Between T+50 and T+60 seconds, only one major event is listed in the official "**STS 51-L Sequence of Major Events**," (Commission, Vol. I, p. 37): The appearance of "flame on RH SRM" at T+58.788 seconds. Yet for the same interval, I had discovered numerous "Major Events" as described below.

At NASA and COMSAT, we had a technical bond in the 1960s and 70s. We generated the specifications and RFPs and evaluated input from contractors at home and abroad. That required us to be familiar with leading edge technology everywhere, and not only in a given company or country. We helped each other. In the 1970s, I participated in the ATS and other tests at Goddard, exchanged views with NASA engineers on testing new composites, fuel cell design, wind tunnel tests, general-purpose-computer-programs, and I provided technical analysis, through chain-of-command, for launch vehicle failures and, even, Apollo 13 – And yes, my input on 13 related to the stresses produced by the sudden start-up transient dynamic overshoot. When I shared my "sequence of events" with managers at HQ in 1986, half of the experts agreed with my findings while the other half strongly disagreed. The mood was a new experience.

I will describe some of the evidence discussed in the NASA HQ meeting in '86. I will also describe objections raised by NASA and my specific answers.

Photos #1 and 2 show an anomalous puff of exhaust that projected "upward" from the far side, or the right SRB side, at T+54 seconds. Some NASA experts said that that was a plume feature. I had not seen that before, not on the belly side, which exhibits smoother aerodynamics.

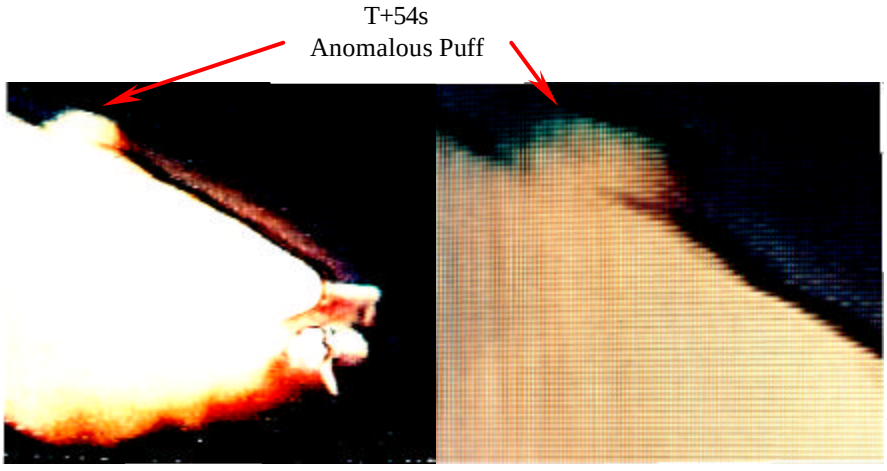

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Photo #1 Photo #2

Photos #3 and 4 show the same event in a US TV Network (for credit, I'll find out which one from my old files) side-by-side replay of Challenger (left) and a previous Shuttle mission (right). The plume boundary on the bottom for Challenger is certainly coarser than the previous mission. The anomalous puff is clearly seen on the top at T+54.1s. Also, note that at T+55.0s, there are "two anomalous puffs."

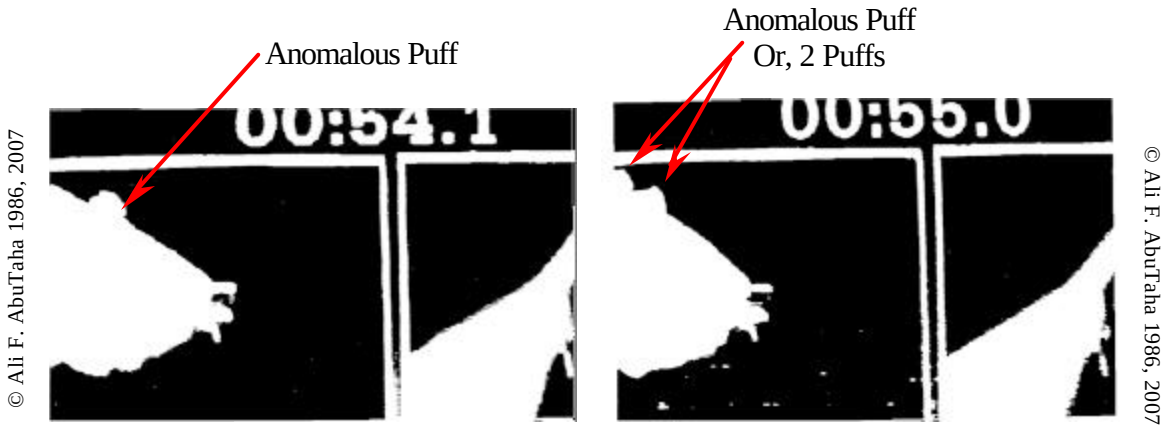
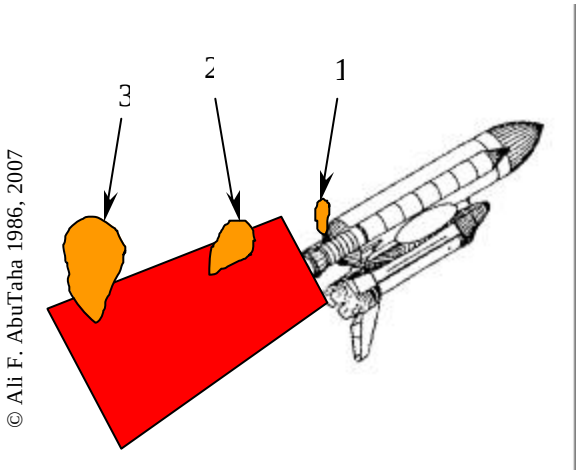


Photo #3 Photo #4

US TV Network side-by-side Comparison
Challenger (Left) and Previous Shuttle (Right)

The two puffs in Photo #4 indicate that either the initial puff (in Photos #1-3) broke up in two, or that there were two independent puffs that initially overlapped and appeared as one puff. I favor the second explanation for the reasons and further evidence described below.

My Sketch #1 helps to visualize what might have happened. At 1, one or two pieces of the right booster's aft-walls ripped off, which caused the emergence of the 2 puffs. At 2, the two puffs were hidden by the plume (red) and not captured on film from that camera. At 3, the two puffs overlapped and emerged as one puff. Down stream (Photo #4), the two puffs became distinctly visible.



Sketch #1 – Source of odd Puff(s)

Not even magical wind can explain the appearance and progress of the T+54s puff(s). A chunk of propellant flying out of the right booster might be proposed, but that is highly unlikely. Such mass would tend to sink downward and disappear in the main plume. I also captured the T+54s puff(s) in the New Smyrna Beach and other views.

What pieces of the stricken right booster could have fallen off? Figure 25, in the Commission Report (Vol. I, p. 68), shows reconstruction of the failed right booster segments and the primary "**burn area**" near the aft ET Attach Strut. The booster pieces to the left of the "**burn area**" were not found despite the most intensive search and recovery effort in history. The missing RSRB pieces are exactly in the location that could produce the anomalous puffs described above, if those pieces were to fall off suddenly.

During the Commission hearings, it was specifically revealed that at T+60s, the pressure in the RSRB fell off suddenly:

> NASA: At that time they (controllers in Houston) do not see the righthand rocket. It attempts to stay down, and is affected in some way and does not build. (IV, p. 217)

NASA examined many failure scenarios. One of these led to the following conclusion:

> NASA: To us that is telling us that … we are literally losing part of the steel case to meet that type of model. (IV, p. 565)

I have very long lists for many Challenger events. Just look at the above facts:

- Two anomalous puffs of exhaust appear from the right booster's stricken area.
- Two pieces of steel went missing from the right booster's stricken area.
- The pressure in the right booster fell precipitously.
- Top experts conclude from engineering studies, "*we are literally losing part of the steel case to meet that type of model.*"

Someone go out and look for potential pieces falling from the Challenger assembly before T+60 seconds. Where? Begin with the photographic record. Where were all the authors who wrote books, reports, papers and articles and the experts who produced TV specials, talk programs and failure programs? At T+57s, I discovered falling pieces in the NASA TV-feed that was available to everyone all over the world. And then, I found the "falling pieces" from other views and cameras, including, the extensive photo record of Time Magazine, which Tim Furniss writes about. In the Dec. '86 meeting at HQ, I showed the "falling pieces" in normal, forward, backward, slo-mo, pause, rocking and other modes. Again, half the experts agreed: A Major Event; the other half insisted: Plume features seen before. Well, I hadn't seen the events before.

Here is a photo of what I showed NASA in Dec. '86 – Photo #5.

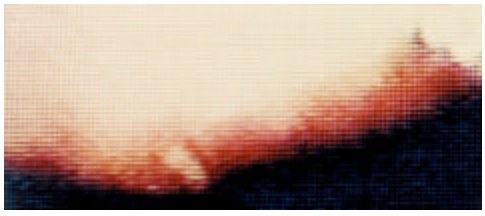


Photo #5
T+57s Event: Debris or plume-feature

The primary objection to the photo (or video) was that the purported debris lied within the boundary of the plume, which made the "potential pieces" part of the plume – a plume feature.

After the NASA meeting, it occurred to me (from past experience) that the edges of the visible plume glow due to the hot 5,000^{o} to 6,000^{o} temperature. So, filter out the glow. The results are shown in Photos # 6 and 7. The falling piece(s) lied outside the edge of the plume, sans glow.

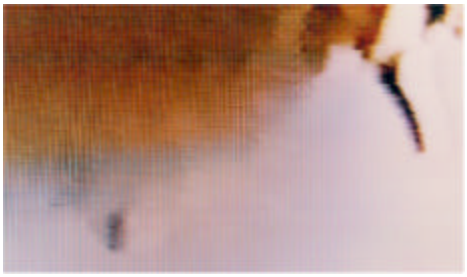


Photo #6

Photo #7

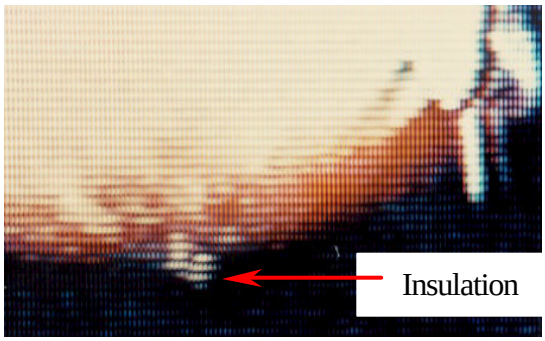
Two pieces of debris swirl outside of the Challenger plumes at T+57s

Here, you see that the T+57s event was not one piece falling off the assembly (as I had initially thought), but two pieces. In video, you clearly see the appearance of the first piece (Photo #6), then the second piece (Photo #7) swirls by, etc.

This is not the end of my sequence of Major events between T+50 and T+60s.

Around T+58s, the Challenger assembly experienced a brief violent vibration, a jolting motion – which I cannot show in still photographs. But if you read the 4 Items I listed above, you will grasp why the stack experienced the vibration.

At T+60s, I captured several white pieces flying at the edge of the plume, as you see in Photo #8. Now these are similar to "plume features" that were seen in the past. Photo #9 shows similar white pieces flying at the edge of the boosters' plumes at SRB separation in a previous Shuttle mission. Specifically, these are "insulation" pieces stripped off in areas where the propellant was completely consumed.



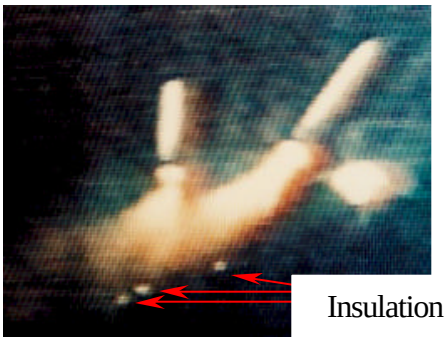


Photo #8: Challenger @T+60 seconds

Photo #9: STS @ SRBs' burnout

What does the appearance of "insulation" pieces at T+60s mean? It means that some of the propellant in the stricken right aft segments was consumed a minute after lift off. This is the source of the energy that drove Challenger alarmingly faster than projected before the T+40s event, which I described in my last Post. Most of the recovered forward segment pieces still had 2-4 inches of unburned propellant left near the walls. Yet, if you carefully read the reports of the Search, Recovery and Reconstructions Teams, you will find that the RSRB aft segments had no propellant left in them at all, e.g., for pieces #21-1, ""*there was no propellant on this piece*," #21-2, "*There was no propellant on this part,*" #21-3, "*There is no propellant on the part*," #21-5, "*There is no propellant on this piece*," and so on (Commission, Vol. III, p. O-272).

As I said before, I am writing many things from memory and a few references scattered around me, and without my 1986-87 files. Any "**Sequence of Major Events**" for Challenger should consider some of the following events:

- T+52s: Throttle up Command.
- T+54s: Anomalous puff appears from the RSRB stricken area.
- T+55s: Two anomalous puffs become visible.
- T+57s: SSMEs throttle up to 104%.
- T+57s: Two pieces of debris appear in video.
- Two steel pieces missing from the RSRB's stricken area.
- T+58s: Assembly experiences jolting motion.
- T+60s: Pressure in the right booster falls off precipitously.
- T+60s: Insulation flying out of RSRB.
- T+60s: NASA engineering study concludes, "*losing part of the steel case.*"
- T+60s: The puffs seen from New Smyrna Beach become semi-continuous trail.

I classify the T+54s puffs, the T+57s debris and the T+60s insulation event as Major Events, which, with my other findings, lead to a different "sequence of events," than accepted to date.

Remember that you are looking at photo evidence developed in 1986. We didn't have in our homes Adobe or Image Composers, nor CDs or DVDs, nor HDTV or digital enhancements at the tips of our fingers. I took couple video clips to high tech outfits and tried to digitally enhance what I was discovering with massive helium-cooled and noisy equipment. The results weren't much better than I was getting with supplies from Kodak, Radio Shack and Sony.

One "theory" might have derailed the investigations. The Commission noted:

> Fracture mechanics analysis indicates that a hole in the (SRM) case larger than one inch would cause the entire case to rupture in a few milliseconds. (Vol I, pp. 55-56)

In layman's terms, this says that if a hole the size of a "quarter" opened in the wall of the motor case, then the booster would have disintegrated instantly! We all thought that in the 1970s. This is the argument that McDonald and Hansen use against my assertions that the right booster leaked continuously from lift-off. Yet reconstruction of the failed aft segments shows that the "**burn hole**" area grew in size to about 30 inches across. One can fit 20 to 100 dollars worth of quarters in that area. I knew and respected the fracture mechanics experts who proposed the above theory, but when observations show otherwise, the theory must be amended or completely discarded. McDonald and Hansen, and others, should reevaluate their assertions.

Ali