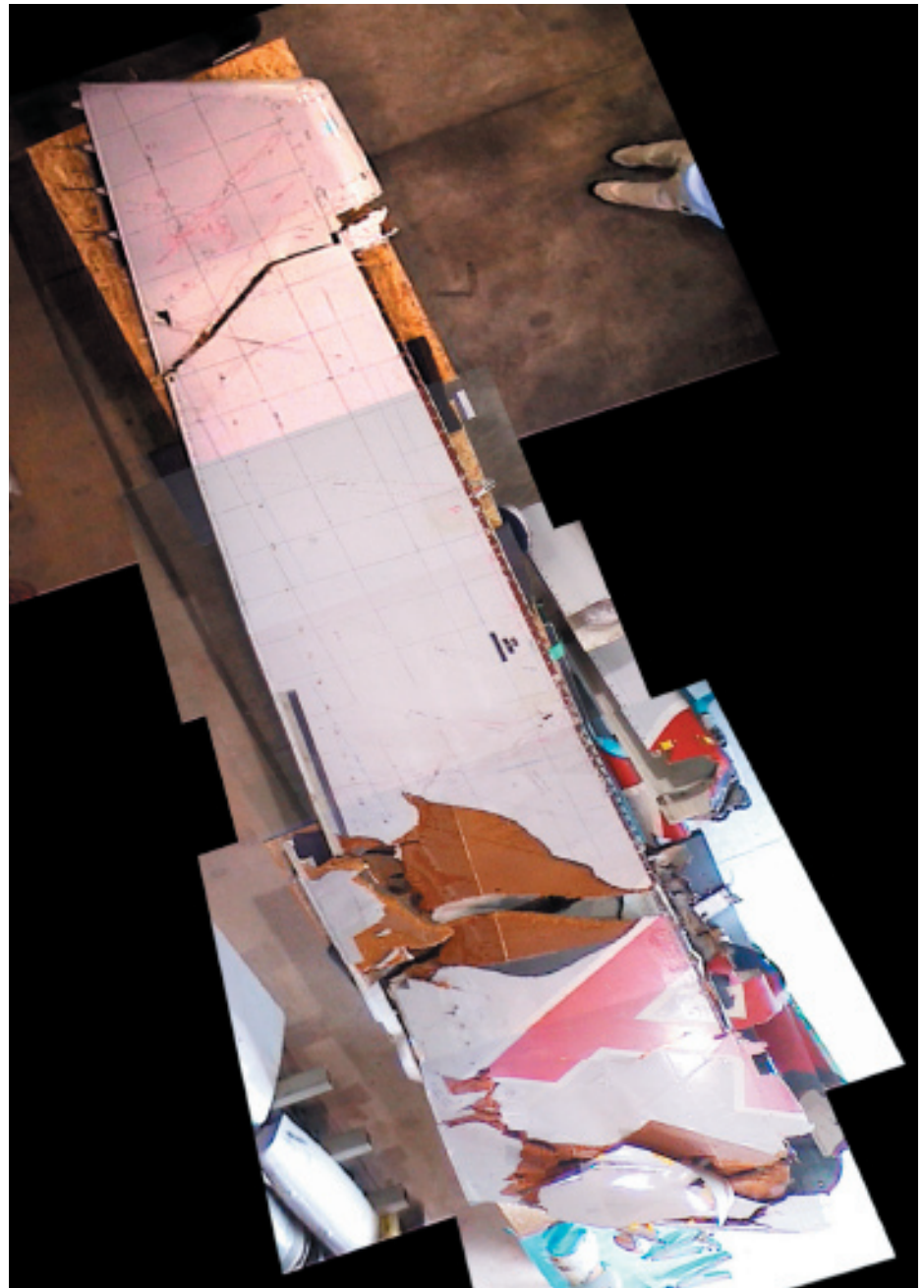


Flight 587 Rudder Breakup

A Theory of the Breakup Sequence



by Murdo Messer

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Caveat

I make no claims what so ever to having any technical expertise or expert knowledge of the Airbus A300 rudder. Nor do I make any claims to expert knowledge of the composite materials of which the Airbus A300 rudder is constructed or how it is assembled. The theory I present below is my own and based solely on my interpretation of available photographs and limited understanding of the physics and forces applied to an object moving through the air. All suggestions and corrections are welcome.

Focus

The focus of this theory will be on the breakup of the Airbus A300 rudder on American Airline Flight 587 that crashed on November 12, 2001. While the separation of the vertical stabilizer is most likely connected to the separation of the rudder I will leave that for discussion at a later date.

Starting Point

The last known reliable rudder position according to the NTSB's Safety Recommendation is 9.5° starboard. I used this as my starting point to interpret what can be seen in the photographs available. I used the 9.5° starboard as the position of the rudder at the start of the breakup.

Thesis

I believe the rudder failed initially at the top and then broke sequentially top down at or near the hinge attachment points.

Reasoning

Following pages outline how I think the rudder broke into the pieces seen in the photographs. I began by examining the photos of the hinges and their attachment points.

Flight 587 Ruddermap

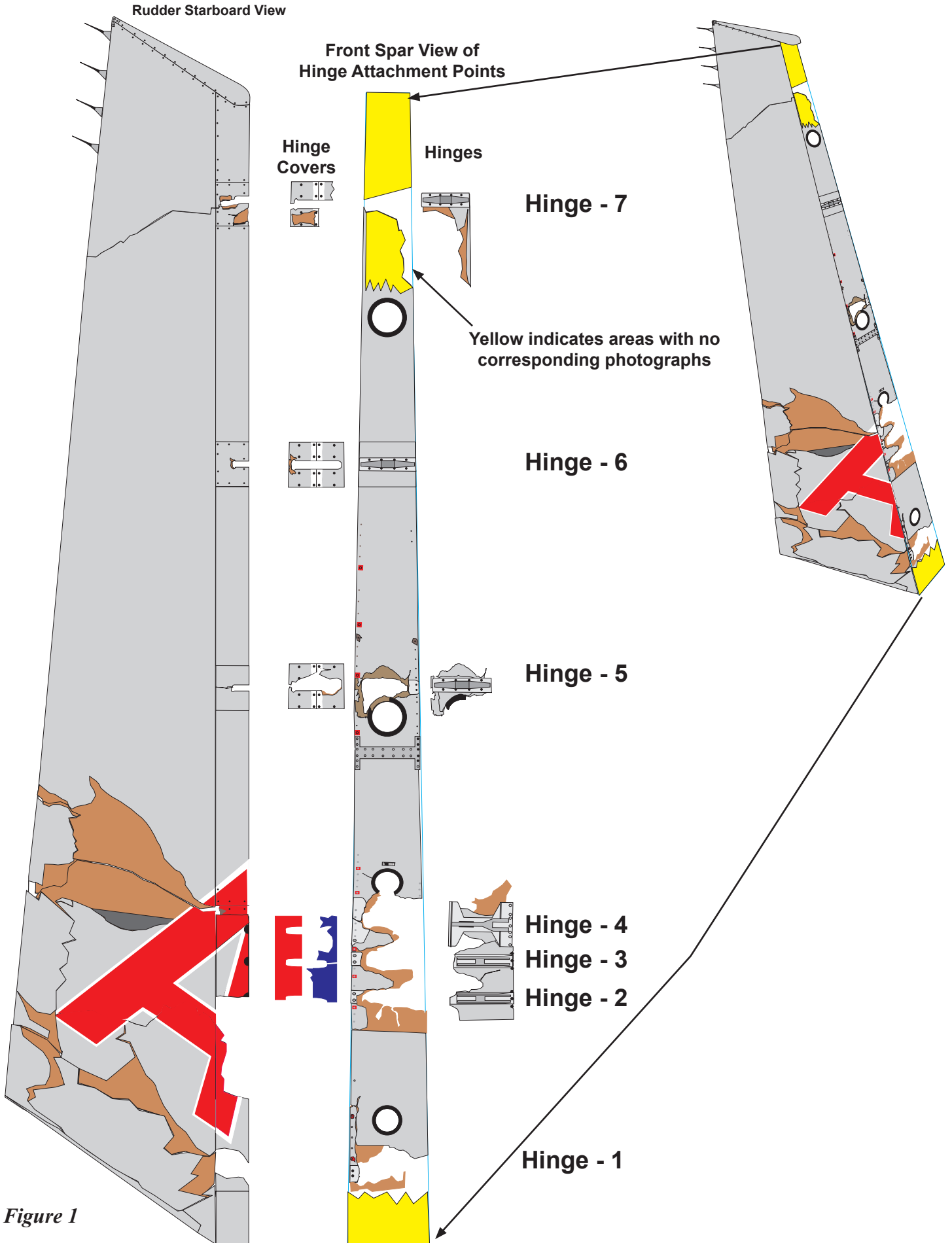


Figure 1

Hinge 7

I think that the break-up sequence began at the top of the rudder. The photographs show that one of the major pieces that remains of the rudder came from the top most section. From diagrams it can be seen that there is about 4 feet of rudder above the top most attachment point, hinge 7. I think that, if the force being exerted on the rudder was sufficient, this top portion broke from starboard to port, (*figure 3*), in line with the hinge. The force would be concentrated along this point.

The break on the starboard side is very clean, (*image 1*) indicating to me that the pieces here were pulled away from each other. A photo of the port side (*image 2*) of this piece seems to show much more damage which one would expect as the two edges along the break are being compressed together. Also in image 2 the large tear, (A), level with hinge 7 appears to have been created by a force pulling from inside the rudder out or by the top rudder piece twisting or rotating as it broke away. Similar material can be seen still attached to the area around the remains of hinge 7, (*image 3*).

The twisting motion probably weakened the hinge on the rudder side where it failed. When this hinge failed the 5 feet of rudder between it and hinge 6 came under similar stress experienced by the top portion. This placed hinge 6 under considerable load which ultimately failed at the vertical stabilizer.

Approximately 4 feet of rudder extends above last attachment point, hinge 7.

Top of rudder breaks starboard to port and is torn away, leading edge rotating up and back.

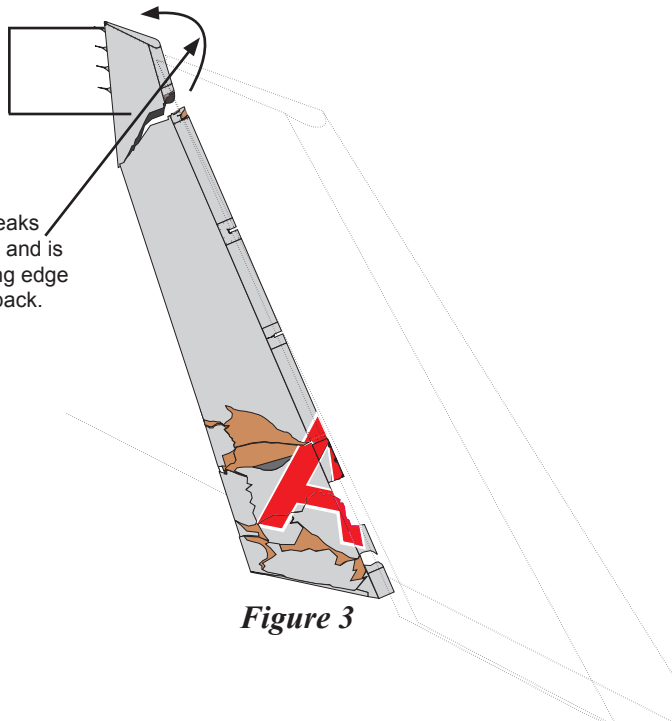


Figure 3

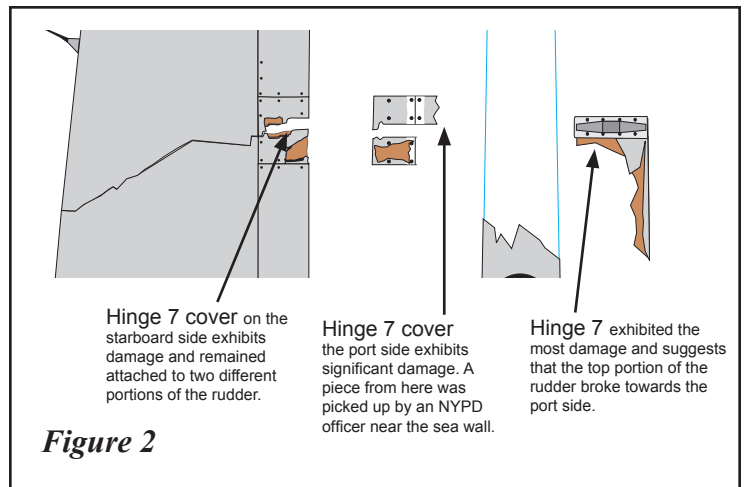


Figure 2

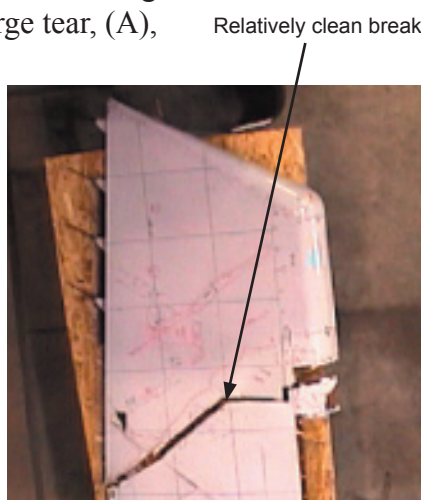


Image 1

Photo, US Read



Image 2

Photo, US Read

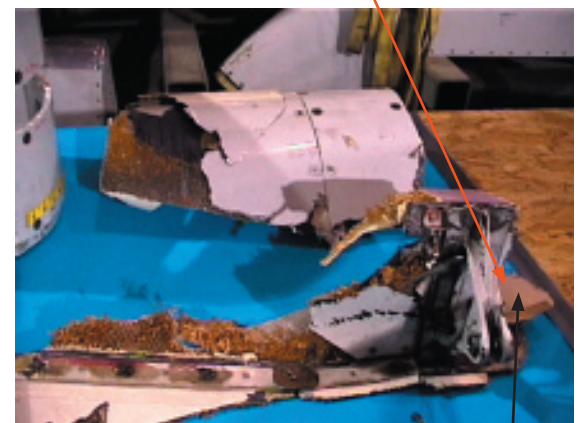


Image 3

Material here corresponds with damage at A in image 2.

Hinge 6

Hinge 6 was the only hinge that broke at the vertical stabilizer. There is minor damage on the starboard and port side of the hinge cover, (figure 4, image 4). This damage would indicate that the hinge arms moved freely back and forth beyond their normal operating range suggesting that the damage to the hinge cover occurred after the rudder separated from the vertical stabilizer.

The tearing pattern of the laminate material, (image 5), (black in photo) indicates that the hinge separated from the vertical stabilizer in a starboard to port and slightly downward direction. This would be consistent with a force applied to the starboard side of the rudder.

When hinge 6 failed all the stress and weight of the top portion of rudder was transferred to hinge 5 about 11 feet below the first break at hinge 1, (figure 5).

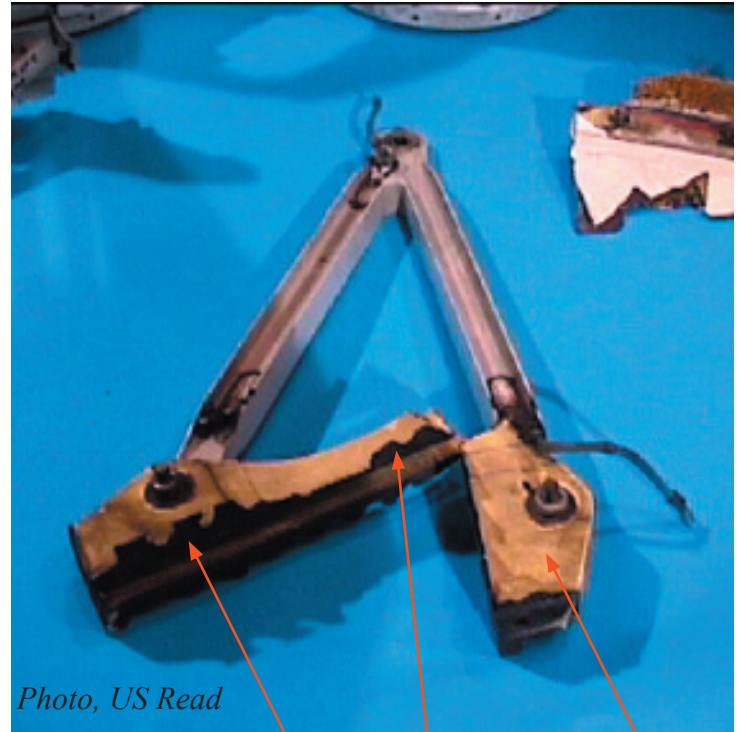
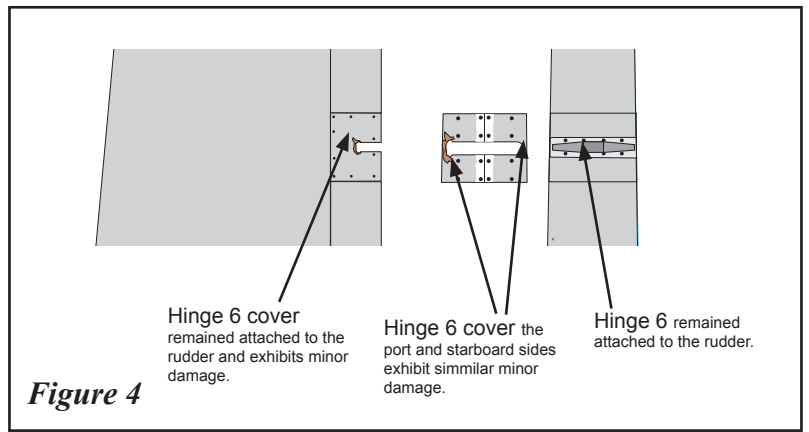


Image 5 Port side Starboard side

Hinge 6 removed from the rudder shows damage at vertical stabilizer attachment point. The tearing pattern of the laminate (black in photo) material indicates that the hinge seperated from the vertical stabilizer in a starboard to port and slightly downward direction.

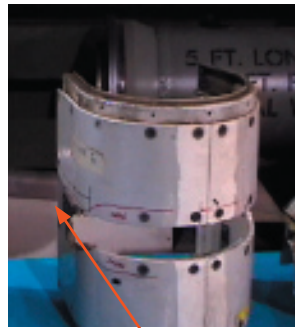


Image 4

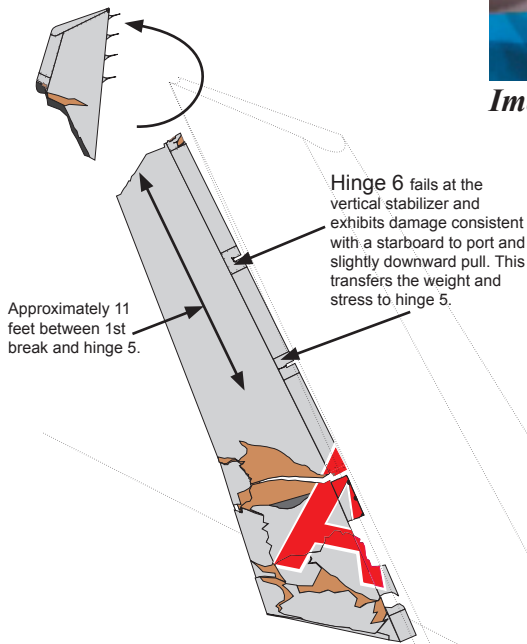


Figure 5



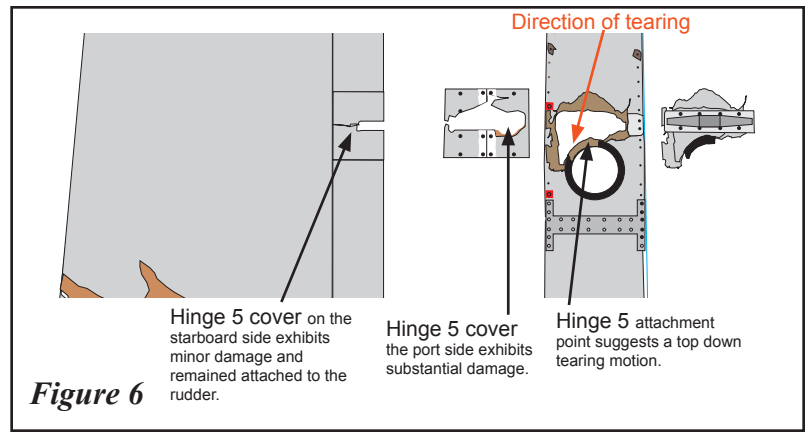
Image 6 Photo, Michael Hvozda, USCG

Hinge 5

Hinge 5 is the lower hinge of the largest piece of the rudder. The hinge cover (*image 6*) exhibits the same port side damage seen in the actuator hinges. The damage to the hinge (*image 7*) itself and the attachment point seem to imply a top down tearing (*figure 6*), with a port twisting. I think it failed in a downward motion and is pulled through the port side of the hinge cover as the rudder section pivots backwards.

A top down tearing would seem possible when viewed in light of the damage to the trailing edge near the base of the rudder (*figure 7 & image 8*).

Ultimately this large piece of the rudder broke inline with the area above hinge 4, the top most actuator hinge. As this piece separated it weakened the trailing edge of the lower portion of the rudder and exposed the widest, most hollow part of the rudder to the slipstream.



Hinge 5 cover exhibits extensive port side damage.

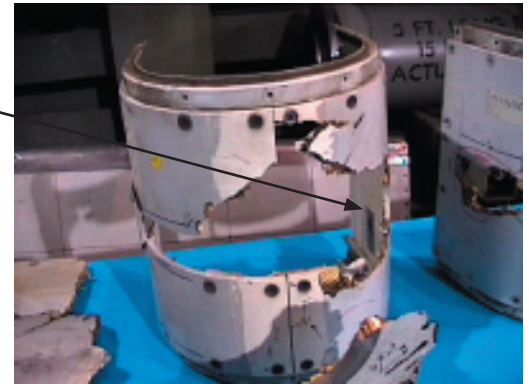


Image 6 Photo, US Read

Hinge 5

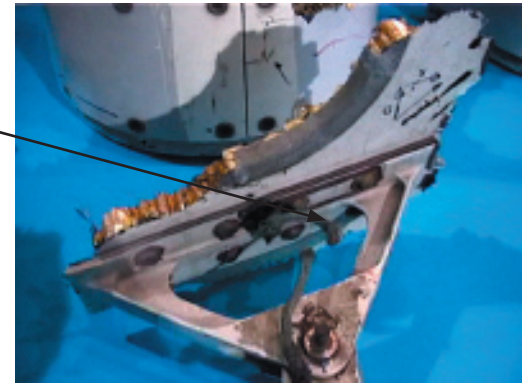
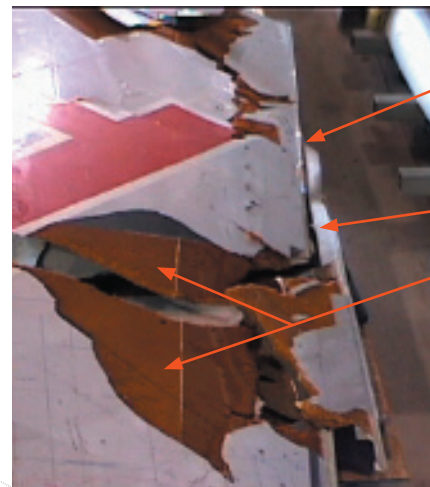
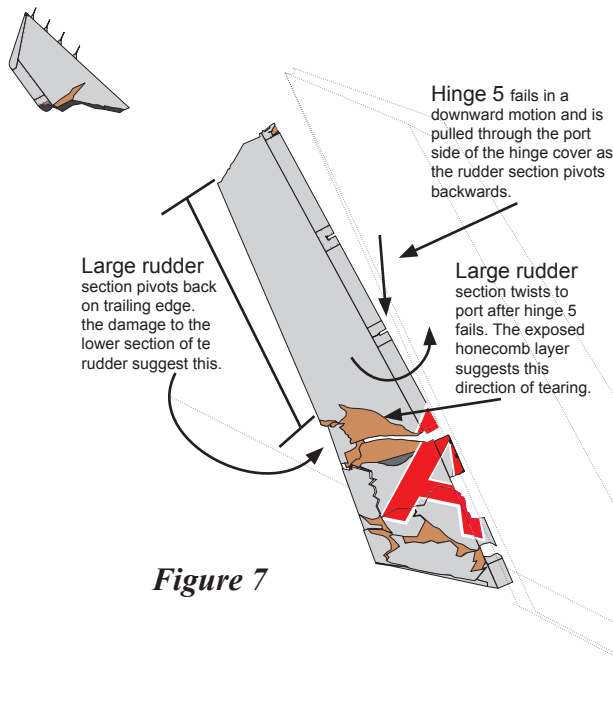


Image 7 Photo, US Read



Trailing edge damage suggests the top portion of the rudder section pivots backwards and twists starboard to port. This strip of metal from the port side trailing edge suggests this pattern of failure as does the loss of the laminate layer here.

Image 8 Photo, US Read

Hinge 2-4 (Actuators)

The area around the actuator hinges exhibits the most damage to the rudder. The same tearing left to right as seen around hinge 1 can be seen here. Photos of the port side actuator hinge cover shows considerable damage. This would indicate that when the actuator rudder hinges separated they tore through the hinge cover toward the port side.

From photographs it can be seen that most of the rudder hinges remained attached to vertical stabilizer after the rudder broke. If the actuators remained in the 9.5° starboard position I interpret the separation of the actuator hinges as seen in (figure 9).

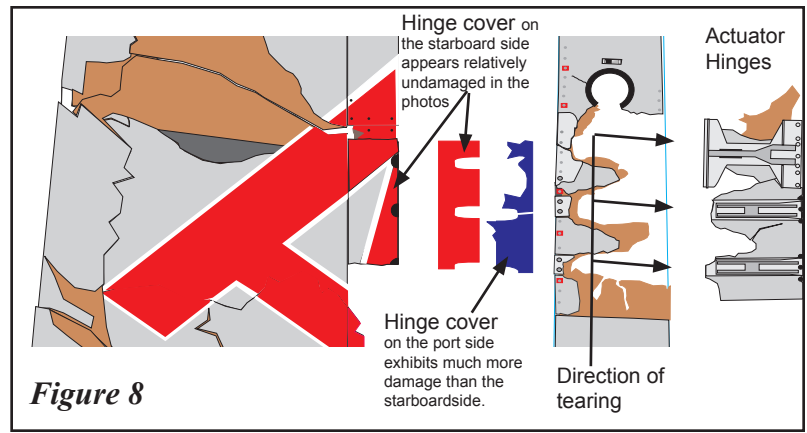


Figure 8

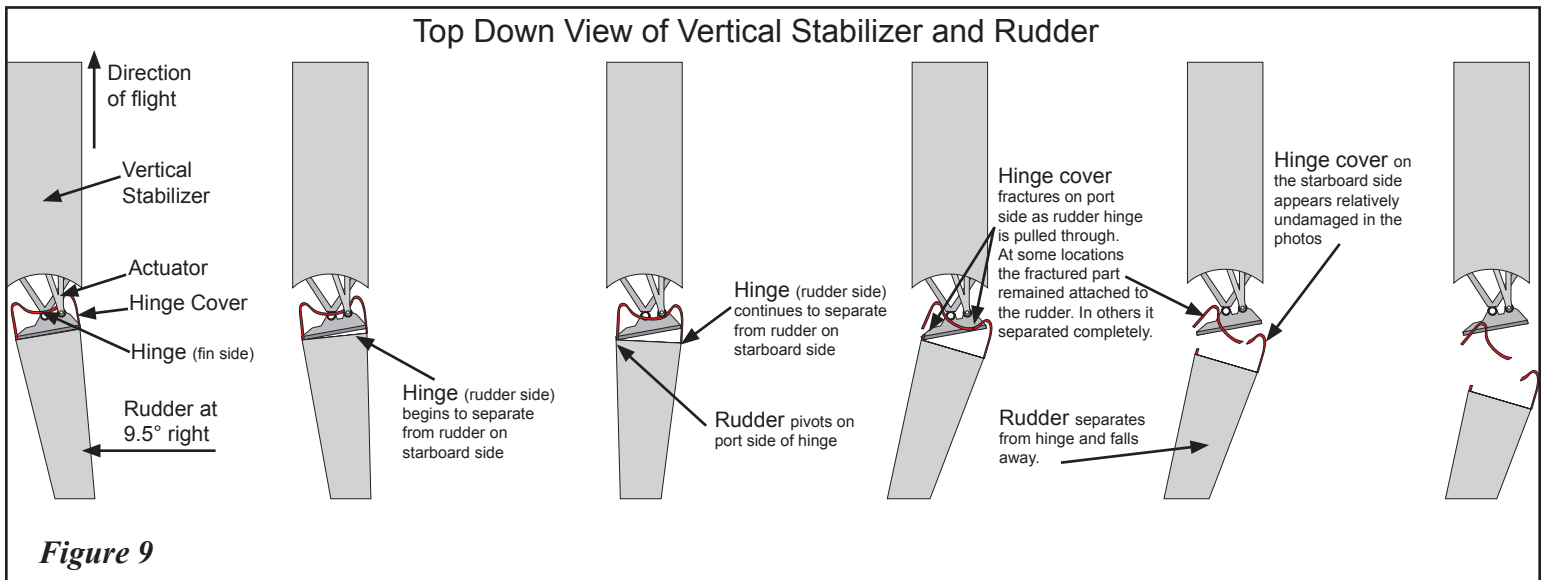


Figure 9

Actuator hinges placed in photo for illustration purposes.

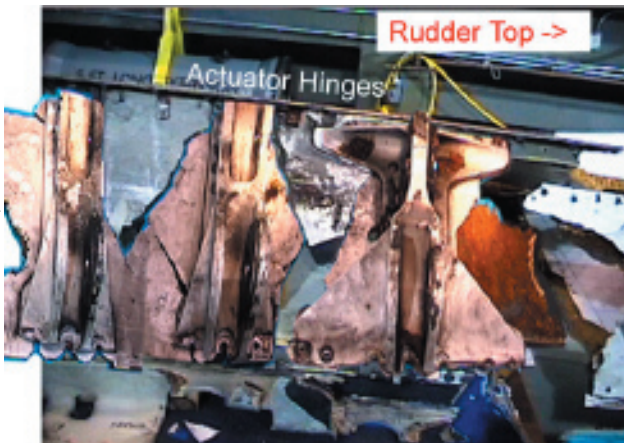


Image 9

Photo, US Read

Area where actuator hinges were torn from the rudder.



Image 8

Photo, US Read

Hinge 2-4 (Actuators continued)

Rudder Damage at Actuator Hinges

It is difficult to determine exactly how the area around the actuators broke, however, given the extent of the damage considerable force must have been exerted upon it. One possible explanation, (figure 10), for the damage is that the area around the actuator hinges is quite wide and hollow, a potentially weak area of the rudder. When the hinges broke away from the rudder and the upper portion of the rudder separated this wide area would have been exposed to the slipstream and quite possibly “blown” apart by the onrushing air. Conversely it is also possible, though I think less likely, that the damage done occurred when the rudder hit the water.

Photos, Michael Hvozda, USCG



Image 10

Image 11

Trailing edge damage suggests that the lower portion of the rudder was pulled apart. The starboard side shows triangular tears pulled inward suggesting that it was pulled away from the port side. The port side of the same area shows the rivets intact

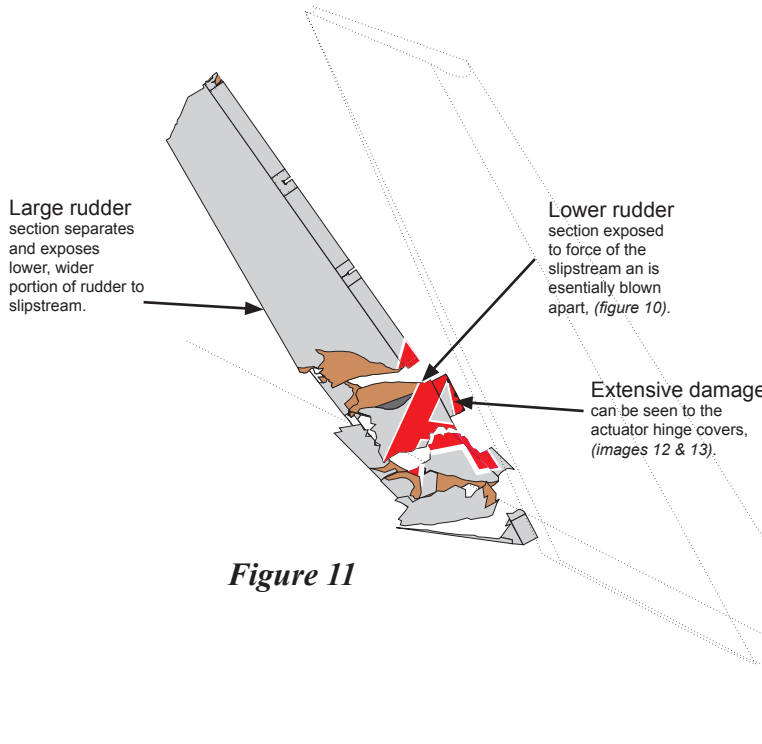
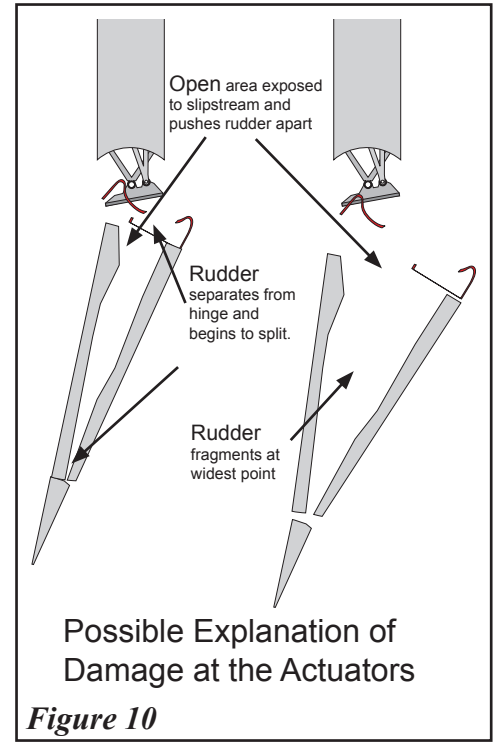


Figure 11



More damage on port side

Photo, US Read
Image 12



Less damage on starboard side

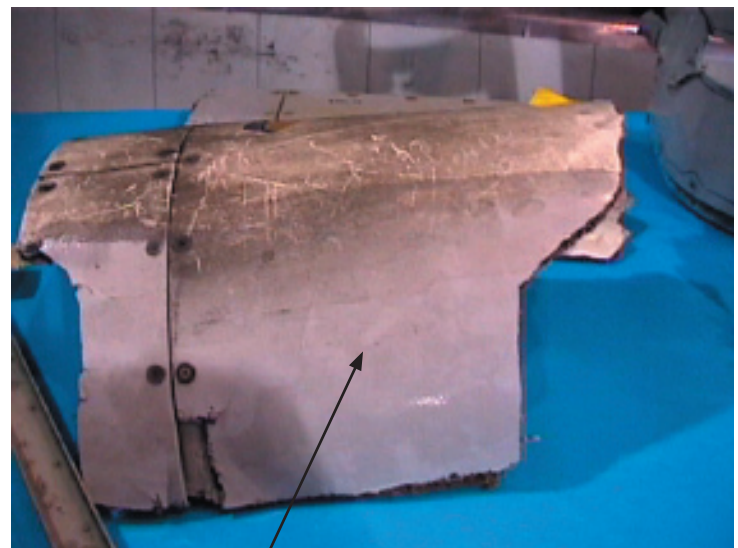
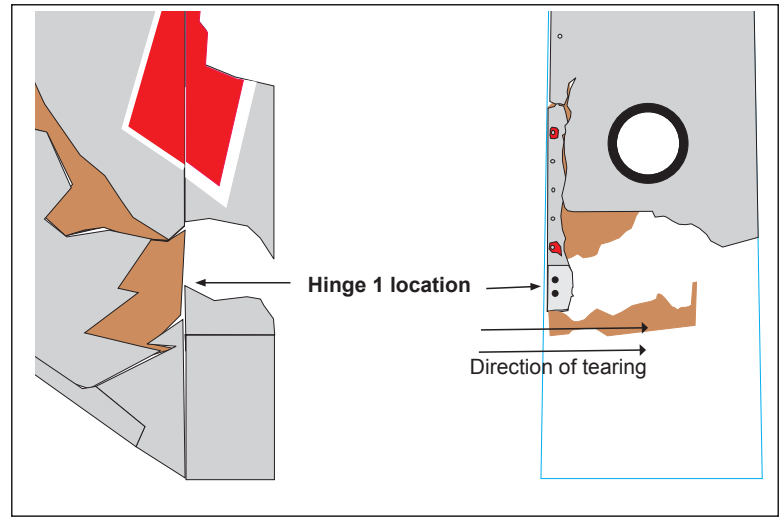
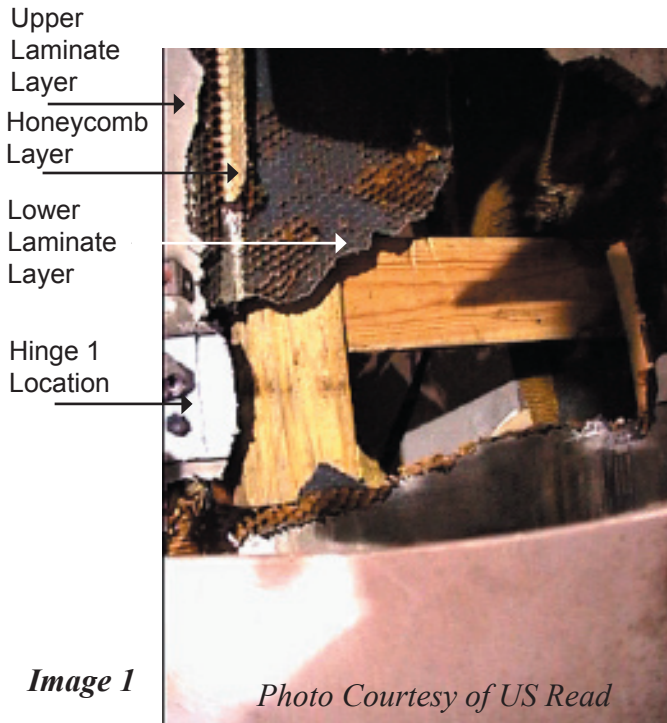
Image 13

Photo, Michael Hvozda, USCG

Hinge 1

There are not many pictures of hinge 1 available, however from (*image 1*) it can be seen that hinge 1 was torn from the rudder attachment point. My reading of the picture is that the composite material around the hinge broke starting on the left hand side of the photo (starboard side of the rudder) and tore left to right pulling material away. I infer a rightward tearing motion from the layering of the composite material. On the left we see the upper layer of the laminate material (light grey), next the honeycomb layer and then the bottom laminate later.

Though not visible in the picture I would surmise that, like the other attachment points, the tearing continued through to the right side leaving only a little bit of material where the rivets held it to the frame, see (*figure 12*).



Hinge 1 Cover Pieces

