ETHICS CASE STUDY: *COLUMBIA DISASTER*

ME 481 Senior Design

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Some Quotes

Henry Pohl, former Director of JSC Engineering Directorate: *"Safety is everyone's job."*

National Safety Reporting System (NSRS) poster: *"If it's not safe, say so!"*

Columbia Debris Traveling Display-Exhibit at JSC: *"Everyone that touches a mission, on every level, is responsible for what it represents and the lives that are involved."*

JSC Mission Operations Directorate, JSC Building 4 Lobby: *"To always be aware that suddenly and unexpectedly we may find ourselves in a role where our performance has ultimate consequences. Vigilance."*

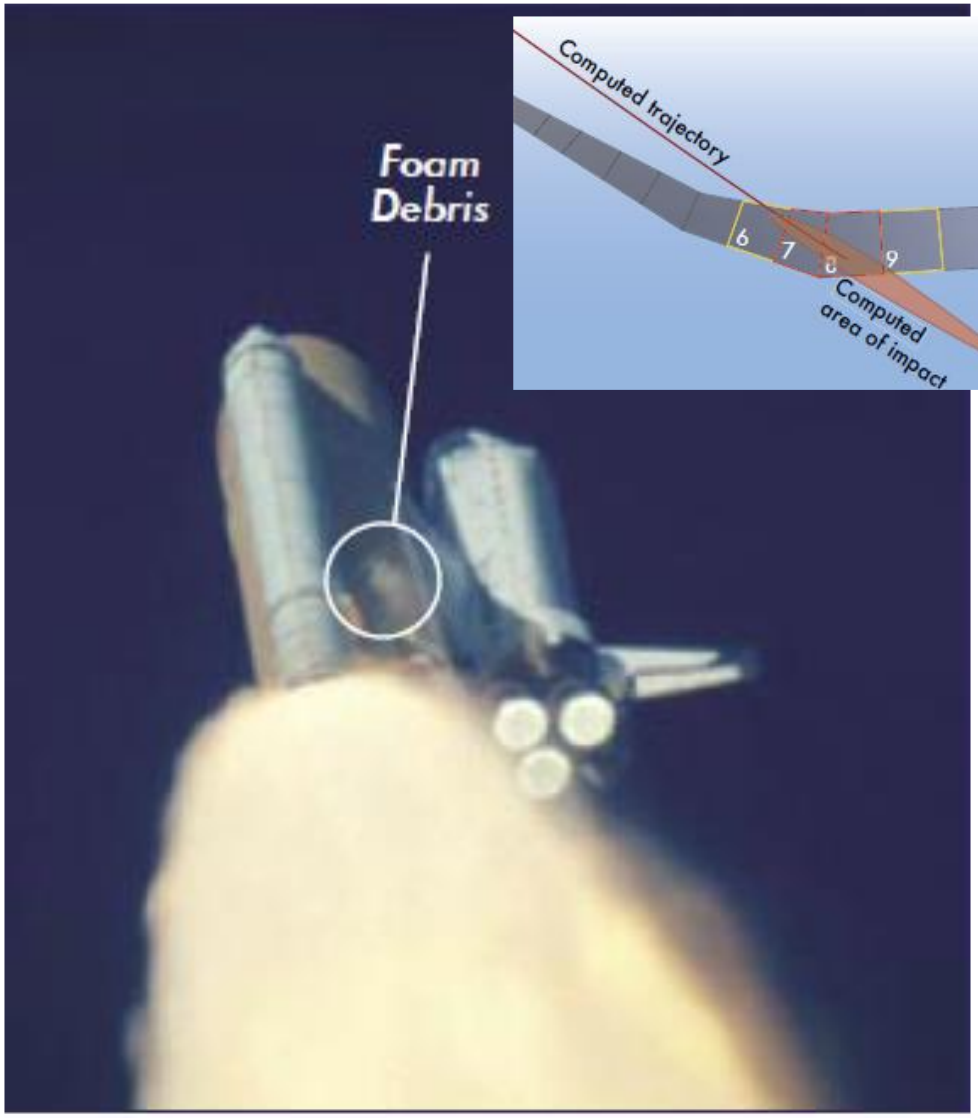
The STS-107 crewmembers pose for their traditional in-flight crew portrait aboard the Space Shuttle Columbia. From the left (bottom row) are astronauts Kalpana Chawla, mission specialist; Rick D. Husband, mission commander; Laurel B. Clark, mission specialist; and Ilan Ramon, payload specialist. From the left (top row) are astronauts David M. Brown, mission specialist; William C. McCool, pilot; and Michael P. Anderson, payload commander. Credit: NASA

STS-107 Background

- On February 1, 2003, Space Shuttle *Columbia* was destroyed in a disaster that claimed the lives of all seven of its crew [*Ref. CAIB Report]
- On launch day (Jan. 16, 2003) a large chunk of foam, weighing about 1.7 lb, broke loose from the External Tank during ascent and struck the left wing at a relative speed of over 500 mph. This was observed during powered ascent by ground camera video and reported to the Shuttle Program managers the day after launch when the video had been reviewed.
- Although mass of foam was small, because of velocity its kinetic energy was large enough to breach thermal protection system of reinforced carbon-carbon (RCC) panels.
- As a result, the vehicle suffered severe overheating and burn through of its left wing leading edge and disintegrated during planned atmospheric re-entry.
- Despite the wing impact damage, *Columbia* and its crew operated on-orbit throughout the 16-day mission with only a few minor problems and performed successful science objectives.

[*Details are documented in the official Columbia Accident Investigation Board (CAIB), Report Vol. 1, August 2003.]


Debris Source
Impact Site


Foam Debris
Computed trajectory
6
7
8
9
Computed area of impact

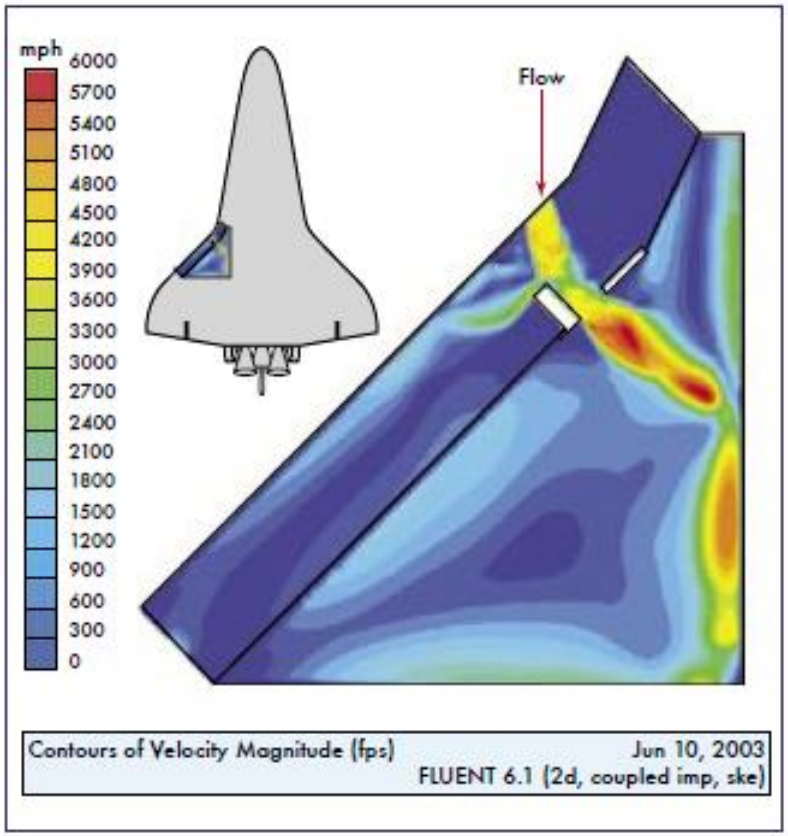


Figure 3.6-11. The computational fluid dynamics analysis of the speed of the superheated air as it entered the breach in RCC panel 8 and then traveled through the wing leading edge spar. The darkest red color indicates speeds of over 4,000 miles per hour. Temperatures in this area likely exceeded 5,000 degrees Fahrenheit. The area of detail is looking down at the top of the left wing.

Debris Assessment Team (DAT)

- Formed on Flight Day 6 by United Space Alliance/Boeing. Had 30+ members, including multiple NASA Center & contractor engineers, and Safety. Had no clear management direction.
- DAT only had 3 days to get "The Answer" to the Mission Evaluation Board (MEB) and to the Mission Management Team (MMT)
- Engineers' concerns heightened by their interpretation of the FD-2 video (although blurry and projectile strike location and damage unknown)
  - JSC's Thermal Design Branch engineers very concerned that the wing strike could be potentially catastrophic
  - Inter-center Photo Working Group expressed concerns
  - All wanted extra images
- DAT and others submitted urgent requests for definitive, extra imagery (e.g., by AMOS on Maui). All requests for imagery refused by Space Shuttle Program managers.
- No way to even initialize a meaningful and applicable damage-tolerance model & assessment without a clear view of actual damage.

DAT (cont.)

- **Ethical Dilemma #1:**

If program management says "No" or states, "not interested" to a gravely urgent request, then what to do next? Stand down our concerns? Do your best but "reasonable" assumptions, but don't guarantee a bad answer? My job is finished?

DAT (cont.)

- Despite lack of critical info, DAT proceeded to produce a highly uncertain and flawed analysis. Met the 3-day deadline and presented to Mission Evaluation Room (MER) and Space Shuttle Program (SSP) on Jan. 24, 2003.
  - Empirical tools were extremely sensitive to inputs. Usage was far outside the bounds of the test data. No actual damage configuration available, thus, not anchored to reality.
  - The DAT assessment, though citing high uncertainty and cautions on the assumptions and tools used, indicated "no safety of flight issue" – they were wrong.

DAT (cont.)

- Week after DAT presentation, some engineers were still concerned about the possibility of an overheated tire exploding and catastrophically damaging *Columbia* during reentry.
  - Equivocal emails sent to NASA labs, JSC Mission Operations Directorate, and NASA HQ caused confusion
  - Another request for shuttle imagery went to the STS-107 Ascent/Entry Flight Director and MOD reps, who in turn asked Shuttle management again. Once again the request was denied and was considered a "dead issue"
- Mixed message from management to DAT:
  - "This foam strike is urgent, keep me informed, let me pose you questions, hurry and produce and analysis, but I'll ignore your requests for more data"
  - "I integrate information down, not upward."

Communication Breakdown

- Ineffective and failed communication paths
  - Confusion about ownership of issue – under MER or MMT or neither?
  - Emails without management reply; emails with equivocal or unclear requests; face-to-face heated arguments with no follow-up or resolution
  - Lack of clear processes and reporting paths for DAT
  - Over-emphasis on communication protocol (“Don’t email managers in high positions”)
  - Final DAT assessment did not emphasize large uncertainties of modeled damage and their fallacious conclusion was taken at face value

CAIB Report Conclusion

- Management decisions made during *Columbia's* final flight reflect missed opportunities, blocked or ineffective communications channels, flawed analysis, and ineffective leadership.
- Perhaps most striking is the fact that management – including Shuttle Program, Mission Management Team, Mission Evaluation Room, and Flight Director and Mission Control – displayed no interest in understanding a problem and its implications.

CAIB Report Conclusion (cont.)

- Because managers failed to avail themselves of the wide range of expertise and opinion necessary to achieve the best answer to the debris strike question – "Was this a safety-of-flight concern?" – some Space Shuttle Program managers failed to fulfill the implicit contract to do whatever is possible to ensure the safety of the crew.
- In fact, their management techniques unknowingly imposed barriers that kept at bay both engineering concerns and dissenting views, and ultimately helped create "blind spots" that prevented them from seeing the danger the foam strike posed.

Warnings Ignored

What the Experts Have Said

Warnings of a Shuttle Accident

"Shuttle reliability is uncertain, but has been estimated to range between 97 and 99 percent. If the Shuttle reliability is 98 percent, there would be a 50-50 chance of losing an Orbiter within 34 flights … The probability of maintaining at least three Orbiters in the Shuttle fleet declines to less than 50 percent after flight 113."[21]

-The Office of Technology Assessment, 1989

"And although it is a subject that meets with reluctance to open discussion, and has therefore too often been relegated to silence, the statistical evidence indicates that we are likely to lose another Space Shuttle in the next several years … probably before the planned Space Station is completely established on orbit. This would seem to be the weak link of the civil space program – unpleasant to recognize, involving all the uncertainties of statistics, and difficult to resolve."

-The Augustine Committee, 1990

Shuttle as Developmental Vehicle

"Shuttle is also a complex system that has yet to demonstrate an ability to adhere to a fixed schedule"

-The Augustine Committee, 1990

NASA Human Space Flight Culture

"NASA has not been sufficiently responsive to valid criticism and the need for change."[22]

-The Augustine Committee, 1990

Warnings Ignored (cont.)

- The CAIB also explored other incidents of foam shedding from the external tank on previous shuttle missions. Of the 112 previous shuttle missions, 79 had qualifying imaging and there was evidence of foam shedding on 65 of them (82%). The CAIB noted that the original shuttle design requirements included:

"The Space Shuttle System, including the ground systems, shall be designed to preclude the shedding of ice and/or other debris from the Shuttle elements during prelaunch and flight operations that would jeopardize the flight crew, vehicle, mission success, or would adversely impact turnaround operations…No debris shall emanate from the critical zone of the External Tank on the launch pad or during ascent except for such material which may result from normal thermal protection system recession due to ascent heating."

Warnings Ignored (cont.)

- Even though the shuttle requirements called for no foam to be shed from the ET during ascent and engineers were aware of foam shedding on previous flights, they accepted the risk.
- This is an example of the "Normalization of Deviance" belief at work - "We've had foam strikes before and always landed safely"
  - This was also exhibited by the Shuttle continuing to fly with the known problem with the SRB seals prior to the *Challenger* disaster.

Lessons for All Engineers

- Levels of briefing and detail presented to managers depends of their individual management style – not standardized. Great sensitivity immediately after an accident to listen to everything. Wanes with the passage of time.
- Not as much direct soliciting of dissenting opinions or offers to abet them. They are not as strongly invited as in the accidents' immediate aftermath. Today one has to be quite assertive to be heard.
- Subtle and unconscious return to the "Prove it's unsafe" paradigm.
- Emotional interaction factors are real and still can color what should be technical, rational discussions.

Lessons for All Engineers

- Beware of "Kill the (lone) messenger" mind set. Take your urgent message forward and upward with your informed and knowledgeable group of experts.
- Don't overwork, don't over-stress. Take good care of yourself, physically and mentally. However, these caring messages are seldom voiced by managers nowadays and seem to have become extinct.
- Aerospace vehicle operation always presents high risks and hazards. It is managers' prerogative to accept risk. NASA HQ-Safety, Brian O'Conner said, "I do accept risk, but I need engineers to tell me precisely what the risk is."
- ***Engineers need to remain ever the vanguards of risk identification, its elucidation to management, and methods to reduce risk.***

Final Question

- **Ethical Dilemma #2:**

What would you tell seven astronauts if you knew their space shuttle was crippled on orbit, there was no way to fix it, and it could result in their death on reentry?

- It was a question that faced NASA's Mission Control after initial suspicions that something might be wrong with Space Shuttle *Columbia* as it was preparing to make its doomed reentry in 2003.

Final Question

- Dr. Wayne Hale, former Flight Director, wrote in his blog:

"After one of the MMTs [Mission Management Team] when possible damage to the orbiter was discussed, he [Flight Director Jon Harpold] gave me his opinion: 'You know, there is nothing we can do about damage to the TPS [Thermal Protection System]. If it has been damaged it's probably better not to know. I think the crew would rather not know. Don't you think it would be better for them to have a happy successful flight and die unexpectedly during entry than to stay on orbit, knowing that there was nothing to be done, until the air ran out?"

- A bleak assessment. Orbiting in space until your oxygen ran out. The dilemma for mission managers is that they simply didn't know if the space shuttle was catastrophically damaged.

- The doomed astronauts were not told of the risk.

References & Bibliography

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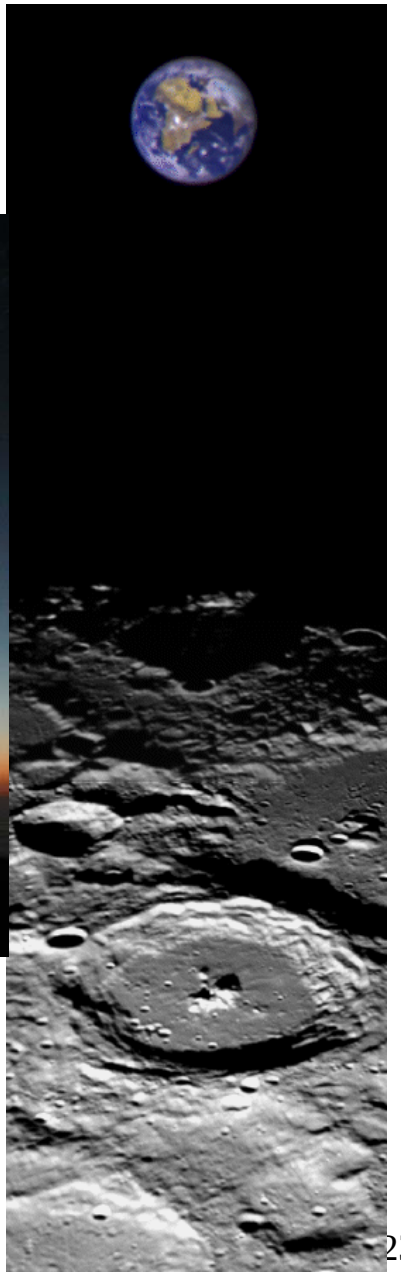
- McDonald, A.J., "Ethics Lessons Learned from the Space Shuttle *Challenger* Disaster," National Society of Professional Engineers, Seattle WA, July 17, 2015.
- Space Shuttle Challenger Disaster: Ethics Case Study No. 1 - Bing video

Space Spectaculars!

STS-98 Launch
2/7/2001

MMIII Launch
VAFB 9/19/02



Clementine's View of Earth Over Lunar North Pole Mar. 1994