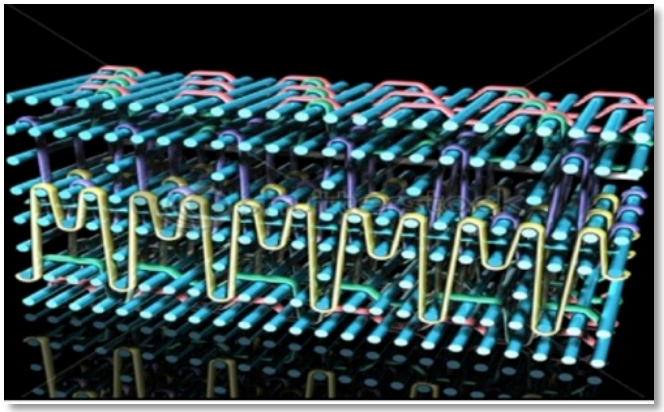
HEATSHIELD FOR EXTREME ENTRY ENVIRONMENTS TECHNOLOGY (HEEET)

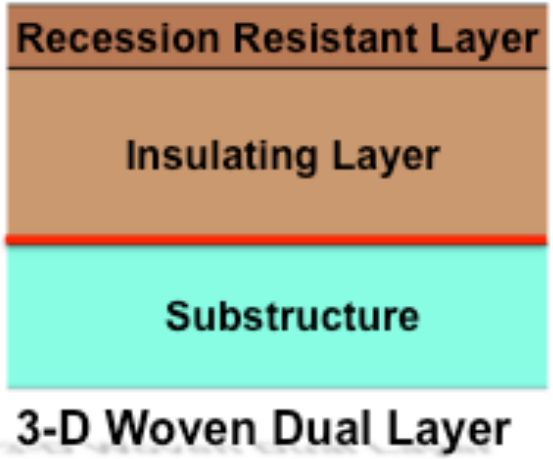
Ethiraj Venkatapathy
TPS Materials Project Manager
&
Donald T. Ellerby
HEEET Element Manager

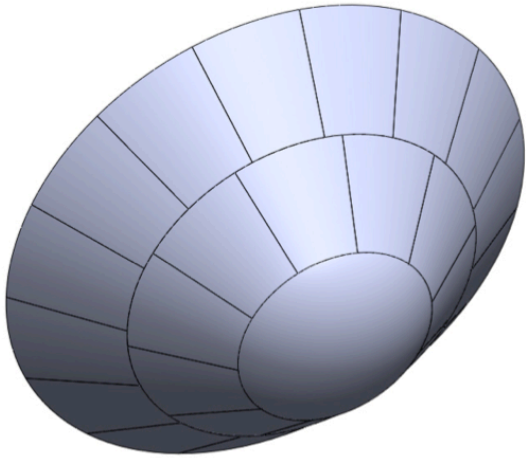
April 9, 2014

Technology Workshop for Discovery
Washington, DC
April 9, 2014

Baseline HEEET Architecture



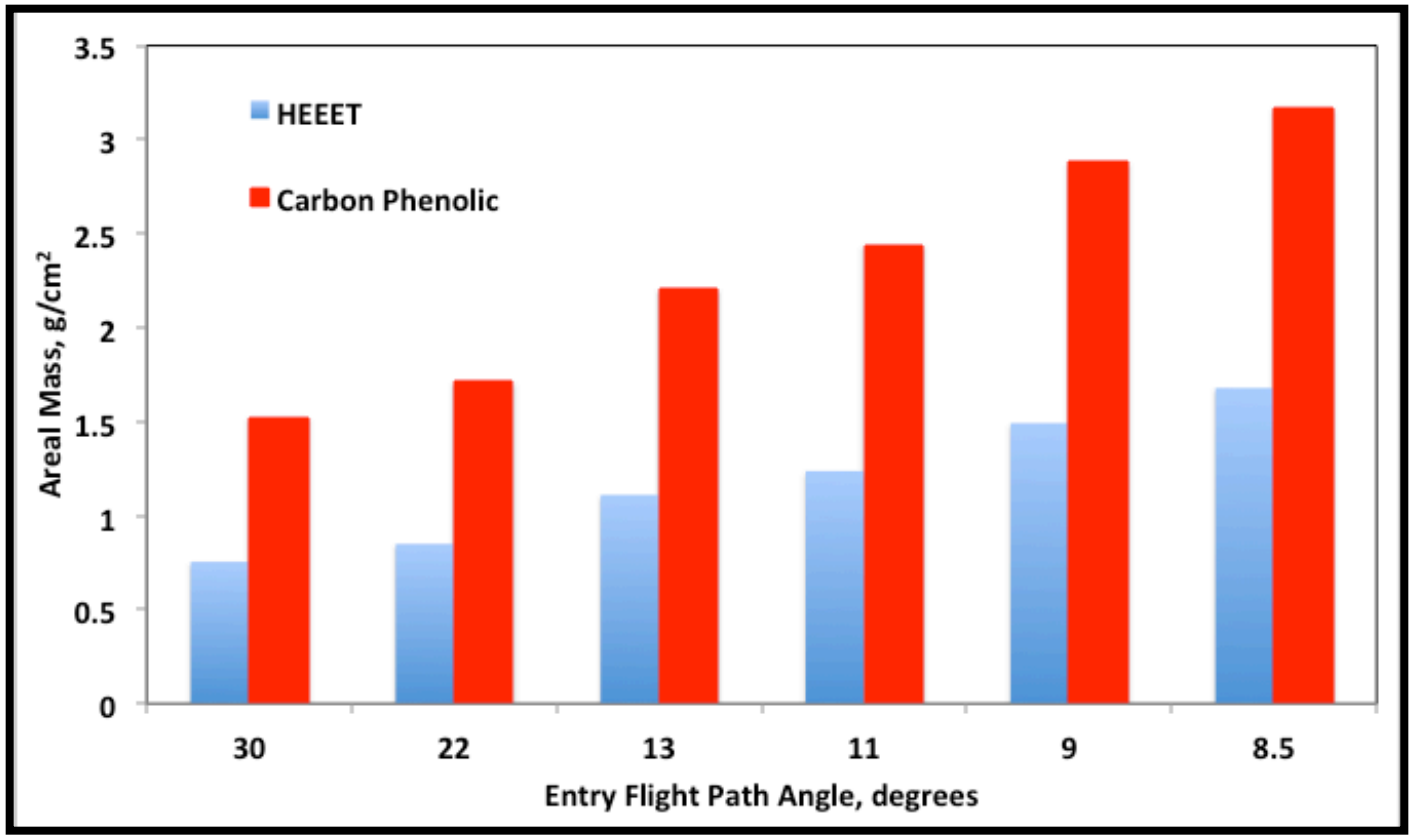




- **Goal: Mission infusion into Discovery 2014 and New Frontier-4**
- **An integrated 3-D Woven, dual-layer, multi-material, resin infused architecture**
  - Capable of withstanding extreme entry environments
    - Fills the TPS Gap - Peak heat flux >> 1500 W/cm2; Peak pressure >> 1.0 atm.
    - Example missions: Venus, Saturn and High Speed Sample Return
  - Single step, uniform resin infusion (PICA like)
- **Segmented heatshield configuration**

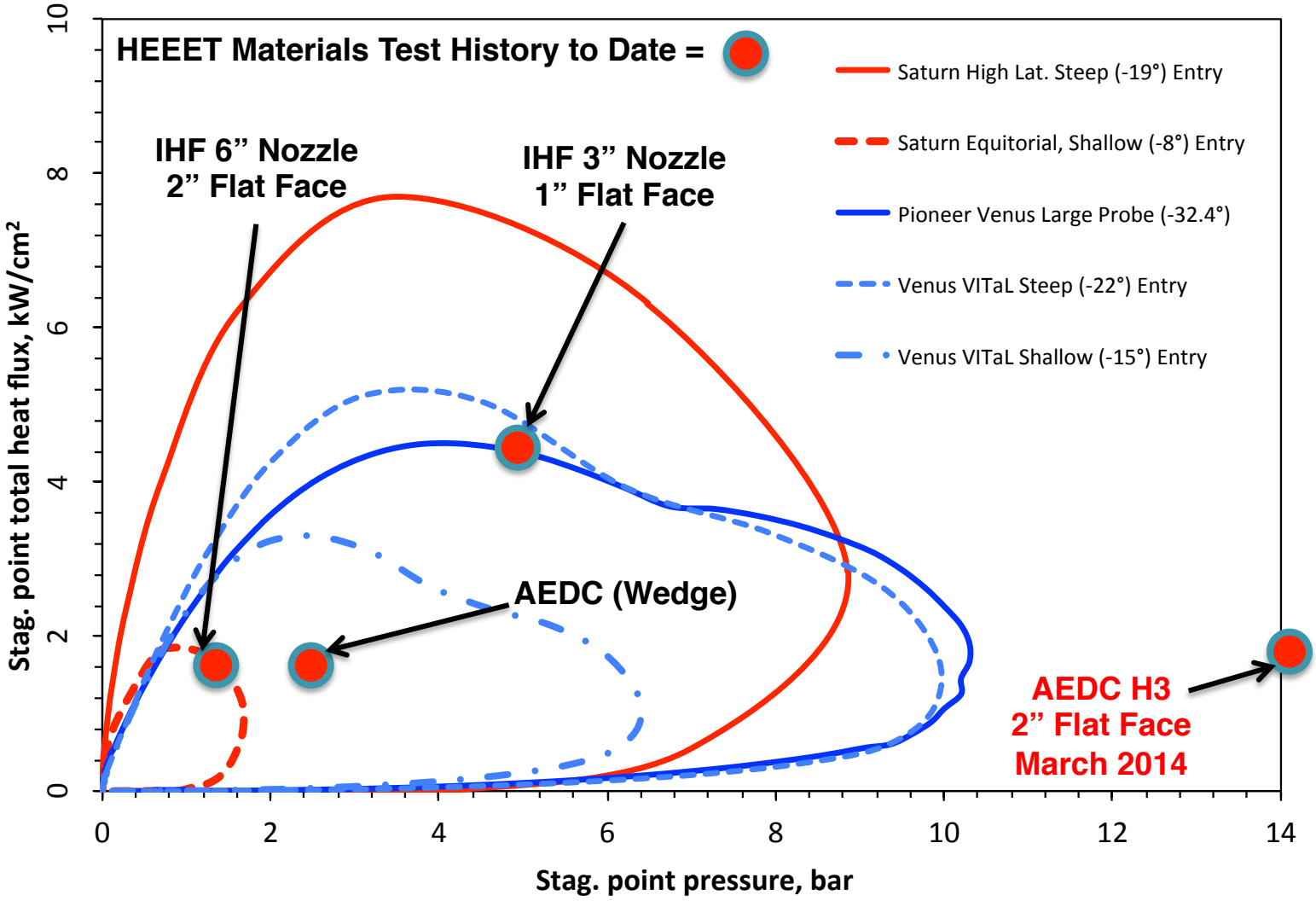
POC: Ethiraj.Venkatapathy-1@nasa.gov

Venus Entry at 10.8 km/s Areal Mass Comparison



- Aeroshell - 3.5m dia., 45° sphere cone, 2,000 kg total mass
- Areal mass of HEEET is ~ 50% of Carbon Phenolic (CP) for a broad range of entry trajectories
  - Efficiency of HEEET allows for trade between TPS mass vs lower entry g'load.
- Performance combined with robustness makes HEEET an exceptional choice

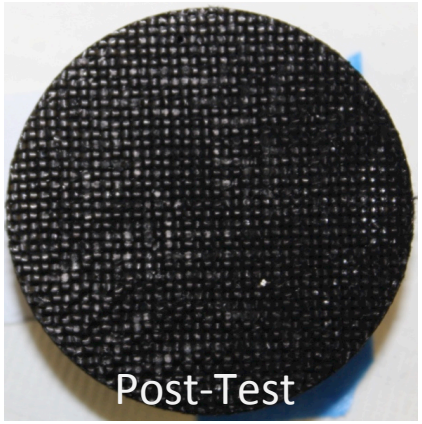
Design Space & HEEET Arc-jet Test History

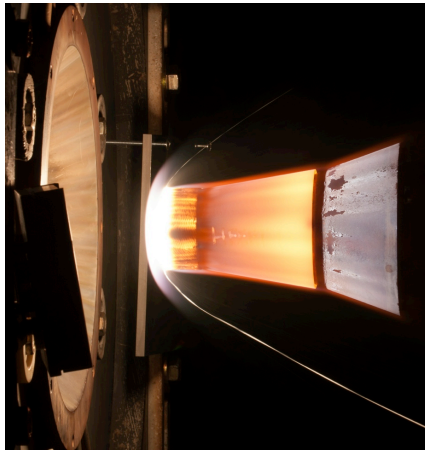


POC: Ethiraj.Venkatapathy-1@nasa.gov

HEEET Thermal Testing

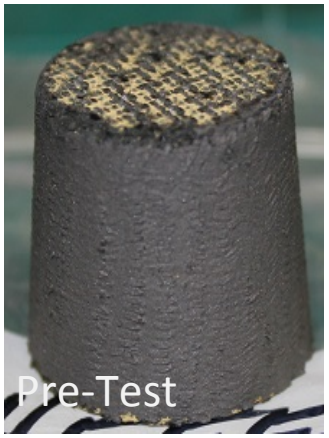
~1600 W/cm², 1.3 bar

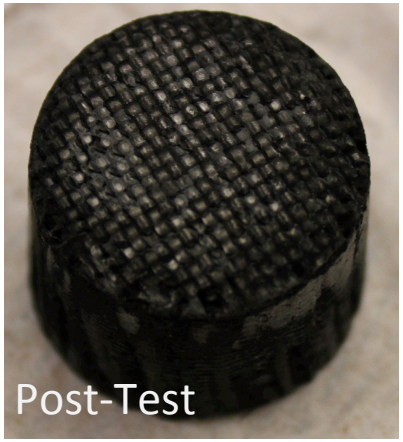




~1800 W/cm², 14 bar

~4000 W/cm², 5 bar





Testing to date has not induced thermal failure modes in acreage material.

POC: Ethiraj.Venkatapathy-1@nasa.gov

Requirements Development

- **The project team has extracted generic, high-level, heat shield requirements from MSL, Orion and Stardust experience**
  - Requirements addressed both functional requirements and sustainability (manufacturability, operability, etc.)
- **Requirements presented and reviewed at HEEET workshop (June 2013)**
- **General TPS requirements have been flowed down to HEEET specific requirements for technology development**
- **Verification strategies/approach for each requirement have been identified**
- **Development tasks are traceable to verification**
- **TRL can be assessed against requirement verification status**

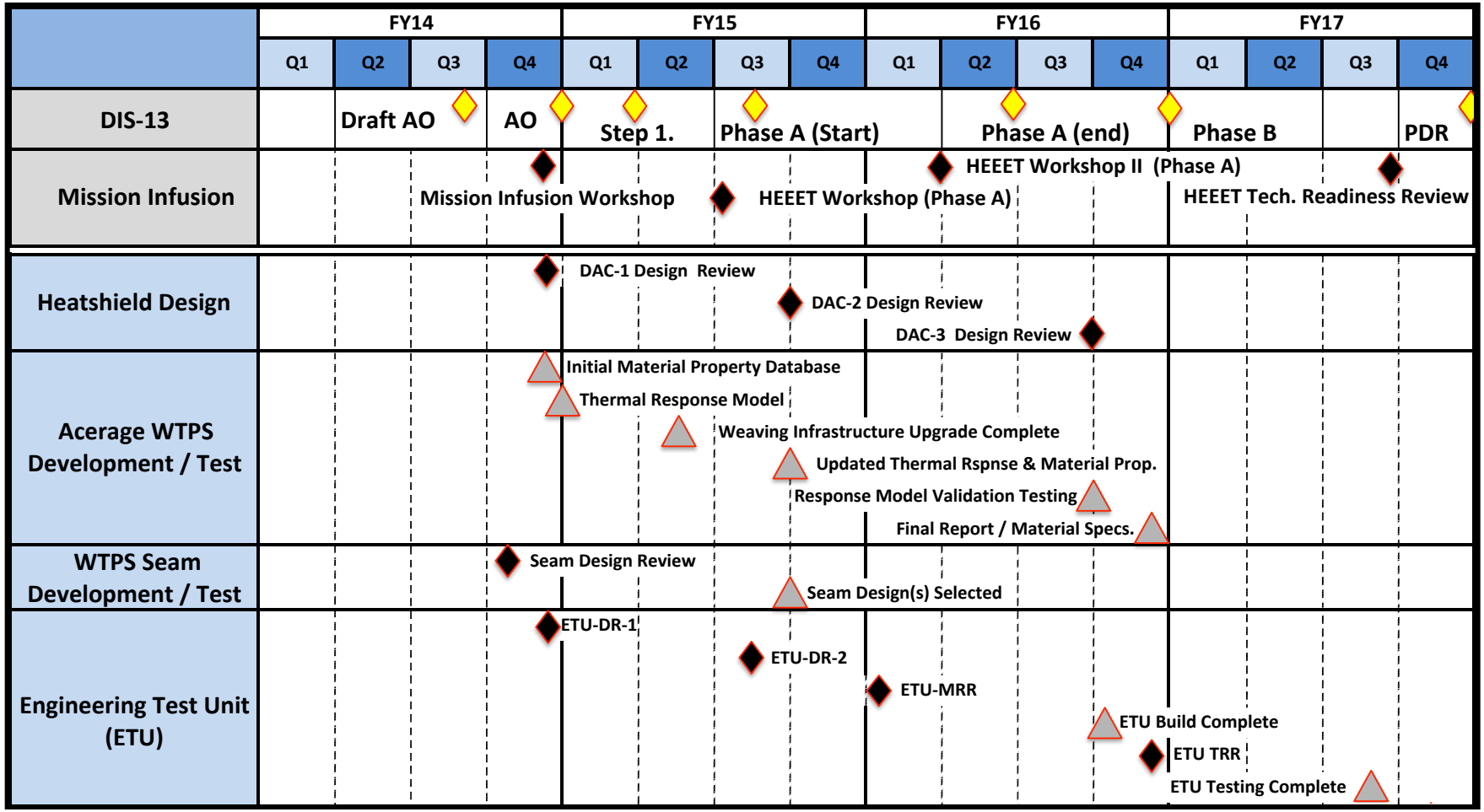
POC: Ethiraj.Venkatapathy-1@nasa.gov

Current TRL for HEEET is 3+

TRL Level	Hardware description	Level 1 Requirements					
		Function Thermally	**Function Structurally**	**Be Operable**	**Be Manufacturable**	**Interface with Vehicle**	**Be Certifiable**
3	**Analytical studies place the technology in an appropriate context and laboratory demonstrations, modeling and simulation validate analytical prediction.**	Mission studies indicate feasible thicknesses and good TPS mass fractions.	Strength requirements established from analysis of mission-relevant loads. Coupon testing of candidate seams indicate adequate strength achievable.	Analogy with other TPS systems involving carbon and phenolic: benign dust, out-gassing, etc.	Trade studies on candidate manufacturing approaches.	Concepts for penetrations and closeouts are established.	Integrated inspection and repair study is in work. Traceability from ground test to flight similar to previous TPS.
4	**A low fidelity system/component breadboard is built and operated to demonstrate basic functionality and critical test environments.**	Tests of acreage material and candidate seam concepts over a range of arc-jet environments.			Weaving, cutting, bonding, infusion and seam production demonstrated at subscale.		Flaw detection in weave, infusion and seams demonstrated at subscale.

POC: Ethiraj.Venkatapathy-1@nasa.gov

Key Milestones



- HEEET Maturation is aligned with the Discovery 2014 Mission Selection and Proposal Phases
- HEEET project milestones, deliverables and workshops focuses on proposals and study report development

POC: Ethiraj.Venkatapathy-1@nasa.gov

HEEET Challenges

- **Weaving scale-up (in place ~ Feb. 2015):**
  - Critical to maturing manufacturing processes: molding, seams, resin infusion
    - Current capability: ~1” thickness x 6” width
    - Expanded capability: ~3” thickness x 24” width
- **Seam Design (down-selected by early 4th Q FY’15):**
  - Single piece heat shield is not feasible. A segmented heat shield is required
  - Goal is an aerothermally monolithic solution
    - Seam thermal performance the same as acreage TPS
- **Infusion Scale**
  - Infusion size currently ~1.2 m due to industrial vessel limitation
    - Once demo’ed at 1.2m scale further scale up is not considered a significant challenge but will need to be demonstrated
  - Scale-up is not currently planned beyond 1.2m size
    - Resin Infusion may or may not limit the size of the heat shield
  - On-going trades may lead to heat shield integration approaches not requiring the infusion to be scaled-up

POC: Ethiraj.Venkatapathy-1@nasa.gov

Planned AO Library Content and Support for HEEET Mission infusion

- **Announcement of Opportunity (AO) Library planned contents:**
  - Questionnaire to be filled out by proposal team planning to use HEEET
  - Documented requirements and requirements verification plan
  - HEEET exit criteria for TRL 6
  - Mission studies report for Venus, Saturn and High-Speed Sample Return missions
  - Arc Jet test summary report
  - Preliminary material property database
  - Conference papers and publications
- **HEEET team plans to support proposal teams in Step 1 and Step 2 proposal phases by engaging with them directly**
  - Will perform limited sizing studies
  - Consultation on integration approaches
  - Guidance on mission design that take into account TPS manufacturing and integration, testing and verification for flight.

POC: Ethiraj.Venkatapathy-1@nasa.gov

POC for HEEET

Ethiraj Venkatapathy

NASA Ames Research Center

(Primary interface with proposal teams)

ethiraj.venkatapathy@nasa.gov

650-248-1596 (Cell) primary

650-604-4282 (office)