

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



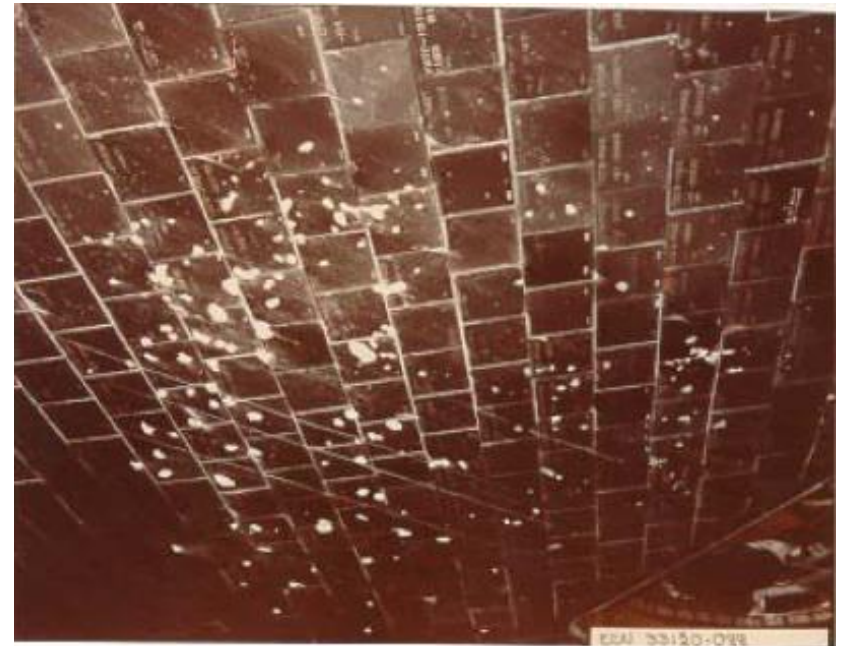
STS-27R



STS-41D



STS-41G



STS-51F

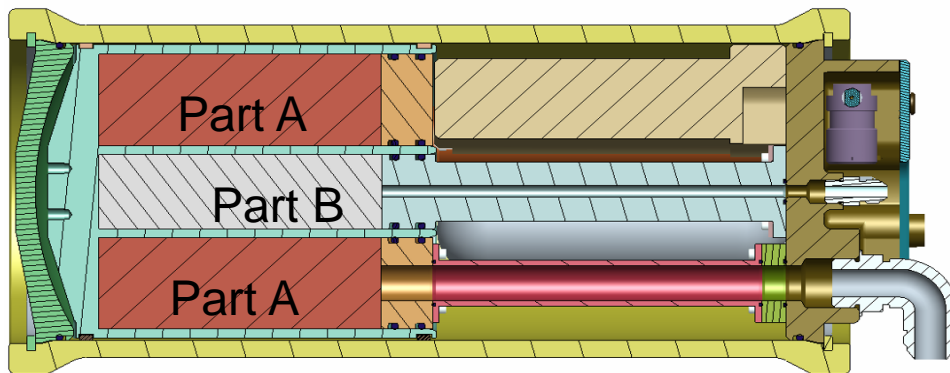


CIPAA

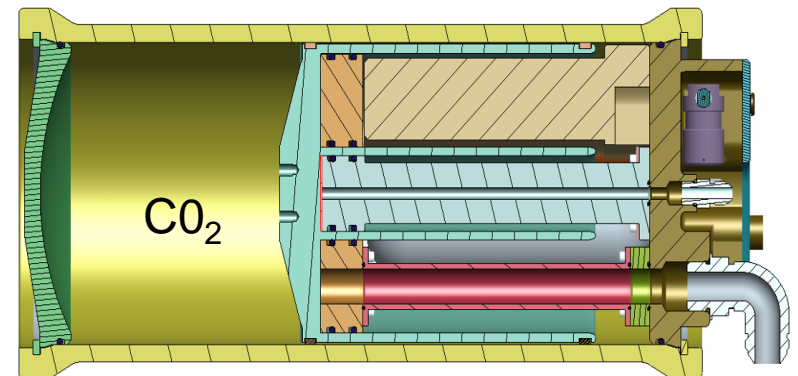


- Cure In-Place Ablator Applicator (CIPAA)
 - Held 300 in³ of CIPA, two chambers
 - Part A – RTV 511, Fe₂O₃, glass microballoons, glass fibers
 - Part B – Catalyst, glass microballoons
 - Static mixer at end of hose mixed Parts A and B
- Issues with hardware
 - Heavy
 - Bulky
 - Redundancy requirements 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

- Tile Repair Ablator Dispenser (T-RAD)
 - Smaller – dispense volume of 70 in³, 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



Pre-dispense



During Dispense

- 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



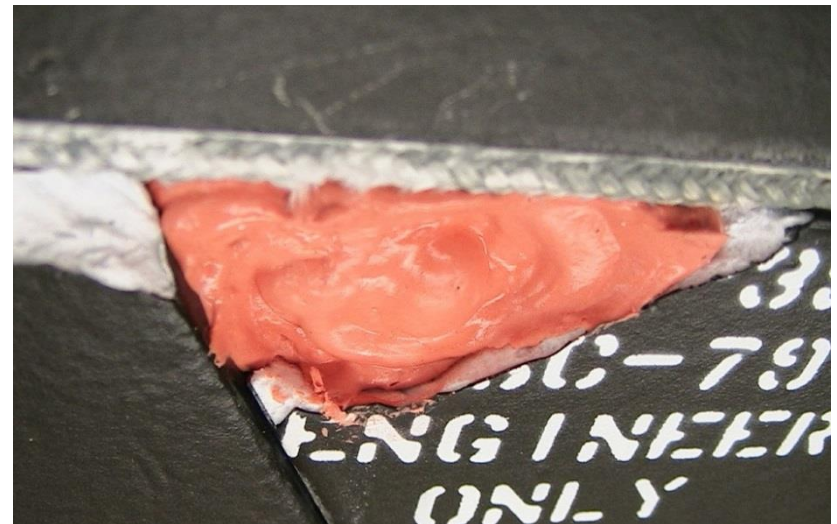
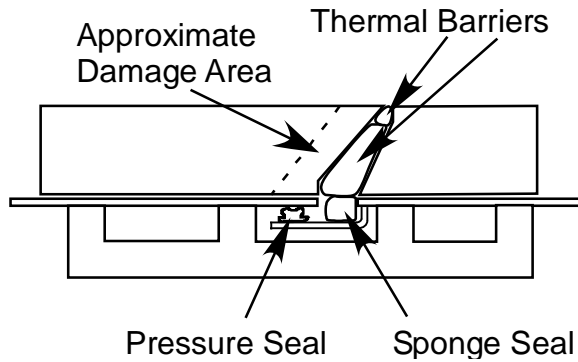
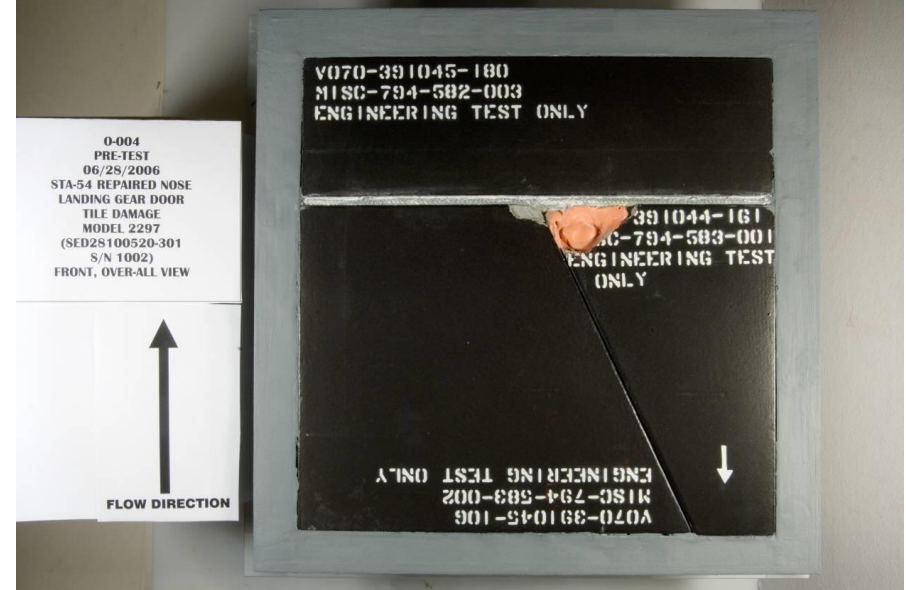
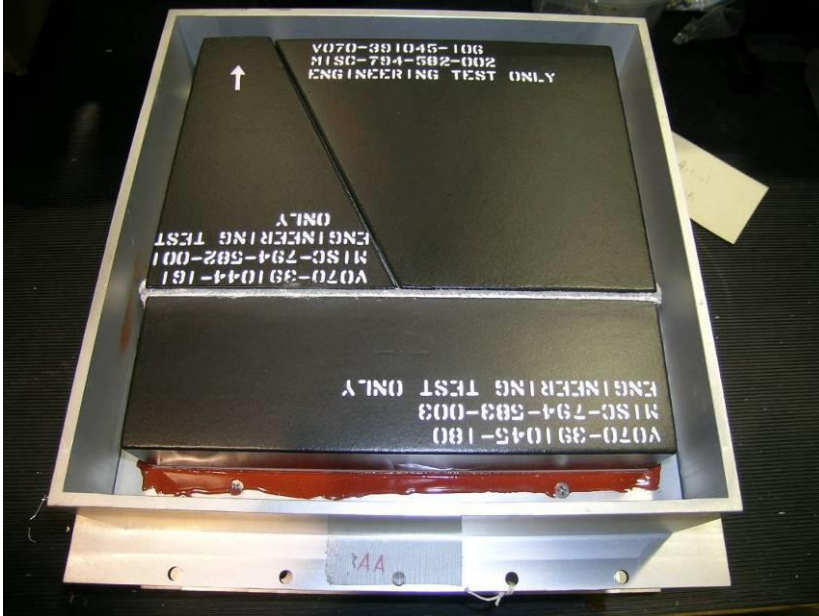
NLGD Test

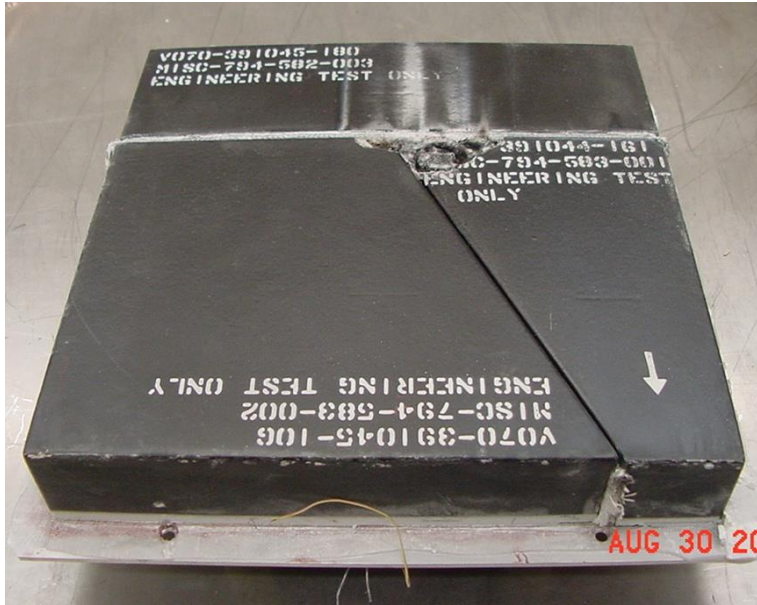


- Objective
 - Demonstrate STA-54 would seal flow path in test article, protecting underlying structure
 - Demonstrated swell of STA-54 would not detrimentally affect the surrounding TPS
- Test Article
 - Three tiles
 - Structure had interface similar to door with thermal barriers and seal
 - Hole drilled 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 ΔP



NLGD Test

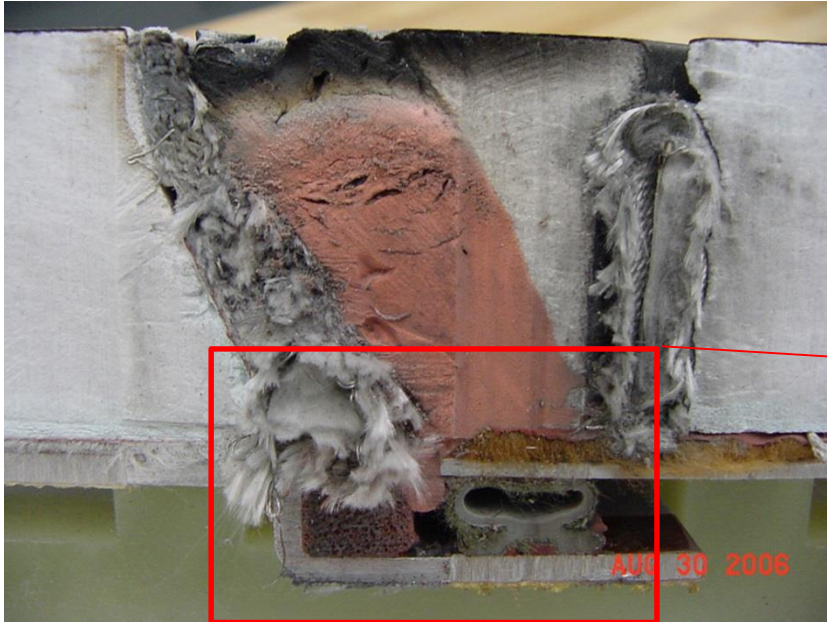




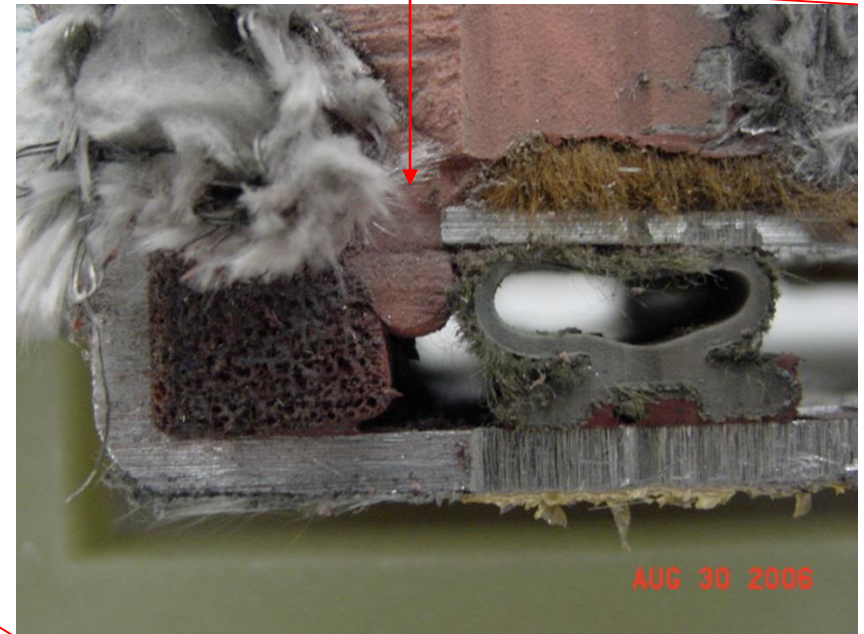
No-swell
above OML



Cross-section



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

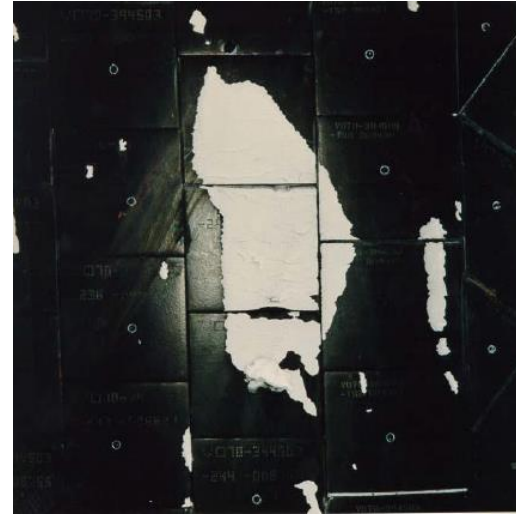


Back-up

Damage Photos



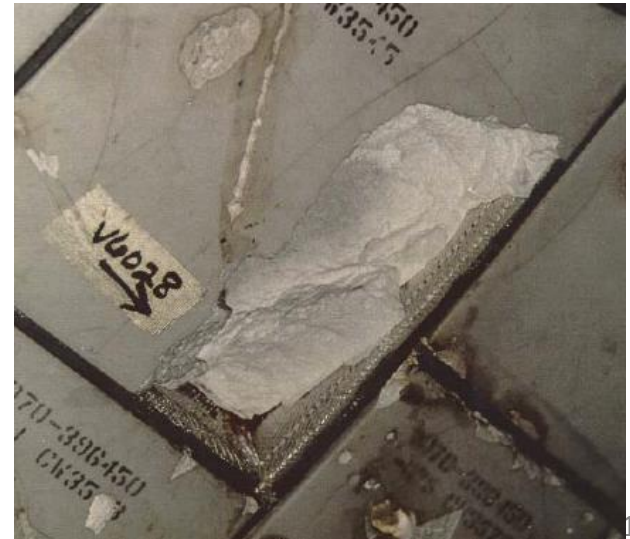
STS-26R



STS-27R



STS-62



STS-65