NASA, and NACA before, pioneered the study and photography of shock waves. We used to hunt for shock wave pictures hoping to better understand the complex equations and analysis of supersonic flight. Around June 1987, NASA released a summary videotape of the official Challenger investigation. The narrator said that NASA looked for a "shock wave" from the main explosion that broke the assembly apart, but couldn't find one. I had found the shock wave that the investigators couldn't find. My photo and its significance are described here.

Let me begin with a shock wave that both NASA and I captured in photos. The right booster safety system destruct (T+110 seconds) is shown in Photo #1 (Commission, Vol. III, p. N-58). I captured the same event, Photo #2, where the explosion of two charges on the RSRB is shown. The doughnut shape reveals the shape of the charges on the booster. The near circular shape indicates that the speed of the booster had little effect on the wave fronts. The shape also indicates that no external bodies obstructed the travel of the wave fronts. And so on.

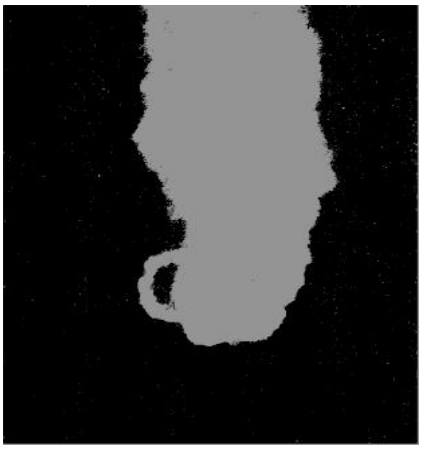


Photo #1 Right SRB

Photo #2 Right SRB

But the situation is different with the "shock wave" of the main explosion, which can give a clear picture of what happened before and after the explosion, including, to the Crew Cabin. Let me first mention some related facts.

Photo #3 shows the fire that appeared between Challenger and the ET in the close-up view that we saw on TV just before the explosion. Some experts told the Commission that the fire was the result of oxygen leaking down from the LOX tank on the top of the stack and hydrogen (defying the laws of nature) climbing up to meet the oxygen. Commissioners Covert and Feynman ridiculed the explanation – hydrogen climbing up against a vehicle moving at Mach 2? This puzzle was not solved, and it is related to the main shock wave.

Photo #4 is taken after the LOX tank exploded suddenly and violently – a few frames ahead of Photo #3. By then, the shock wave of the LOX tank explosion has already cleared the screen. But notice in particular that the same fire (or

Photo #3 Fire between Challenger

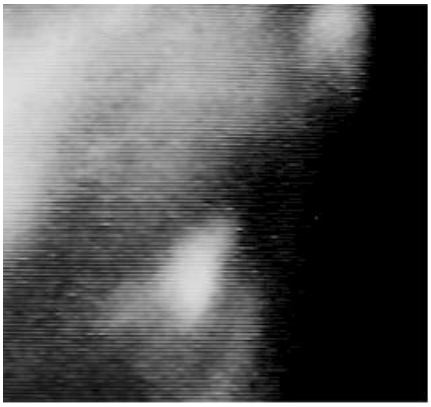


Photo #4 Fire persists after LOX

glow) that appeared in Photo #3 is still persistent in Photo #4, after the LOX tank exploded and its wave front cleared the scene. The fire between the Orbiter and the ET had nothing to do with hydrogen-oxygen burning or leaking oxygen. This is worth pursuing a bit further.

A frame is about 40 milliseconds, and I am going to say 1 frame = 50 ms. Look at what happened beginning one frame before the LOX tank explodes:

- (T+0.000s): I am on a frame similar to Photo #3, where you see the right booster fire in the background on the bottom, hydrogen gushing out of the aft dome on the ET, and the glow between Challenger and the ET.

- (T+0.050s): I move one frame forward, and the picture is filled with shaded areas moving outward. The LOX tank explodes in this timeframe.

- (T+0.100s): One more frame forward, and I am in Photo #4. The LOX explosion is over. The "shock wave" is come and gone. It's all over. Yet, the glow that appeared between the Challenger and the ET is still there! That's another story.

My point: Once one oxygen molecule found a surface or another molecule to oxidize, it was all over. All the oxygen in the feed lines and the LOX tank exploded violently and instantly – literally in less than 50 milliseconds. NASA gave times in milliseconds, which means that they probably had 50 frames to find the "shock wave." I had only one frame (worth 50 milliseconds) to work with, and I could only glimpse signs of the "shock wave" in the close-up views. The LOX tank explosion was violent. It had to produce a shock wave.

I am going to skip several events, of roll, pitch, yaw, vibration and other actions, that I found in video clips, photos and telemetry; all of which add up to a coherent account of what happened to Challenger in those terrible moments.

Here is my photo of the "shock wave" of the main explosion (the LOX tank explosion), captured in the New Smyrna Beach video – Photo #5. Catching that

picture was difficult. I couldn't see the shock wave at normal speed or in slow motion, and I could hardly get a glimpse of it in frame-by-frame scroll. I'd find it, stabilize the frame on a monitor and by time I set up the camera, the shock wave was gone. Start all over, but the shock wave wouldn't show up again! That was the most frustrating picture to capture and, perhaps, the most gratifying to trap. Shock waves are elusive. Estimating the Mach-cone and Mach-angles in my head for the Concorde as it passed from Mach 1.0 to above Mach 2, I was unable to see any Mach lines outside the window. The books said there should be shock waves out there. Were those photographed from outside the craft? I don't know. But here is a summary description of the Challenger shock wave:

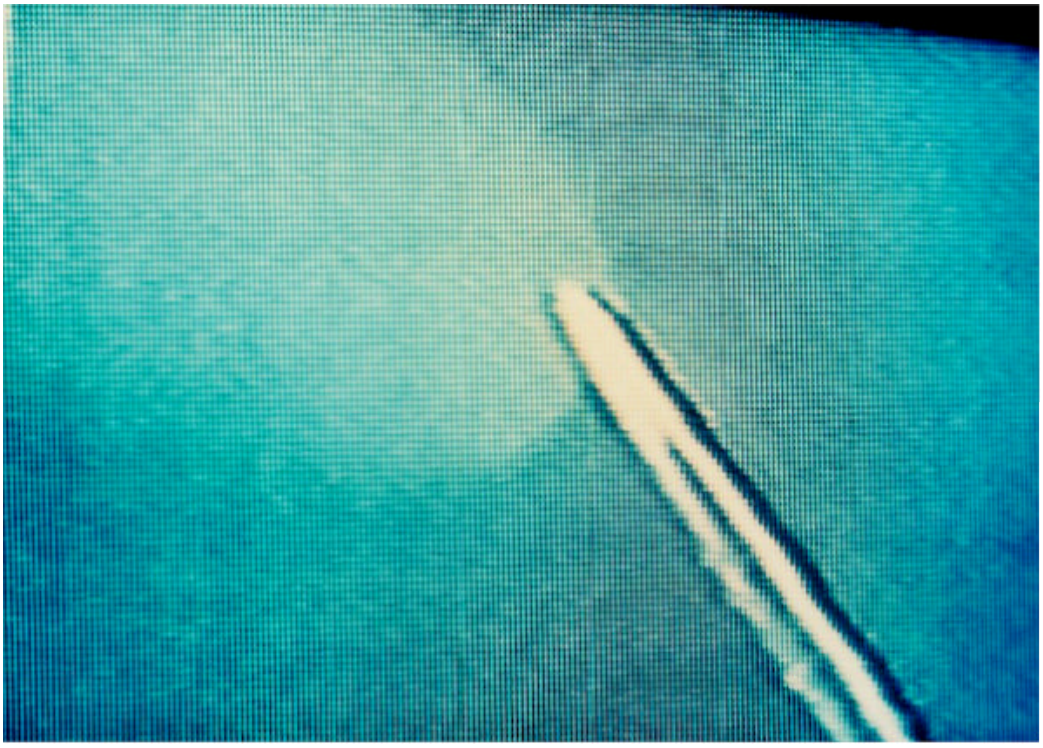
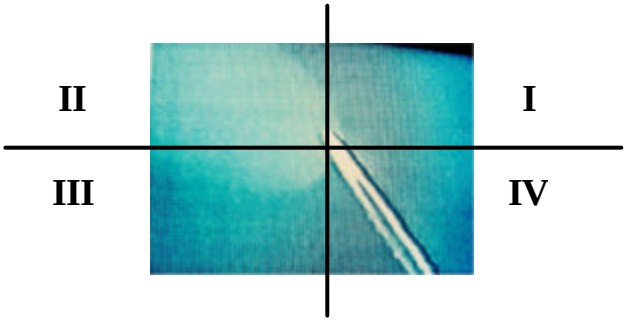


Photo #5 LOX Tank Explosion Shock

- Imagine standing near New Smyrna Beach, some 30 miles north of the Cape.
- Challenger launches facing east, executes the roll maneuver and begins to climb over the water to your left (or to the east) with a slight inclination to the north. Use my previous NSB photos to get oriented. Photo #5 shows the shock wave of the LOX tank explosion.
- Imagine a stationary LOX tank suspended at that location. If it explodes, its shock wave will travel in all directions (sphere) and the camera will capture a picture of a circle.
- Imagine the LOX tank moving in the direction of the plume at Mach 2.0, and exploding at the same location. The shock wave will be deformed – more oval than circular.
- Now, put all the pieces together (Challenger, ET, SRBs) and study the geometry of the shock wave in Photo #5, and try to see what happened.

It is helpful to divide the scene into 4 quadrants, as shown in the next thumbnail and to evaluate each quadrant separately. The most important, and telling, is Quadrant **I**. But first, some comments on the other 3 quadrants:

- **Quadrant II**: Here you see the effect of speed on the wave front.
- **Quadrant III**: Here, we see the effect of speed plus the ET intertank structure obstructing the downward motion of the wave front.
- **Quadrant IV**: There is no trace of a shock wave in this quadrant as the Orbiter absorbed the energy of the explosion in this direction.



Quadrant I: This is the Quadrant of primary interest. The LOX tank towers above the Orbiter. The shock wave should have penetrated into this region, to the right, but it didn't. Something got in the way and obstructed the progress of the wave front in this direction. The Crew Cabin traveled farthest south (to the right) than any other Orbiter piece, which indicates that the Crew Cabin was hit broadside by the wave front of the violent explosion.

We can calculate the force that a bat imparts to send a baseball several hundred feet away or the force a club head imparts to send a golf ball couple hundred yards. The same force will hardly move a bowling ball a few feet, and will impart no motion to a small car or a pickup truck. The force required to kick a body the mass of the Crew Cabin several hundred meters horizontally is enormous. From other photos, I estimated distance and time and then calculated the initial horizontal velocity of the Crew Cabin leaving the explosion zone. From the velocity, calculation shows that the CC experienced enormous horizontal force from the shock wave. The g-forces indicate the astronauts died instantly from the explosion. Without the picture, and analysis, of the shock wave, the horizontal motion of the Crew Cabin would have remained a mystery forever.

File size again. Other photos must wait. The more formidable problem to solve was the initial "vertical" velocity of the Crew Cabin that sent it to a higher altitude than the other Orbiter's parts. In the event anyone pursues this further – with the incredible software and hardware available today – the following comments will be useful:

- The Crew Cabin was hit broadside by the shock wave of the LOX explosion, which explains the horizontal (southern or to right in photo) distance the Cabin traveled.
- This requires the Crew Cabin to advance "forward" from its position on the stack, how?
- The forward travel of the CC requires that the Cabin broke off from the Lower Forward Fuselage section, which was mistakenly identified by NASA as the Crew Cabin.
- The location, distance, altitude and times related to the Lower Forward Fuselage indicate the LFF was in its place near the ET intertank area when the LOX explosion happened.
- The CC climbed to the highest altitude of all Orbiter pieces after the explosion.

- The shape of the shock wave precludes any possibility that the explosion's wave front propelled the CC upward.
- Then, what propelled the Crew Cabin upward?

The last question requires more photos, telemetry and input, mostly from the excellent Accident Teams' reports, and straightforward analysis. 2-D, 3-D? After the basics are done, we can do simple coordinate transformations. The first-cut answers are good enough.

The 1987 NASA videotape – without the shock wave of the main explosion – signaled the end of my effort to incorporate my findings into the official reports. By then, I had numerous meetings and conversations with senior agency managers, House and Senate Committees' staff and some members of the Commission about it. There was a lot of politics. My supporters, the silent minority, lost the day, and my detractors, the boisterous many, won it. I did not lose on merit, and that's why I extended my posts on this thread, which I hope to conclude soon.

I had given Tim Furniss and Flight International (and other reputable journalists and publications at home and abroad) tens of photos, often at their request, showing the events you have seen in this thread, including the shock-wave photo. I explained in detail the meaning of the photos and the relevant events. I don't remember Flight International publishing my photos, and that might have led to lack of reference for Tim in writing about the Challenger investigations.

Ali AbuTaha

Based on my experience with reputable publishing houses, agents, co-authors and attorneys, I doubt that my Challenger work will be published in the normal way. I don't believe in self-publishing, and my work remained dormant until this thread. It was my intent to make a couple posts on behalf of Tim Furniss and get back to my work. The "side walk rocket scientist," "junk science," and other derogatory remarks by Hansen and the terrible memories of Spencer on space.sci.history forced me to extend my lengthy posts. If only these people and their friends, acquaintances, and business associates stop the "ill informed, ill qualified and ill mannered" comments about me, then it was all worth it. But I wouldn't stop here without extending my sincere thanks and appreciation to the Moderator, Mr. Robert Pearlman,