The following is about the SRB joint that did not rotate and, hence, was not the likely cause of the Challenger accident.

Bob writes:

> To quote Occam's razor, "All things being equal, the simplest solution tends to be the best one."

We are not at the razor of the Doctor Singularis Occam yet. We don't have 2 or more solutions to select the simplest. We have 2 diametrically opposite views of HOW and WHY the accident happened. I propose we are in a "paradigm shift," similar to those described by the great science historian, Thomas Kuhn. A paradigm shift requires two ingredients:

1. Something is wrong with our knowledge – We need new knowledge.
2. We develop the new knowledge – or we cannot do it.

Emphasis has been placed on my "dynamic overshoot" work, which falls under II above. This is like placing emphases on the roundness of our planet, but forgetting to put to rest the flatland concept, once and for all. Item I should have been done concurrent with or before II and, in reality, it was, as described below. In history, the same person or group did not always do I and II; someone finds I while someone else finds the new knowledge. Also, I can be found with certainty, while II could take centuries to do, e.g., Aristotelian physics or the Ptolemaic system. Also, I can be established, while II simply not found at all, as with the Forms, which the great Plato gave up on and which no one has been able to complete to date.

In fairness to Tim Furniss, he covered my dynamic overshoot work, or Phase II above, extensively after 1990. I think he wrote about my earlier Challenger work, but I do not remember speaking with him then, particularly during 1986-87. It is my responsibility to describe Phase I, which is the subject of this post. Phase II, about new knowledge or dynamic overshoot, may make more sense then.

Let me say to Bob that at least one of the distinguished Commissioners, the honorable David Acheson, was briefed in person on what you will read, that he spoke with other Commissioners about it and that he discussed it with the late Administrator Fletcher. The events and analysis go back to 1986-87. That at the time one of my objectives was to find a way to amend the Commission Report (after it was released) so that this discussion would not take place ten, twenty (today) or hundred years after the Report. Mr. Acheson volunteered the opinion that making my results public was an honorable thing to do, and I do it here in that spirit.

Early in my Challenger studies, I wrote a report on "joint rotation" and I discussed it with other experts, including, Chairs of a Conference to be held then in California. They invited me to give a "talk" at the AIAA/ASME/… Conference. On Registration day, a Chairman called; we had a lengthy talk interrupted several times – apparently for negotiations or consultations with other people. There were problems. I was told that some delegates threatened to boycott the Conference if I took the podium. I did not ask the identity of those folks, but was told they were senior engineers. I was ready to describe how "joint rotation" was not the likely cause of the accident. I was packed and ready. I canceled my trip. My '87 report, which is mentioned often below, was the

same report that was revised by the editors of Aerospace America for publication, but, then, not published because of interference of others, as reported by Tim in his Challenger chapter.

Another objective I had at the time was to find a position in NASA that would allow me to handle the dynamic overshoot technical problem in the Shuttle. You could not fix the overshoot problems by dealing with the Orbiter Contractor(s) alone, the ET Contractor(s) alone, or the SRB Contractor(s) alone, etc. Let me add that I was semi-recruited then by top agency managers, to use a line from Dwayne, "*whose names you would recognize.*" To do the above, I wanted nothing to do with politics, the media or other distractions. That did not happen.

"FFrench" (thank you) referred me to the link where Oberg's posting and "*follow up opinions of others*" could be found. I clicked on it, and there it was – The circus of 10 years ago led by the same mc, Henry Spencer. I mention Spencer here because he wrote about my "joint rotation" study, as if an expert. On "1996/07/04," he wrote:

> Joint rotation is somewhat reduced, overall, at the joint, but it is still present. (In fact, loads added by the mounting strut aggravate it over small portions of the joint.)

Did Spencer do the analysis that showed "*in fact*" the struts aggravate the joint? His post began with his insulting clichés:

> That wouldn't be **Ali AbuTaha**, would it? If so, be aware he is a known crank on the subject. (Spencer's emphasis)

How convenient, to insult someone while using his or her work to look good. Find your old post, Henry; your questioner was not even referring to me. When Henry used my material matter-of-factly, which made him look good to other, it didn't occur to him to reference my work or me. Why do it, he could lose the respect of Oberg, Pearlman and the fans on sci.space.history if he referenced "facts" from a "crank." In another thread here, Bob writes, "*Henry Spencer, a respected contributor to sci.space.history.*" Anyone "respected" references his or her sources. Spencer wrote "*joint rotation is somewhat reduced*." How much? Did he calculate it? In my '87 report (which he seemed to use), I said that other complex factors show that joint rotation is nil or zilch. He didn't mention it, nor calculate it. I mention these things because Spencer did the same elsewhere. When someone typed Tim Furniss' entire Flight International article on my "pulsing thrust" invention in October 1995, posted it, and asked Spencer about it; Henry used bits that came from my write-ups, as if these were his, without referencing them to me. Yet, he was eager to begin that post with his clichés:

> Unfortunately, the source is not promising. AbuTaha is a certifiable crank, previously noted for several wild theories about the cause of the Challenger accident (for example that the SRB joints had been strained by the turn the crawler has to make to reach pad 39B.

I mentioned my pulsing thrust in a previous post, and I wonder if Henry read about it. "FFrench" directed me to Spencer's den; maybe someone will direct him to this post. Furniss describes in his Challenger chapter how people like Henry "*led themselves up the garden path*" about the turn to Pad 39B. Spencer should read Tim's Chapter, carefully. And if Henry insults me, or my name,

again, I will respond to all of his posts from 97, 95 and before and share my comments with the University of Toronto and all his readers and cheerleaders on the net.

Some may hastily accuse me of disrespecting the Presidential Commission by writing about the "joint rotation" issue. The Commissioners were distinguished and honorable in their service to the Country and they remain so today. The fault lies with the engineers who should have done their work more accurately. Engineering is a precise art within tolerances. Give me your numbers, and make sure your numbers are correct. I don't need umpteen decimal points; only correct values. I don't buy hunches, guesses and gut feelings, though I consider them. This goes to all the engineers who were involved in the teleconferences on the eve of the tragedy, in the investigations or in the review of the results of the official investigations.

I couldn't list everything I did with respect to the subjects of joint rotation, O-rings, and cold temperature in 1986-87. But, here is a sample list:

1. First, what is joint rotation? If you put two soda cans in a freezer for a while, the water content freezes, expands and pushes on the inner walls causing the cans to bulge in the middle. If you stack the two cans and look sideways, you will see the sides sloping in different directions where the cans meet. This is joint rotation. Generally, we calculate the bulging using standard elasticity equations and transfer the result using geometry and trigonometry to obtain the slope where the two cans meet, and the joint rotation, and the gap opening. For young students, balloons can be used to demonstrate the effect.

   The pressure inside the boosters causes the SRB segments to bulge, which causes the joint rotations. The Commission was told that all the joints were equal. That is not true. The aft joint that failed on Challenger is very different. In the Commission Report, it was stated that the "rotation" in the aft joint is about 25% less than the forward joints. That is incorrect. The pressure alone in the aft segments, compared with the forward segments, accounts for 15% reduction. There are greater reduction factors.

2. Back to the soda cans. Place a stiffener ring in the middle of one can and freeze it. You will see two bulges – smaller than for the full cans. Hence, smaller joint rotations. If you put two more stiffener rings, in addition to the center ring, on the can and freeze it, you will see less bulging and less end rotations. The aft segments have those stiffener rings I mentioned in a previous post, added to counter the mysterious lift-off forces, or dynamic overshoot. Hence, smaller joint rotations.

3. Now, if you can find a short soda can with the height of a cat-food-can, repeat the freezer tests. The short can bulges less. The aft segment that failed on Challenger is a short one, hence, smaller joint rotation. Where are we going with all of this? I want to show that rotation in the joint that failed was nearly 50% less than the forward joints, just due to the stiffeners alone. Spencer tried to play expert in his above post when, apparently, responding to my report without mentioning it, he wrote:

   The stiffener rings are below the joint, and do not affect ballooning of the segment above the joint.

That's right Henry. In my '87 report, which you were using, to your credit, but not to enlighten others, particularly young students who seem to count on your word, I wrote:

The aft segment is constrained from swelling by stiffeners, which are used to strengthen it, and the strongest stiffener is only a few inches below the failed aft joint. Here, joint rotation is reduced by nearly a half.

So, here we have about 50% rotation reduction, from the segment "below" the joint plus the 15% due to pressure difference, and the failed joint rotated about 65% less than the forward joints. Mr. Pearlman writes that Spencer found my write-up "*incoherent*." I doubt that Spencer grasped it. Or, did he? The 65% less rotation was not the end of it.

4. In my '87 report, I wrote, "*There are other more complex considerations which also contribute to further reduction in joint rotation.*" The detailed analyses and data were part of the talk I prepared for the AIAA/ASME/… Conference. Spencer could not peek into my "talk" because it was canceled. He didn't, or couldn't after reading my words, show that there was hardly any rotation in the joint that failed.

Imagine placing thick cylindrical-shaped plastic material with a small core inside a soda can, glued to the inside walls. If the same internal pressure, as in the freezer examples, is generated in the center area, the can will not bulge as with the empty cans. Try it – but be careful. Before the thin walls bulge, the thick bulk of silly-putty, play dough or solid propellant must bulge first. The analysis is not impossible. The stress in the outer layer of the solid propellant in the boosters "at lift-off" is less than 100psi – that's all. There is hardly any bulging of the walls with the propellant in place. The SRM Team Analysis Report (Commission, Vol. II, Appendix B, p. L-110) reported that the propellant reduces the bulging (and joint rotation) by about 12%. That is greatly underestimated. But that's what the computer said! You only get out of the computers what you put into them. I belong to a unique generation of engineers who went from pad and pencil, to mechanical adding machines, to slide rulers, to hand calculators, to computers. The very thick propellant bulk undergoes outward radial deflection, which can be easily calculated. The propellant bulk expands a little outward, but does not bulge.

I am not saying there was no erosion or blow-by of O-rings. I am saying that maximum joint rotation happens late in boosters' burn, when the propellant is nearly depleted, the pressure is acting directly on the walls causing the thin walls to bulge, the ends to rotate and the gaps to possibly open.

If joint rotation played a significant role in the Challenger accident near lift-off, then fire would have surged from all the forward joints. The Commission wrote, "*All things being equal these (the forward) joints should leak first.*" Well, if the accident was not caused by joint rotation, because there wasn't any or much at liftoff, then what caused the accident?

5. The Aft Field Joint that failed on Challenger had the struts that connect the SRBs to the ET. In my '87 report, I quoted from the Commission, "*Segment L-06, the right aft clevis component, had been flown on 51-C as the left aft clevis member.*" That's impossible. As everyone knows, you can rotate the tires or wheels on your car, but you cannot switch the right and left doors on your car. The struts are like the hinges on the door of a car. Senior NASA engineers and possible peer-reviewers were furious with me, in a HQ meeting in December 1986, for pointing out to them that their input to the Commission was wrong. In my '87 report, I wrote extensively about this, e.g., "*Was the accident caused by the deterioration of a field joint, or adjacent hardware, that was used repeatedly in the same location?* And, "*because the section is subjected to significant and concentrated forces in the same circumferential area before lift-off, it would have been distorted out of round,*" etc. Wear and tear is the engineers' worst enemy.

6. The struts imposed concentrated forces on the failed joint. In my '87 report, I wrote:

   "The adverse effect of the forces transmitted through the struts to the aft joint was underestimated before the accident and during and, even, after the investigation."

   And,

   "My study of the early reports of the accident showed that the combined loads in the aft struts varied by 40% between missions, and by more than 100% for individual struts."

   Didn't the engineers in the famous teleconferences before Challenger note the 40% variation, which equals the ultimate safety margin for the system, or the 100% jumps, which exceeded all safety margins? Spencer chastised people on sci.space.history:

   "It helps if you actually read the report. (I've referred extensively to my copy in composing this posting.)"

   In addition to reading, one needs hands-on experience to read numbers, understand them, check them out, etc. Spencer writes as if he were an expert. In his extensive reading of the Report, he did not recognize the massive 40 and 100% disparities in important numbers (Vol. I, page 53), or he didn't care. Maybe, my first sentences on this thread may now make sense:

   "Ten years ago, someone told me that rude remarks were made about my work and me on the net. I checked it out and decided not dignify the ill informed, ill qualified and ill-mannered folks … with answers."

7. The engineers told the Commission that their NASTRAN computer models of the failed joint incorporated the lift-off loads from the struts to the joint area. That was impossible. I was the in-house expert on NASTRAN at Comsat Labs in the early 1970's, I tried to solve a similar problem with the program, and I couldn't. I even tried tricks to make NASTRAN solve the problem, but couldn't. Reading the above, I called people from NASA, NRC, and elsewhere – there is a problem.

The input to the Commission is wrong. Then it came out in the Accident Analysis Team's report, "*No strut loads were considered"* in the analysis. You can see that the ruckus I raised in 86-87 was not frivolous. Those loads through the struts would prove crucial later on.

8. The emotional teleconferences on the eve of the tragedy are now understandable. But the position of the experienced NASA engineers should also be put in proper perspective. There was concern about erosion and blow-by and cold temperature in the joints, and the primary culprit, according to the Thiokol engineers, was "joint rotation." From this post, you see there was no joint rotation, especially, at lift-off. Perhaps, the confusion will sort itself out. We are moving towards a more likely culprit for the observed damage – the lift-off loads through the struts into the failed joint.

9. I am trying to use words from my early '87 report so no one, Spencer included, would accuse me of rewriting history. In the epigraph to the '87 report, I wrote:

"According to a senior Director with the National Research Council, a recent test showed that the failed aft joint "opens and closes" when subjected to the lift-off loads through the struts "contrary to NASA's earlier expectations." The Director also said that errors were discovered in the computer models of that joint."

The excessive loads in the struts and errors in the computer models was the product of my detailed '86 studies, which I shared with NASA and NRC. Everyone was shouting erosion, blow-by, O-rings, joint rotation, gap opening, and cold temperature then. The primary and secondary O-rings' gap-openings are given in the Commission (Vol. I, p. 60) as, "*0.029 inches and 0.017 inches*" respectively. This is what all the fuss was about, 29 and 17 mils gap-openings. But, the joint that failed on Challenger was permanently deformed out of shape about 30 times more than the secondary gap opening! In my '87 report, I quoted from the Commission:

"Taken across the 0-180 degrees axis, the tang diameter measurement exceeded the corresponding clevis dimension by +.512 inch;"

I went on,

"The aft center segment was distorted to conform to an already deformed section."

The permanent deformation was in the exact direction of the forces passing through the struts. Either there were greater forces than previously anticipated or all the engineers did not know how to design steal parts that do not deform plastically, or permanently – or within the elastic limit. If, as an engineer, I were worried about a possible gap opening of 29 mils, I would be frightened by a definite 512 mils opening in the same area.

It was thoughtful of the NRC to send me courtesy copies of their reports, although the stream of my contributions was not acknowledged. But, then I noticed that the Council acknowledged the

work of other experts and organizations for other contributions. When I asked that my work be also acknowledged, they declined to do it. That led to regrettable parting of ways with the NRC.

10. I mentioned in previous posts how the messy loads in the struts led me to the dynamic overshoot. While I did not then write about the effect explicitly because of national security concerns, the effect was couched in my write-ups, e.g., in the same '87 report, I wrote,

    The adverse effect of the forces transmitted through the struts to the aft joints was underestimated before the accident and during and, even, after the investigation. This was a serious mistake, which should have been brought to the attention of the Commission before the investigation was completed.

    I am not going to rewrite my previous posts, but the adverse consequences of the dynamic overshoot on Challenger and the Shuttle, including the joint that failed, should be clearer now.

11. There was much more to the loads through the struts to the failed Challenger SRB joint. After accounting for the dynamic overshoot in 1986, there were still more forces unaccounted for, even after considering the forces impressed on the struts by the shrinking ET after tanking. Those forces were not found in fancy conference rooms or from senior experts or peer-reviewers, but from the great men and women in the front lines, the great workers who put the Shuttle stacks together at KSC. In meetings in trailer offices and sitting on the hoods and trunks of cars carrying out intelligent discussions about the system, other crucial findings were made. Here are words from my '87 report:

    "For example, the incorrect rotation of the adjustment nuts on the struts during assembly could account for some of the variations. Clockwise and counterclockwise directions can be easily confused when one changes orientation, such as when you reach under a car to loosen a bolt. Arrows will be added to the adjustment nuts to preclude potential mistakes in the future. This was not noted in reports of the accident, though the forces through he struts play a very important role in the behavior of the failed aft joint."

    If only the arrows showing the direction of preload with certainty resulted from my work, then it was all worth it. A loose or overly tightened strut could spell disaster. I might add that I had experience with similar simple mistakes, which almost led to serious disasters in different systems.

I don't have my detailed studies before me now, and I am sure there were other useful and compelling findings. Some may say that NASA and others were going to discover all of the things mentioned above without any input from me. That's not relevant; all these things should have been put before the Presidential Commission, the Congress and the public during the investigation itself.

Ali AbuTaha