In-Situ Repair of TPS

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Overview

• Orbiter Repair Background
• CIPAA
• T-RAD
• MMOD damage and repair concept
• Summary
Orbiter TPS Damage

- Damage to Orbiter tiles from ET cork and foam as well as ice an ongoing concern during life of program
- Numerous examples of small dings and gouges to Orbiter tiles through multiple missions
- STS-27 – extensive damage to the right side of the orbiter due to cork loss from SRB, tile over antenna sheared off
- STS-107 – loss of Columbia due to foam insulation impact of leading edge
- Columbia accident led to effort to revive an on-orbit tile repair procedure
Damage Photos

STS-27R

STS-41D
CIPAA

- Cure In-Place Ablator Applicator (CIPAA)
  - Held 300 in³ of CIPA, two chambers
  - Part A – RTV 511, Fe₂O₃, glass microballoons, glass fibers
  - Part B – Catalyst, glass microballoons
  - Static mixer at end of hose mixed Parts A and B
- Issues with hardware
  - Heavy
  - Bulky
  - Redundancy requirements led to two CIPAA’s
- Issues with ablator
  - Out-gassing caused bubbles in repair
  - “Dusty” tiles required primer
  - Verification of cure required second EVA
    - Witness specimen brought back to cabin
    - Witness specimen not fully cured in relevant environment
- CIPAA cancelled December 2006
T-RAD

- Tile Repair Ablator Dispenser (T-RAD)
  - Smaller – dispense volume of 70 in$^3$, about the size of handheld vacuum cleaner, could be stowed in mid-deck lockers
  - Parts A and B contained in bags, T-RAD punctured bags for mixing in static mixer, contained materials, allowed for inspection of material
  - Sold as repair for door seals
STS-118

- Damage to NLGD adjacent to seal
- Thermal analysis showed environment low enough to enter without repair
- Led to Arc Jet test

On-orbit

Runway Photo
NLGD Test

• Objective
  • Demonstrate STA-54 would seal flow path in test article, protecting underlying structure
  • Demonstrated swell of STA-54 would not detrimentally affect the surrounding TPS

• Test Article
  • Three tiles
  • Structure had interface similar to door with thermal barriers and seal
  • Hole drilled in tile down to structure
  • Two holes drilled in structure to give flow path should plasma breach repair
  • Vacuum applied to back-side of article to ensure $\Delta P$
NLGD Test

Thermal Barriers
Sponge Seal
Pressure Seal
Approximate Damage Area
NLGD Test

No-swell above OML

Cross-section
NLGD Test

Note: STA-54 extruded into gap
MMOD

• Damage from MMOD is expected to be a teardrop shape, or at least have an undercut to the OML of the TPS – damage at OML smaller than underlying damage
• Undercut will mechanically lock any repair in-place
• May not need cured material to affect repair
• STA-54-like material could be made with viscosity high enough to ensure repair will remain in-place without curing, but low enough to ensure flow into all cavities
  • Makes hardware simpler – no Part B chamber
  • No bubbling from catalyst
  • No witness specimens
  • No second EVA
• Caveat – this repair concept will not be applicable to structural damage below TPS
Summary

- STS experienced many damages of significant size and volume.
- Repair strategies used a cure in-place ablator based on silicone.
- Hardware complicated and large due to volume of potential damage sites.
- Repairs for in-space damage expected to be much smaller in size and less frequent.
- Repair hardware could be much simplified from orbiter repair hardware if it can be shown that a mechanical lock is adequate to ensure repair will stay in-place during entry.
Damage Photos

STS-26R

STS-27R

STS-62

STS-65