# STS-51L:
# The *Challenger* Accident
## Conspiracy Theories, Challenger, and Solid Rocket Boosters



Everyone has their opinions, and given the almost universal accessibility of the Internet, now they can be broadcast with relative ease. The Lunar Landing Hoax has its own page[s][1], the Alien landing and Area 51 people have theirs, etc. If you have an idea, you can publicize it on the Internet.

Unfortunately, information can be easily packaged for the Internet so as to appear credible, whether it actually is or not. One example of a web site[2] that makes surprising claims is devoted to the sale of a book called "The Betrayal of Mission 51-L", by John Thomas Maxson. Mr. Maxson (in his book and/or online in the Usenet newsgroup, sci.space.shuttle) accuses NASA, its industry partners, and individuals in the government at the time with a gigantic, criminal, cover-up – possibly even with the intentional destruction of Challenger and her crew.

As with many other conspiracy theorists' books, Mr. Maxson's book has not been peer reviewed as would a technical/research paper. This shortcoming has been addressed in a fashion by discussions on the sci.space.shuttle Usenet newsgroup. However, even when faced with the withering scientific/engineering criticism that his book has drawn there, Mr. Maxson has never budged. He claims – in conflict with the Presidential Commission Report on the Challenger Accident[3] - that there never was a burnthrough in the right hand Solid Rocket Booster (SRB), and that the O-ring failure scenario is a fabrication. One of his more interesting claims is that the two SRBs crossed paths while obscured by the cloud created by the release of propellants from the External Tank (ET). If true, this transposition would render null and void one of the key conclusions reached by the Presidential Commission on the Challenger Accident.

Do Mr. Maxson's claims have any substance? If not, does he have a motive for making these claims?

[Note: The report produced by the Presidential Commission on the Challenger Accident (hereafter known simply as the PC Report) is a thorough and persuasive document. It is organized quite well and is readable by a layperson, though complete supporting detail is also provided in appendices.

This paper introduces some of the key items that figured prominently as the Presidential Commission reached its conclusions. The presentation here proceeds with an eye towards specifically addressing some of Mr. Maxson's points. As well, some supporting topics not specifically presented in the PC Report are discussed here. The sole purpose for this paper is to provide a condensed primer for those not familiar with the Challenger accident details or with the PC Report, and to provide clarification on some questions they may have upon hearing of Mr. Maxson's conspiracy claims.]

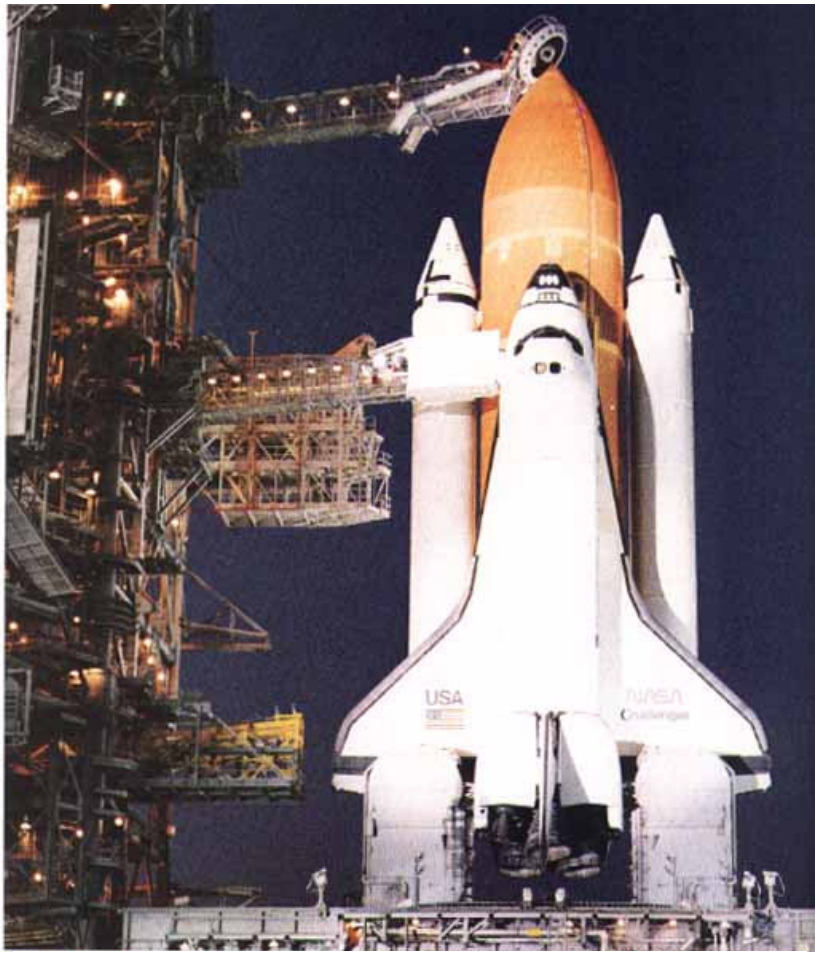
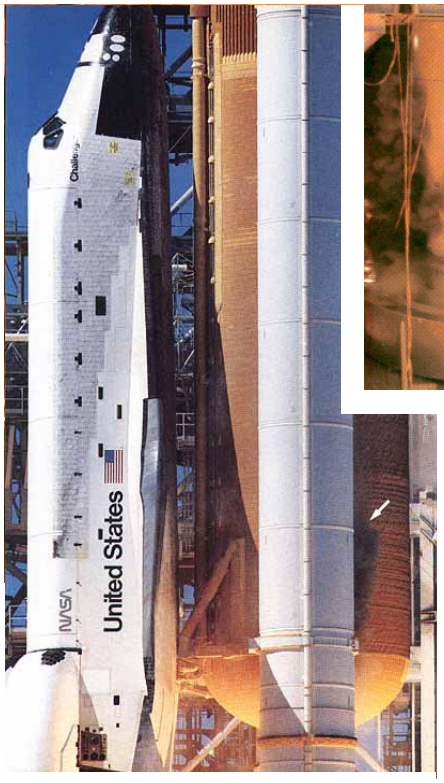



**Figure 1 Challenger Mission 51-L Vehicle**

[1] http://batesmotel.8m.com/, etc.
[2] http://www.mission51l.com
[3] http://history.nasa.gov/rogersrep/genindex.htm



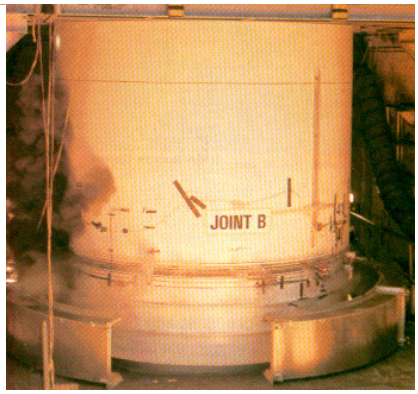




**Figure 2 Black smoke at liftoff**

## The Solid Rocket Boosters: Initial Evidence

The PC Report presents a case for the direct cause of the Challenger accident as the failure of an O-ring. Here are just a few of the observations made that contributed to that conclusion:

1) At liftoff there were several releases of black smoke photographed near the aft field joint where two individually manufactured segments of the SRBs are mated, and nearest the side adjacent to the ET[4]. Later tests by Thiokol (the SRB manufacturer) duplicated liftoff conditions as closely as possible and found that a failed O-ring would exhibit the same smoke characteristics (see inset. Figure 2). The smoke is seen above the joint because of the geometry of the joint seal – the joint opens to the outside in an upward direction (see Figure 3). Additionally, the smoke was emitted at a particular rate: "The puffs appeared at a frequency of about three puffs per second. This roughly matches the natural structural frequency of the solids at lift off and is reflected in slight cyclic changes of the tang-to-clevis gap opening."[5]
2) At about 59 seconds into the flight, a bright spot appeared at or near the same spot from which smoke appeared to emanate in item 1, above. Analysis showed this spot was a tongue of flame escaping from the aft field joint of the right SRB[6] (Figure 4).
3) At this same time, the chamber pressure trace for the right SRB began diverging from nominal (Figure 5).
4) Debris recovered from the ocean floor and identified via serial number and other means showed the right SRB to have suffered a burnthrough from the inside out at the aft field joint.[7]

## Betrayal of Truth and a Mission to Mislead

Given the weight of complementary evidence supporting an SRB breech as the culprit for the disaster, it might be viewed as surprising to see the O-ring cause argued against. Nevertheless, Mr. Maxson presents his views against this accepted scenario. One of the arguments he makes is that the "purported" breech seen in the right SRB beginning at 59 seconds into flight (Figure 4) was not a breech in the SRB. In actuality, the "glow" seen at the site of the presumed breech in several images taken from different angles during ascent displayed a luminance similar to the SRB plume exhaust, and there is a smoke contrail associated with the plume. But, Mr. Maxson claims that it was in fact the ET that was breeched, and that it was hydrogen that was burning. However, hydrogen burns colorless, and requires an ignition source – which he suggests came from the RCS jets![8] A geometric analysis of relevant images suggested the glowing plume was located on the SRB[9]. Taking into account the fact that the right SRB combustion chamber pressure began dropping abnormally and diverging from that of the left SRB at the same moment the plume became visible (see Figure 5), and that recovered SRB hardware showed a burnthrough in that same exact area, those observations combine to paint a strong picture of an SRB breech in that area. Add to that the images from liftoff showing the black smoke pulses – a proven indicator of an O-ring seal failure – that emanated from the same spot where the glowing plume was seen beginning at 59 seconds into

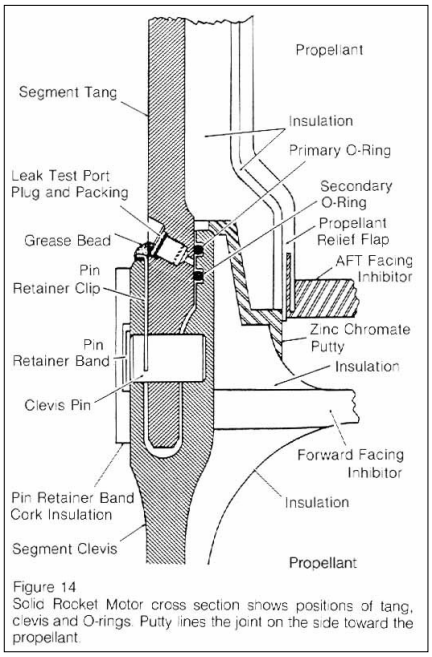



Figure 14
Solid Rocket Motor cross section shows positions of tang, clevis and O-rings. Putty lines the joint on the side toward the propellant.

**Figure 3 SRB Field Joint**

[4] http://history.nasa.gov/rogersrep/v3n29.htm
[5] http://history.nasa.gov/rogersrep/v1ch4.htm#4.10
[6] http://history.nasa.gov/rogersrep/v3n43.htm
[7] http://history.nasa.gov/rogersrep/v2appl2a.htm
[8] RCS jets are NOT used during a nominal ascent during first stage.
[9] http://history.nasa.gov/rogersrep/v3n37.htm

flight, and a strong case can be made that it was an SRB breech that was captured in the ascent images and video.

Mr. Maxson has also used what he calls "expert opinions" to bolster his claims. Some of the individuals quoted are no longer easily contacted so Mr. Maxson's claims can be verified. Some have either passed away or retired. Most are no doubt experts in their particular field. Some may be making media-hurried analysis, or they may even be misquoted. It appears most likely, however, that these experts' reputations have been hijacked for Mr. Maxson's own purposes of attempting to paint the Challenger accident in his chosen light.

For instance, Mr. Maxson claims, "first impressions of rocket disasters by rocket experts cannot be overlooked". He recalls an example from his book (Chapter 10) in a Usenet post (from sci.space.shuttle, 08/14/2002):

*"The comments of knowledgeable aerospace experts were already at odds with reports of a 'burnthrough.' John Osborne, Professor of Aeronautics and Astronautics at Purdue University, had been a rocket expert for 35 years. Osborne made the following press statement: "After the explosion, I see a normal exhaust pattern and an intact solid booster; I see a central cloud and two contrails. This indicates there's no problem with the solids." Other rocket experts quickly echoed Osborne's outspoken viewpoint."*

**Figure 4 Right SRB breech after 59 seconds**

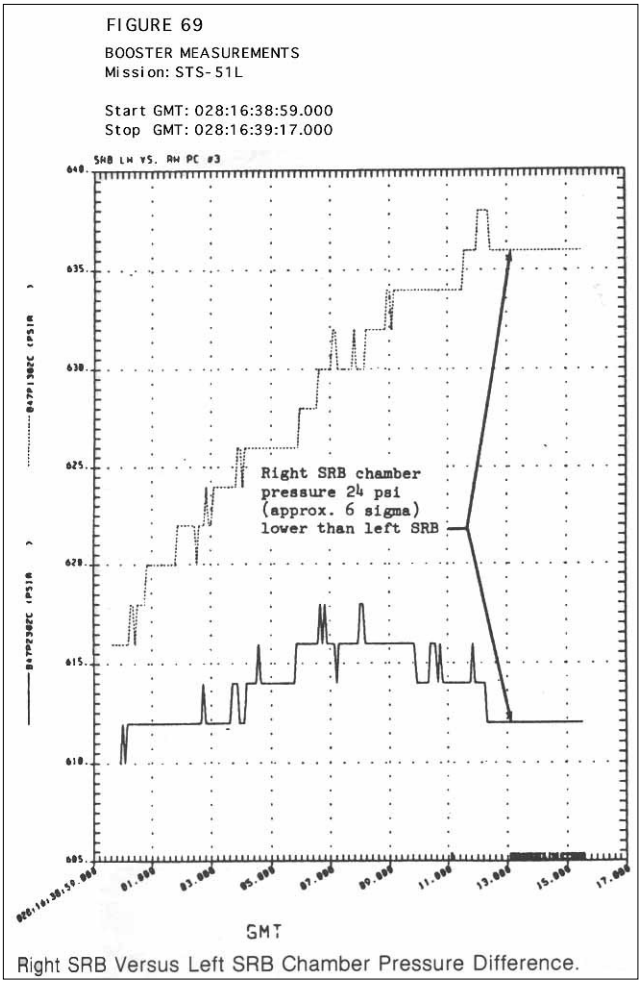



**Figure 5 SRB chamber pressure plots**

Mr. Maxson also attributes a second quote to Mr. Osborne:

*"... An SRB leak would cause an <u>increase</u> in pressure. A liquid hydrogen / liquid oxygen explosion without thorough mixing is suspicious. NASA is holding something back." [Emphasis added.]*

The view expressed by Mr. Osborne, if truly his, is given with no context – at least as Mr. Maxson quoted his own book in the newsgroup post. We suspect that Mr. Osborne's purported analysis was a shoot-from-the-hip opinion of what happened, given his observation of the single-viewpoint video supplied by NASA (NASA Select), in the hours following the accident. We can suspect this because the quote attributed to Mr. Osborne describes what he "sees", and gives no details - only overall impressions. Indeed, it <u>does</u> appear as though the SRBs emerge intact from the fireball – and they *are* still thrusting – in the long-range video that the TV networks broadcast repeatedly following the accident[10]. The various other views of Challenger's SRBs showed an entirely different story – though Mr. Osborne didn't have immediate access to those. It is disingenuous to portray Mr. Osborne's comments as his final word on the subject without noting under what circumstances his comment was made.

Note also that while it is true that early eyewitness accounts of aviation disasters are very important in eventually determining a cause, early *interpretations* of aviation disaster accounts are quite often wrong. Mr. Osborne's purported statement indicating there was "no problem with the solids" was not only incorrect, but also premature in practice. Likewise, Mr. Maxson's assertion that "*the comments of knowledgeable aerospace experts were already at*

[10] Contrast this with the spectacular explosive failure just seconds after liftoff of a Titan 34D solid rocket booster just three months after 51-L. When a solid booster fails, it is usually unmistakable and dramatic. The *lack* of such a pyrotechnic display seems to have lead Mr. Osborne to conclude prematurely that the SRBs were perfectly intact and blameless.

*odds with reports of a 'burnthrough.'"* was a premature statement, presumptuous, of little or no value, and it flew in the face of aviation accident investigation protocol. Consider what an NTSB instructor had to say to his class[11] after one student made a premature judgment in a hypothetical accident investigation exercise: "Describe factually what you are seeing, and leave your opinions at home. Your job is to gather the facts – the National Transportation Safety Board members make the interpretations." Aviation accident investigations are careful and methodical procedures. For an example of one such accident report (a *simple* one), see the NTSB account of the accident investigation that claimed the life of singer/songwriter John Denver.[12]

The second quote attributed to Mr. Osborne is also misused. Mr. Osborne purportedly stated that an "SRB leak would cause an increase in pressure", which is true under a particular circumstance, though not necessarily in the Challenger case. But the use of the quote by Mr. Maxson gives one the impression that Challenger's leaking right SRB *must* have shown an *increase* in chamber pressure and not the *decrease* that it did show. A solid rocket booster might show an increase in chamber pressure if the propellant grain had suddenly cracked, thus presenting more exposed surface area instantaneously which would burn and produce higher chamber pressure. However, in the case of Challenger, no propellant grain needed to be cracked in order to find a path to the outside - the breech occurred at a joint. Mr. Maxson made the claim in a Usenet post[13] (14 Aug 2002) that, *"The key point for Berndt/Balettie[14] to grasp here is that in Osborne's expert opinion, a "burnthrough" would *not* have been expected to result in a *decrease* of SRB chamber pressure. My cold-soaking explanation, on the other hand, does explain such a decrease."* Of course, this statement reveals Mr. Maxson's bias, the misuse of a general statement about chamber pressure in the presence of a breech (irrelevant in this case), and an implausible alternative explanation. Cold soaking *can* result in lower chamber pressure and thrust in a solid rocket booster. However, it would be apparent from liftoff, and would certainly not choose to reveal itself suddenly and with a diverging increase in magnitude at a point well into the flight.

There are other examples where Mr. Maxson has used a quote out of context or inappropriately in his book. One particular instance involves a Mr. Leo Krupp (Mr. Maxson spelled his name incorrectly as "Krup" in his book, and mistakenly identified him as Enterprise test pilot), in which Krupp gives his analysis of the explosion in the hours following the accident. Mr. Maxson trumpets Krupp's preliminary comments as an authoritative analysis - even in light of Krupp's insistence that his comments should be viewed as preliminary and speculative. Those were the best quotes Mr. Maxson could locate in support of his hypothesis. He has steadfastly defended as appropriate his use of these experts' statements. Nevertheless, sometimes experts make mistakes. In fact, Mr. Maxson depends on this fact – if the experts comprising the Presidential Commission made no mistakes, Mr. Maxson's hypothesis would be ruled out.

**Figure 6 Growing plume**

## The Mechanics of the Space Shuttle Challenger Breakup: SRB Crossing, or Not?

The crux of Mr. Maxson's hypothesis regarding the Challenger accident lies with the answer to the question of whether or not the SRBs crossed paths prior to exiting the propellant cloud, for if they did not, his hypothesis disintegrates as Challenger did. If they did cross, the Presidential Commission conclusions are wrong. This claim merits close scrutiny.

As mentioned before, at 59 seconds into the launch, the PC Report describes – and the photo and video record displays – a breech in the right SRB[15] at the aft field joint at or near the same spot where a suspected O-ring failure was viewed at launch. At 59 seconds, the right SRB chamber pressure abruptly began to differ from that of the left SRB (see Figure 5). The plume seen in the photo and video record left its own smoke contrail, and the plume itself was of similar luminance to the main SRB exhaust plumes. As time progressed this plume was seen to grow. The breech plume also appears to be reflecting off the OMS "stinger" where the RCS nozzles are located (Figure 6).

At 72 seconds after liftoff the yaw and pitch rate traces for the two SRBs begin to diverge. This indicated that the SRBs were changing their alignment with respect to each other. There is a fine point to interpreting this data, however. The question can

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[11] http://www.airspacemag.com/ASM/Mag/Index/2001/JJ/rtwk.html

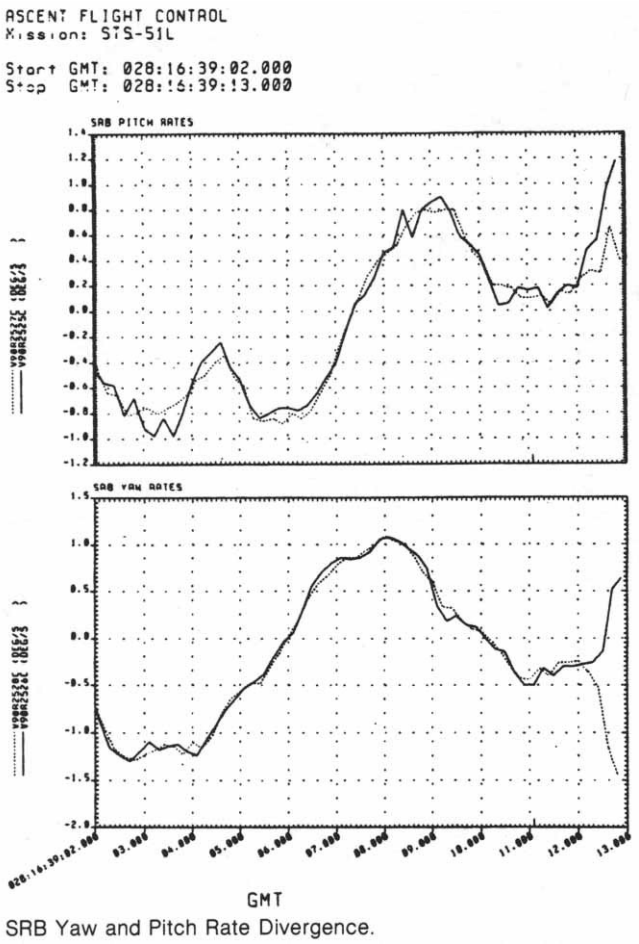
[12] http://www.ntsb.gov/ntsb/brief2.asp?ev_id=20001208X09045&ntsbno=LAX98FA008&akey=1

[13] http://groups.google.com/groups?selm=f69b49a9.0208140711.3e41aa3%40posting.google.com&oe=UTF-8&output=gplain

[14] Former space shuttle Flight Dynamics Officer (FDO) Roger Balettie, http://www.balettie.com. Roger has also addressed questions raised about John Maxson's book: http://home.austin.rr.com/sts51lvideo/

[15] http://history.nasa.gov/rogersrep/v3n37.htm Computer processing removed the unchanging portion of the images comprising the ascent video, which revealed the location from which the plume had sprung and developed.

be raised: what was each SRB doing with respect to the ET? Were they both becoming detached? The PC Report answers this question both in the body of the report and in testimony. From key testimony given by Thomas Moser, Deputy Administrator for Space Flight[16] (key concepts underlined by this author):



SRB Yaw and Pitch Rate Divergence.

**Figure 7 Pitch and Yaw Rate Divergence, SRBs**

> **MR. MOSER**: … Then at a little greater than 72 seconds into the flight is where we see motion of the right-hand solid rocket booster to the rest of the launch vehicle, and that is shown on chart M-19, where here I display the rotation of the pitch of the right-hand solid rocket booster to that of the left-hand. Not shown on this data is the fact that the left-hand solid rocket booster rate gyro is tracking exactly with that of the orbiter, and that is the way all three of the elements or all four elements – the orbiter, the external tank, and the two SRB's – have been tracking up until this point. It is 72.201 seconds, we see a deviation from the right-hand solid rocket booster. It is our indication that something has failed in the aft attachment of the solid rocket booster to the external tank, and I will show you more of why we have concluded that. If I could have chart M-20, please.
>
> This is a computer-drawn picture [see Figure 8, next page] of the launch vehicle looking down on top with the solid rocket booster released from its lower link. The evidence that we have is that we have lost the load pad at that link. If that results, then the right-hand solid rocket booster then is free to pivot about its forward attachment point and one of the remaining aft attachment points. This is consistent with maintaining a data source from the solid rocket boosters, because the integrity of everything going on in the solid rocket boosters, the data flows through the top aft link. What is hypothesized here, and is supported by the analysis, is that the lower left-hand or the lower link has failed, the solid rocket booster has both rolled about that new hinge line so it has a new pitch and yaw attitude. That is what we measure from the flight data. When it does that, it impacts the inner tank region, as shown here on this drawing, between the LOX tank and the hydrogen tank, there. It impacts it just at the lower portion of the frustum of the right-hand cone of the solid rocket booster. If I could have the next chart, please.
>
> In a different view, we see that the SRB has moved up toward the orbiter at the aft end. And the next view, please.
>
> This is a view which looks at that same configuration from the forward end, and here you can get a better feel for how it has rotated about its new hinge line. This impacts the tank, as I said, causing the tank to load up, rupturing the forward L0X tank, the hydrogen tank, and at the same time probably causing the aft bulkhead of the hydrogen tank to rupture.
>
> **DR. FEYNMAN**: In order to determine the motion of this thing, of the right-hand booster, you have gyros that determine its orientation?
>
> **MR. MOSER**: Yes, sir.
>
> **DR. FEYNMAN**: Do you also have inertia measurement to tell whether it moves forward or back?
>
> **MR. MOSER**: No, sir, just the rate gyro, sir.
>
> **DR. FEYNMAN**: You don't have any inertia measurement?
>
> **MR. MOSER**: No, sir.
>
> **DR. FEYNMAN**: So there's no way to determine the absolute position except to guess that the upper support hadn't slipped yet, is that right? That is how you did that?

[16] http://history.nasa.gov/rogersrep/v5part3b.htm#4, March 7, 1986

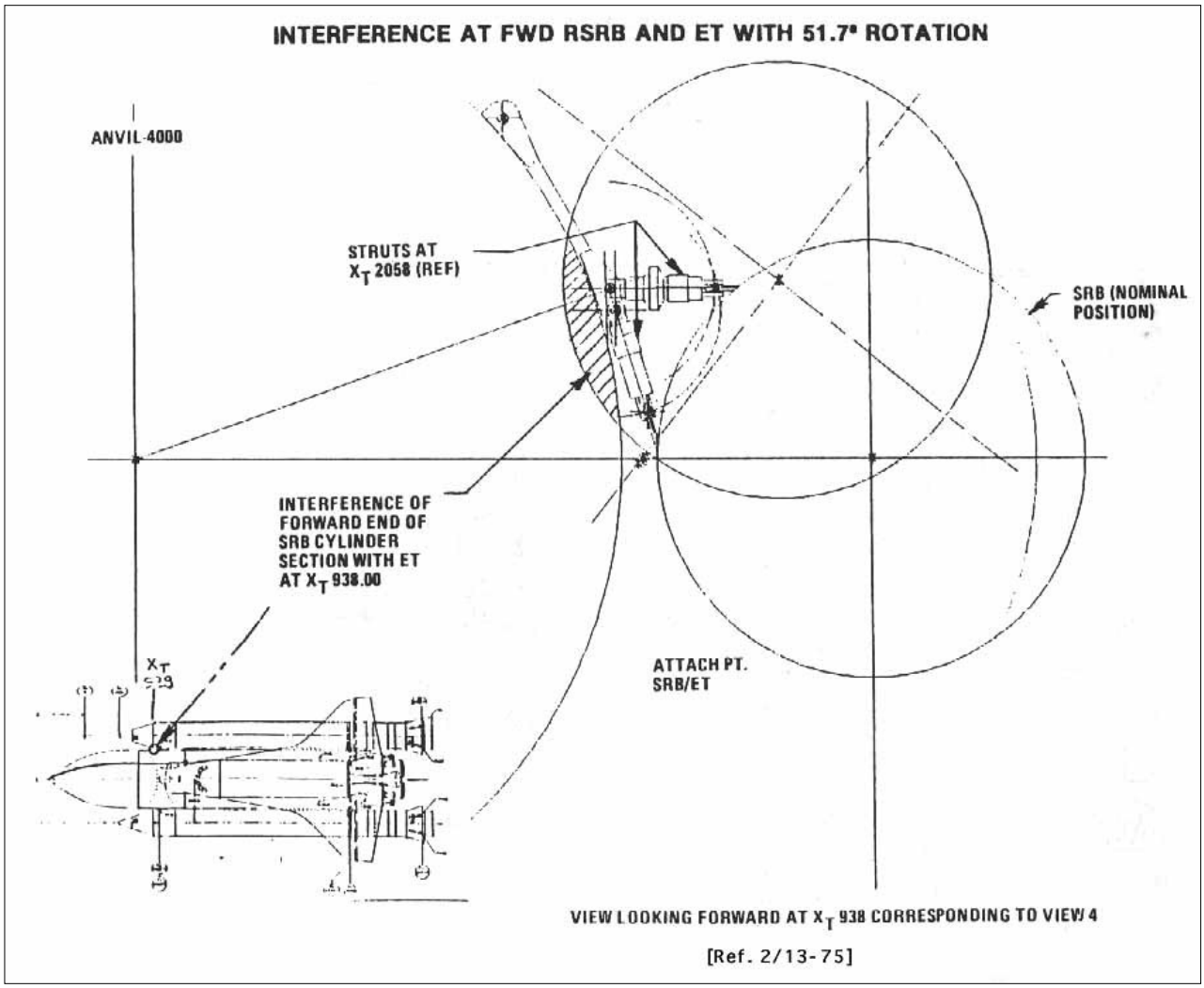



**Figure 8 SRB rotation dynamics following lower aft strut failure**

**MR. MOSER**: That is correct, sir, yes. And then that is part of the continuing photo analysis, too, is to verify that it is in fact still attached there. We did not see any other motion, and I don't know that it is a sufficient solution to look at the rate of change of both pitch and yaw, given that the fixed geometry, okay, of rotating about those points, all of that data supports itself. And then looking at the times at which the SRB rotating would have bottomed out and induced high loads in the tanks, is when we see changes in the pressure and also see physical evidence, visual evidence I might add, from the tanks, where they are beginning to lose liquid hydrogen and liquid oxygen. And so we have about three pieces of data which supports that.

**MR. RUMMEL**: The aft rupture in the ET is after the explosion, due to explosive force? On what do you postulate the cause to be?

**MR. MOSER**: I'm sorry, Mr. Rummel. Could you repeat that, please?

**MR. RUMMEL**: I think you mentioned that after the LOX tank and the hydrogen tank and the inter-tank area had been damaged, that was followed by a separation in the aft end of the hydrogen tank. Did I understand that correctly?

**MR. MOSER**: Yes, sir. Let me verify that. We first see that, the spillage of the aft dome of the liquid hydrogen tank, at 73.137 seconds. We see-that is visually, and I think I'm going to show you a picture of that in just a moment.

**MR. RUMMEL**: Well, my question-perhaps you're coming to it-is the cause of the aft rupture. It appears that the SRB didn't hit the tank in that area. Was this due to overstressing from the rupture forward?

**MR. MOSER**: Yes, sir. The aft attachment is connected, the remaining aft attachment about which it is rotating, is connected right at the seam of the aft bulkhead to the cylindrical portion of the tank. And as soon as it rotates over and interferes with that region, then it loads it up in an out-of-plane load for the tank, and so it should rip the tank right in that region. Plus, the solid rocket booster is rotating about 40 degrees per second at that time, and so it fits with the analysis that we have done that says that, it should have in fact tore the tank in that region.

**MR. RUMMEL**: So you're postulating the failing of that part of the attach fitting that is attached to the ET at that point in time?

**MR. MOSER**: That is correct, sir.
**MR. RUMMEL**: Thank you.
**CHAIRMAN ROGERS**: Mr. Moser, yesterday we looked at the debris and the right frustum is badly damaged. The left one looks as though it's not damaged at all. The right one seems totally consistent with this photograph. Have you seen that debris? In other words, the right frustum has damage which would be almost totally consistent with that photograph.
**MR. MOSER**: It was reported to me. I have not physically seen it myself, but it was reported to me what it appeared, and it does appear to be consistent with our failure model here, yes, sir.
**DR. RIDE**: Do you think that the contact between the SRB and the upper portion of the tank, the LO2 tank, is what caused the LO2 tank to rupture?
**MR. MOSER**: Yes.

In separate testimony[17] given by Jack Lee, Deputy Director, Marshall Space Flight Center, Mr. Lee echoes the statement that the right SRB telemetry is being compared with the rest of the stack, and so it is the right SRB that is moving with respect to everything else:

> **MR. LEE**: That's right. It's leaking out faster than the gas is going in. At the same time period we see an unusual occurrence of the right hand, what appears to be the right hand solid rocket booster, the base, what appears to be at the base coming out, okay. So like it is pivoting about the top, and it is in fact rotating relative, at an angle relative to the rest of the stack. And we compare that data with what is happening in the orbiter and the other SRB.

The right SRB rotated about the new hinge line created by the upper aft attachment and the forward SRB attachment, and it eventually rotated so far that it the top portion of the SRB cylinder contacted the ET intertank area and damaged it. The idea that the SRB rotated out at its base and "*nosed* into" the ET is wrong.

[17] http://history.nasa.gov/rogersrep/v4part5a.htm#1 February 13, 1986