The Space Shuttle Thermal Protection System

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Outline

- Requirements and design
- TPS performance and evaluation
- New requirements
- Maintenance techniques
- New technology
- Conclusions
**TPS requirements**

- Orbiter structure temperature < 350°F
- Reusable for 100 missions
- Maintain integrity
- Acceptable aerodynamic surface
- Minimal weight, maintenance, and refurbishment
Design summary: Ceramic Tiles

- High purity silicon
- HRSI – black
- LRSI – white
- Reaction cured glass (RCG) coating
- SIP
- Room Temperature Vulcanizer (RTV)
- Gap Fillers
**Design summary: RCC**

- Leading edge structure system (LESS) and nose cap
- All-carbon composite: rayon cloth graphitized & impregnated with resin polymer
- Regions of orbiter > 2300° F

- Operational temp. of -200 to 3000° F
- LESS consists of 22 RCC panels
- RCC parts form a hollow shell → internal radiation

**Space Shuttle Thermal Protection System**
**Performance Summary**

- Overall, measured surface temperatures lower than requirement, and lower than predicted
- Some areas of excessive tile-to-tile heating (gap filler fix)
- Excellent mechanical performance
  - Test phase: no tiles from underneath detached, small amount of damage to tiles, some LRSI tiles fell off
  - Recommend similar system (SIP, RTV) for future designs
Evaluation

- Positive aspects
  - Extremely good thermal performance
  - Reusable
  - Ease of maintenance

- Negative aspects
  - Low impact resistance
  - Loss of gap fillers (localized heating)
New Requirements

1. Maintain higher amount of structural integrity
2. Tile condition must be easily monitored during a mission
3. TPS must have on-orbit repair capabilities
4. Reduced maintenance to reduce costs
Meeting maintenance requirements

- **Challenges:**
  - Large number of components: > 30,000
  - Complex tile acceptance logic

**New Techniques**

- **On-orbit maintenance**
  - Backflip maneuver, Tile repair kit, RCC repair kit (GRABER), SAFER propulsion system, laser topography sensor
- **Rapid Re-Waterproofing**
- **Electronic tracking (maintenance) system**
**TUFI: Toughened Uni-Piece Fibrous Insulation**

- Ceramic tile concept developed by NASA Ames
- Coated with Alumina Enhanced Thermal Barrier (AETB)
- Same SIP, RTV used
- 1-2 order of magnitude more resistant to damage
- Maximum operational temp = 2500° F
Blanket Insulation: TABI and CRI

- Silica-based blanket type TPS
  - Upgrades to FRSI
  - Quilted blankets with integrated ceramic

- Improve strength and outer surface

- Tailorable Advanced Blanket Insulation (TABI) – NASA Ames
  - Ceramic fiber with Q-fiber felt insulation

- Conformal Reusable Insulation (CRI) - Boeing
  - Ceramic matrix composite
Metallic TPS

- Lightweight metallic structure enclosing a high-efficiency fibrous insulation
- ARMOR (Adaptable Robust Metallic Operable Reusable) TPS – NASA LaRC
- Inconel honeycomb structure enclosing Saffil insulation
- More damage tolerant, but lower operational temperatures
Several variation of Metallic TPS exist

- Honeycomb material
  - Inconel, Titanium, other alloys

- Insulation layer
  - Saffil, Internal Multiscreen Insulation (IMI)

- Operational temperature: 2000 - 2200° F
**Hot Structures**

- Metallic primary structure acts as a heat sink
- Integrated structure and TPS $\rightarrow$ large mass savings
- Progress highly dependant on materials research and fabrication processes
- Operational temperatures $\sim 1500^\circ F$

**Candidate systems**
- Gamma Titanium aluminide (TiAl)
- Metal matrix composites
- Nickel metal foam
Conclusions

- TUFI tile system replaces HRSI
- TABI systems used to upgrade FRSI
- No RCC replacement
- Metallic TPS have high future potential
- Improved maintenance techniques currently in practice
Interfaces 1: Interactions between shuttle subsystems

- Structures
- Aerodynamics
- Environmental control system
- Guidance, Navigation, & Control
- External Tank and Solid Rocket Boosters