

What to make of this video? How serious is the threat? What actions should be taken in response? A quick, smart analysis is needed, since Columbia will re-enter the atmosphere in about 12 days. Although the evidence is uncertain and thin, for only a single camera showed debris impact, the logical structure of the engineering analysis is straightforward:

$$\text{debris kinetic energy} \quad + \quad \begin{array}{l} \text{debris hits locations} \\ \text{(function of mass,} \\ \text{velocity, and angle} \\ \text{of incidence)} \end{array} \quad \rightarrow \quad \begin{array}{l} \text{level of threat to the} \\ \text{Columbia during} \\ \text{re-entry heating} \\ \text{of wing} \end{array}$$

*Angle of incidence* is uncertain; *location of impact* is uncertain (wing tiles? leading edge of the wing?); *mass* and *velocity* of the foam debris can be calculated. Profoundly relevant is the *difference in velocity* between the shuttle and the piece of free-floating foam, since the kinetic energy of the foam impact is proportional to that *velocity squared*. Even though the errant foam was lightweight (1.67 lb), it was moving fast (600 mph) relative to the shuttle. Velocity squared is like shipping and handling: it will get you every time.

To help NASA officials assess the threat, Boeing Corporation engineers quickly prepared 3 reports, a total of 28 PowerPoint slides, dealing with the debris impact.<sup>8</sup> These reports provided mixed readings of the threat to the Columbia; the lower-level bullet points often mentioned doubts and uncertainties, but the highlighted executive summaries and big-bullet conclusions were quite optimistic. Convinced that the reports indicated no problem rather than uncertain knowledge, high-level NASA officials decided that the Columbia was safe and, furthermore, that no additional investigations were necessary. Several NASA engineers had hoped that the military would photograph the Columbia with high-resolution spy cameras, which would have easily detected the damage, but even that checkup was thought unnecessary given the optimism of the 3 Boeing reports. And so the Columbia orbited for nearly 2 weeks with a big undetected hole in its wing.

On the next page, I examine a key slide in the PP reports made while the Columbia was damaged but still flying. The analysis demonstrates methods for how not to get fooled while consuming a presentation. Imagine that you are a high-level NASA decision-maker receiving a pitch about threats to the Columbia. You must learn 2 things: Exactly what is the presenter's story? And, can you *believe* the presenter's story? To assess the quality of intellect and credibility of presenters, close readings of their work will prove revealing. To be effective, close readings must be based on *universal* standards of evidence quality, which are not necessarily those standards operating in Houston that day. Also this reading reveals some shortcomings of PowerPoint for technical work, a point made by several investigations of shuttle engineering practices.

<sup>8</sup>C. Ortiz, A. Green, J. McClymonds, J. Stone, A. Khodadoust, "Preliminary Debris Transport Assessment of Debris Impacting Orbiter Lower Surface in STS-107 Mission," January 21, 2003; P. Parker, D. Chao, I. Norman, M. Dunham, "Orbiter Assessment of STS-107 ET Bipod Insulation Ramp Impact," January 23, 2003; C. Ortiz, "Debris Transport Assessment of Debris Impacting Orbiter Lower Surface in STS-107 Mission," January 24, 2003. These reports were published in records of the CAIB and at NASA websites.

#### Summary and Conclusion

- Impact analysis ("Crater") indicates potential for large TPS damage
  - Review of test data shows wide variation in impact response
  - RCC damage limited to coating based on soft SOFI
- Thermal analysis of wing with missing tile is in work
  - Single tile missing shows local structural damage is possible, but no burn through
  - Multiple tile missing analysis is on-going
- M/OD criteria used to assess structural impacts of tile loss
  - Allows significant temperature exceedance, even some burn through
    - Impact to vehicle turnaround possible, but maintains safe return capability

#### Conclusion

- Contingent on multiple tile loss thermal analysis showing no violation of M/OD criteria, safe return indicated even with significant tile damage



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