Columbia Accident Data Collection and Assessment Lessons Learned

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Thermal Protection System Damage Assessment Team

ASNT IN-SPACE INSPECTION WORKSHOP

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Presentation Summary

Background and History – Shuttle damage history, STS-107 Columbia accident, and Agency response

Individual Lessons Learned for STS-114 Return to Flight, and subsequent flights

Summary of Lessons Learned

Questions and Answers

List of References
History

STS-1 post-landing

STS-27 post-landing inspection
History

In January 2003, the capability to perform integrated real-time imagery collection, evaluation, and damage assessment was extremely limited, and for all practical purposes could not be performed with the tools and processes which existed at that time.

Debris strike STS-107
https://www.youtube.com/watch?v=czOs0sfBOi8

Foam Test
https://www.youtube.com/watch?v=ySiyzJEi01M
History

Better imagery
Capability to do on-orbit inspection
Capability to do on-orbit repair
Utilize all assets available
Recognize that limited flight experience makes each mission unique
History

Understand why are you inspecting on-orbit – are actions or additional risk acceptance required if inspection is not performed

Expedition 50 crew on ISS
Lessons Learned

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Need clear accountability for end to end technical assessment - hierarchy

Need to have clear timeline as all vehicles are time constrained — ensure sufficient time for evaluation and risk mitigation or repair

What is the mitigation if inspection indicates a problem — is there enough time to act

Need to have common access to data and information exchange, common inputs to various models, and clear process for data flow and decisions

If time constrained ensure enough time for data review with management and sleep — multiple shifts may be required

Prioritize your inspection areas and assessments before the mission — know what are you looking for and how to optimize time and resources

Success criteria — develop a guideline to determine when the data and analysis good enough

Expect to deal with unknowns — integrate with vehicle and systems teams on underlying effects

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MER Tiger Team structure

Damage Assessment Team structure
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<table>
<thead>
<tr>
<th>Process Inputs</th>
<th>PE Cert #</th>
<th>Tile Inspection (e.g., Y) Criteria</th>
<th>Standard Real Time Assessment</th>
<th>Mild Operational Constraints</th>
<th>Moderate Operational Constraints</th>
<th>Risk Trade: Negative MS</th>
<th>Risk Trade: Significant Weight Restriction</th>
<th>Risk Trade: TILE Repair</th>
<th>Risk Trade: Significant Ops Restraint vs. CSCS</th>
<th>Risk Trade: Aggressive Realization of MS vs. CSCS</th>
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<tr>
<td>Mechanical Conditions TAEM Ns / Touchdown Risk Rate</td>
<td>2.5g / 9.6g ps (1)</td>
<td>2.6g / 9.6g ps (2)</td>
<td>2.5g / 9.6g ps (3)</td>
<td>2.0g / 7.8g ps (5)</td>
<td>1.7g / 5.8g ps (5)</td>
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<tr>
<td>Thermal Environments / Weight</td>
<td>Cet Trajectories</td>
<td>Max EOM Entry</td>
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<td>MOD Mission Specific</td>
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<td>MOD Mission Specific w/ MPLM</td>
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</tr>
<tr>
<td>Tile Damage Conditions</td>
<td>N/A</td>
<td>Simplified Cavity with measured dimensions</td>
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Failure Conditions

| Structural | Max Temperature | 350F | 350F | 350F | 350F | 350F (4) | 350F (4) | 350F (4) | 350F (4) | 350F (4) |
| Margin of Safety (F. S. 1.4) | MS ≥ 0 | MS ≥ 0 | MS ≥ 0 | MS ≥ 0 | MS ≥ 0 | MS < 0 | MS < 0 | MS < 0 | MS < 0 | MS < 0 |
| Tile Failure Propagation | RTV temperature / Tile integrity margin of safety (F. S. 1.4) | 625F | MS ≥ 0 | MS ≥ 0 (6) | MS ≥ 0 (6) | MS ≥ 0 (6) | MS < 0 (6) | MS < 0 (6) | N/A | MS < 0 (6) | MS < 0 (6) |
| Flight History Comparison | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes | yes |

(1) Mechanical loads are 2.5g at TAEM and 9.6g ps landing for vehicle weights less than 21K
(2) Discussing Flight Rules change to limit TAEM Ns to 2.8g max (would become a baseline rather than an ops restriction)
(3) Selecting values to obtain equivalent benefits from TAEM Ns/Touchdown Risk Rate - need to verify that TAEM envelope entry for 1.5 g - final values are TBD
(4) Evaluating ability to increase max structural temperature - requires evaluation of underlying subsystems and impact of MS calculations - TBD
(5) Considering some reduction in the MS for Mach < 5 (1.0)
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QUESTIONS?
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THANK YOU!
References

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A Renewed Commitment to Excellence – An Assessment of the NASA Agency-Wide Applicability of the Columbia Accident Investigation Board Report, January 30, 2004

NSTS 60540, STS-114 Operations Integration Plan for Thermal Protection System Assessment, April 12, 2005

Final Report of the Return to Flight Task Group, July 2005

Benjamin Pawlik was the NASA Mission Evaluation Room Manager for the Space Shuttle Return-to-Flight missions following the Columbia accident, and led the development of the post-Columbia real-time Damage Assessment Team process.

Benjamin is currently a Mission Manager within the NASA Commercial Crew Program Office.

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