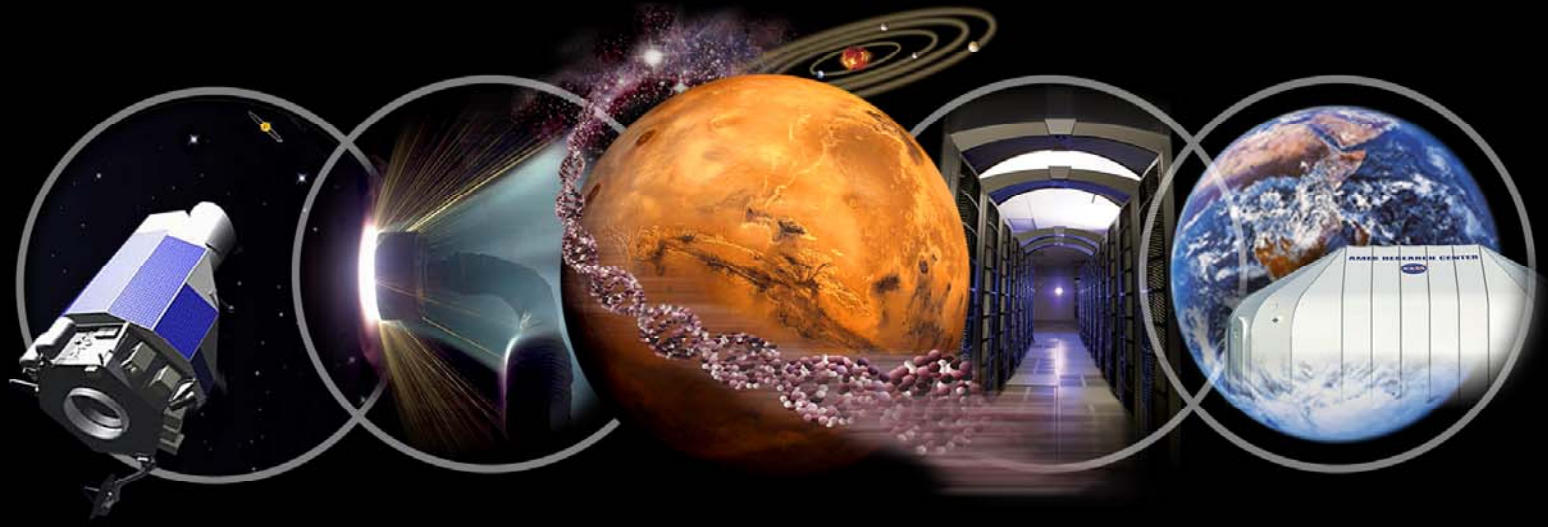
Discovery ➲ Innovation ➲ Solutions



Entry Systems Technology

Charles Smith

Chief, Space Technology Division

650-604-5857, charles.a.smith@nasa.gov

Ames Exploration Systems Technology Partnerships Forum

July 22-23, 2004

Visibility ➲ Excellence ➲ Impact

Ames Research Center

Overview

- **Contributions to past Exploration missions**
- **Ames expertise in Entry Systems Technology**
- **Entry system technology needs for future missions**

NASA Missions Enabled by Ames Thermal Protection System R&D

SPACE SHUTTLE

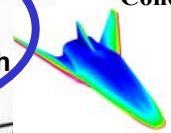
X-34

X-33

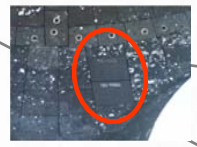
SHARP-B1 & B2

ACCESS TO SPACE
•Shuttle Upgrades
•Orbital Space Plane
• Next Gen Launch Tech
• DoD

Sharp Body Concepts

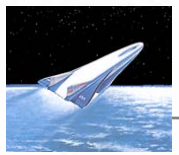


Shuttle Upgrades



PLANETARY
• Mars Science Lab
• Mars Sample Return
• Outer Planets

NASP



APOLLO

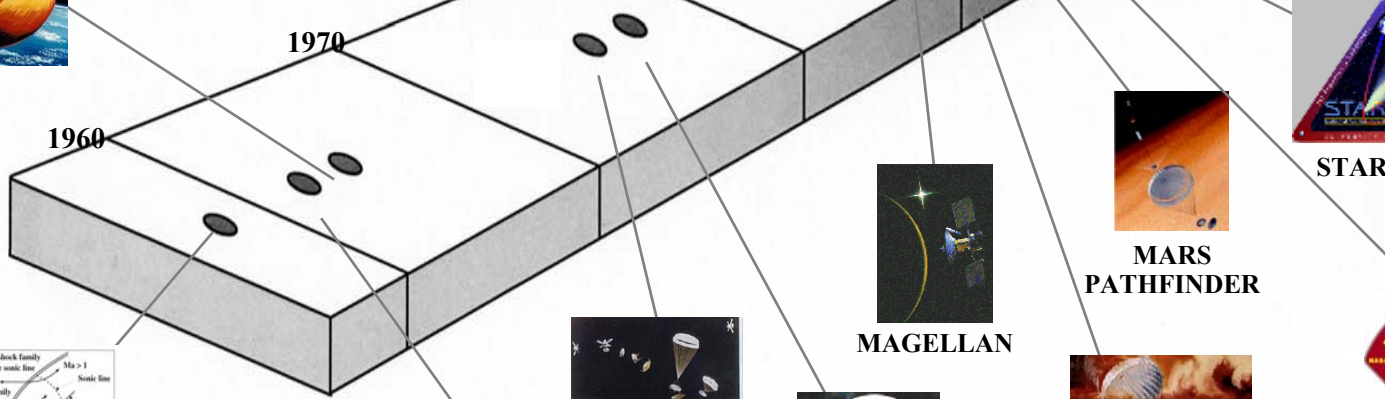
2000

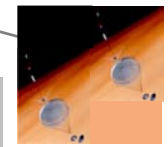
1990

1980

1970

1960



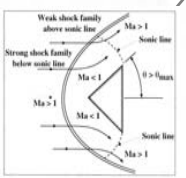


MER

STARDUST

MARS PATHFINDER

MAGELLAN

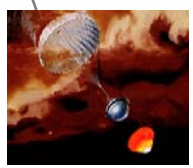


BLUNT BODY CONCEPT
(H. Allen)

PAET

VIKING

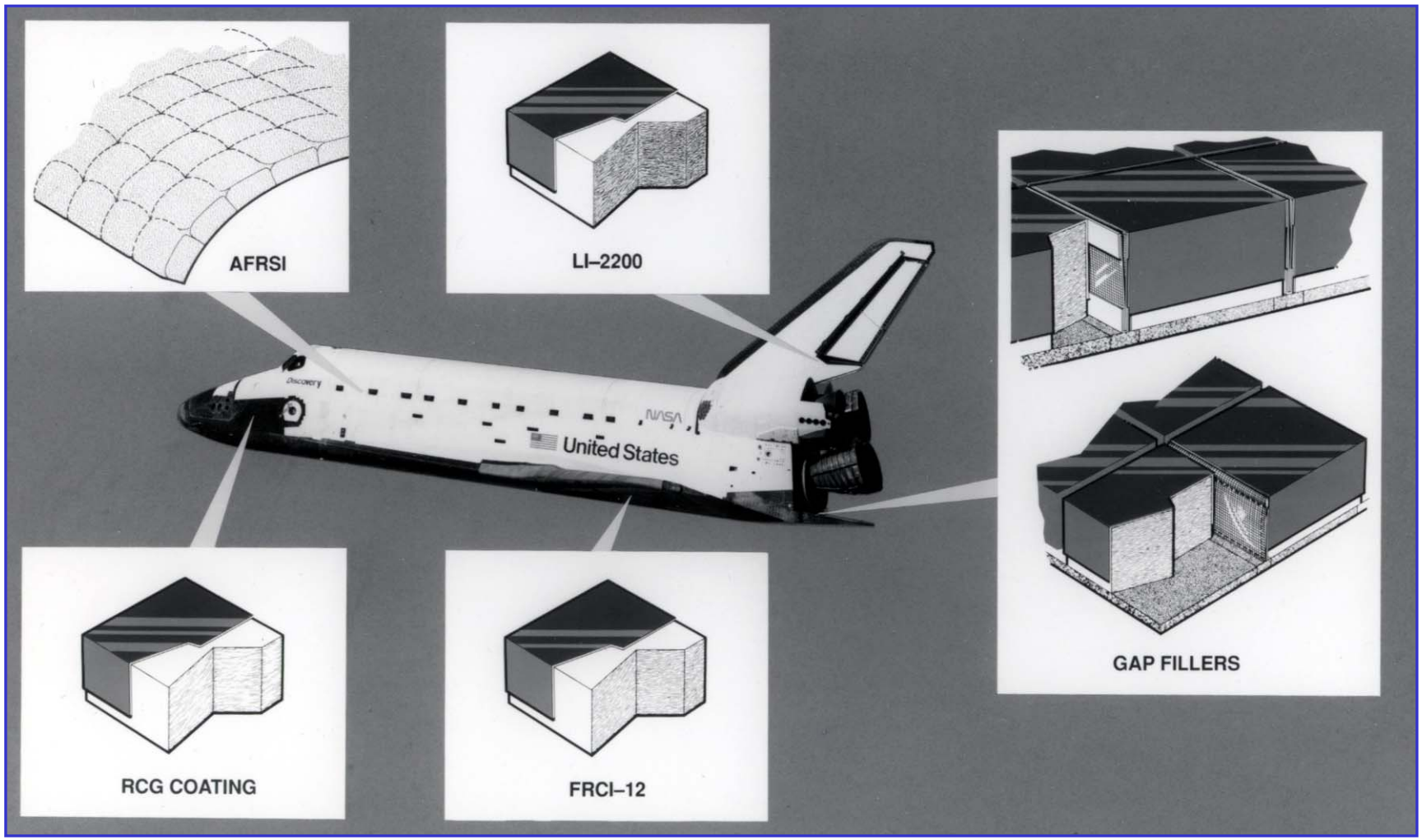
PIONEER-VENUS



GALILEO

MARS DS-2

Ames Developed Thermal Protection Materials

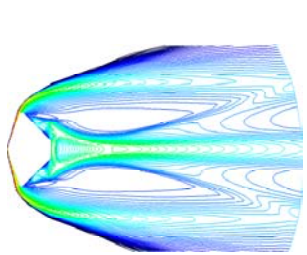


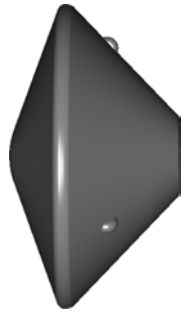
Mars Exploration Rovers-Spirit & Opportunity
Ames' Entry System Contributions

Technology & Major Facilities Enabled the Mission

- **Thermal protection systems analyses, design and verification**
- **TPS hardware fabrication (SIRCA) and integration**
- **Arc Jet TPS material development and qualification testing**
- **Wind tunnel full-scale parachute testing**
- **Membership on agency project reviews**

TPS design analyses





TPS (SIRCA) fabrication

TPS arc-jet testing

MER Parachute Testing in 80 by 120 foot Wind Tunnel

X-37 Orbital Vehicle

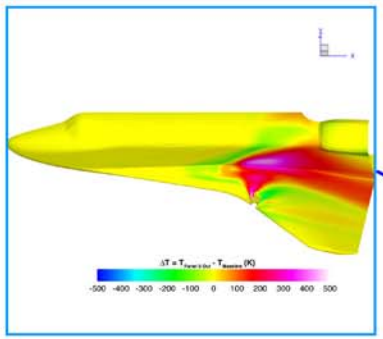
- **Ames supports the MSFC-led X-37 project in Orbital Vehicle key technologies with respect to the Thermal Protection System (TPS)**

- **Ames' major contribution is the development, qualification, certification, and product demonstration, with Boeing, of the wing leading edge TPS material.**

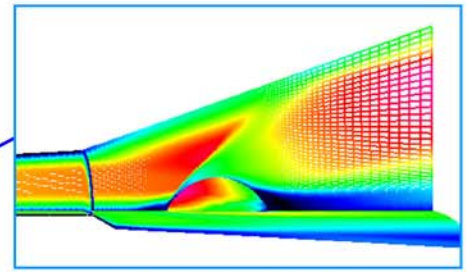
- **Recently completed testing of the Swept WLE Gap Configuration Evaluation in the Ames Arc Jet.**

Integrated Capability Provides Mission Critical Support

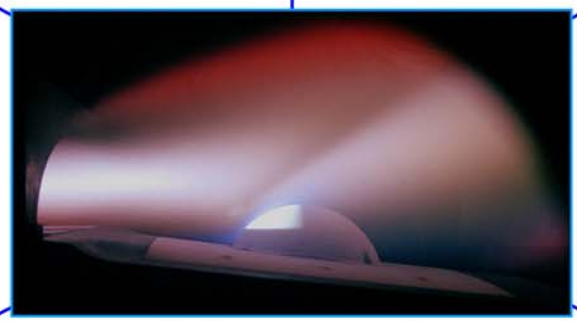
MATERIALS DEVELOPMENT AND CHARACTERIZATION LABS



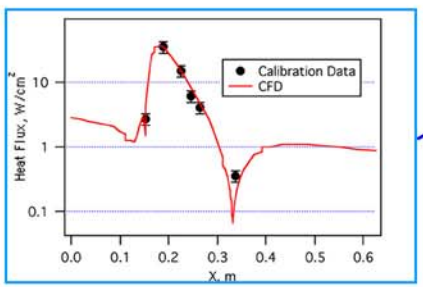
FLIGHT PREDICTION AND MODELING



FACILITY MODELING



GROUND TESTING
(MER Transverse Impulse Rocket System (TIRS) Calibration Test)



VALIDATED SIMULATION MODELS

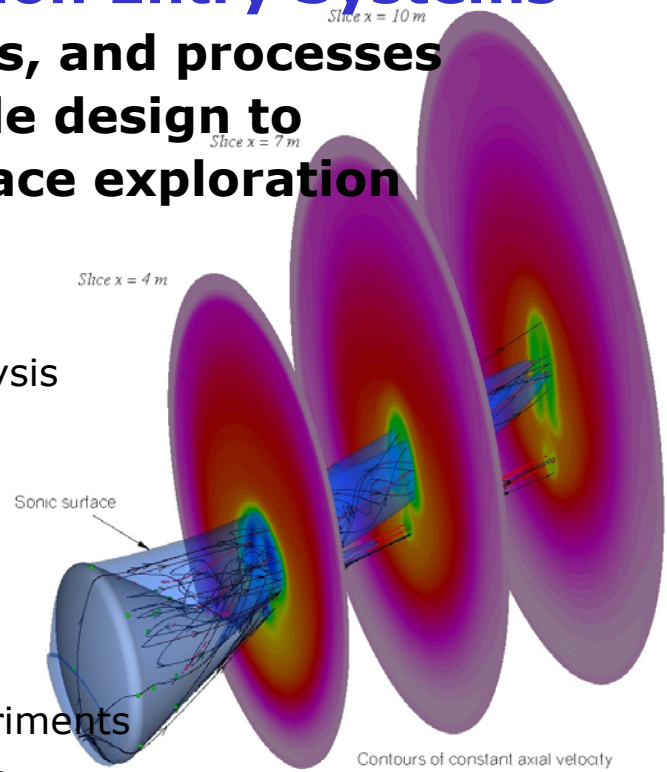
FABRICATION

ALL CAPABILITIES REQUIRED FOR DEVELOPMENT OF SUCCESSFUL TPS SYSTEMS DONE "UNDER ONE ROOF"

Aerothermodynamics for Exploration Entry Systems

Objective - develop and apply models, tools, and processes for aerothermal analysis and TPS/vehicle design to support NASA strategic objectives in space exploration

Points of Emphasis:



Ground to flight traceability

- Facility modeling and development, flight testing and analysis

Rapid, Hypersonic, CFD modeling: CAD-to-solution

- Physics, numerics, and grid generation
- Provide required level of accuracy in minimum time
- Inject high-fidelity analyses earlier into design cycle

Shock layer radiation and high temperature gas physics

- Model development through analysis and shock tube experiments
- Analysis techniques, reduction of aeroheating uncertainties

Translation of analysis data to useful design data

- Synthesis of multiple data sets: multiple CFD, CFD and lower-order methods

Development and integration of analysis tools and *processes* for entry vehicle TPS design and sizing

- Aerothermal, aerodynamics, trajectory, TPS, shape optimization
- Risk, uncertainty and sensitivity analyses

Dr. Dean Kontinos: 650-605-4283

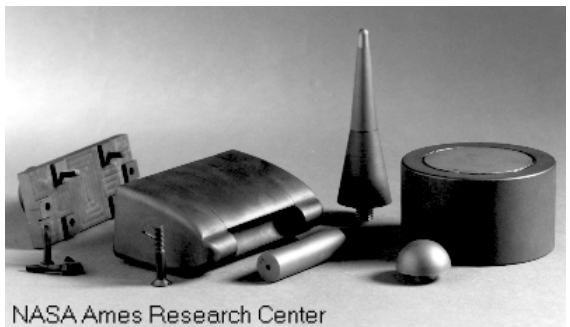
Materials Development

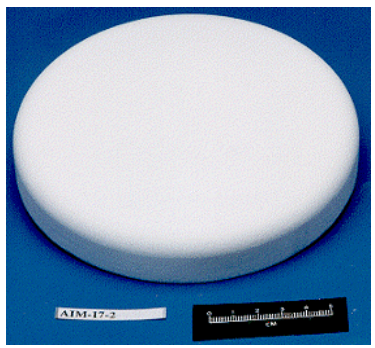
- **An integrated approach to Materials Development by highly skilled personnel is applied from conception to fabrication**
- **Material concepts are developed and implemented in four laboratories: Ceramics, Materials Characterization, TPS Development, and Ultra-High Temperature Ceramics**
- **Analysis and design efforts are supported by commercial and in-house developed software tools used to create test and flight hardware models, predict aerothermal environments, and perform thermal/mechanical response of TPS for both reusable and single-use applications**
- **NASA Ames has applied its expertise to Shuttle insulation and upgrades, Return to Flight Repair, X-33, X-34, SHARP-B1 & -B2, and the Mars Exploration Rover**
- **New TPS materials will need to be developed to enable critical national missions, as demonstrated by the reemerging importance of ablative TPS concepts**

Dr. Sylvia Johnson: 650-604-2646

Fabrication

- **The materials development laboratories fabricate samples and components for testing and application**
  - **Material samples for mechanical and thermal characterization**
  - **Coupons for arc-jet material response tests**
  - **Flight-like arc-jet articles for system response tests**
  - **In some instances, the laboratory provides flight hardware**
    - **For example, X-37 wing leading edge and Mars Exploration Rover TIRS cover**
- **Work is performed in close partnership with clients, to ensure best fit and practices**





Dr. Sylvia Johnson: 650-604-2646

Ames Arc Jet Complex

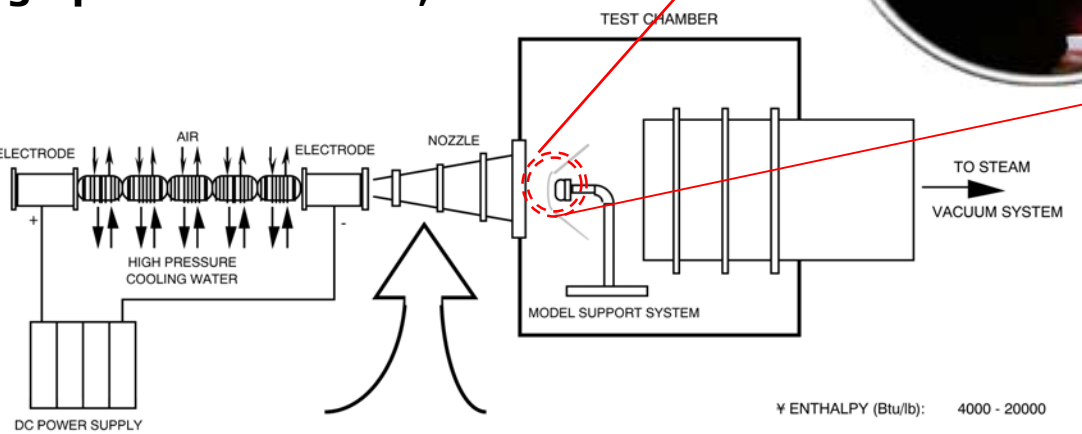
- **The Ames Arc Jet Complex has a long heritage in TPS development for every Agency Space Transportation and Planetary program, including Apollo, Space Shuttle, Viking, Pioneer-Venus, Galileo, Mars Pathfinder, X-33, X-34, Stardust, SHARP B1, and SHARP B2.**

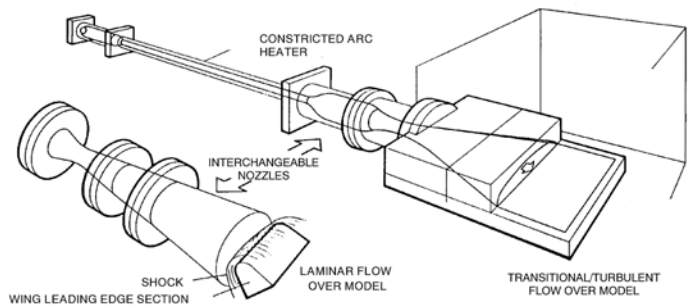
- **Currently operates at high production rates, ~500 tests per year.**

- **Continuous plasma flow generated by DC discharge within a constrictor tube.**

- **Maximum rating: 8000 VDC at 6000 Amp**

- **Interchangeable nozzles: (1) conical, and (2) panel test configurations**





- ENTHALPY (Btu/lb): 4000 - 20000
- STAGNATION PRESSURE (atm):
  - FLAT-FACE MODEL 0.005 - 1.2
  - WEDGE MODEL 0.0001 - 0.15
- HEATING RATES (Btu/ft ^{2}-sec):
  - FLAT-FACE MODEL 20 - 660
  - WEDGE MODEL 0.5 - 45
- SAMPLE SIZE (ft):
  - FLAT-FACE MODEL Up to 1.5
  - WEDGE MODEL Up to 2.5 × 2.5

Mr. Joe Hartman: 650-604-5269

Ames Arc Jet Complex

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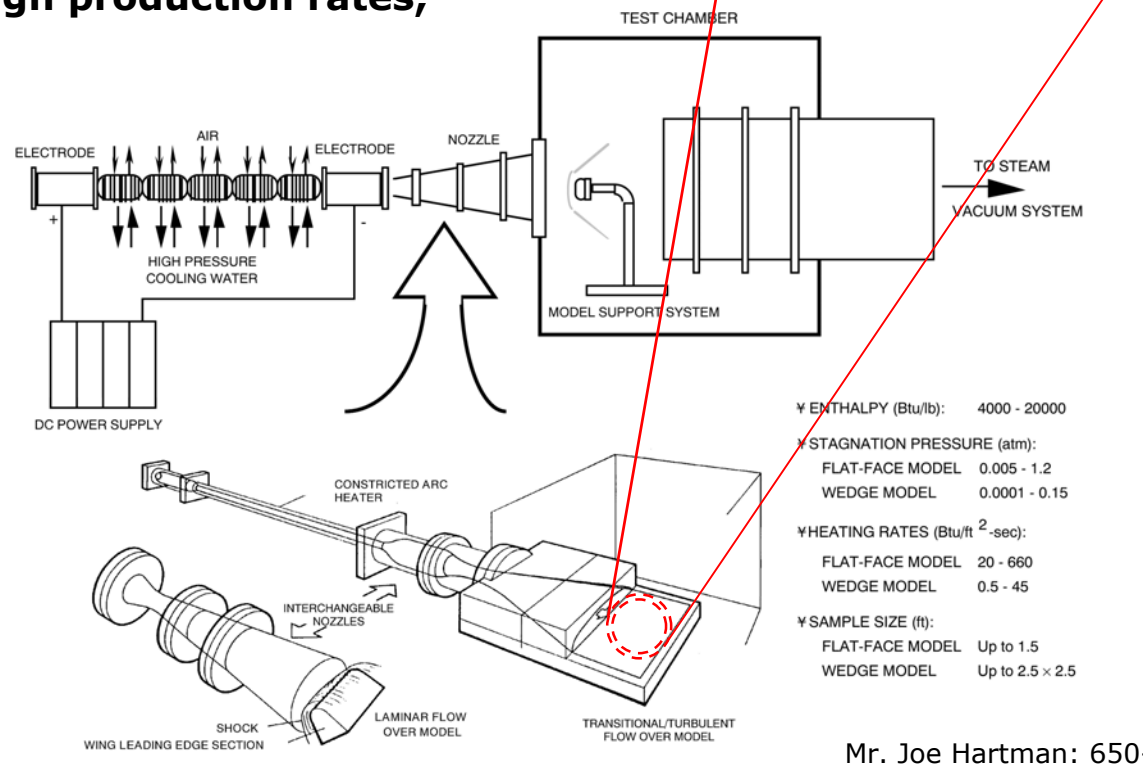
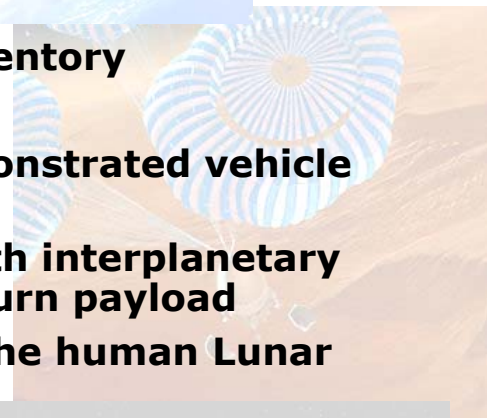


Mr. Joe Hartman: 650-604-5269

Significant Entry Systems Challenges Exist for Exploration



- **Non-availability of human rated ablative TPS**
  - **Ablative TPS likely required for crewed Lunar a**
  - **Apollo ablator no longer in production (Avcoat**
  - **No other human rated ablator currently in the US inventory**
- **Demonstration of adequate sample return capability**
  - **Potential bio-hazard payload requires very-high demonstrated vehicle and entry system reliability**
  - **Limitations on launch and orbital mass, combined with interplanetary delta-V and ops requirements, significantly limits return payload**
- **Demonstration of sufficient Entry System capabilities for the human Lunar and Mars exploration campaigns**
  - **Pin-point landing and hazard avoidance at the Moon and Mars**
  - **On-orbit Entry System health management, inspection and repair**
  - **Descent and landing systems for Earth return with acceptable performance, reliability and cost**
- **Entry, descent and landing identified by Aldridge Commission as one of 17 "enabling technologies" for exploration**

Entry System Key Elements & Capabilities

Key Elements

Hypersonic entry

- **TPS*, structure, trajectory, NG&C, aerothermodynamics, control systems**

Descent systems

- **Aerodynamics, NG&C, decelerator design/parachutes, control systems**

Landing systems

- **Mechanisms, control systems, autonomous systems**

Supporting Capabilities

Analyses and Simulation

- **System analysis, TPS design, hardware design**

Information technologies

- **IVHM, automation**

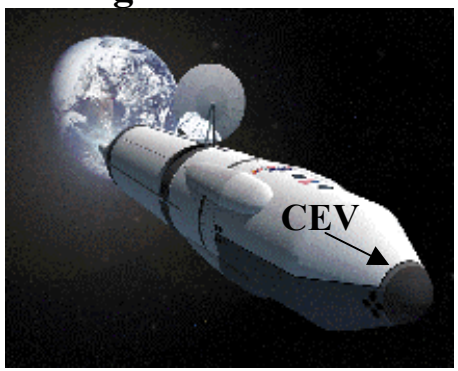
Critical facilities

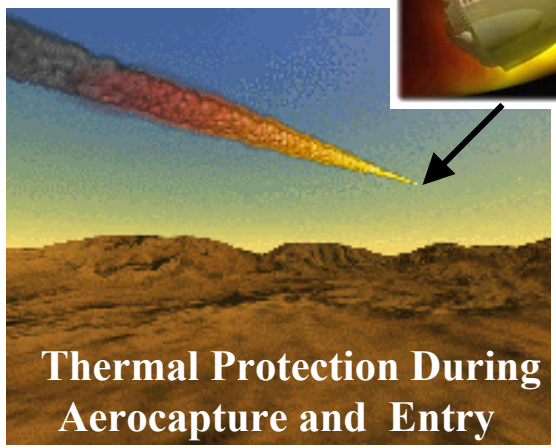
- **Arc-jets, wind tunnels, landing simulators**

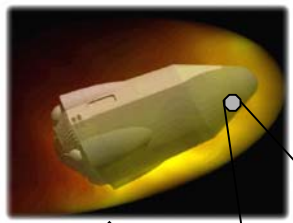
* Underlined items indicate Ames competencies

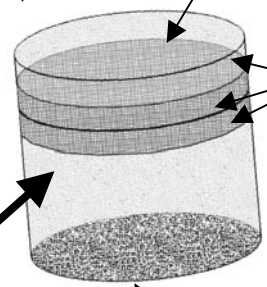
Examples of Mars Mission Impact: Thermal, Radiation and Impact Protective Shields (TRIPS)

Radiation, Impact Shield During Transit to Mars





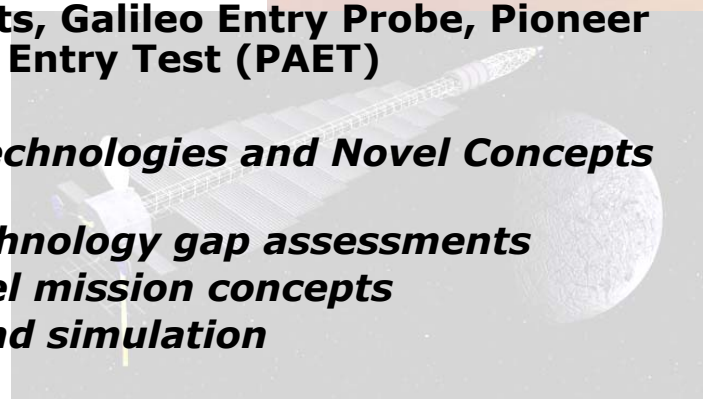




Spiral Development Proposal

- Determine Rad shielding of existing Carbon Phenolic (CP)
- TRIPS at TRL 4 by 2008
- Thermal , Radiation on mid-density CP for Out-of-Orbit CEV
- TRIPS on Lunar return CEV
- TRIPS on Mars CEV

IMPACT: One shield replaces three -> Reducing mass & cost while improving mission safety



Take Away Message about Ames and Entry Systems

Ames has significant capabilities in Entry Systems, and historically has provided key products and services

Key technologies

- **TPS, Aerothermodynamics**

System and Subsystem analyses, and Simulation

- **Entry vehicle & TPS design and optimization**
- **Simulation of novel vehicle concepts with innovative technologies**

Critical facilities

- **Arc-jet testing, Wind-tunnel testing, Landing Simulators**

Ames has conceived and successfully led, and participated in, pioneering flight projects, including

Shuttle, MER, SHARP-B1 & B2 Entry Flight Tests, Galileo Entry Probe, Pioneer Venus Entry Probes, Planetary Atmospheric Entry Test (PAET)

Ames can be the "Go To" center for Innovative Technologies and Novel Concepts for Entry Systems, serving to

Perform system analyses, simulations and technology gap assessments

Provide innovative technologies enabling novel mission concepts

Supply crucial ground development, testing and simulation

Lead pioneering flight projects