DOCKET NO. **SA-516**

EXHIBIT NO. **18C**

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

METALLURGY/STRUCTURES SEQUENCING GROUP CHAIRMAN'S FACTUAL REPORT
Nose Landing Gear Doors Sequence
Materials Laboratory Report No. 97-155
(16 pages)

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

October 6, 1997

METALLURGY / STRUCTURES SEQUENCING STUDY — Report No. 97-155

A. ACCIDENT

Place	: East Moriches, New York
Date	: July 17, 1996
Vehicle	: Boeing 747-131, N93119
NTSB No.	: DCA96-M-A070

B. COMPONENTS EXAMINED

Nose landing gear doors and surrounding structure

C. DETAILS OF THE EXAMINATION

1.0 INTRODUCTION

The Metallurgy and Structures Sequencing Group was reformed from September 8 to 12, 1997, to evaluate the sequence of the structural breakup of the nose landing gear doors and associated structure. The Group consisted of Jim Wildey (the undersigned) and Deepak Joshi from NTSB, Dan Rephlo from TWA, Ray Stettner from ALPA, Jack Winchester and Warren Steyaert from Boeing, Jon Hjelm from FAA, John Desmond from IAMFA, and Charles Hale from IAMAW.

Documentation of the factual observations of the nose landing gear doors and surround structure is contained in the Structures Group Notes. This Report covers the most likely sequence of events associated with these doors based on observations of damage and fracture directions, on recovery positions of the pertinent pieces in the ocean, and on stress analysis. The methodologies used in this report were similar to those used in the sequencing report on the main portion of the airplane (issued by the NTSB Materials Laboratory as Metallurgy and Structures Sequencing Report No. 97-38). The nose landing gear doors were of particular interest because they were tagged as "Red" zone pieces with diver tags. This report also addresses the fuselage pieces with 2000 series tags (assigned in the hangar) from the nose portion of the airplane near the landing gear.

The nose landing gear wheel well is roughly a block-shaped cavity in section 41 and serves as a stowage area for the nose landing gear during flight. The sidewalls and forward bulkhead of the wheel well are canted inward. The sidewalls and bulkheads of the wheel well also serve as pressure barriers between the interior fuselage cabin pressure and the ambient atmospheric pressure.

The cavity consists of two interconnected bays. The forward bay is of much larger volume than the aft and accommodates the nose gear wheels, steering mechanism, and the lower length of the shock strut while the aft bay accommodates the upper length of the shock strut along with the retraction mechanism and associated structural bracing.

The aerodynamic shape of the fuselage in this area is maintained by four doors, two forward and two aft, that serve to enclose the entire nose landing gear assembly during flight and provide aerodynamic fairing with the adjacent fuselage skin. The doors do not serve as pressure barriers between the fuselage and the ambient atmospheric pressure (although the aerodynamic forces on the airplane may result in a slight pressure differential across the doors).

The forward doors are hydro-mechanically actuated, and each door, left and right, rotates 87 degrees about three hinges that are located along the lines of intersection of the gear well sidewalls and the fuselage skin. In the closed position, the travel of these forward doors is limited by adjustable mechanical stops at the forward and aft ends of the doors. The forward doors are caused to move open and closed by an actuation system at the forward canted bulkhead consisting of a single linear hydraulic actuator mounted to the airframe structure on one end by a lug and clevis configuration to allow rotational freedom with translational rigidity. The opposite end of the actuator is attached to a beam-type actuator arm, which is also mounted on one end to the airframe structure with similar freedom of rotational movement. At the opposite end of this arm (the actuator attaches at an intermediate position on the arm), two push-pull control rods are attached, one control rod for the left door and one for the right. In the open position, the travel of the forward doors is determined by the full stroke of the actuator and the length of the control rods. The geometrical relationships and physical constraints cause the right door to necessarily overlap (externally) a blade seal attached to the left door at the centerline in the door closed position.

The door hinges are a lug and clevis type configuration, with the lug half attached to the door and the clevis half mounted to the airframe with four bolts. The clevis half is vertically adjustable by means of serrated plates.

The aft doors are mechanically actuated, driven by a series of control rods and bellcranks connected directly to the nose gear trunnion. The extent of door opening is directly a function of the nose gear shock strut travel about the trunnion. The aft doors also hinge at the intersection of the gear well side walls and fuselage skin. These hinges are also of the clevis and lug type with the lug attached to the door and the clevis to the airframe. The aft doors have only two hinges each. Adjustable up stops for the aft doors are mounted on the aft bulkhead at the centerline.

2.0 OVERALL OBSERVATIONS

The pieces of the nose landing gear area wheel well structure, including the recovered portions of the nose landing gear doors, were assembled together and examined in a mock-up. The left aft door contained heavy damage consistent with being attached to other structure at water impact. In contrast, the three other doors contained much less damage, indicating that they separated from the other structure before water impact. Recovery positions in the red zone, as indicated by the tags on the door pieces, indicated that the two forward doors and the right rear door separated from the airplane early in the sequence of the breakup of the airplane.

The pieces in the mock-up were examined for evidence of the position of the landing gear when the structure impacted the water. The right side of the forward portion of the bay (pieces RF177, RF185, RF184, and RF50) contained what appeared to be heavy black rubber transfer deposits from contact with a tire. The presence of transferred tire material on the right side wall would indicate that the gear was in the retracted position when the nose portion of the airplane impacted the water.

3.0 COMPONENTS SEQUENCE

3.1 Sequence of the Forward Left Door

The forward left door separated from the airplane in one piece. Examination of the hinges and associated structure revealed ample evidence indicating that the door separated from the airplane by overtraveling in the opening direction. This evidence included (1) overtravel deformation in the opening direction on the three door hinges, (2) the fracture types and damage patterns associated with the hinge areas, (3) witness marks and deformation on the inboard edge of the fairing between the door and the fuselage and on the outboard edge of the door, and (4) a rivet contact pattern on the exterior skin of the door where it contacted the protruding head rivets of the lap joint just outboard and above the hinge location. The forward doors normally are curved outward from front to rear, consistent with the changing slope of the exterior fuselage in this area. In its recovered condition, the overall shape of the forward left door was nearly flat, but the exterior surface contained compression buckling, consistent with contact and impact of the door with the exterior of the fuselage as it was forcibly opened. There are inward deformations of the outer skin over an approximate 15 inch by 15 inch square area at the forward inboard corner of the door. This damage was also consistent with contact with the fuselage as the door separated from the airplane.

The forward left door also contained damage that did not appear to be directly associated with the final separation of the door from the airplane. This included damage to the door created by the forward stop (progressing in a slight arc from the pad on the interior surface downward across the forward box web, and through the exterior skin flange) and damage to the control rod that opens and closes the door. The remainder of this section will sequence this damage to the door relative to the final separation of the door from the airplane.

Motion of each of the forward doors for the nose landing gear is controlled by rods that attach to an actuator arm and to the forward edge of the door. The control rod for the forward left door contained a tensile separation at its upper end where it attached to the actuator arm. The control rod was also fractured in bending at an impact dent where the rod had contacted the inboard edge of the left door. The dented area contained a series of bolt head imprints within the dent. Comparison of these imprints with the bolt heads on the perimeter of the forward left door interior surface indicated that the control rod impacted the inboard edge of the door three separate times, leaving three sets of imprints. Geometric considerations indicate that the dent could not have been created by inward motion of the door while the rod was undamaged and attached at both ends. Therefore, denting of the rod was not caused by inward motion of the door from its closed position, and tensile separation of the upper end of the rod (by downward motion of the door) preceded creation of the dent. The tensile separation at the upper end of the control rod may have been the first damage created on the door or associated hardware. Subsequent denting of the rod could have been created by flailing motion of the rod after separation of the upper end from the actuator arm.

The aft stop contact pad on the forward left door contained multiple impact marks from contact with the stop, but there was no evidence that the door significantly overrode this stop, based on other indications. The forward stop pad on the door was deformed and the stop was broken off the fitting attached to the forward canted bulkhead. The stub of the forward stop fitting created a witness mark along the forward edge of the door and through the exterior skin flange, indicating that (at some time before final separation of the door) this corner of the door moved inward relative to the stop (opposite to the direction of the final failure direction of the door). Consideration was given to the possibility that the damage created by the separated stop was generated, not by inward motion of the door past its closed position, but by downward motion of the stop and the forward bulkhead of the nose landing gear compartment. However, this was believed to be unlikely because the forward bulkhead was relatively intact, and the door actuator and actuator arm remained attached to the bulkhead. An initial downward motion of the bulkhead would be expected to carry the doors with it, and only minimal relative motion of the door relative to the stop would be expected to be created by this motion. Therefore, the damage created by the forward stop did appear to be created by inward motion of the forward inboard corner of the door past its closed position.

The witness marks left by the stub of the forward stop fitting on the forward left door extended completely through the door thickness, indicating a minimum upward deflection of the door of about 5 inches. There were no indications that the door moved inward an amount substantially greater than the thickness of the door. (See a discussion in later paragraphs of this section concerning the inward overtravel damage to the hinges.) When the landing gear is retracted, there normally is a space between the tire and the center of the inside surface of the door. Information available at the time of this report indicates that this space is approximately 4.5 inches. Dynamic inward movement of the door (sufficient to create impact damage to the aft stop pad and to fracture the forward stop) could cause the forward inboard corner of the door to move inward past the broken stop, even when the landing gear is retracted and situated within the wheel well.

In addition to the stops at the forward and aft ends, possible inward motion of the forward doors (past the normally closed position) is also constrained by the door opening components that connect from the door through the rods, through the actuator arm, through the actuator and to the mechanical lock in the actuator. It is therefore likely that the tensile separation of the upper end of the right front door rod preceded the inward motion of the front left door past the stop. There was no evidence that the right door overrode its forward stop.

The forward and center hinges for the forward left door contained witness marks between the lug and clevis indicating that these hinges had overtraveled in the door closing direction. This damage was more severe on the center hinge compared to the forward hinge. The aft hinge did not have this type of damage.

The Group considered various methods by which the overtravel damage could have been produced on the hinges. First, consideration was given to the possibility that the door overtraveled inward a sufficient amount to create this damage or the side wall of the compartment rotated inward and down, bringing the outboard portions of the hinges with it. However, the presence of the tires within the compartment would easily prevent these types of extreme motions, and there is no evidence that the tires ever departed the wheel well. Even if the tires were not present within the wheel well, the physical interactions of the door with the sidewalls and forward canted bulkhead preclude rotation of the hinges an amount needed to create the observed overtravel damage while the door is attached. It was concluded that the overtravel damage in the closing direction was not created by inward motion of the door or by collapse of the sidewall.

Other possible scenarios of causing overtravel damage in the closing direction considered by the Group included (1) flutter or vibration and associated localized sidewall deformation with the door open and the control rods separated, (2) springback of the hinges from an extreme overtravel in the opening direction in the door closing direction as the door separated from the airplane, (3) relative motion of the hinge pieces after the door separates from the structure, and (4) water impact. The Group was unable to determine which of the above scenarios was responsible for the overtravel damage in the door closing direction.

The sequence of events experienced by the forward left door appears to be as follows:

a. Tensile separation of the control rod by downward motion of the door,
b. Return motion of the door toward the close position, causing impact of the door with the stops, fracture of the forward stop, and continued inward motion of the forward inboard corner of the door, past the stub of the stop.
c. Separation of the door from the airplane by overtravel in the opening direction.

3.2 Sequence of the Forward Right Door

The forward right door separated into two pieces midway between the center and aft hinges. Generally, the door retained its proper curvature, except that the interior skin of the door contained compression buckling adjacent to the door fracture. The door also contained inward deformation of the outer skin over an approximately 15 inch by 15 inch square area at the forward inboard corner. The damage in this square area was consistent with contact with the fuselage as the door separated from the airplane. The center and forward hinges contained damage or fractures indicating failure at these locations was the result of extreme overtravel in the door opening direction. The damage and fractures on these two hinges were very similar to the corresponding hinges on the forward left door. Evidence of overtravel in the opening direction was not found on the recovered lug portion of the aft hinge. The clevis portion of the aft hinge separated from the lug portion of the hinge and was not recovered. This separation mode was different from the aft hinge on the forward left door. (The lug portion of the aft hinge on the forward left door pulled out of the door.) The stops for the forward right door contained no evidence that the door overtraveled in the door closing direction.

The control rod for the forward right door was separated at its upper end under tension loads, and at its lower end under tension / bending loads. The rod also contained denting damage approximately at its midlength from contact with the inboard edge of the door. Geometric considerations again indicated that the upper end of the rod must have separated before the denting damage could have been created. The tensile / bending fracture at the door end of the control rod occurred after the denting damage.

The fracture in the forward right door between the center and aft hinges was initiated by bending loads along the length of the door. These bending loads buckled the interior skin of the door at the fracture location. The buckling damage to the door interior surface was at least partially created before final separation of the door from the structure. However, the exact sequence of hinge separation, creation of the buckling damage, and door fracture was not absolutely confirmed.

The geometrical arrangement of the actuator, actuator arm, and control rods causes the forward right door to close after the forward left door. The inboard edge of the forward left door has a seal on the door exterior that the right door closes against. This seal and the inboard edge of the right door were largely undamaged, indicating that, during the separation sequence, the right door moved downward, out of the way of the left door seal, before the left door moved downward.

All three of the hinges for the forward right door contained overtravel damage in the door closing direction. Similar to the forward left door, the physical constraints of the wheel well and the presence of the tires within the well prevent this damage from being created before separation of the hinges.

The sequence of events experienced by the forward right door appears to be as follows:

a. Tensile separation of the control rod by downward (opening) motion of the door.
b. Impact of the control rod on the door edge at some time after separation of the upper end of the rod.
c. Overtravel of the door in the opening direction causing separation of the forward hinge and allowing bending loads to buckle the interior surface of the door between the center and aft hinges.
d. Separation of the door from the structure as a result of continued overtravel in the opening direction.

3.3 Sequence of the Aft Right Door

The aft right door separated from the airplane in one piece. The control rod for this door contained a tensile separation at its upper end and was slightly bent. Most of the rod remained attached to the door. The door and door hinges contained ample evidence that the final separation direction of the door was overtravel in the door opening direction, similar to the forward left door.

The forward hinge contained evidence of overtravel in the door closing direction. The aft hinge separated between the lug and clevis, as well as between the lug and the door and between the clevis and the fuselage structure. Physical limitations (the presence of landing gear components in the wheel well when the gear is either extended or retracted) make it extremely improbable that the hinges could overtravel in the closing direction while the door is attached. In addition, the interior surface of the door did not contain evidence of impact with landing gear structure. Also, the presence of the trunnion fitting makes it improbable that the sidewall collapsed and created the damage to the hinge in the door closing direction. Therefore, the overtravel damage in the closing direction on the aft hinge occurred after separation of the door.

The aft right door contains a lip on its forward edge that extends under the aft edge of the forward right door. No deformation damage was noted on this lip, indicating that the forward right door was out of the way before the aft right door moved in the opening direction.

The sequence of events experienced by the aft right door appears to be as follows:

a. Tensile separation of the control rod by downward (opening) motion of the door after the forward right door moved out of the way.
b. Final separation of the door in the opening direction.

3.4 Sequence of the Aft Left Door

Heavy crushing damage on the aft left door indicated that it remained attached to the nose structure until water impact.

3.5 Sequence of Damage to the Landing Gear Wheel Well and Surrounding Fuselage Structure

As previously stated, the right sidewall of the front portion of the nose landing gear wheel well contained apparent transferred material from a nose landing gear tire. Samples of this transferred material were removed and will be tested to confirm the composition. The structure with this transferred material was heavily crushed along with the nearby right side fuselage structure. This crushing damage is consistent with the structure in this area being intact and impacting the water. The left sidewall of the nose landing gear wheel well was bulged to the left (both vertically and horizontally), consistent with overpressure loads on the right side of the left sidewall at water impact.

A group of fuselage pieces (including RF107, RF89, RF84, RF91, RF87, RF88, LF8B, and RF8A) from the nose portion of the airplane were labeled with 2000 series red zone tags or were from an unknown area. The damage on all of these pieces, as well as on the mating yellow zone pieces, was consistent with the nose portion of the airplane remaining largely intact (after separation of the forward left, forward right, and aft right landing gear doors) until water impact. The Group concluded that these pieces remained with the forward fuselage until water impact and should be treated as yellow zone parts.

4.0 OVERALL SEQUENCE

Five different general categories of possible failure sequence initiation and propagation were considered by the Group:

a) Initial door deployment and/or failure precipitated by an independent event preceding and unrelated to anything currently identified and documented in the structural breakup sequence.

b) Initial door deployment and/or failure as a direct result of the earliest event currently documented in the structural breakup sequence; failure of the CWT due to a fuel-air explosion.

c) Initial door deployment and/or failure as a result of separation of the forward body which may have followed the initial CWT fuel-air explosion by several seconds.

d) Initial door deployment and/or failure propagation following separation of the forward body but still at close to the same altitude and speed.

e) Door failure associated with water impact of the forward body in the yellow area.

The team was unable to absolutely conclude which of the preceding scenarios occurred. However, it was possible to specifically look for evidence to either support or refute each scenario and form a consensus on which ones are more or less likely to have happened. Unfortunately potentially key information on the internal status of the door retract actuator will not be available until a teardown inspection can take place. In sections 5.1 through 5.5 the above scenarios are discussed in terms of supporting and non-supporting evidence. A general summary of conclusions reached by the Group is then presented in section 5.6.

4.1 Initial Door Deployment and/or Failure Precipitated by an Independent Event Preceding and Unrelated to Anything Currently Identified and Documented in the Structural Breakup Sequence.

The condition and recovery location of 3 of the 4 doors (both forward doors and aft right door) does support an early departure from the airplane. However, the recovery locations are enveloped by those of other red zone fuselage and CWT pieces suggesting a more simultaneous departure. Close inspection of the three red zone doors showed no unexplained penetrations or otherwise suspicious damage. As discussed in sections 4.1, 4.2, and 4.3 it was concluded that the three red zone doors could not have failed inward (i.e. from an external overpressure of unknown origin). The surrounding wheel well structure was heavily damaged during water impact making it difficult if not impossible to identify more localized evidence of an earlier event had it occurred. In summary the Group was unable to identify any direct evidence to support this scenario, but on the other hand could not find sufficient evidence to rule it out.

4.2 Initial Door Deployment and/or Failure as a Direct Result of the Earliest Event Currently Documented in the Structural Breakup Sequence; Failure of the CWT Due to a Fuel-Air Explosion.

In this scenario the overpressure from the venting CWT explosion would travel down the forward cargo compartment, past the 4 containers, through the E&E bay into the region surrounding the nose wheel well. It should be noted that there is 16 inches of clearance between the outer side of the LD-3 containers and the sidewall. There would then be two possible outcomes leading to door deployment/failure.

First, there could be a general collapse of the wheel well sidewalls, etc. leading to venting into the wheel well and failure of the forward door and aft door control rods. Secondly there could be a more localized breach of the wheel well structure allowing venting to occur without a general collapse of the sidewalls. The more localized venting could still have the same effect of pressurizing the wheel well cavity and failing the control rods.

The Group was unable to find direct evidence of either of the above. Although the sidewalls and bulkhead were heavily damaged from water impact, their condition does not appear to be consistent with a general collapse of the structure due to overpressure. Due to the extent of damage and missing structure a more localized breach in the wheel well structure cannot be ruled out however. The recovered portions of the four containers loaded into the forward end of the forward cargo compartment were also examined and showed no identifiable evidence of overpressure damage.

The flat sidewalls of the nose wheel well have significantly less capability to sustain overpressure than the basic fuselage monocoque (skin, stringers, and frames). Therefore, sidewall failure (general or localized) could occur without discernible deformation in the fuselage structure between the front spar and nose wheel well. The exception is the main deck floor structure which has much lower capability and is believed to have failed as far forward as approximately Sta. 600 due to the overpressure vented from the CWT and/or decompression (see previous Sequencing Report 97-38).

It has been confirmed by stress analysis that an overpressure capable of causing venting into the nose wheel well cavity would be more than sufficient to cause failure of the door control rods, allowing the doors to deploy unrestrained into the airstream. This would almost certainly result in loss of the forward doors since the airplane was also traveling at well above the door design placard speed (270 knots). A more detailed discussion of loss of the doors as a result of deployment into the airstream is provided in section 5.3.

In summary this scenario would be generally consistent with the currently documented breakup sequence, condition and location of door hardware, etc. However in the absence of direct supporting evidence in the wheel well structure it is not possible to substantiate it or rule it out.

4.3 Initial Door Deployment and/or Failure as a Result of Separation of the Forward Body Which May Have Followed the Initial CWT Fuel-Air Explosion by Several Seconds.

There are both hydraulic and mechanical systems which transit the red zone of the fuselage (about STA 740 to STA 1000) and are directly involved in the deployment of the nose landing gear and doors. It is a given that these systems would be first disrupted then severed as the forward fuselage separated away from the airplane.

The basic landing gear control system takes its input from the cockpit via a pair of cables to separate control valves aft of the WCS in the main wheel well. One valve controls the wing gear while the other valve controls both the body gear and nose gear (including doors). To provide actuation power for the nose gear and doors hydraulic lines are then routed forward through the fuselage from the control valves to the respective actuators in the nose wheel well.

It is possible that the fuselage separation process could have resulted in a commanded deployment. There is some indication of this in that one control valve (wing gear) is in the "gear down" position while the other (nose and body gear) is in the "gear up" position. It should be noted that the valves are mechanically interconnected to provide synchronized deployment. Therefore, the fact that they have different settings raises the possibility that one or both of the valves moved during the separation of the nose from the remainder of the airplane. Therefore, fuselage separation could cause a commanded deployment of the forward doors (sufficient to unlock the doors) and an immediately subsequent loss of hydraulic power. This would probably have resulted in the doors partially deploying, with only minimal restraint provided by the actuator.

It is also possible that the process of elongating, then severing the relatively ductile hydraulic lines could have produced a pressure spike capable of unlocking the nose landing gear door actuator. In this case, the forward doors would have been free to deploy, only restrained by the actuator which probably no longer had hydraulic resistance from an active system.

In either of the above cases of door deployment, the expected outcome would be failure of the forward door control rods followed by departure of the doors given the airplane speed at the time of the event. Once the doors open, rotation about the hinge axis is essentially unrestrained. This would make the door vulnerable to a flutter/vibration type excitation to initiate the failure sequence. Relatively high vibration amplitudes and accompanying loads would have failed the control rods in the weaker upper end in tension through the net section at the double crossbolt holes. The vibratory mode would also have likely been capable of driving the forward inboard corner of the door against the stops resulting in yielding of the right door stop and failure of the left door stop with the left door actually driving past the stop an estimated 5 inches inside of contour. There was also evidence of multiple aft stop impacts on the left door. Following failure of the control rods, the vibration amplitude would increase to a point where the door hinges and adjacent fuselage would have begun to short couple probably resulting initially in failure of one of the end hinges. The door would then have one half essentially cantilevered adding a fore and aft bending mode to couple with the rotational mode. This would be consistent with the midspan skin buckling on the right door and the failure of the right door in the same region. The relatively violent excitation of the doors would have culminated in the unrestrained doors over-rotating outward resulting in a short coupling failure of the remaining hinges with the rotational momentum of the separating doors causing them to wrap upward against the adjacent fuselage skin before finally dropping away from the airplane. Indentations and witness marks on the door exterior surfaces are consistent with contact with the adjacent fuselage. The final violent action just preceding and/or accompanying hinge failure could have resulted in relative motion between the respective hinge fittings on the door and fuselage giving witness mark indications of the doors over-rotating deep into the wheel well. The Group determined that the doors themselves could not have rotated inward to cause this damage.

In the event the forward doors were deployed and lost, the aft doors would also be subject to failure whether they were stowed (along with gear) or deployed (along with gear). In the stowed position they would be overloaded either concurrently with or subsequent to the failure of the forward doors. The aft doors would also have been subjected to dynamic loads of a non-steady-state nature, resulting in the failure of the right door control rod. Failure of this rod results in an unrestrained surface in the airstream vulnerable to the same flutter/vibration modes which contributed to failure of the forward doors. Failure of the right door could tend to relieve the load associated with the wheel well cavity, allowing the other door (i.e. left) to remain attached. If the gear had deployed at the speed of TWA 800 then loss of one or both aft doors due to overload and/or a flutter/vibration type excitation as described for the forward doors would not be unexpected.

Key additional evidence for this scenario as well as others may be revealed when the actuator for the forward doors is inspected during teardown. If the door actuator can be confirmed as unlocked it would be strong supporting evidence for this scenario. If warranted, inspection of the nose gear actuator may give an indication of the nose gear position at the time of water impact providing further evidence on whether it had been deployed.

4.4 Initial Door Deployment and/or Failure Propagation Following Separation of the Forward Body.

In this scenario a combination of airloads and cavity pressure create a differential loading across the door sufficient to fail the actuator lock and/or control rods initially allowing the forward door to be free to move into the airstream. Stress analysis indicates the above could begin to happen at outward acting pressure gradients as low as approximately 2.2 psi. It is not possible to predict actual airloads and cavity pressure due to the abnormal configuration and uncertain angle of attack. However, it is believed that 2.2 psi could be a realizable number at more than 300 knots and 14000 feet. It is also possible that deflection of the door under excess loading resulting in partial venting into the nose wheel well could, in turn, result in unstable cavity pressures which, coupled with the door aeroelastic behavior, could finally result in flutter/vibration excitation of the doors similar to that described in section 5.3. If actuator lock and/or control rod failure did allow the doors to deploy into the airstream (unrestrained about their hinge axis) then the sequence described in 5.3 above (along with supporting evidence) will apply to this scenario as well. The determination of whether the door actuator lock was failed or simply unlocked will be the key evidence in concluding which of the scenarios described in 5.3 or 5.4 can be ruled out.

4.5 Door Failure Associated With Water Impact of the Forward Body in the Yellow Area.

Of the five categories of failure scenarios this one can essentially be ruled out. If the three red zone doors had been separated on water impact in the yellow zone, it would have been necessary for them to remain floating, and then drift back up the flight path to be dispersed consistent with their recovery locations. Cracks and fractures within the door structure indicate that the doors would be expected to float only briefly if at all. Furthermore, the condition of the doors as compared to the structure known to have impacted in the yellow zone also provides compelling evidence the two forward doors and aft right door departed from the airplane before the forward fuselage impacted the water. Therefore, this scenario was given the very lowest probability (essentially negligible) of occurrence.

4.6 Overall Sequence Summary

The Group tried to approach the exercise by identifying all possible scenarios potentially consistent with the initial nose gear door evidence. This provided a path for a more focused search for specific evidence to support or refute any given scenario. No direct evidence could be found to either confirm or refute the first two scenarios (sections 5.1 and 5.2). However the absence of any direct evidence supporting their existence probably indicates a relatively low likelihood of occurrence. The third scenario (section 5.3) related to door deployment due to systems disruptions/failures is very plausible given the documented nature of the airplane breakup sequence. The fourth scenario (section 5.4) related to door overload/failure due to aerodynamic loading effects is also plausible. Confirmation of the door actuator lock status will be a key step toward concluding which of the third or fourth scenarios is in fact the most likely overall scenario. The final scenario (section 5.5), door failure on water impact, has been essentially ruled out.

James F. Wildey II
National Resource Specialist - Metallurgy

NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

October 31, 1997

METALLURGY / STRUCTURES SEQUENCING STUDY Report No. 97-155A

A. ACCIDENT

Place	: East Moriches, New York
Date	: July 17, 1996
Vehicle	: Boeing 747-100, N93119
NTSB No.	: DCA96-M-A070

B. COMPONENTS EXAMINED

Nose landing gear doors and surrounding structure

C. DETAILS OF THE EXAMINATION

This document is an addendum to NTSB Materials Laboratory Report No. 97-155 and contains corrections and additional information.

The references on page 9 of Report No. 97-155 to "sections 5.1 through 5.5" and "section 5.6" (in the paragraph starting "The team was unable to . . .") should be "sections 4.1 through 4.5" and "section 4.6".

The reference of page 11 of Report No. 97-155 to "section 5.3" in the first paragraph should be "section 4.3."

The references on page 14 of Report No. 97-155 to sections 5.1, 5.2, 5.3, 5.4, and 5.5 (in the entire last paragraph) should be to sections 4.1 through 4.5.

Following the Group's examination of the nose landing gear doors and associated components, the nose landing gear door retract actuator was inspected to determine the internal condition and status of the locking mechanism. The results of this inspection indicated that the locking mechanism was not damaged and was within specification limits.

The lack of damage to the locking mechanism indicates that the actuator lock was released and not overcome by loads transmitted from the doors. This condition therefore supports the sequence described in section 4.3 of Report No. 97-155 (initial door deployment due to systems disruptions or failures as a result of the separation of the forward body from the remainder of the airplane).

James F. Wildey II
National Resource Specialist - Metallurgy