Return to Flight Project Management Perspectives from the Tile Repair Project

March 31, 2004

Tim Brady
Timothy.k.brady@nasa.gov
282-483-9118

Return to Flight Background

- **Philosophy of the Return-to-Flight (RTF) has been to put in several layers of protection to prevent the reoccurrence of an accident**
  - *Eliminate/minimize sources of debris shedding*
  - *Understand tolerance of TPS systems to debris impact*
  - *Improve ground inspection capabilities*
  - *Develop on-orbit inspection capability*
  - *Develop on-orbit repair capability*
  - *Provide Contingency Shuttle Crew Support*

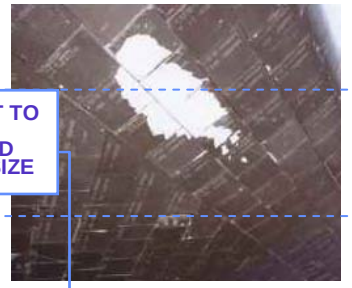
If Damage Occurs…

- **We have to detect it**
- **We have to know if it is catastrophic or not**
- **We have to get access to the damage site to effect repair**
- **We have to apply a material with an EVA crewmember**
- **The material must be capable of withstanding the heat of reentry, and**
- **We have to have confidence, through sound engineering rationale, that the damaged or repaired vehicle can return with the crew safely**

Project Overview

- **The tile repair project objectives for return to flight are to:**
  - *Develop and qualify material for use in on-orbit repair*
  - *Develop and certify EVA tools to deliver material to repair worksite*
  - *Develop analytical tools to provide real-time engineering support*
- **Ultimately repair capability is the ability to:**
  - *Provide technical rationale to support a use-as-is disposition (no repair required) for damaged tile*
  - *Provide physical on-orbit repair as required (EVA tools and techniques)*
  - *Provide technical rationale to support disposition of the repair, if required, for re-entry*

Simplified On-Orbit Tile Repair Process



INSPECTION TEAM

PERFORM INSPECTION

REINSPECT TO OBTAIN DETAILED DAMAGE SIZE

ESTABLISH MISSION SPECIFIC AEROHEATING LOADS

ANALYSIS TEAM

INITIATE DAMAGE ASSESSMENT

FULLY CHARACTERIZE DAMAGE SITE

ANALYZE DAMAGE SITE FORM, FIT FUNCTION FOR SAFE RETURN USE-AS-IS

IS DAMAGE SITE VALID FOR SAFE RETURN ?

ANALYZE PLANNED REPAIR FORM, FIT FUNCTION FOR SAFE RETURN

IS DAMAGE REPAIRABLE?

NO

YES

IS REPAIR SITE VALID FOR SAFE RETURN ?

NO

YES

OPERATIONS

PERFORM EVA REPAIR

REPAIR CLOSEOUT INSPECTION (TBD)

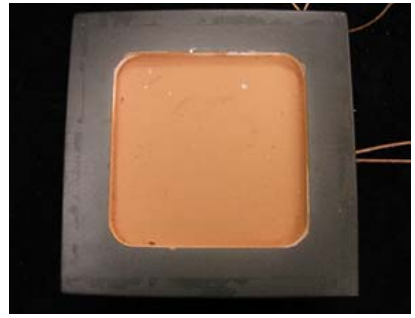
REPORT SAFE RETURN DISPOSITION TO MMT

MMT

REPORT TO MMT: DAMAGE/REPAIR OUTSIDE OF EXISTING CAPABILITY TO DISPOSITION FOR SAFE RETURN

Repair Material

- **Material Selection**
  - *Based historically on MA-25S material tested in 17979-1980 timeframe*
    - » *Development test focus: control swell, cured state fully porous, meet thermal performance*
  - *RTV-based Cure-in-place ablator formed from two-part mixture (12 part resin: 1 part catalyst)*
- **Material Requirements**
  - *Fill an irregular volume*
  - *Cure in a vacuum*
  - *One hour working life*
  - *Interface strength capable of withstanding reentry loads*
  - *Survive thermal reentry environment*
  - *Material swell within ±0.25 inch of the outer mold line (OML) contour*
  - *Provide thermal protection to aluminum substructure*

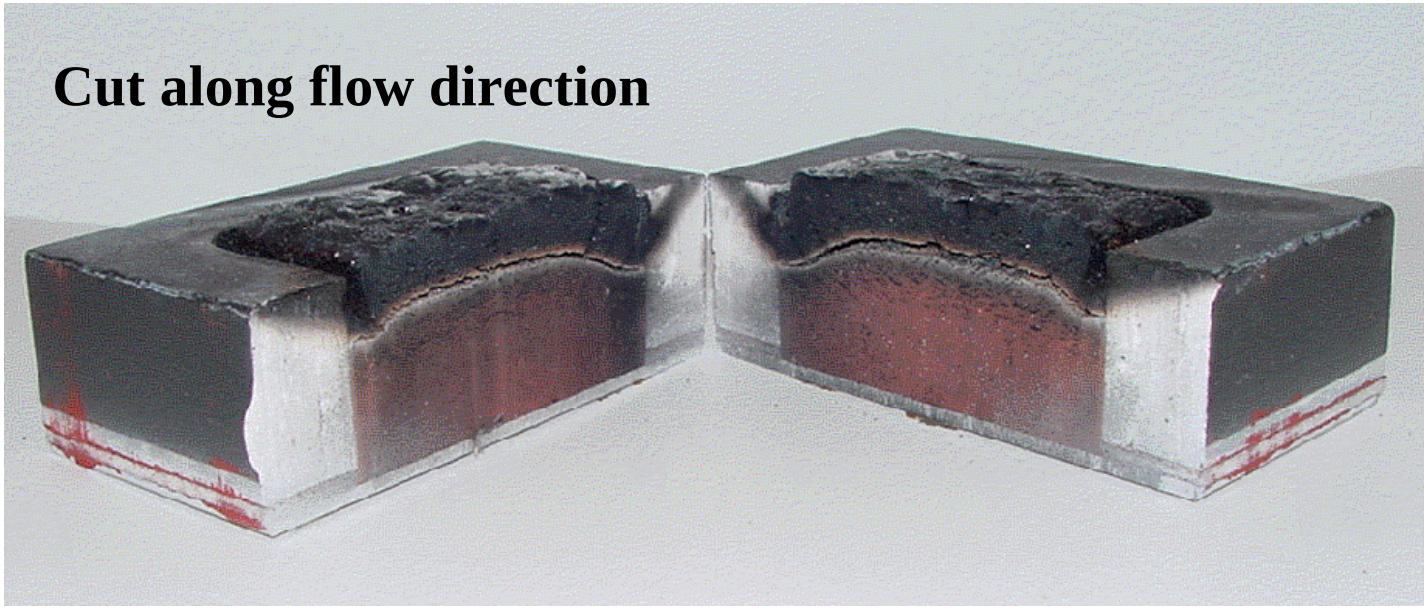


Cured Material in Tile

Post-Arc Jet Test

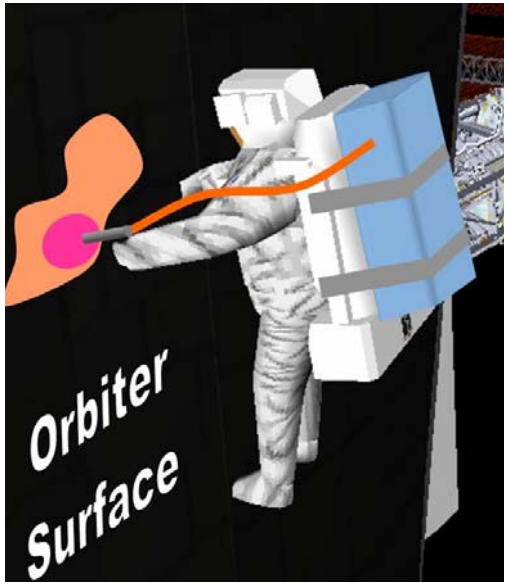
Arc Jet Testing

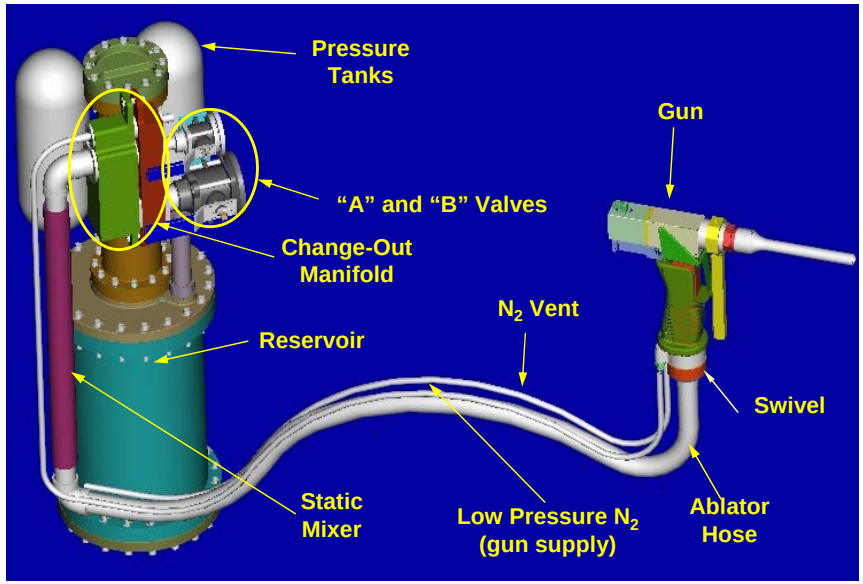
- Arc jet test simulates re-entry plasma environment
- Char layer forms on top surface
- Char layer swell protrusion inter the outer mold line contour must be minimized



EVA Tools

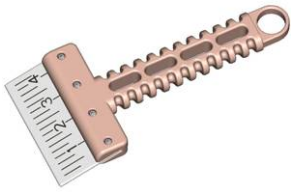
- **CIPA applicator to contain, mix, and extrude viscous, 2-part material**
  - *Vacuum-sealed material contained in two separated reservoirs*
  - *Pneumatic drive system employed to propagate materials through a static mixer and extrude the mix through a hose and gun/nozzle*
  - *EVA-removable/changeable mixer, hose, gun assembly*
  - *IVA and EVA heating and MLI provisions to maintain material temperature*
  - *Middeck volume packaging for launch/landing stowage*
- **Backpack to interface with the PLSS for on-orbit translation use**



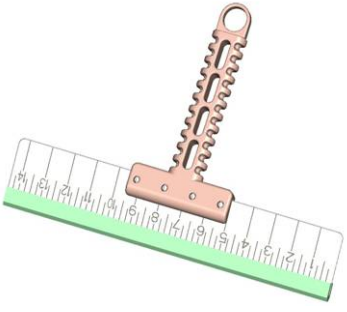


Tile Repair Support Tools

1.5” Trowel

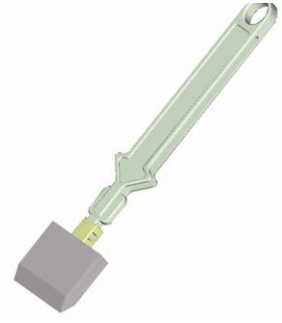


4.5” Trowel



14” Foam Trowel

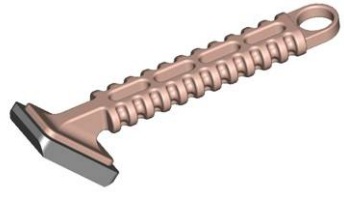
- **Measurement/inspection tool for gauging pre- and post-repair depth and area dimensions**
- **Hardness measurement instrumentation**
- **Silicon brushes for tile-cavity cleaning prior to material injection**
- **Foam brushes to lightly smooth and remove voids in cavity**
- **Scrapers for removing excess material**
- **Flat and angled foam stamps for flattening, smoothing material**
- **Trash bags and EVA wipes for material clean-up and containment**



Foam Brushes

With Removable Brush Handle

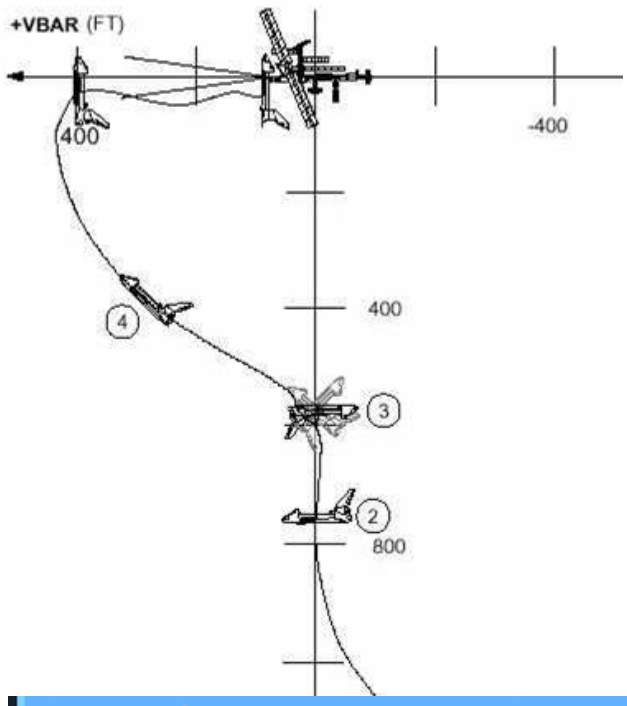
Flat Stamp

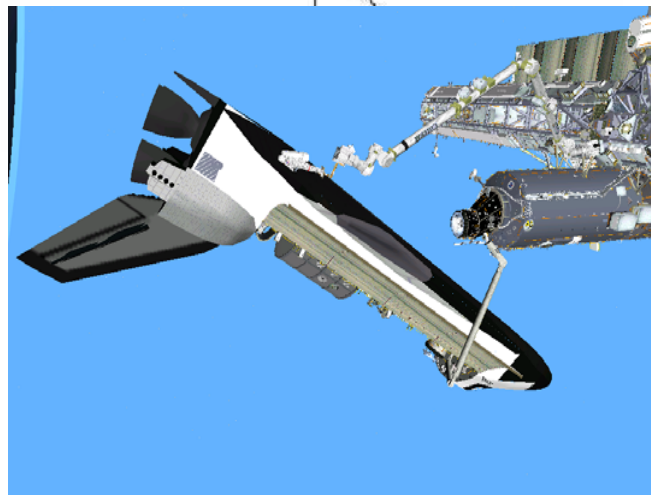


Angled Stamp

Inspection and Pre-Repair Operations

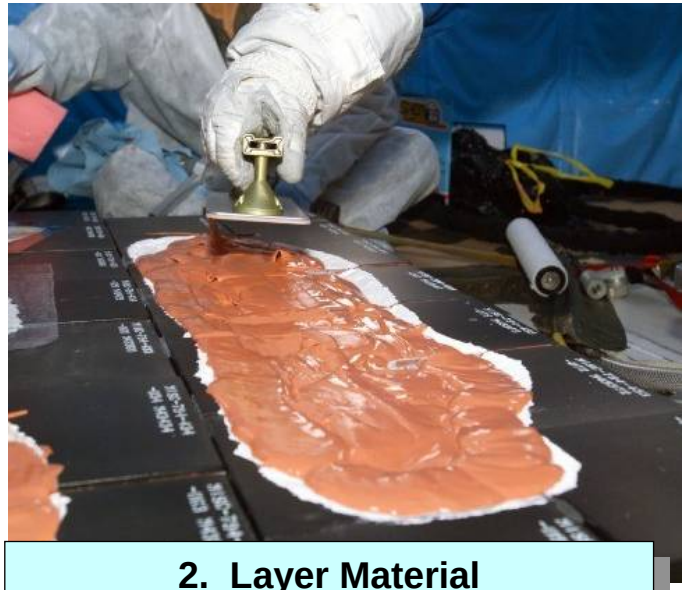
- **Inspection**
  - *Tile is inspected from ISS (using cameras) with a pitch maneuver at 600 feet during approach*
  - *A boom and sensor system attached on the end of the SRMS will available to re-inspect damage areas to measure depth*
  - *Data from these inspections used to determine if a repair is necessary and if a repair will be effective*
- **Access to repair site**
  - *Grappled unberth from ISS using the Shuttle robot arm*
  - *Orbiter repositioned for crewmember to access worksite while using the ISS robot arm*
  - *Access available until JEM module launch*





Repair Procedure

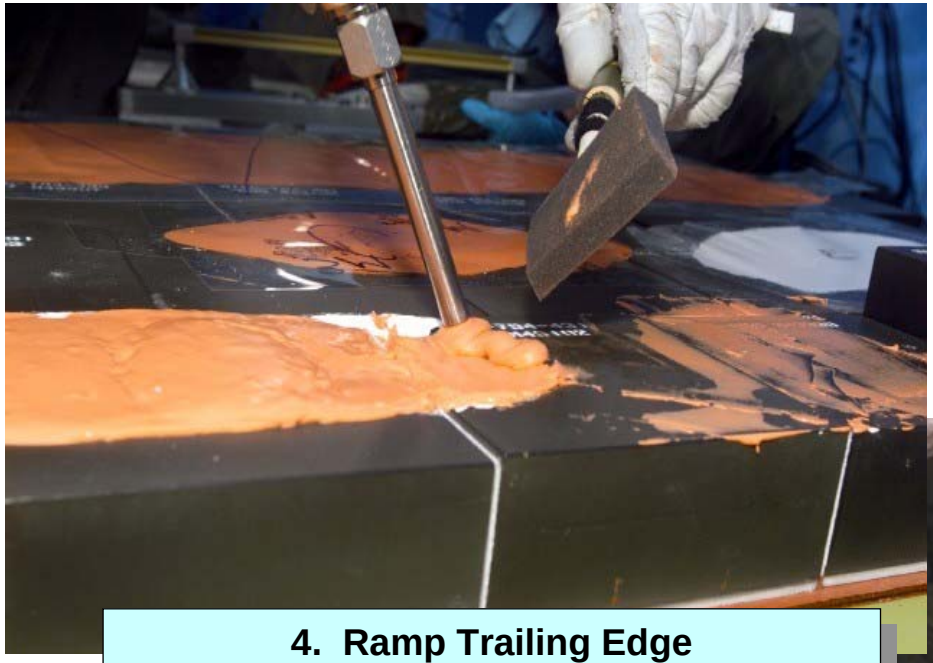
1. Trim Gap Filler as Required
   Clean Tile with Gel Brushes



2. Layer Material

3. Flatten / Smooth Repair

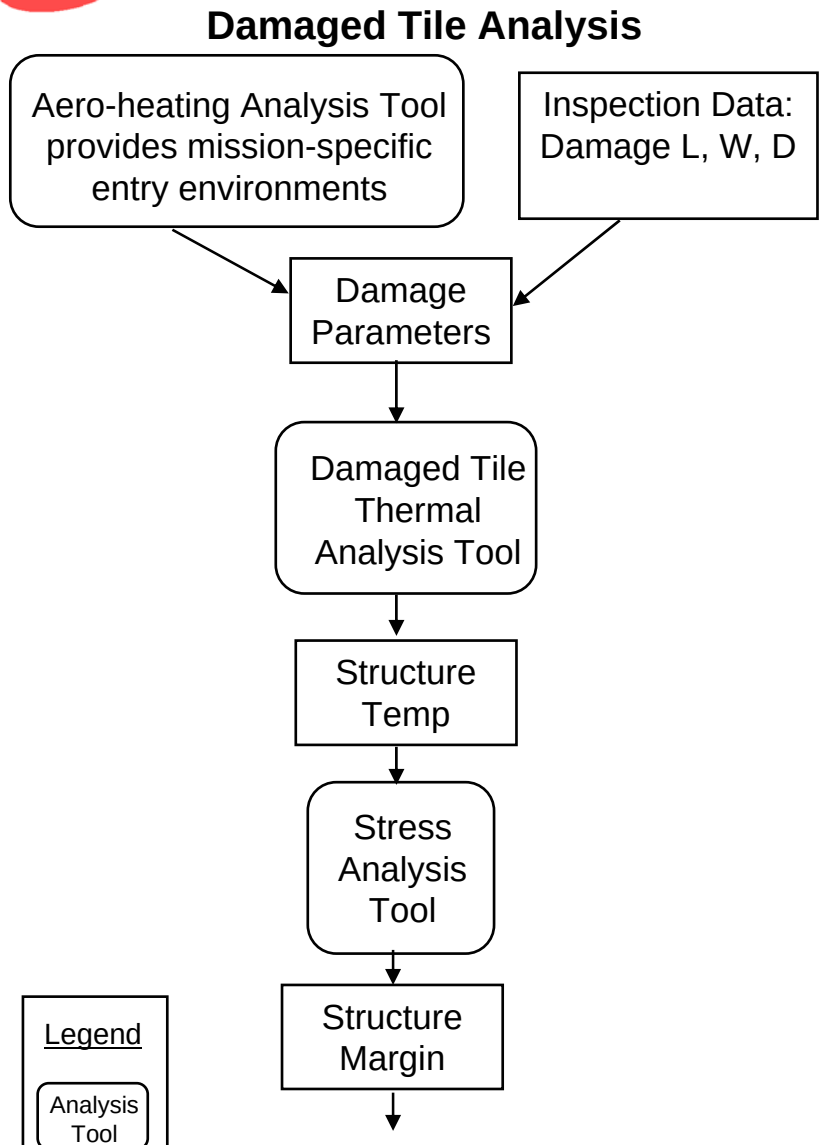
Repair Procedure (Cont)

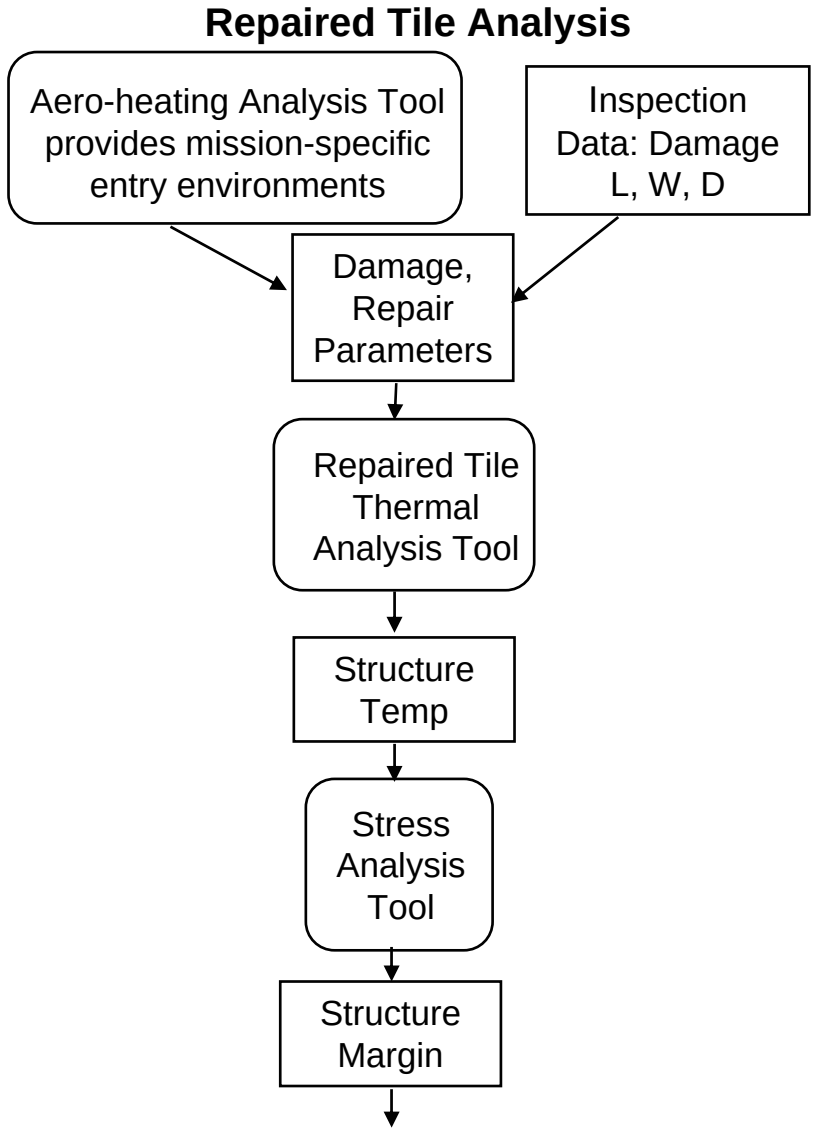


4. Ramp Trailing Edge

5. Verify Step

Role of Analytical Tools in Damage/Repair Disposition





Project History

- **Prior to formally establishing tile repair as a project a flight techniques panel was established**
  - *Panel led by flight director Paul Hill*
  - *Major operational issues addressed*
  - *Technical feasibility testing and analysis initiated*
  - *Approximately 15 meetings over 6 months*
- **Flight techniques panel activities laid a solid foundation for the RTF activities**
  - *Springboard for boom sensor, tile repair and RCC repair projects*
  - *Technical development activities initiated*
  - *Identified major project interdependencies and technical risk*

Project Hurdles Remaining

Project Mid-term Lessons Learned

Backup Material

Tile and RCC Repair Flight Experiment

Development Test Objective (DTO)

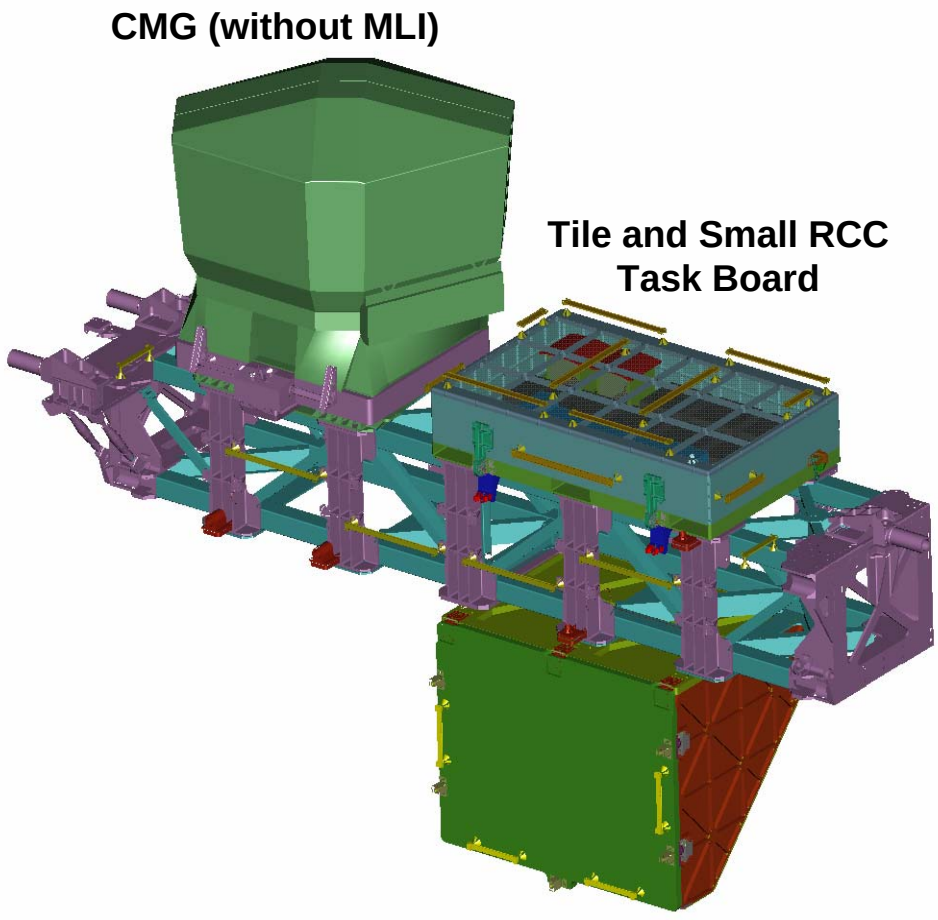
to be flown on STS-114 and STS-121

Tile and RCC Repair Flight Experiment

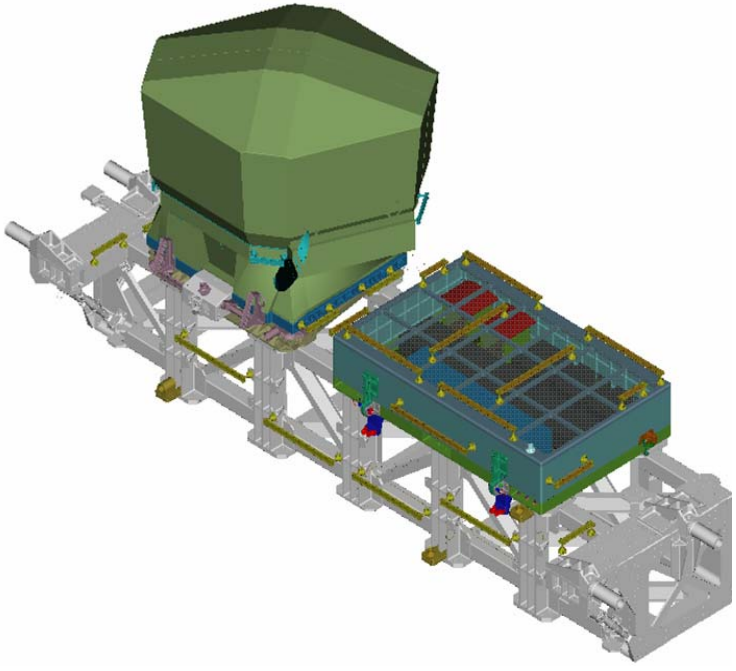
- **Tile and RCC repair demonstrations are planned for the STS-114 and STS-121**
- **Tile repair objectives include:**
  - *To demonstrate various repairs (shallow, deep) using planned EVA tools and techniques*
  - *To demonstrate performance of an on-orbit repair through post-flight inspection, pull-test and/or arc jet testing*
  - *Investigate microgravity material performance; e.g. voids, cure, working life, foaming etc*
  - *Demonstrate repair of a large tile cavity (on the order of 10”x30”)*
- **RCC objectives are dependent on final selection of repair concepts, however DTO hardware has been designed to provide capability to perform both small and large RCC repairs**
  - *Small repairs will be demonstrated with small sections of RCC*
  - *A full scale panel or simulated panel can demonstrate large scale repair techniques*

Basic DTO Configuration

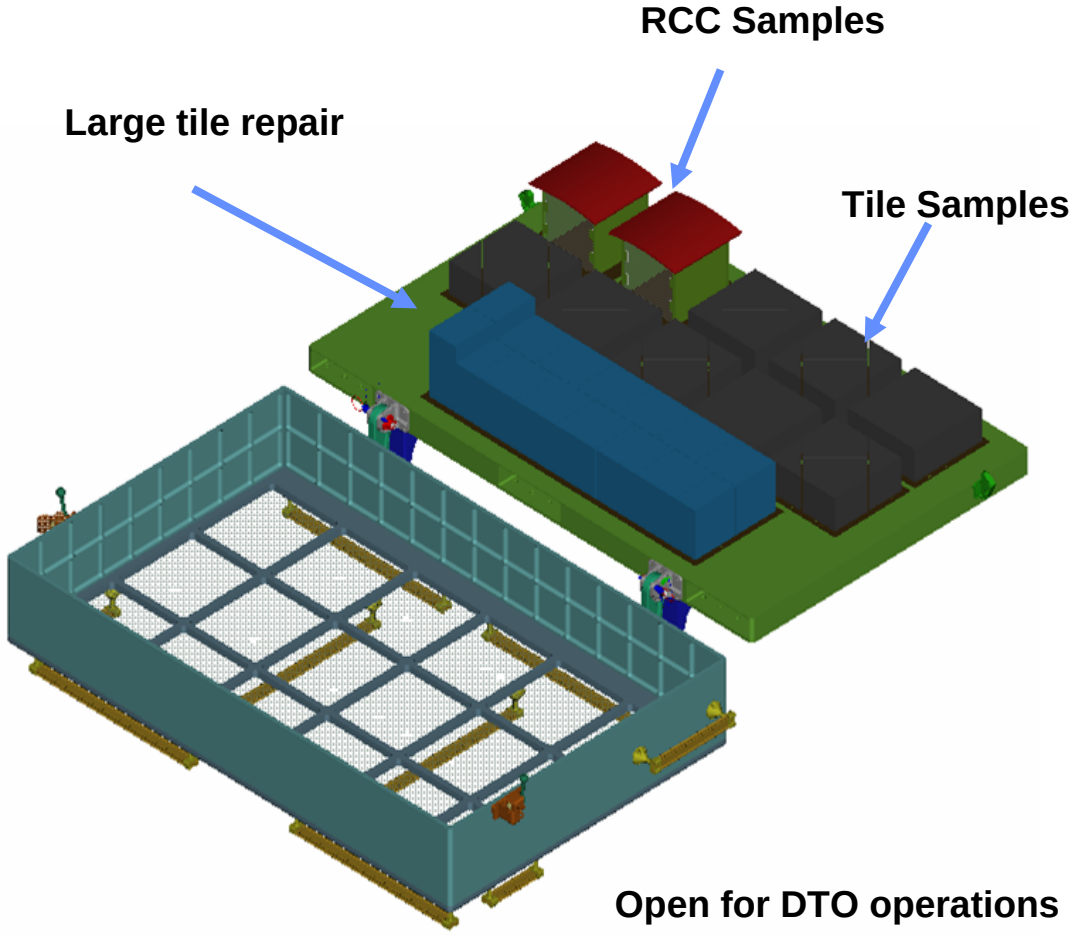
- **Top surface of the LMC:**
  - *Carrier for task board containing tile repair and small RCC repair test articles*
- **Lower surface of the LMC:**
  - *Large scale RCC repair: RCC panel, T-seals, carrier panel and attach structure mounted to the for launch and landing*
  - *Panel will be deployed for RCC repair operations*



DTO Concept Overview – Top Surface Task Board



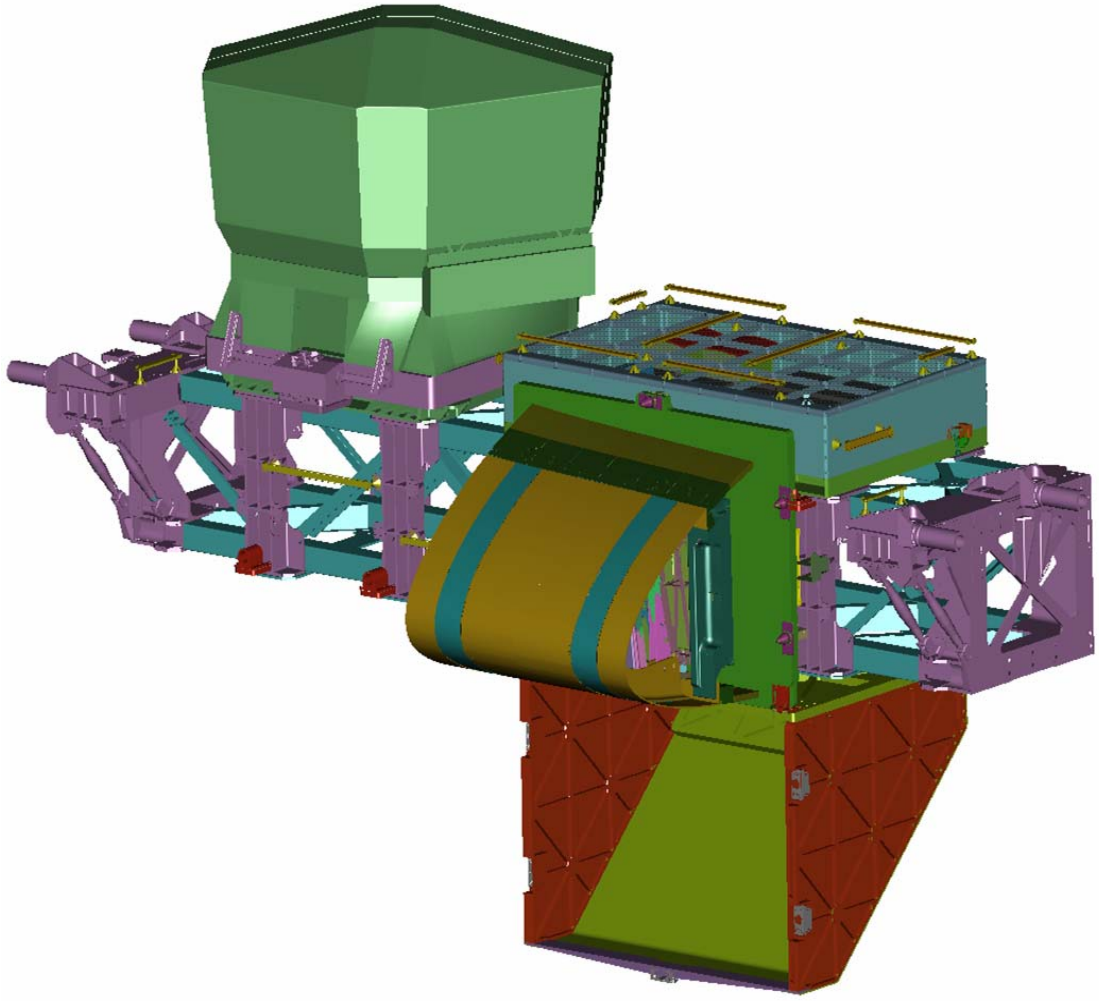
Launch and Landing Configuration



Open for DTO operations

–Custom Box mounted on top of the LMC next to the CMG
–Cover opens forward into the payload bay
–Design utilizes ETSD latches and modified ETSD to CETA hinges

DTO Concept Overview - Full-Scale RCC Panel



- RCC Panel with T-seals and 6” extensions all the way around
- Hard mounted under the LMC for launch and landing
- Panel is hinged up and in front of the LMC for repair task