

# Thermal Protection Systems

- Comments on term project
- Comments on problem set 2
- Thermal heating analysis
  - One-dimensional flows
  - Finite difference formulation
  - Multidimensional heat flows
- Heat shields

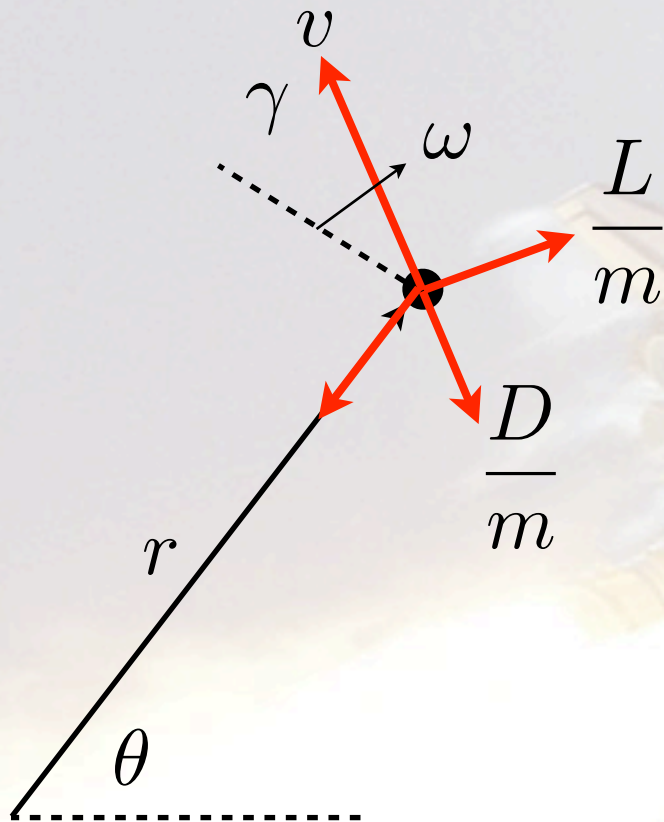


# Term Project - Top Level Requirements

- Design a system to allow the construction of one 10GW SPS per year
  - Launch vehicle(s) for cargo and personnel
  - Crew-carrying spacecraft
  - On-orbit transportation infrastructure
  - Assembly base(s) siting analysis
  - Spacecraft launch abort and EDL systems
- Mission models
  - 4000 MT/year for SPS components
  - All other logistics over and above SPS payloads



# The Canonical Planar State Equations



$$v\dot{\gamma} = \frac{L}{m} - \left(1 - \frac{v^2}{v_c^2}\right) g \cos \gamma$$

$$\dot{v} = -\frac{D}{m} - g \sin \gamma$$

$$\dot{r} = \dot{h} = v \sin \gamma$$

$$r\dot{\theta} = v \cos \gamma$$

Coupled first-order ODEs



# Associated Parameters to State Eqns

$$\frac{L}{m} = \frac{1}{2} \frac{\rho v^2 A c_L}{m} = \frac{\rho v^2}{2} \frac{A c_D}{m} \frac{c_L}{c_D} = \frac{\rho v^2}{2\beta} \frac{L}{D}$$

$$\frac{D}{m} = \frac{1}{2} \frac{\rho v^2 A c_D}{m} = \frac{\rho v^2}{2\beta}$$

$$x_{downrange} = r_o \theta$$
$$\rho = \rho_o e^{-\frac{h}{h_s}} \quad v_c = \sqrt{\frac{\mu}{r}}$$
$$h = r - r_o$$

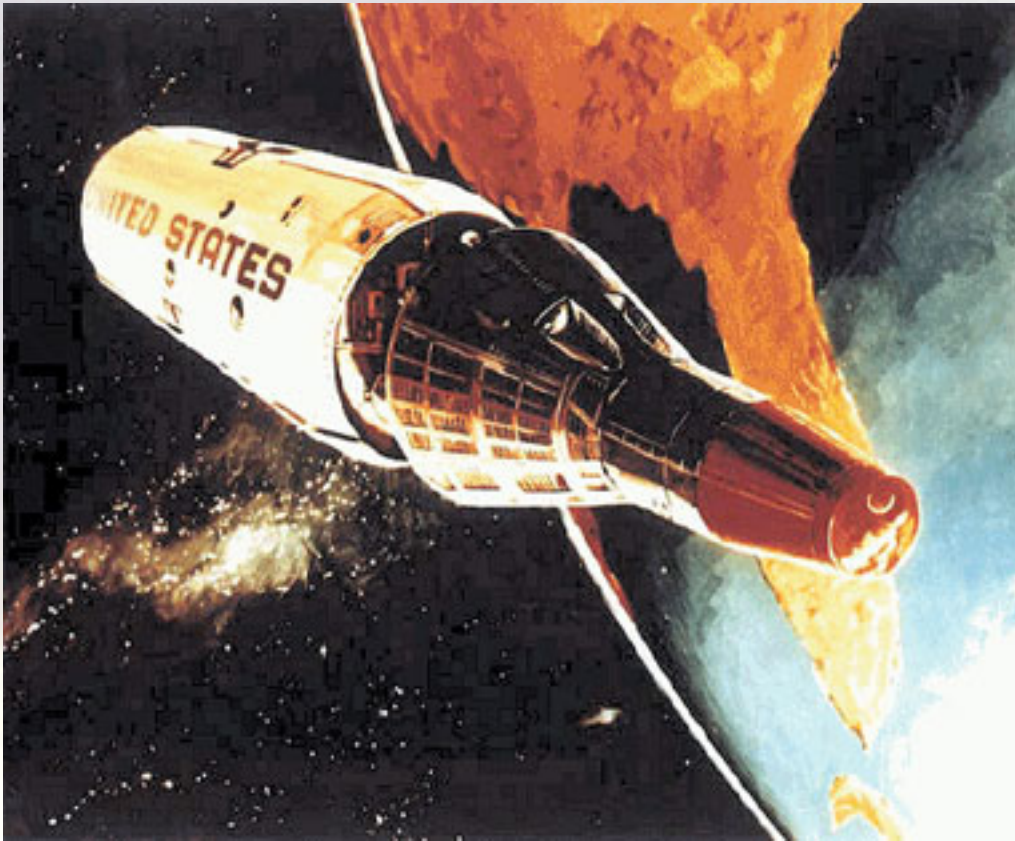
$$g = g_o \left( \frac{r_o}{r} \right)^2 \implies g = \frac{\mu}{r^2}$$



# Mercury Heat Shield Section



# Gemini MOL Heat Shield



# Apollo 11 Heat Shield



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# Orion Heat Shield

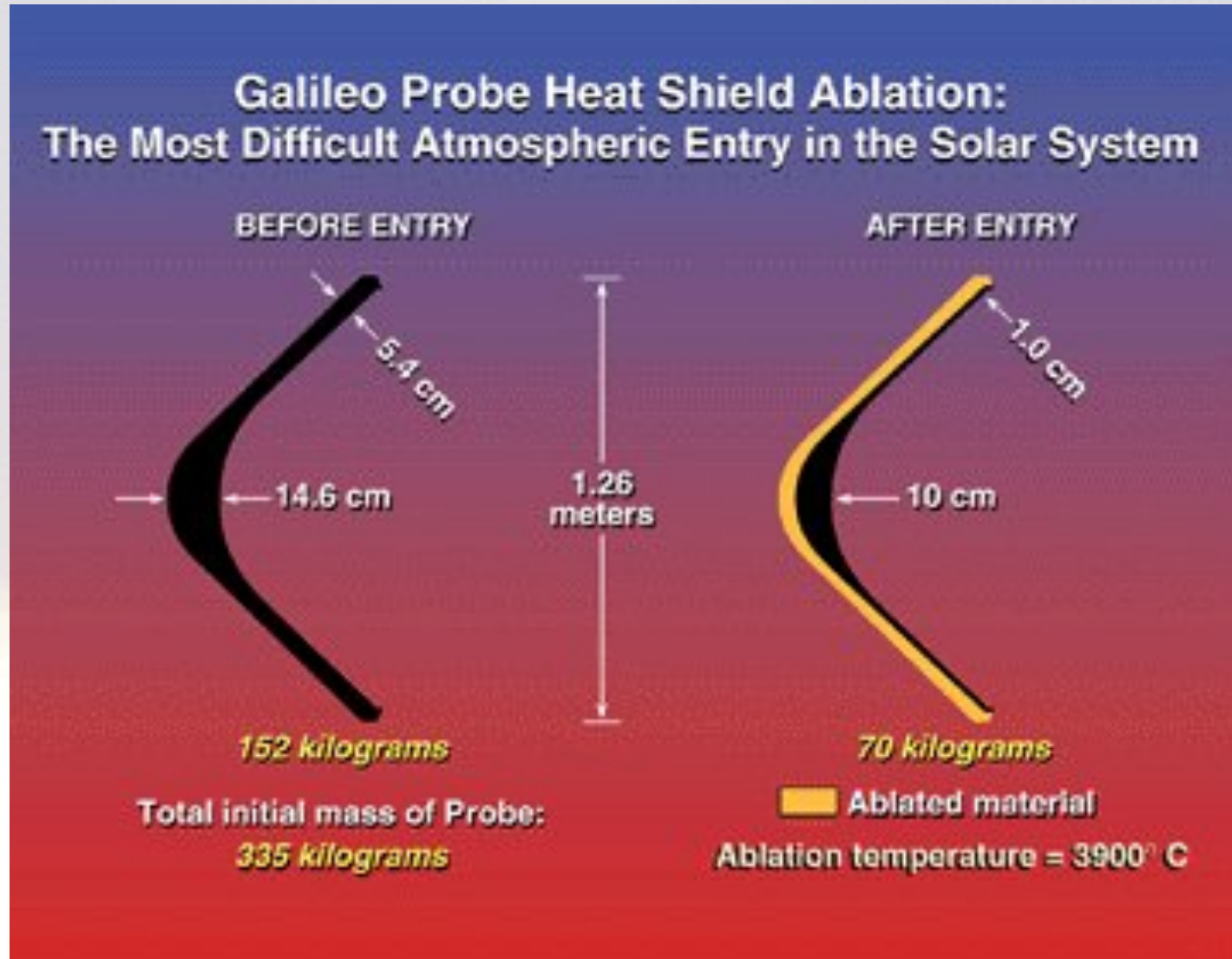


Phenolic Impregnated Carbon Ablator (PICA)

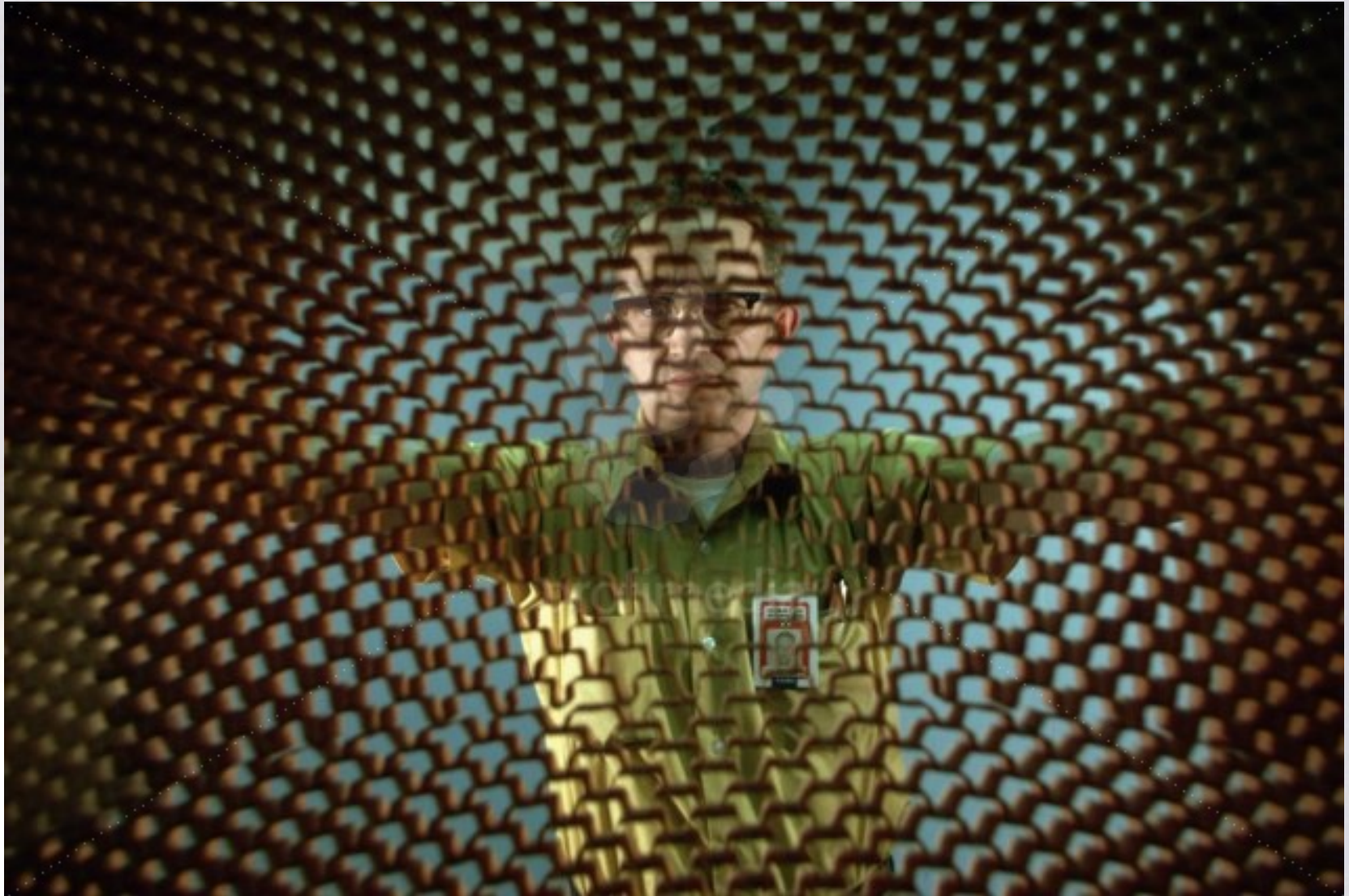




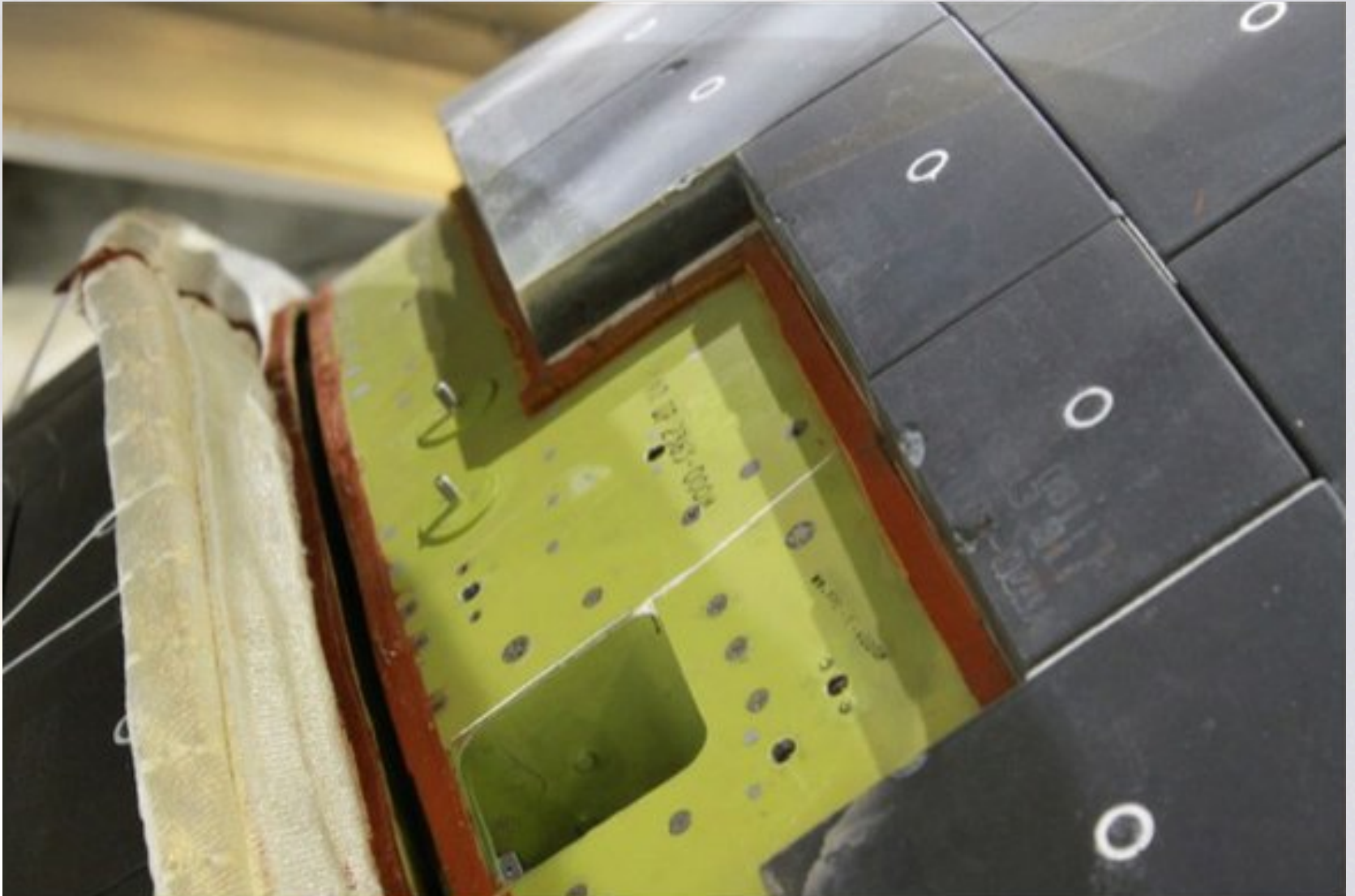
# Galileo Jupiter Probe Heat Shield



# Heat Shield Internal Structure



# Shuttle Tile Installation



# Inflatable Heat Shield (Suborbital Test)

