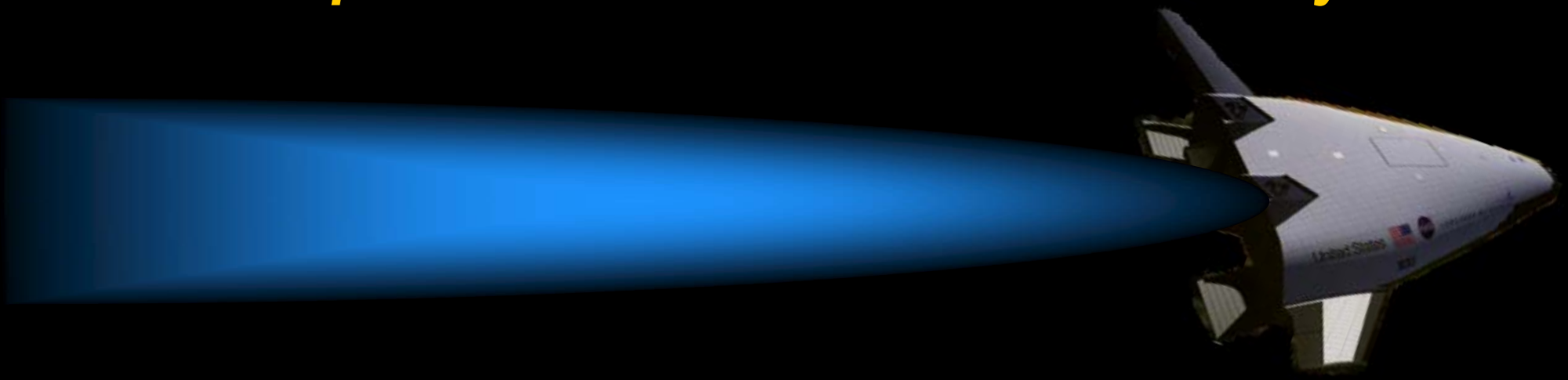
The Space Shuttle Thermal Protection System



Daniel Kwon

16.885J Final Presentation
December 6, 2005

Outline

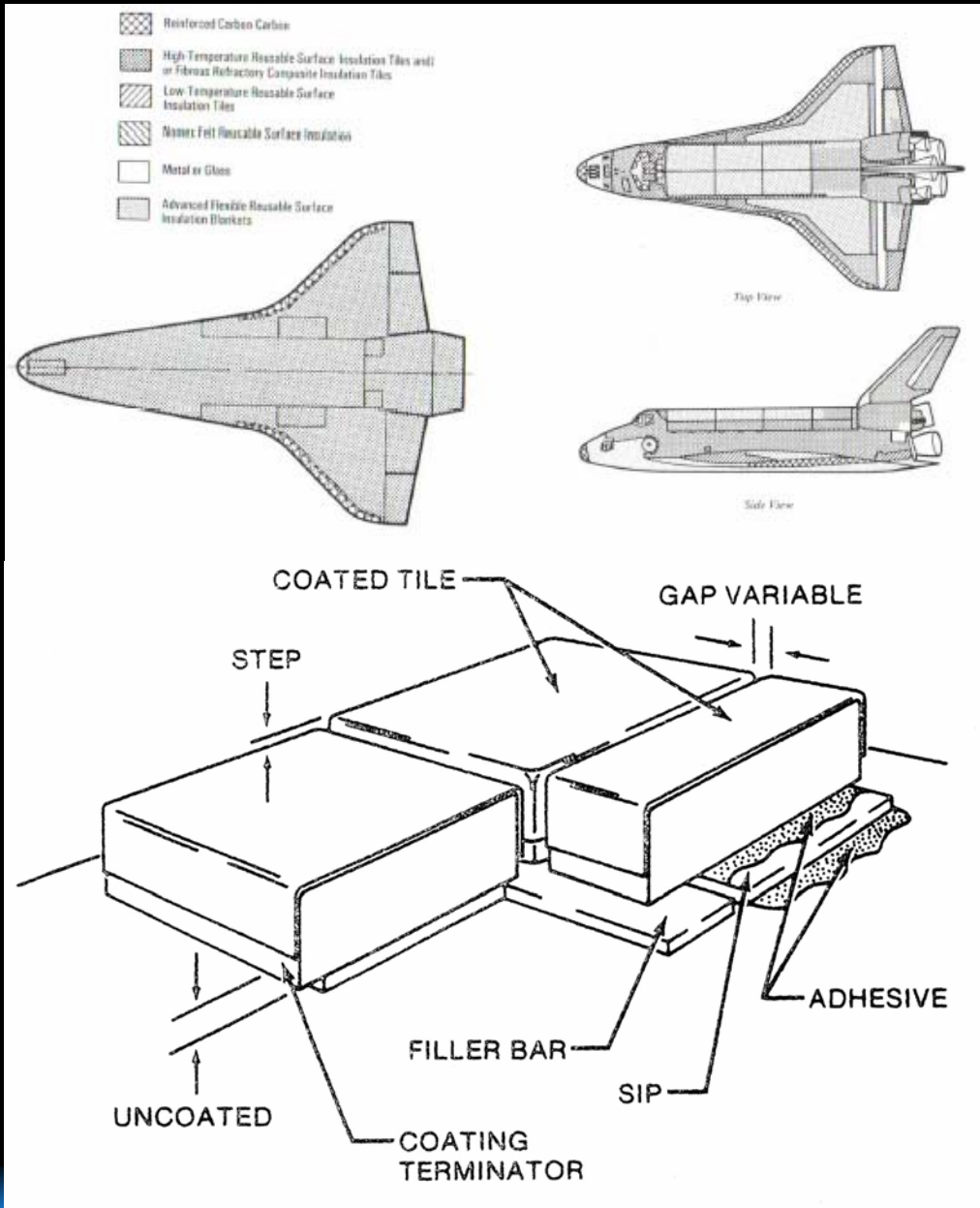
- Requirements and design
- TPS performance and evaluation
- New requirements
- Maintenance techniques
- New technology
- Conclusions

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

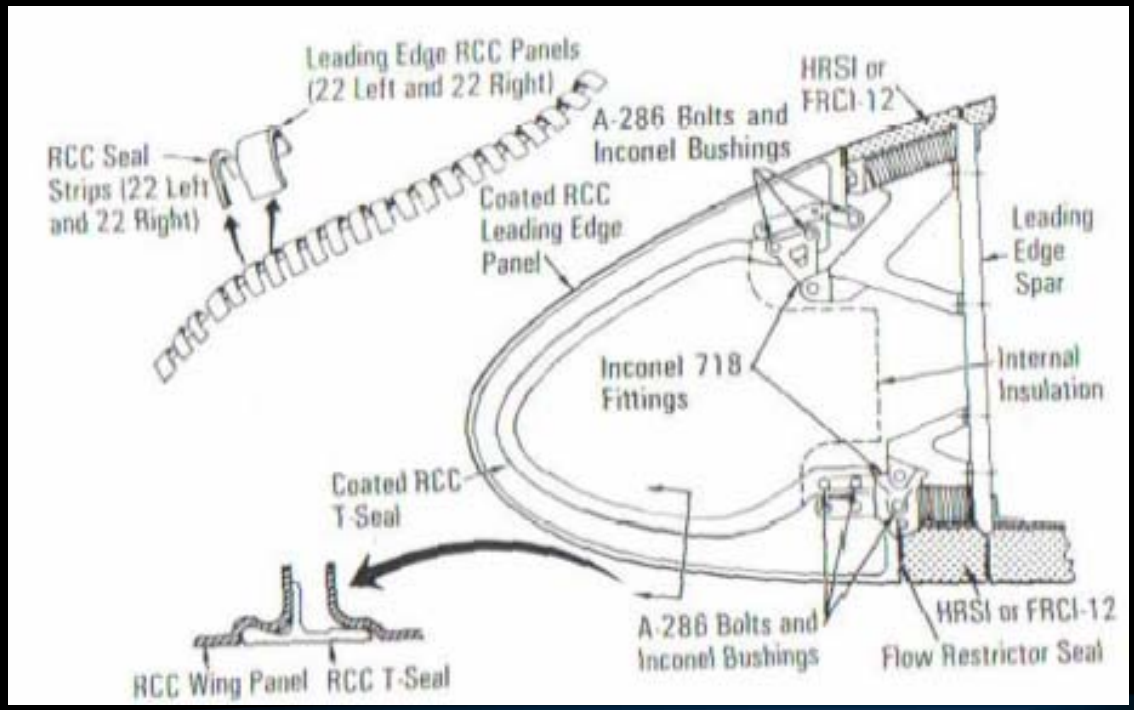
- High purity silicon
- HRSI – black
- LRSI – white
- Reaction cured glass (RCG) coating
- SIP
- Room Temperature Vulcanizer (RTV)
- Gap Fillers



Design summary: RCC

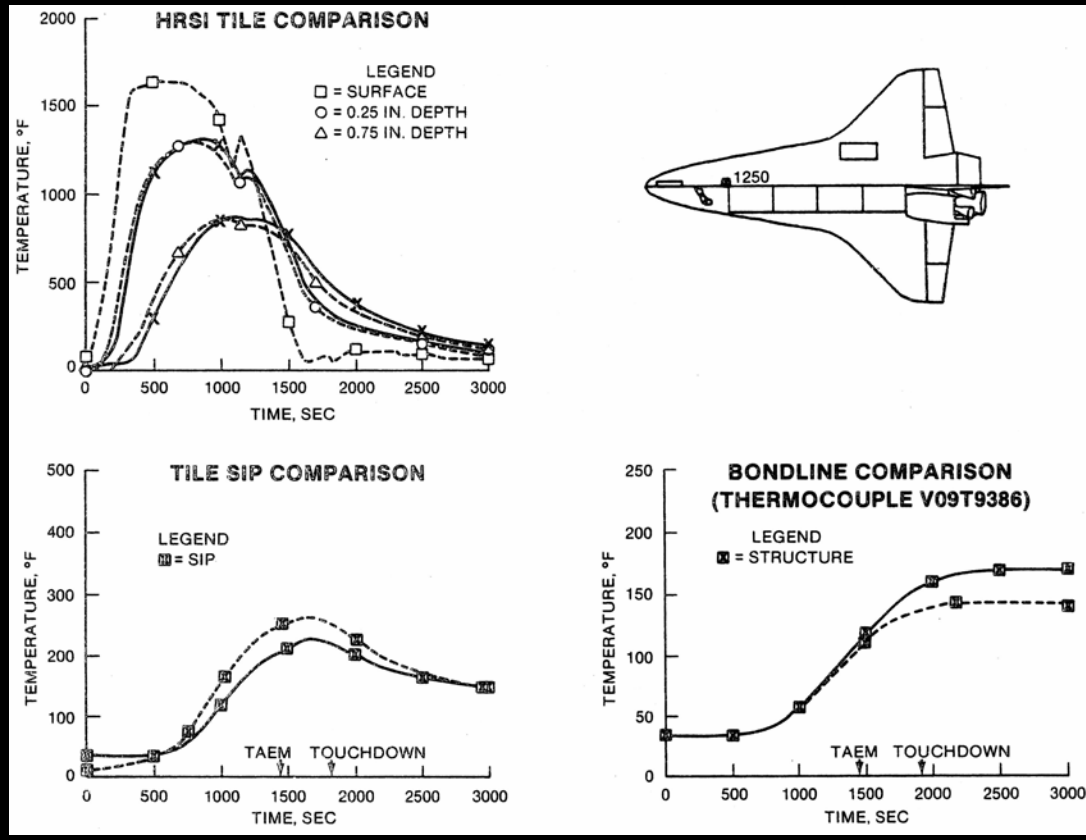
- Leading edge structure system (LESS) and nose cap
- All-carbon composite: rayon cloth graphitized & impregnated with resin polymer
- Regions of orbiter > 2300° F

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



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

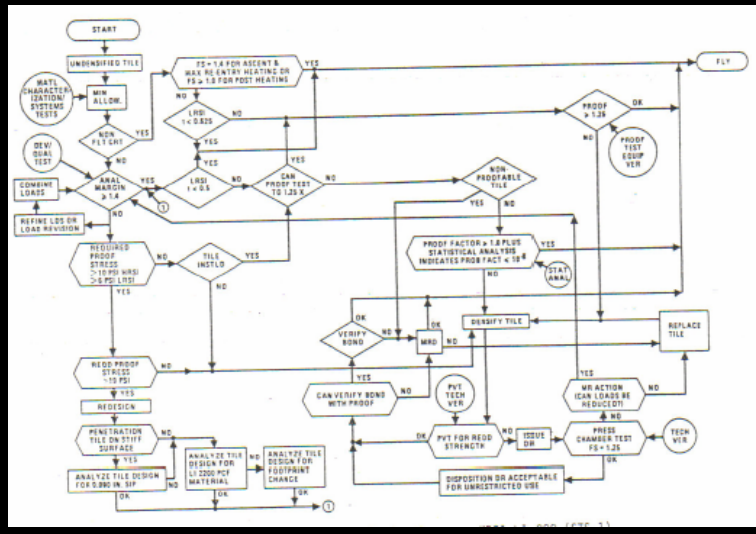
1. Maintain higher amount of structural integrity
2. Tile condition must be easily monitored during a mission
3. TPS must have on-orbit repair capabilities
4. Reduced maintenance to reduce costs

Meeting maintenance requirements

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

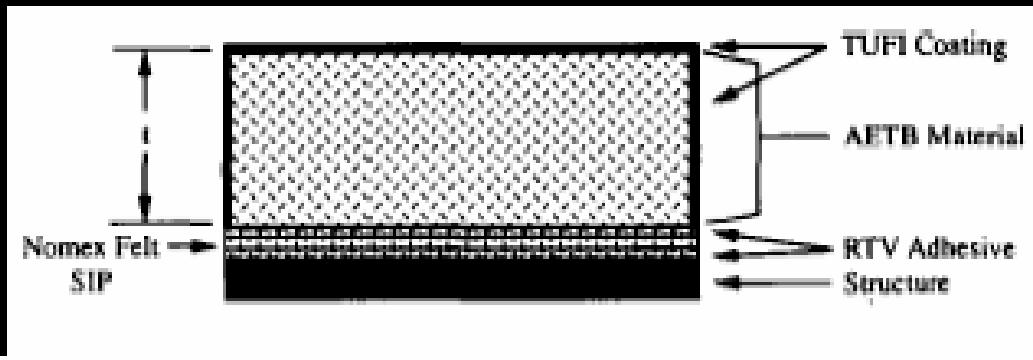
New Techniques

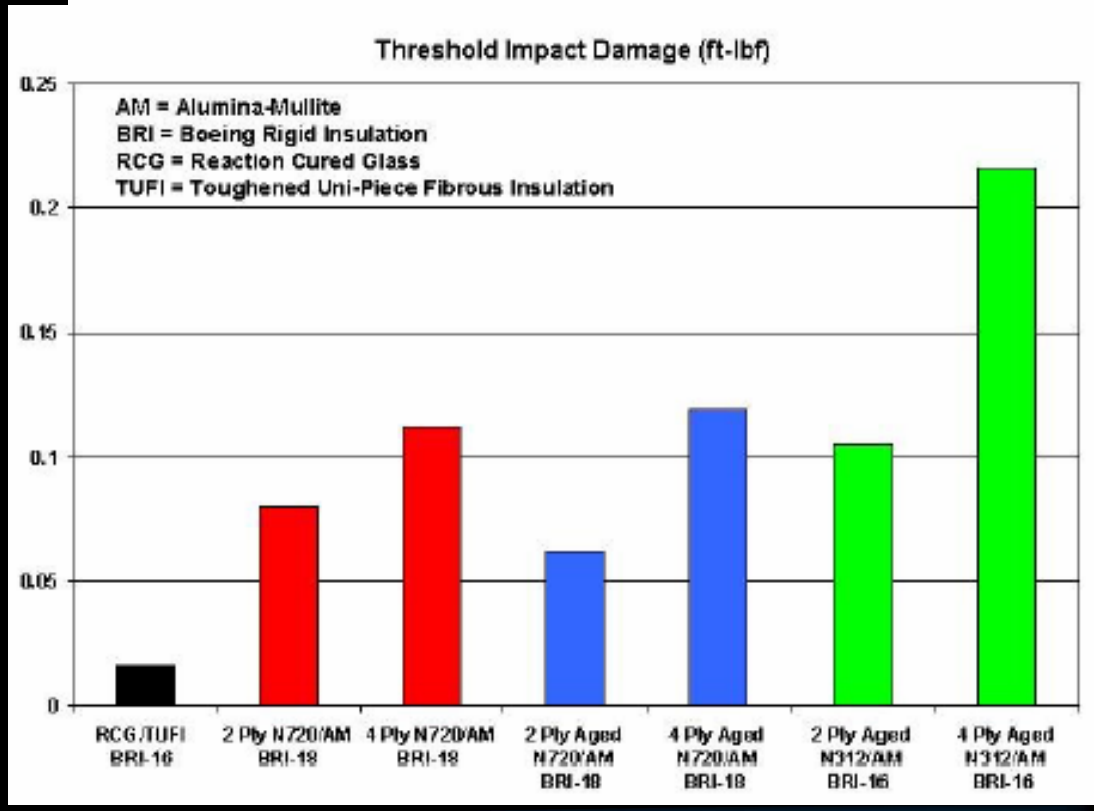
- On-orbit maintenance
  - Backflip maneuver, Tile repair kit, RCC repair kit (GRABER), SAFER propulsion system, laser topography sensor
- Rapid Re-Waterproofing
- Electronic tracking (maintenance) system



TUFI: Toughened Uni-Piece Fibrous Insulation

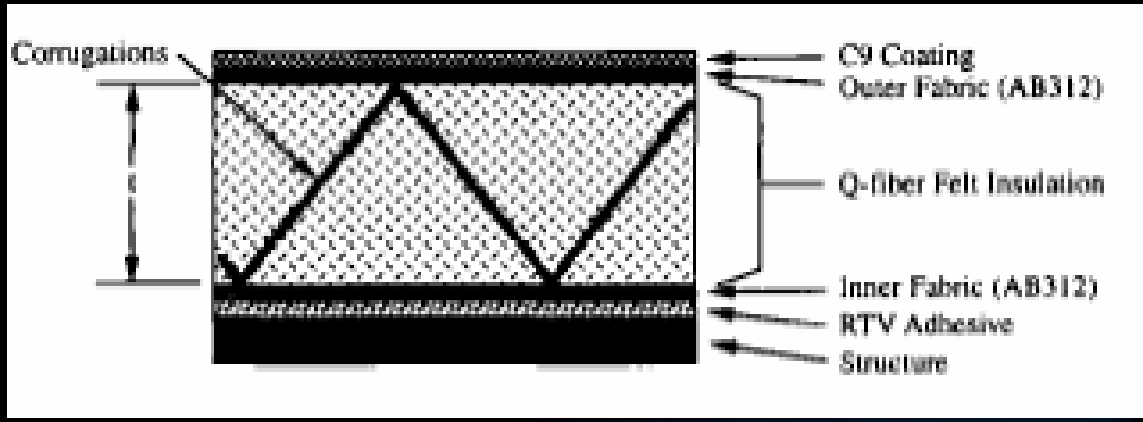
- Ceramic tile concept developed by NASA Ames
- Coated with Alumina Enhanced Thermal Barrier (AETB)
- Same SIP, RTV used
- 1-2 order of magnitude more resistant to damage
- Maximum operational temp = 2500° F





Blanket Insulation: TABI and CRI

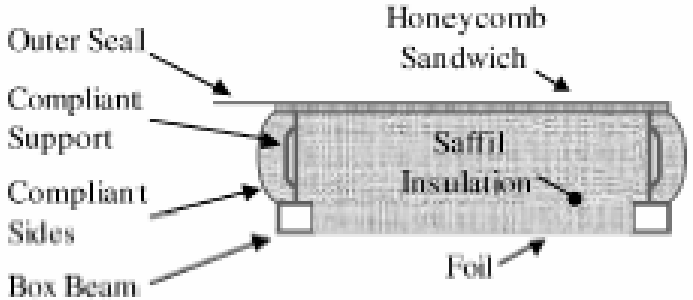
- Silica-based blanket type TPS
  - Upgrades to FRSI
  - Quilted blankets with integrated ceramic
- Improve strength and outer surface
- Tailorable Advanced Blanket Insulation (TABI) – NASA Ames
  - Ceramic fiber with Q-fiber felt insulation
- Conformal Reusable Insulation (CRI) - Boeing
  - Ceramic matrix composite



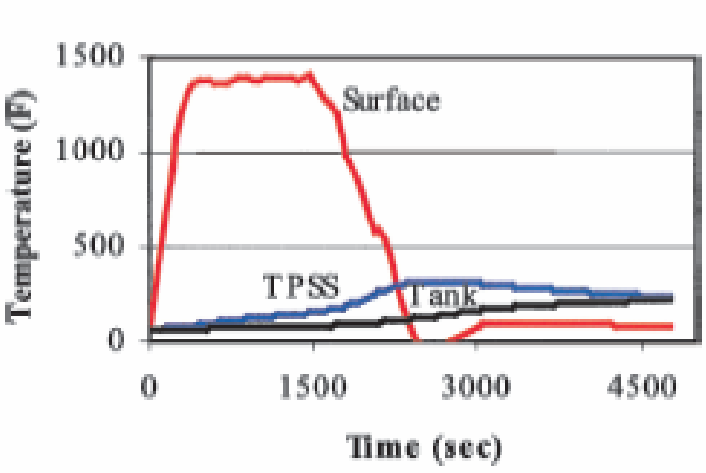
Metallic TPS

- 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

Fabricated Panel

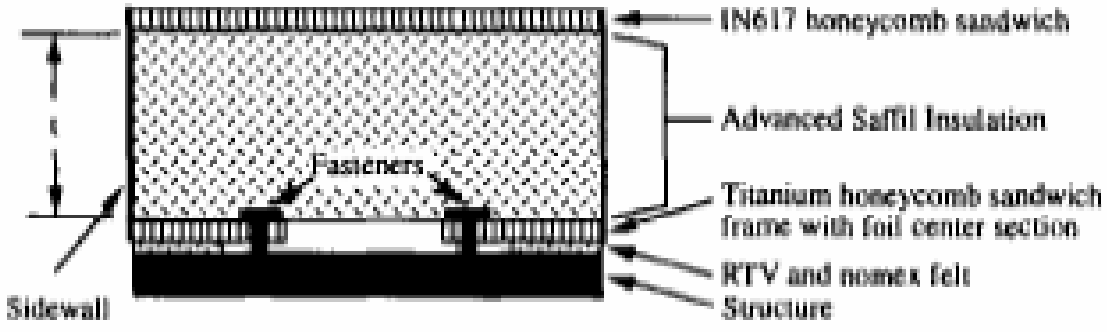


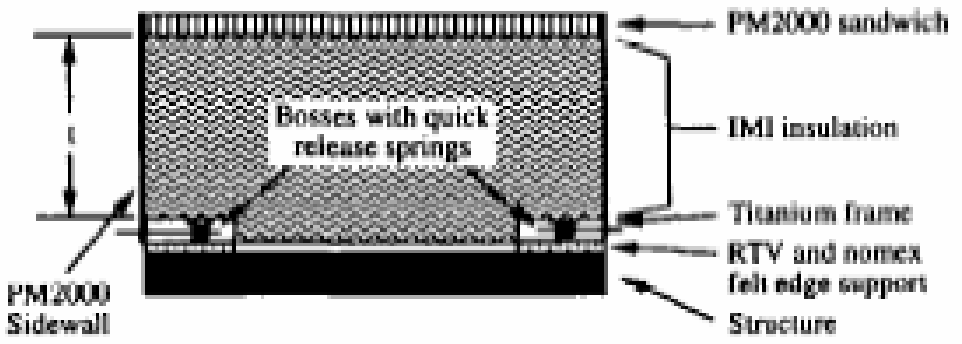
Cutaway View



Metallic TPS, con't

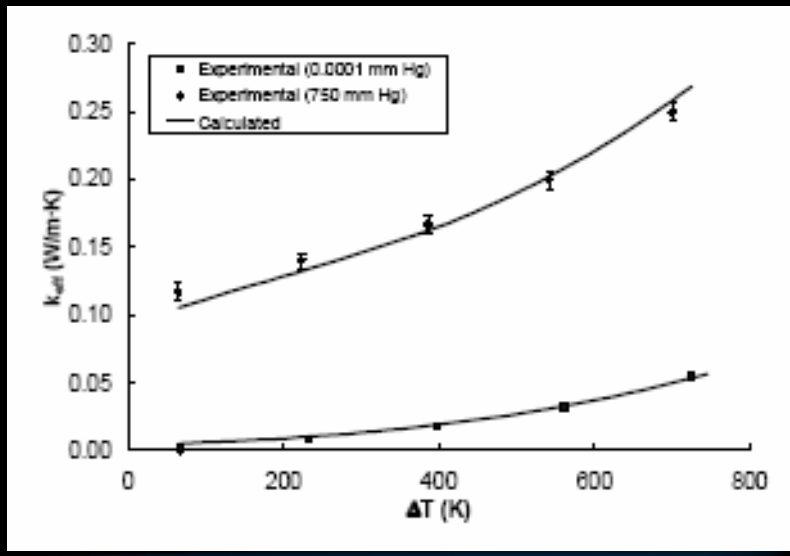
- Several variation of Metallic TPS exist
- Honeycomb material
  - Inconel, Titanium, other alloys
- Insulation layer
  - Saffil, Internal Multiscreen Insulation (IMI)
- Operational temperature: 2000 - 2200° F





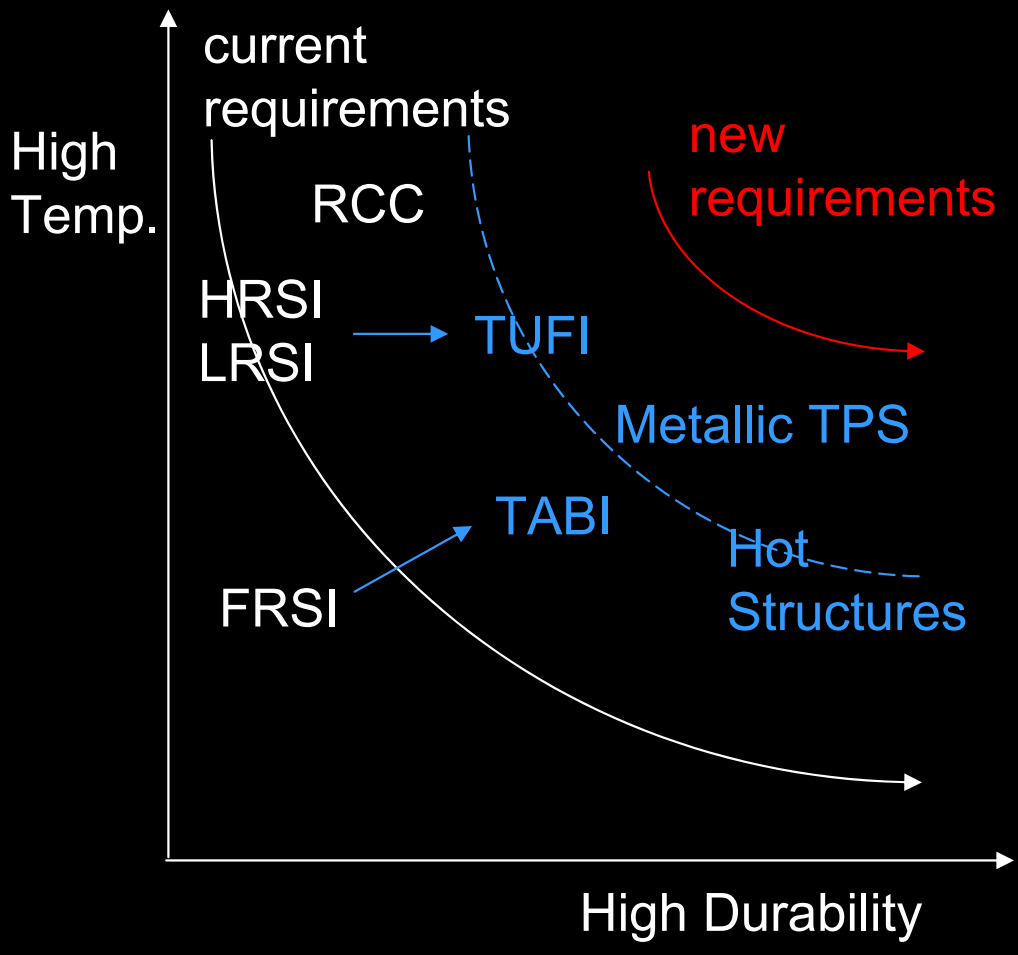
Hot Structures

- Metallic primary structure acts as a heat sink
- Integrated structure and TPS → large mass savings
- Progress highly dependant on materials research and fabrication processes
- Operational temperatures ~1500° 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