question has been answered by Mr. Curbillon this morning.

ACTING CHAIRMAN CARMODY: Yes. Captain Pitts, let's try and get some new information here. If -- if you have more questions, let's proceed with them. I think we've asked this witness several times and let's move on.

CAPT. PITTS: Okay. I'm curious if there's been any refinement in the methods that are used to do -- do the structures analysis since the 1997 event. Has there -- has there been a modification in the -- in the methodology or a refinement?

MR. WINKLER: No.

CAPT. PITTS: Okay.

MR. WINKLER: Concerning structure evaluation, no, nothing. Concerning other domains, I cannot speak.

CAPT. PITTS: All right, sir. In terms of the -- the damage that the 903 tail suffered, you -- I think it was stated that after the accident, the 587 accident, that it was within Airbus acceptable limits, and then later on, the recommendation was that it should be replaced as it had exceeded ultimate limit.

Can you -- can you give me the -- the change in heart there? Can you help me understand why, once it was known that the load limit, plus its safety factor, had been exceeded, that there was now a recommendation to in fact go forward after the previous recommendation had been to not do so?

MR. WINKLER: I'm -- I'm only aware with the decision from Airbus that the fin is no longer serviceable.

CAPT. PITTS: All right, sir. In reviewing the structure, if you were informed today that a structure had exceeded ultimate limit, would it be your recommendation to replace it?

MR. WINKLER: From the situation that the load level is unknown, we have heard in the morning that there is some deficiencies concerning the DFDR recordings, I would say yes, that it should be removed.

CAPT. PITTS: And I wasn't real specifically speaking to 903. So, I apologize. I -- it was a hypothetical in terms of your assessment of a structure that was reported to have exceeded ultimate limit load. Would you recommend that it be replaced?

MR. WINKLER: Once more, please.

CAPT. PITTS: A structure. This is a hypothetical situation. You were made aware that a structure had exceeded its ultimate limit load. Would it be your recommendation that it be replaced?

MR. WINKLER: Depends on the load case. There are some load cases not critical for -- for -- for -- for the lugs. It depends on the type of load case and we have to decide case-by-case when -- when we make -- have to make the decision to remove it from service or not.

CAPT. PITTS: All right, sir. Just very quickly, my last area, couple of questions. We've learned that this aircraft, the accident aircraft, 053, was involved in testing prior to delivery. Are you familiar with the type of testing that is underwent?

MR. WINKLER: No, I am not aware of this.

CAPT. PITTS: All right, sir. Reference the repair, as a matter of fact, we saw a picture of the lug just a moment ago. In terms of a repair method, did -- did that repair methodology equal or exceed the -- the design criteria of the -- of the laminate structure?

MR. WINKLER: The repair which has been done fully restores the strength capability of this lug.

CAPT. PITTS: All right, sir. How -- do you know how that lug was -- was either in the manufacturing or in the testing process damaged?

MR. WINKLER: From 587?

CAPT. PITTS: From the accident aircraft.

MR. WINKLER: No, no.

CAPT. PITTS: Yes, sir.

MR. WINKLER: There were indications which was -- the result of which was done in the inspection.

CAPT. PITTS: Very well. Thank you, sir.

I have no further questions.

ACTING CHAIRMAN CARMODY: Airbus, Dr. Lauber?

DR. LAUBER: Thank you, Madam Chairman.

Just one or two questions here. Mr. Winkler, you've been asked a number of questions regarding the -- the high fin load cases that were looked into subsequent to the 587 accident.

Isn't it true in many of those, at least those that involve loss of control, that the -- the excessive loads experienced by the airframe weren't limited simply to the vertical fin? Weren't other structures also subjected to excessive loads?

MR. WINKLER: Yes, it's correct.

DR. LAUBER: Okay. Thank you.

You've been asked a number of questions about if you designed a certain component to be stronger, wouldn't that be -- wouldn't that result in a better design or something? If you designed the rear fin lug to be stronger than it is, wouldn't that simply mean that some other lug would fail first or some other component in the vertical stabilizer would fail first?

MR. WINKLER: Yes. If the failure is anywhere, can happen anywhere, concerning to the -- to the strength level.

DR. LAUBER: When a structure breaks, something breaks first in it?

MR. WINKLER: Yes, something breaks first.

DR. LAUBER: Thank you. I have no further questions. Thank you.

ACTING CHAIRMAN CARMODY: Thank you.

Moving to the Board, Member Goglia?

MEMBER GOGLIA: No questions.

ACTING CHAIRMAN CARMODY: Member Black?

MEMBER BLACK: No questions.

ACTING CHAIRMAN CARMODY: Are there any further questions from the Technical Panel? Dr. Kushner?

DR. KUSHNER: Erhard, we had some questioning that seemed to imply that it would be a better design if everything failed together at the same time. Within the design community, is that considered a good philosophy?

MR. WINKLER: I think that is a dream but not -- not realistic.

DR. KUSHNER: Okay. I mean, typically, one worries if you have to be concerned with the entire structure failing at the same time. It's not considered an optimum design.

Also, there seemed to be questions implying that in a structure like this, where all the load has to eventually get down to the attachment points, the lugs, there's no other place for it to go, that it would be a better design if the first failure was some place else. Does that mean anything? Does it really change the overall ability of the structure to transfer the loads to the airplane?

MR. WINKLER: Please, once more.

DR. KUSHNER: Okay.

MR. WINKLER: I didn't catch it fully.

DR. KUSHNER: The point is, the vertical fin is taking load that has to -- is needed to maneuver the aircraft.

MR. WINKLER: Yes.

DR. KUSHNER: Having it fail some place else first doesn't really help in terms of the functionality and the requirement to get that load down into the airplane. So, you don't gain anything.

MR. WINKLER: No. That's correct.

DR. KUSHNER: Okay. Thank you.

ACTING CHAIRMAN CARMODY: Was that it, Dr. Kushner. Okay.

Is there any additional questions from any of the parties? I see heads shaking.

Well, my thanks, Dr. Winkler, for your testimony. We appreciate your time and your -- your testimony.

(Whereupon, the witness was excused.)

ACTING CHAIRMAN CARMODY: And let's move quickly to the first of the NASA witnesses. I'd like to do one more today, if we can. Thank you.

MS. WARD: I'd like to call Dr. William Winfree. Please raise your right hand.

Whereupon,

DR. WILLIAM (BILL) WINFREE

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

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

Dr. Winfree, could you please state your full name, your current employer, and your business address?

DR. WINFREE: My full name is William Paul Winfree.

MS. WARD: Mike, please.

DR. WINFREE: It's on now. Okay. My full name is William Paul Winfree. My current employer is NASA Langley in Hampton, Virginia, and I'm a research physicist with them.

MS. WARD: And how long have you been a research physicist for them?

DR. WINFREE: About 24 years.

MS. WARD: And what are your duties and responsibilities in your current position, and please list any training or education that you received to qualify you for your position?

DR. WINFREE: Okay. Well, first of all, my education was a Bachelor's of Science in Physics, a Master's of Science in Physics, and a Ph.D. in Physics. Since I've been at NASA Langley, I've been doing NDE research for almost 24 years and that's been looking at composites as well as metal structures. Typically, what we do is we develop new techniques for inspection of either aerospace or aircraft structures.

In the last 10 years, we've been working on things like Aging Aircraft Program. Actually, NASA equivalent of the Aging Aircraft Program which is an Airframes Structural Integrity Program which is looking at developing techniques, NDE techniques for aircraft and then we've also had the High-Speed Civil Transport Program which was looking at primary, looking at composites for high-speed aircraft and also the Advanced Composites Technology Program which was looking for trying to insert large composite primary structure in the aircraft.

MS. WARD: Okay. Dr. Winfree, I find you fully qualified.

Madam Chairman, I now pass it over to Dr. Matthew Fox for questioning.

DR. FOX: Thank you.

EXAMINATION

DR. FOX: Good evening, Dr. Winfree. I'd like to discuss the non-destructive testing that was performed at NASA Langley and of both the vertical stabilizer and the rudder. The data from these examinations is presented in Exhibit 15B. I'd like to cover -- cover questions about the vertical stabilizer first, followed by questions about the rudder.

What techniques did your non-destructive team use at NASA Langley to examine the vertical stabilizer?

DR. WINFREE: On the vertical stabilizer, we did ultrasonic testing, impulse echo. We also did some Lamb wave testing which is another acoustic technique, and we also did a thermographic technique.

DR. FOX: Okay. For each technique, what type of information related to this accident can be learned about the structure or materials, particularly regarding damage and defects in carbon fiber reinforced polymers?

DR. WINFREE: Well, the ultrasonic technique will tell you something about whether or not there's any delaminations. That's the primary thing we were looking at with it. Also, changes in attenuation will tell you whether or not there's any significant micro-cracking formation in the thing. Lamb wave tells you something about the stiffness and also about the thickness of the structure.

Thermography is more of a kind of a quick look at the structure to see whether or not you have any delaminations or not. It was kind of primarily done to see whether or not there was some area that we should look at real quickly with the ultrasonics.

DR. FOX: Okay. I guess we're still pulling up the audio-visual, but referring to the data presented in Exhibit 15B, particularly for discussing the ultrasound results first that are presented on Page 2 to 11, please -- please describe those results for the vertical stabilizer.

DR. WINFREE: Okay. Well, what we have -- I believe we have, I guess, the first figure there. Want to go through the ultrasonic signal, first of all, or what?

DR. FOX: Sure.

THE WITNESS: Okay. Well, I -- in here, it's -- it's on -- on Page 2. There it is right there. What we have is -- is the ultrasonic signal in which, under the top of the page, is -- is the region of the composite that we felt like had no damage in it. What you see is -- this is a pulse echo technique where we have a water column coupling the -- this ultrasound into the -- the composite. As a result of that, what we get is an echo off the front surface. Then assuming there's nothing that blocks the sound from propagating all the way to the back surface, we also get basically an ultrasonic signal off the back surface, and then the third signal that you actually see in there that's of some height, it's actually a reverberation which has gone through the composite two times back and forth.

So, one of the things we were looking at is the time of flight which is shown there. Time of flight tells you basically how far back the back surface is in -- in the sample. The other thing we were looking at was the amplitude of the pulse. The amplitude of the pulse tells you whether or not there's significant attenuation has occurred on the ultrasonic signal as it propagated through the -- through the composite.

So, in the figure that we show below it, we show a region which, I guess, has an anomaly in it. I guess that's the way to put it. We have an anomalous signal that appears in between the back surface echo and the front surface echo, and in cases where we -- we saw that in the composite, we went ahead and called them out and put them in the thing. One of the things that you'll notice is that when you have that anomalous signal, there's also a significant decrease in the back surface echo and so what we actually show in some of the images that come later on are some of the -- the amplitudes of that back surface signal which is an indication of, in a sense, attenuation.

DR. FOX: Okay. So, I guess, looking at time of flight and -- and thickness measurements, how accurately were you able to make those type of measurements?

DR. WINFREE: The -- what we were able to do was -- was probably do it with about a 100th of a microsecond, that we were able to do it. So, that's -- in that particular case, -- well, it depends on the thickness of the sample. So, off the top of my head, it's probably better than one percent on most of the -- most of the samples that we looked at. So.

DR. FOX: Okay. Were -- were there any complications associated with -- with lay-up of the composite or -- or local geometries or maybe resin-rich areas versus -- or -- or -- or volume fraction-type differences?

DR. WINFREE: Those types of things would give us problems. What we do see is we do see variations in the signal. Probably the biggest problem we have was surface roughness. Surface roughness probably gave us the biggest problem as far as getting a good front surface echo and a back surface echo.

The other anomalies that we -- we got in the back surface echo are probably more related to the fact that there seemed to be attachments on the back side, somebody stuck something on the back side for some reason, some kind of damper or something, and we would pick that up and -- and -- but in that particular case, what you don't see is you don't see that echo between the front surface and the back surface. So.

DR. FOX: Okay. Perhaps you could describe some of the -- where -- where you did the scans, give maybe a map of --

DR. WINFREE: Oh, I think on Page 3, we have the -- the left side, at the top of the page, on Page 3. So, at the top, what we show is -- is the area that we cover with the ultrasonic signals. We came down to -- we didn't go into the lugs, but we came down to basically there was a line, that if I remember correctly, was about 10 centimeters above the bottom edge of the tail. That particular line, there was a rise in the pay-in or something and that would happen is every time.

The way we did this is we had a latex tube that we used and every time it would go over that line, it would basically break. So, we -- we gave up trying to do both sides of that line. So, what you see at the top is -- is basically time of flight. Y is where we have no data. So, any place where we have a color, we have data, we have time of flight data, and that particular case up in the aft part of the tail, you can see the delamination, the major delamination we found which was quite close to the -- to the surface. I believe it was two millimeters approximately from the -- from the surface, and that was actually visible from the outside of the tail. You could actually see a rise where that delamination was, and, you know, then down below it, we show some of the other delaminations we saw on this particular side of the -- of the tail.

DR. FOX: Now, as far as from color, how would we use the color to interpret the results?

DR. WINFREE: What the color shows is -- is yellow tends to be shorter times of flight. So, that would be thinner -- thinner parts of the material. As you get into the orange, you get into the thicker parts of the material or actually longer times of flight. In order to actually turn it into thickness, you'd have to know what the velocity was of the material.

DR. FOX: Sure. Okay. Let's see. I guess, could we take a look at the -- well, most of the -- in this area, you had -- you saw large delaminations, well, relatively speaking, down at the lower end of --

DR. WINFREE: Down -- yeah. Down there.

DR. FOX: Were the -- were there any other areas that you had indications or -- or --

DR. WINFREE: Well, we had -- we had some small indications which I think we list in all the figures that come after that. So, there's, I think, one at the bottom of that page.

DR. FOX: Okay.

DR. WINFREE: Actually, if you go to the bottom of that page, you can -- you can see. One of the things we did was we took a schematic of the tail and we put on it boxes where we found -- basically, those boxes outline the regions where the scans are shown in all the subsequent figures. The one being down below it indicates where we saw that echo between the front and back surface, we circled in red. So, we went through all the images, looked at the attenuation images, and only those attenuated areas where basically we saw loss of signal did we circle in red, if we could see the echo between the front and back surface.

DR. FOX: Okay. And then, could you show the -- describe the map for the right side?

DR. WINFREE: Yeah. The map of the right side is actually on -- on Page -- Page 8 and that, you know, basically the color scale is the same, still yellow is thin, the orange is -- is thicker, and in that particular case, we didn't see any regions where we had delaminations that came out. We still had the same kind of anomalous signals that we -- we reported in the other part, and we also have the schematic and have those laid out on there.

DR. FOX: Okay. Thank you.

Let's see. I guess perhaps could you discuss some of the complexities associated with the examination in the -- in the lug areas themselves?

DR. WINFREE: As far as doing the lugs themselves or what?

DR. FOX: Yes, yes.

DR. WINFREE: Well, there's -- there is a problem, I think, when you do the lugs basically with a composite material. Basically it's anasyntropic. As a result of that, when you put sound in, it doesn't necessarily go in the direction that you would -- you would think it would go. Basically, it kind of follows something called a slodus curve, which has to do with the anasyntrophy of the material, and so it actually -- if the -- the material's highly anasyntropic as this is, actually can follow a curve, so that if you're going to do an inspection, you may put in an ultrasound, and you may think that it's going in the straight rate down to one place, and it may end up in -- in a totally different place in the specimen.

DR. FOX: And the lug areas, you observed the Airbus NDE Team inspecting those lugs?

DR. WINFREE: They did those inspections, right.

DR. FOX: Okay. And what -- what procedures did they use?

DR. WINFREE: Oh, they used the pulse echo technique and what they had was they had, in order to help get around some of the problems with it, they had basically delay lines that they put in and the delay lines were angled so that as much as possible, they could get the ultrasound to go in and propagate at surface normal.

DR. FOX: Okay. Let's see. I guess the next -- the next topic I'd like to move to is the Lamb wave results for the vertical stabilizer, and could you go over those -- those results for us?

DR. WINFREE: Okay. Well, these are -- these -- that's on Page 12. These are showing both the left and right side. These measurements take a considerable amount of time. So, we didn't do as large of an area as we did for the ultrasonics. The principle intent behind this was trying to find regions where there was a significant change in stiffness. They also reflect the thickness of the material which we didn't take out.

Down in the -- in the bottom of the one side, the left side, we didn't do measurements because of the curvature as a result of the delaminations. So, we weren't able to -- to get in there. This is kind of a delicate kind of -- it's a technique that we're -- we're kind of developing for composite materials. We didn't really see any -- any kind of damage to report in these Lamb wave measurements. So.

DR. FOX: Okay.

DR. WINFREE: These also -- the ultrasonics does a very good -- well, a reasonably high resolution technique. This is -- is effectively looking at areas that are sampled over about a two and a half centimeter region and as a result of that, they're not going to see some of the small flaws that basically you're going to see with the ultrasonics.

DR. FOX: So, at the -- at the lower end of the stabilizer on the left side, where we had the delamination found by ultrasound, the Lamb wave may not necessarily show that?

DR. WINFREE: Well, it probably would have shown that if we'd been able to -- to put it over. Like I said, as a result of the -- that curvature, which we had over it, it was hard to get the transducers to lay right on that particular surface.

DR. FOX: Okay.

DR. WINFREE: But what it would have shown is that -- is a thinning of -- of the surface. If you look at the attached points where the -- you know, about the center, where the hinge points attach in, it's a little bit darker there. That darkness is a result of thickening of -- of the Lamb -- of the composite material. So.

DR. FOX: Okay. I guess the next area I'd like to move to is the --

ACTING CHAIRMAN CARMODY: Excuse me. Dr. Fox, we have one question from Member Black.

DR. FOX: Sure.

MEMBER BLACK: Just a question maybe to help me and some of the other people understand it. It appears to be that the dark areas, both in the ultrasound and in the lambda or Lamb -- isn't that the lambda?

THE WITNESS: Lamb. No. It's Lamb. It's actually named after a person.

MEMBER BLACK: Oh, it's a person. Okay. I thought it was -- who knows.

The dark areas are primarily -- are dark because they were close to places where things fractured, are they not?

DR. WINFREE: No. Typically, those are -- are dark because they're -- it's thicker regions.

MEMBER BLACK: They're thicker regions, but they just happen to be at the bottom of the fin where the fractures occurred?

DR. WINFREE: Right.

MEMBER BLACK: Because it's thicker?

DR. WINFREE: Because it's thicker. Right.

MEMBER BLACK: Okay. Thank you.

ACTING CHAIRMAN CARMODY: Go ahead.

DR. FOX: Okay. So, moving -- moving to the -- to the rudder -- well, I guess -- yeah. The -- what techniques did your NDE Team use to -- at NASA Langley to examine the rudder?

DR. WINFREE: We looked at it with radiography for -- looking for water content and we looked at it for thermal primarily for water content as well, and then we also did the Lamb wave for more looking at and seeing what the -- how well the face sheet was connected to the subsurface honeycomb.

DR. FOX: Okay. So, I guess to some extent, you've described it, but for each technique, you know, what -- what type of information can be learned, particularly with sandwich composites?

DR. WINFREE: Well, once again, the primary thing you need from radiography is -- is density or the density along the path of the x-rays, and so if there's any water in there, you should be able to see the water.

In the thermal, what you're looking at is -- is how fast, if you put a flash sheeting on the front surface, how fast does the front surface cool down? It may -- one of the things it does is if there's any honeycombs attached to the back surface, it cools down faster, not in this particular case, but the primary thing we looked at was -- was the very rapid cooling you got where there was water, and then the Lamb wave, like I said, tells you something about the stiffness of -- of the face sheet and where it's detached, we expected a loss of stiffness.

DR. FOX: Okay. I guess, referring to Exhibit 15A, Page 13, could you indicate the areas of the rudder that were examined using these techniques?

DR. WINFREE: Well, we -- we -- primarily, there was only one real large part of the rudder that was intact, and that -- that goes from about Hinge 7 down to about Hinge 5, I believe.

DR. FOX: Maybe Hinge 4? There's -- there's a fracture on the left side at Hinge 4.

DR. WINFREE: Let's see. Yeah. I guess it does go all the way. Well, yeah. We went -- we went past Hinge 5 but not -- not all the way down to Hinge

4.

DR. FOX: Okay.

THE WITNESS: Probably about -- I guess if there -- if the fracture was there, we probably went about halfway down between the two.

DR. FOX: Okay. So, referring to the -- to the data presented in Exhibit 15B, Pages 13 to 16, could you please describe the results obtained from -- from the -- sorry. The results that -- the x-ray/radiography results, I believe.

DR. WINFREE: Yeah. Page 13 shows the x-ray/radiography results. In that particular case, what you're -- we have both a blow-up there at the top of the page which shows typical image that we got and what you can see in there is the indications we've got of water which are effectively the white spots. The lettering on there is lettering we put on, lead lettering that we put on there in order to be able to tell which x-ray film we were looking at.

You can also see the honeycomb and actually in that piece, you can see where a face -- up at the top of it, a piece of the face sheet was missing on one side, where it's kind of dark there. So, kind of a missing corner right there. So, down -- down at the bottom of that page, we show a composite of all the images put together, and in that particular case, what you see is -- is primarily the water was at the bottom end of the rudder where the most damage was done.

DR. FOX: And one thing about the x-ray, it goes through the -- through both --

DR. WINFREE: The x-ray does both sides at one time, yeah. So, you -- you -- you can't dispute -- you can say it's -- you can say there's water in the honeycomb at that particular position. If you do a single shot, which is what we did in this particular case, alls you can do is -- is determine that it's somewhere along the path. You can't say where along the path it is. In order to be able to do -- with the x-ray, you could be able to do more than one, but it would take doing multiple shots with the x-ray.

DR. FOX: Okay. Let's see. I guess the -- on Page 14, we've got the results of the Lamb wave. Could you step us through those?

DR. WINFREE: Yeah. This is -- this is the Lamb wave and -- and what it -- what you see in there primarily is -- is, I guess, some of the -- the characteristics of like the lightening strap is -- is basically the white strip that goes through there which was actually pretty good for being able to -- to register some of these images with each other.

You can also see there's some indications as to where the hinge blocks are at the bottom. The other thing that you notice is there's kind of a white V that's -- it's, I guess, close to the center. It's where that -- that extra piece goes up there and that actually corresponds pretty well with -- with the image that -- on 13 where - where it shows the -- the image where the face sheet has been fractured from the honeycomb. So, that corresponds pretty well with that and probably what it's indicative of.

There's also some regions which are a little bit darker than other regions. Those had to do with the fact that there is a ply overlay at this particular point and that gives you a little bit stiffer region in that particular point.

The bottom one shows some of the same characteristics. Once again, you can kind of see where if you look on -- on Page 13, where there's -- there's a fractured face sheet and that corresponds pretty well with the Lamb data that you get there, and then you see some of the other characteristics as well of the overlap, the -- the lightening strip and stuff like that. So.

DR. FOX: Okay. Thank you.

And then, I guess the -- let's see. The --

the final technique we have is the thermography, and could you discuss those results?

DR. WINFREE: Okay. The -- that's on Page 15, and the top just shows two different signals, two different thermal responses that we get after we flash the flashlamps. The one shows the signal that we get if we have just a face sheet with no water entrapped behind it, and below it, we show a cell that basically has water entrapped in it, and what you can see is the significant change in -- in the cooling off, the way it cools off after the flashlamps.

We actually, went through and analyzed all the different images we have from that and those are shown in the -- in the next viewgraphs or next images. I guess the best thing to do is probably to go to the next page. Those kind of show the reduced images and then go down to Figure 5.4 to start off with, 5.04, and does the color show up? Well, what we -- what we did was we highlighted in the -- in the color images, you can see we highlighted the regions where -- where these look like they had water, and if you -- actually, if you look at them and you look at the -- once again, back at 13 and look at where there's the -- the face sheet has been detached from the honeycomb, it looks like they correspond pretty well to the -- to the regions where the -- the face sheet is detached from the honeycomb and probably therefore a result of the water getting into Jamaica Bay.

DR. FOX: So, -- so, to summarize in general, the results of the -- of the test from the rudder show that the water -- location of the water that you detected from these various techniques seemed to correspond with where you saw visual damage?

DR. WINFREE: Where we saw visual damage and also where we saw the detached -- detached honeycomb. Yeah.

DR. FOX: Okay. I have no further questions. Thank you.

ACTING CHAIRMAN CARMODY: Thank you, Dr. Fox.

Any questions from others on the Technical Panel?

(No response)

ACTING CHAIRMAN CARMODY: All right. Let's move to the parties then. Starting with Airbus, Dr. Lauber?

DR. LAUBER: We have no questions for this witness. Thank you.

ACTING CHAIRMAN CARMODY: All right. And the FAA, Mr. Donner?

MR. DONNER: No questions. Thank you, ma'am.

ACTING CHAIRMAN CARMODY: American, Mr. Ahearn?

MR. AHEARN: No questions, ma'am. Thank you.

ACTING CHAIRMAN CARMODY: And Allied Pilots, Captain Pitts?

CAPT. PITTS: Yes, ma'am. I'll be brief.

Dr. Winfree, are there effective field non-destructive inspection practices or methods available that can assist operators in the -- in the assurance of the quality of these components, especially in light of the fact as we see the more reliance on the composite structures used in aviation?

DR. WINFREE: Are there -- are there techniques already available?

CAPT. PITTS: Well, --

THE WITNESS: Is that what you're asking?

CAPT. PITTS: Sure. I'll break it up. Are there -- are there effective techniques in the field that can be used --

DR. WINFREE: Well, typically, what we do with ultrasonic -- excuse me -- with any NDE technique, first of all, somebody defines for us what is a critical flaw, and then when they define the critical flaw, what we do is we establish whether or not there's a technique to find that critical flaw or not.

I would say for all things like delaminations, even micro-cracks, I would say there are techniques that already are available that, yes, could go into defining those techniques. As other critical flaws are identified, what we would have to do is -- is on a case-by-case basis decide whether or not they exist.

CAPT. PITTS: In the course of this investigation, have you discovered critical flaws in composites that have not been previously identified to you?

DR. WINFREE: No.

CAPT. PITTS: Thank you, sir. That's all the questions I have.

ACTING CHAIRMAN CARMODY: Thank you.

Moving to the Board, Member Hammerschmidt and Goglia, Member Black, any questions?

MEMBER BLACK: Just one on 15C. Could we put that up? I'm sorry. 15 -- 15C, Page 3. Is this the lug map that we talked about with the Airbus witness previously, the one that is shown to -- in his testing to be the first fail, the right rear?

DR. FOX: That's in the analysis that we have so far. The right rear is the lug that is -- is failed first.

MEMBER BLACK: Doctor, are your examinations of this area far enough to -- to say whether you found anything in that area that would get your attention?

DR. WINFREE: I don't remember finding anything. Actually, Airbus is the one that actually did the inspections on this part of the lug. So.

MEMBER BLACK: You didn't look at it?

DR. WINFREE: No, not in this particular lug. No, not down in the lug area. Not where it got thick, we didn't look at it. They had special -- like I said, they had special delay lines and transducers that enabled them to -- to put in signals at surface normal. They also looked at -- at different specimens back at their place that were standards. Typically, you don't look at something like this. You need some kind of standard in order to be able to assess whether or not you can really find a flaw or not when it gets in these complex structures.

MEMBER BLACK: Thank you.

ACTING CHAIRMAN CARMODY: Are there any additional questions from the Technical Panel or any of the parties?

(No response)

ACTING CHAIRMAN CARMODY: Seeing none.

(Whereupon, the witness was excused.)

ACTING CHAIRMAN CARMODY: Well, I think that we will adjourn for the evening and start up tomorrow morning at 8. We have two remaining witnesses. So, we should be able to move quickly then.

Thank you all for your cooperation. Thanks to the witnesses very much.

(Whereupon, at 5:14 p.m., the public hearing was adjourned, to reconvene tomorrow morning, Friday, November 1st, 2002, at 8:00 a.m.)