# Entry Vehicle Design

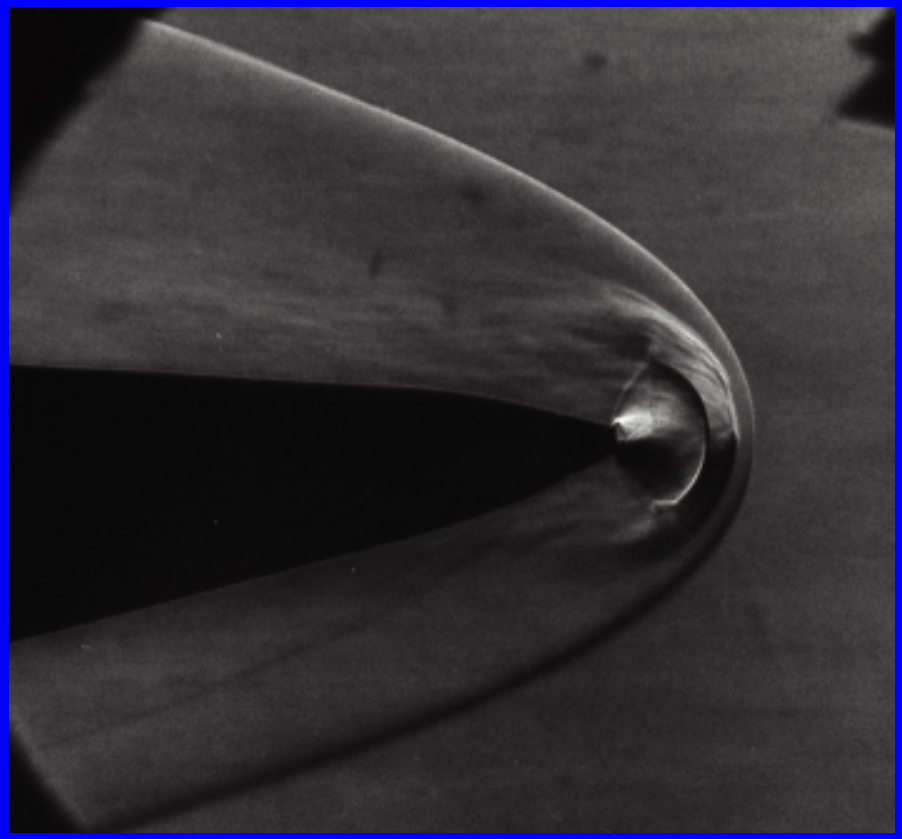
- Everything

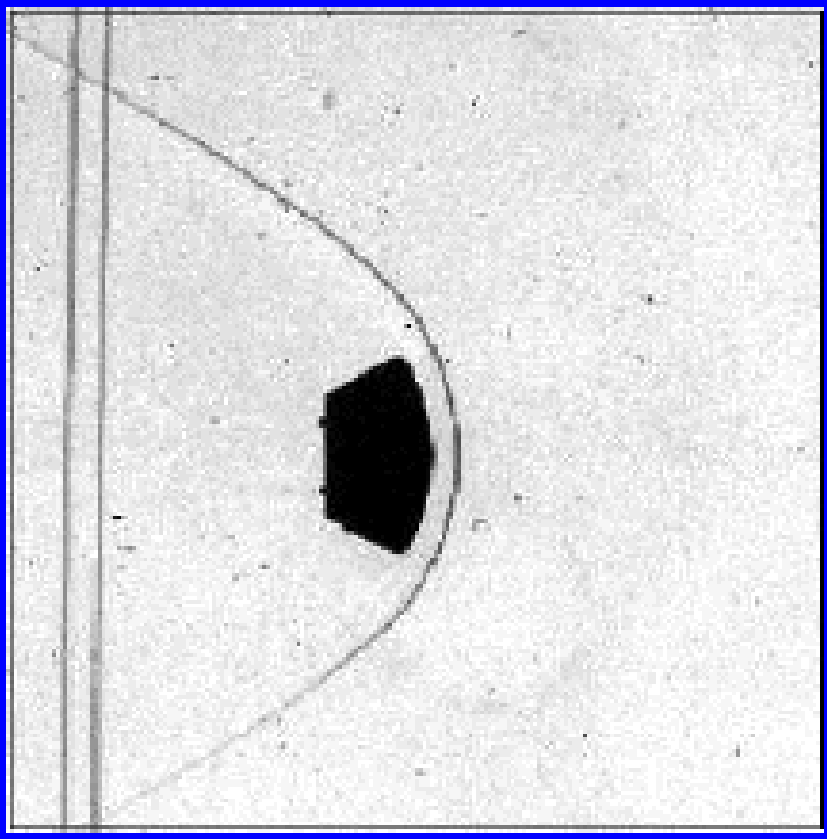
UNIVERSITY OF MARYLAND

# Energy in Orbit

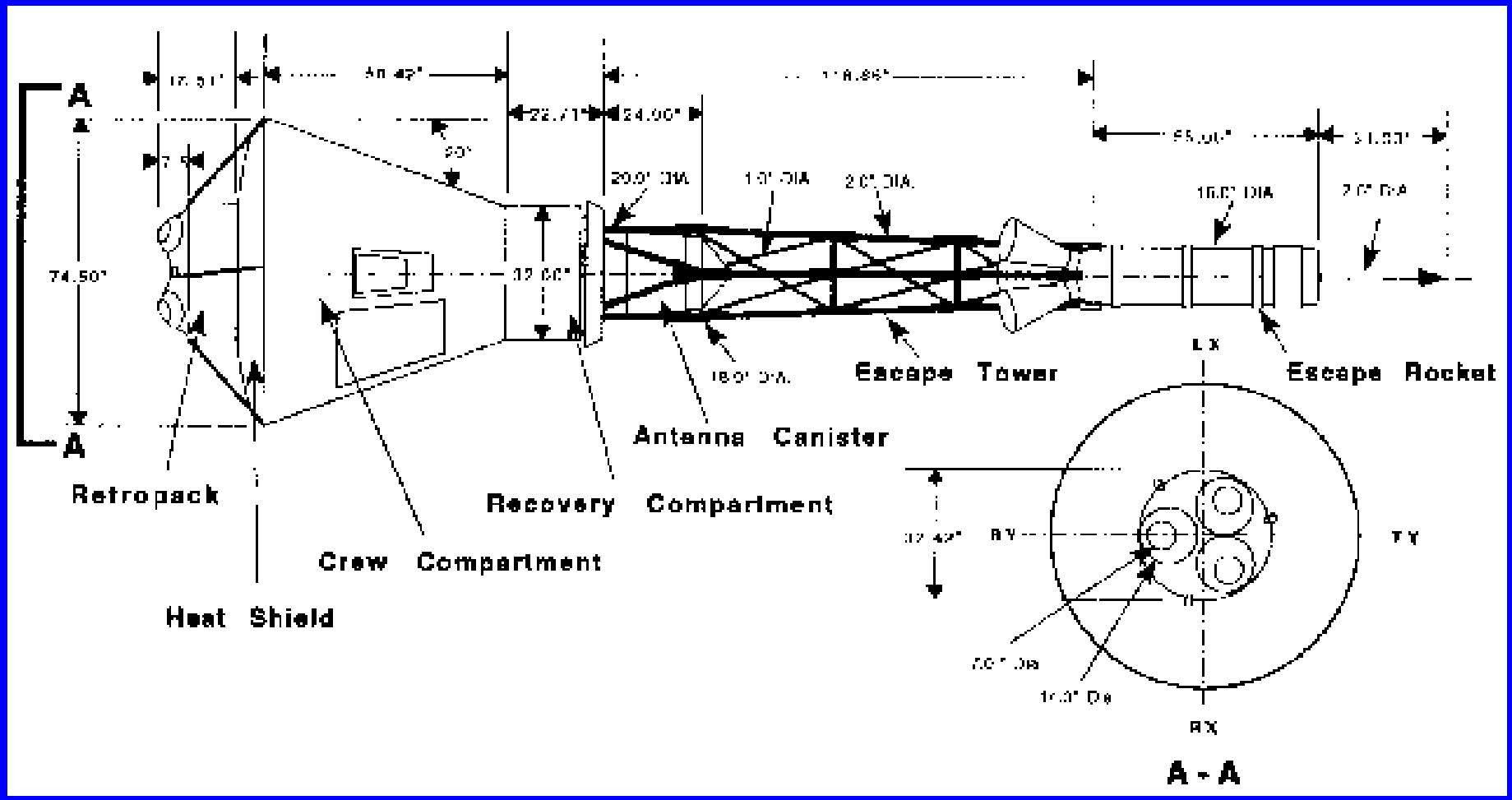
- For 1 kg in a 500 km orbit:
  - Kinetic Energy = $2.9 \times 10^7$ J
  - Potential Energy = $4.9 \times 10^6$ J
- Assuming primary deceleration occurs over a period of ~10 minutes, the average heating rate is 282 kW/kg!!!

# Hypersonic Flow Around Entry Vehicles

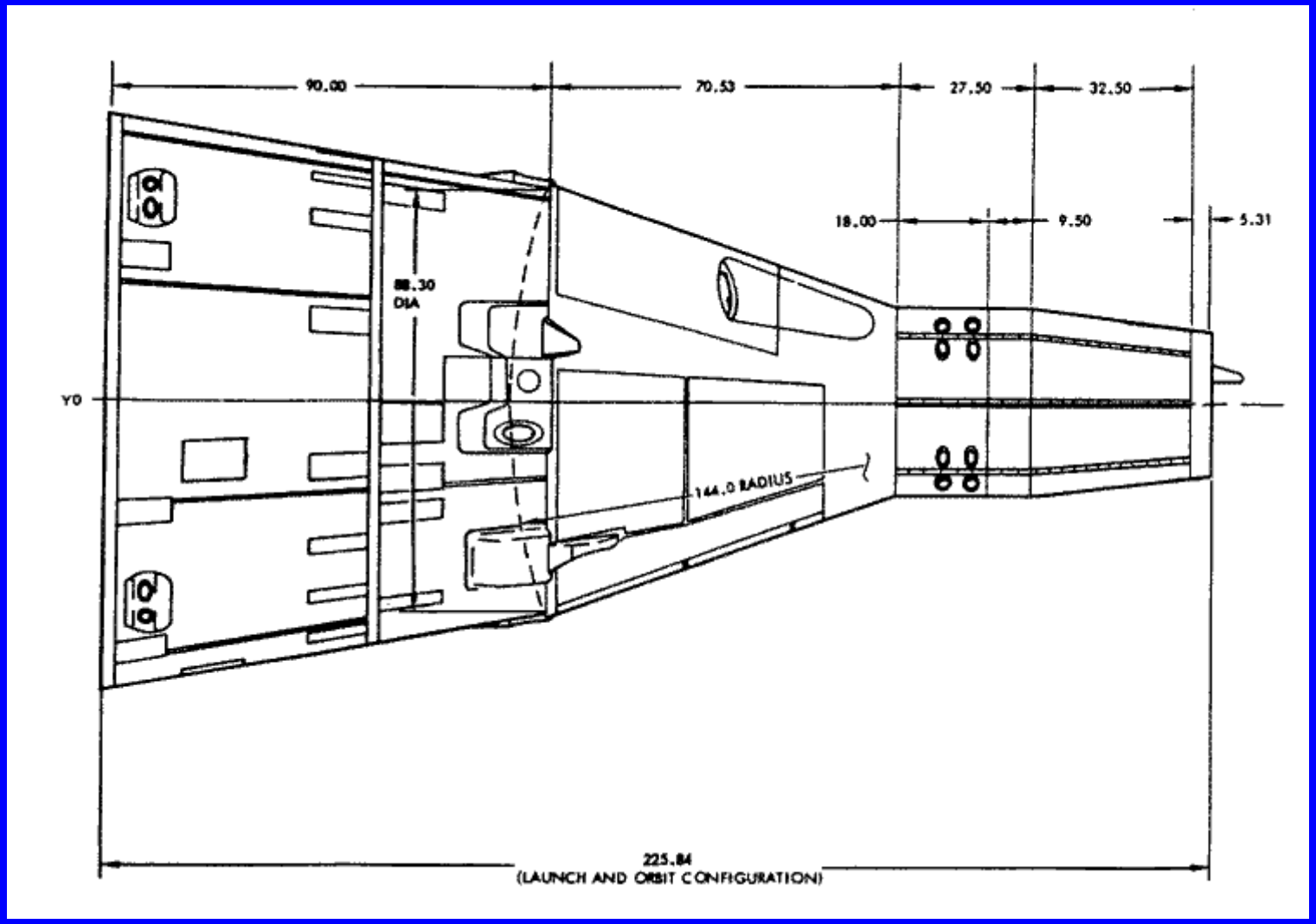




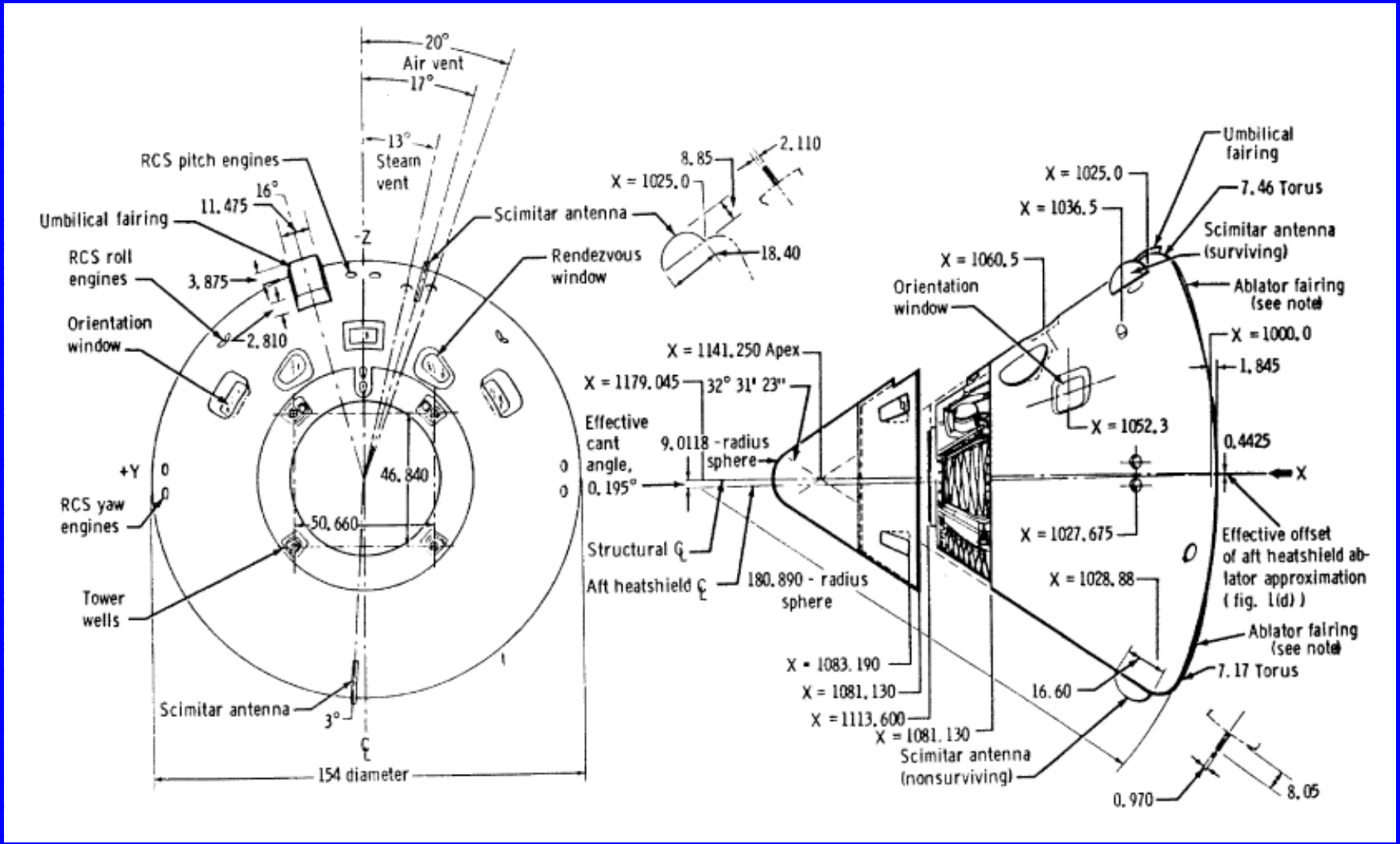
# Mercury Spacecraft Configuration



# Gemini Spacecraft Configuration



# Apollo Command Module Configuration



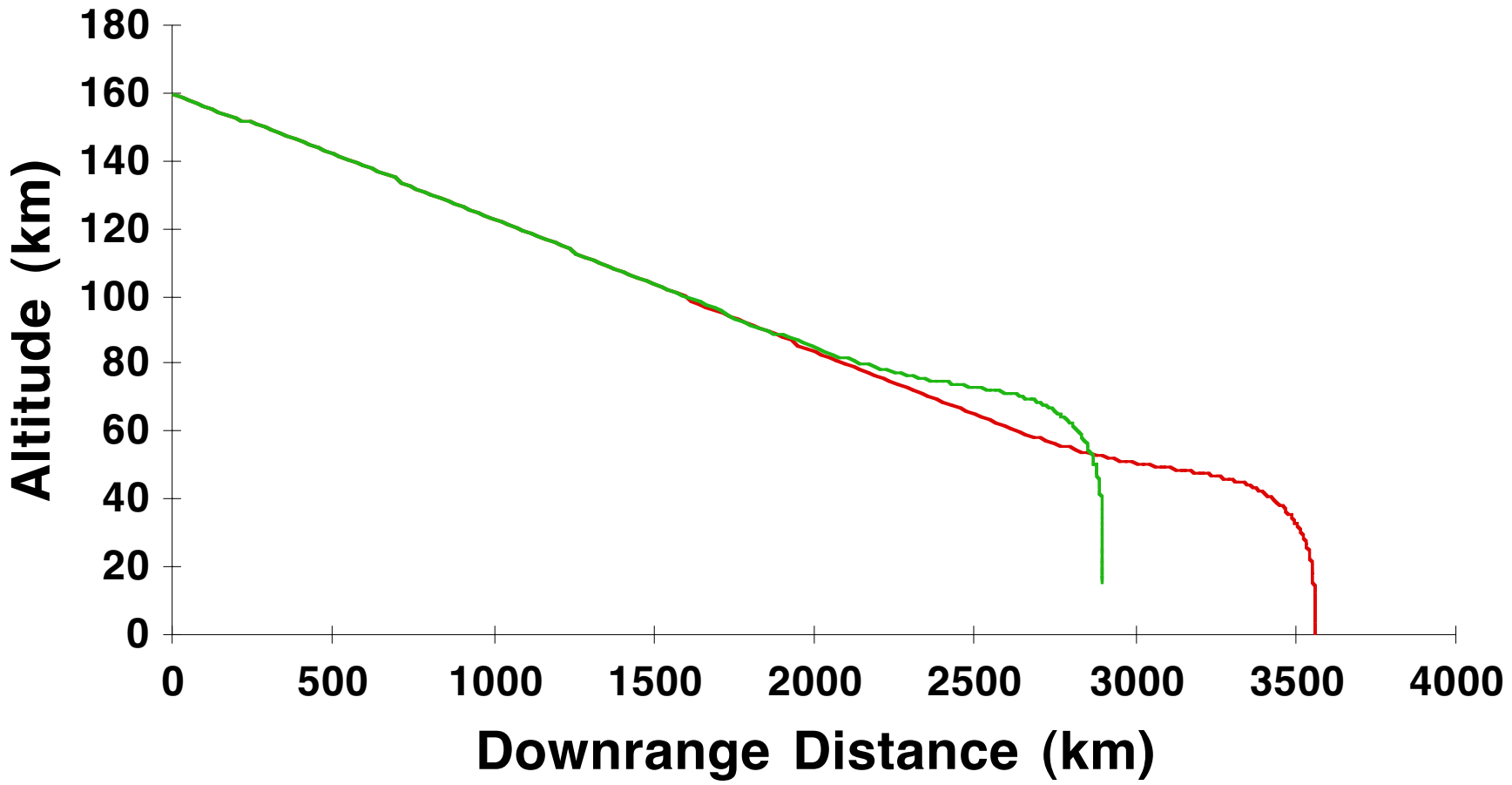
# Chapman Heating Equation

- Empirical formula for convective heating at stagnation point

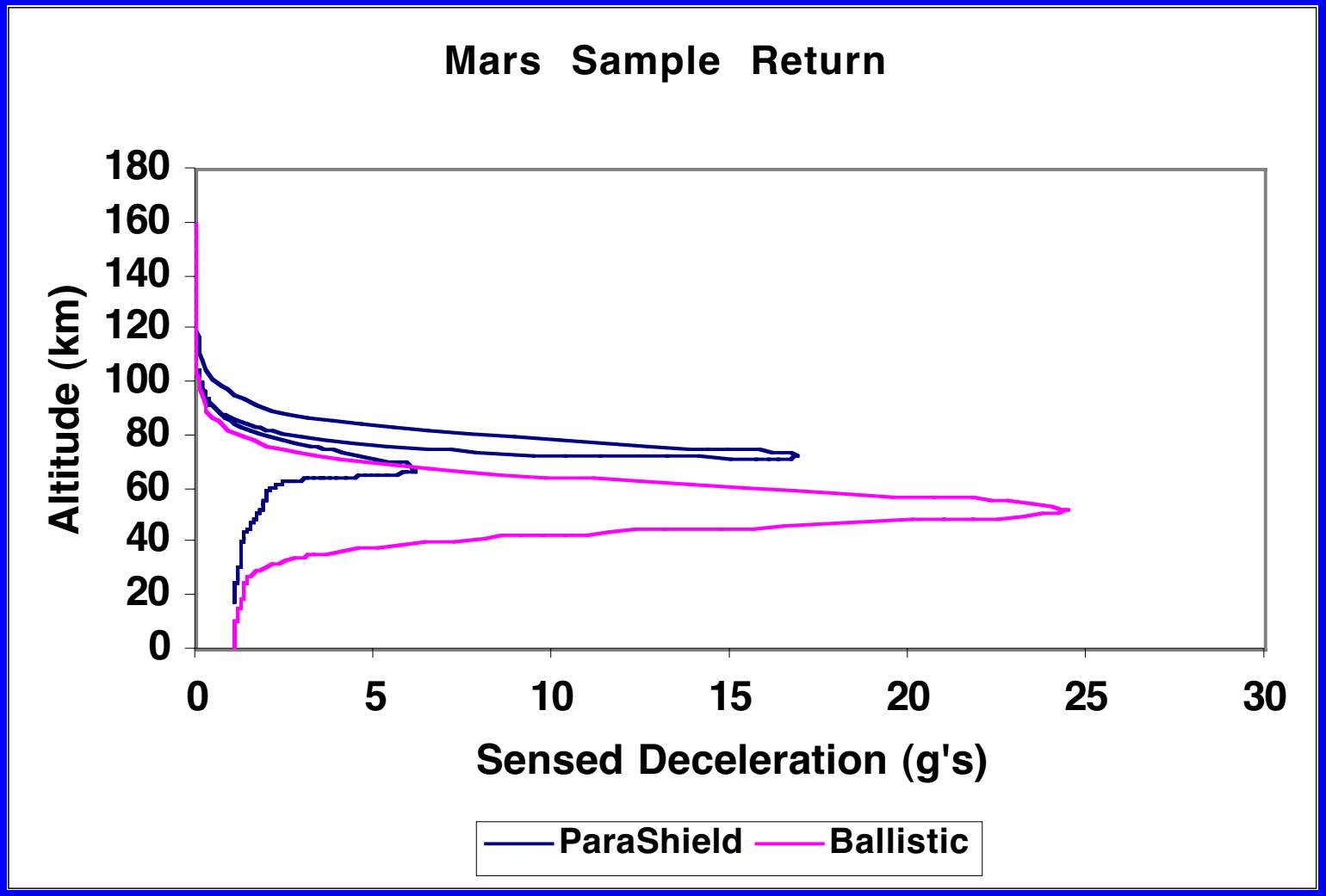
$$\dot{q} = 17\left(\frac{\rho}{R}\right)^{1/2}\left(\frac{v}{1000}\right)^{3}$$

- Where
  - $\dot{q}$ is heat flux (BTU/ft$^2$-sec)
  - R is leading edge radius (ft)
  - v is flight velocity (ft/sec)
  - $\rho$ is atmospheric density (slugs/ft$^3$)

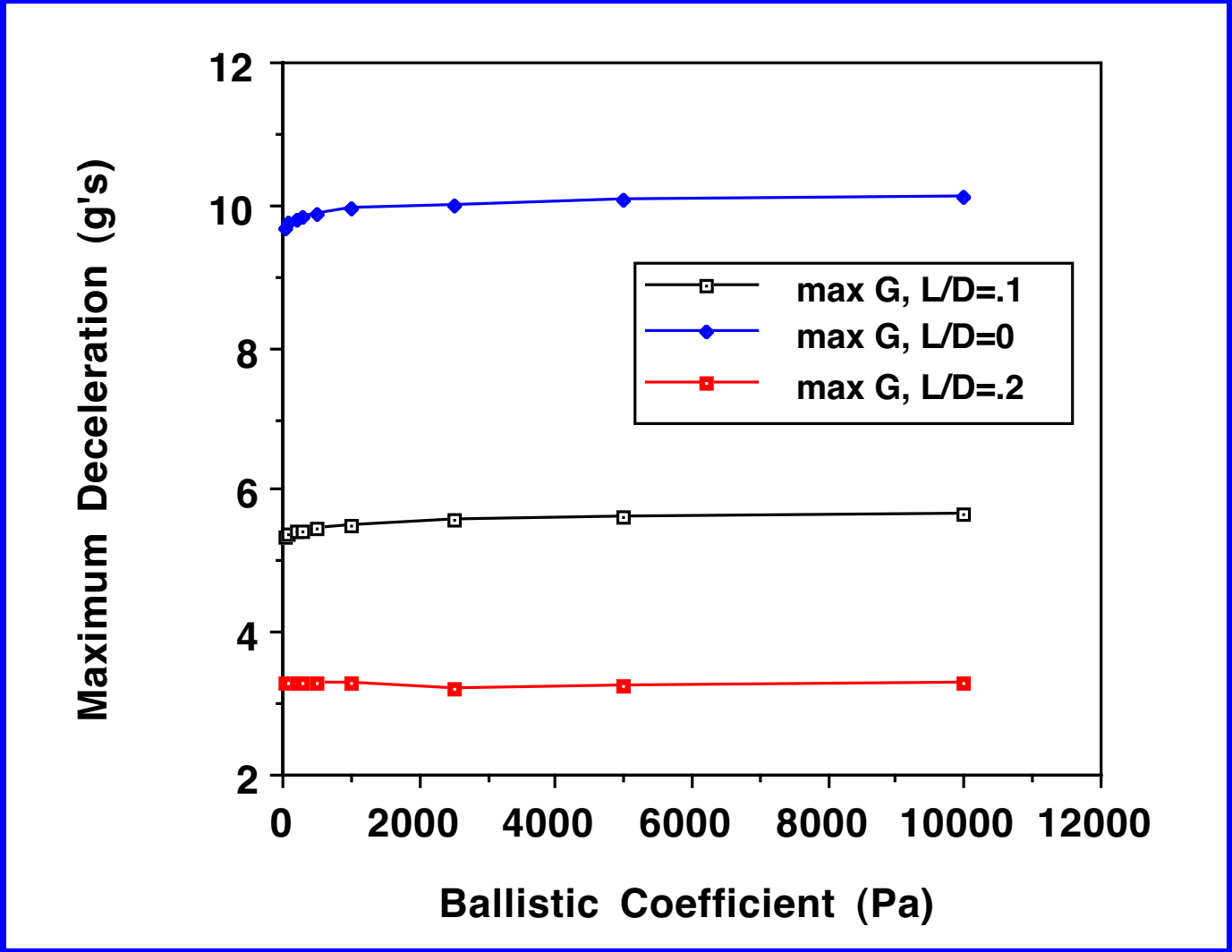
# Entry Trajectories vs. Ballistic Coefficient



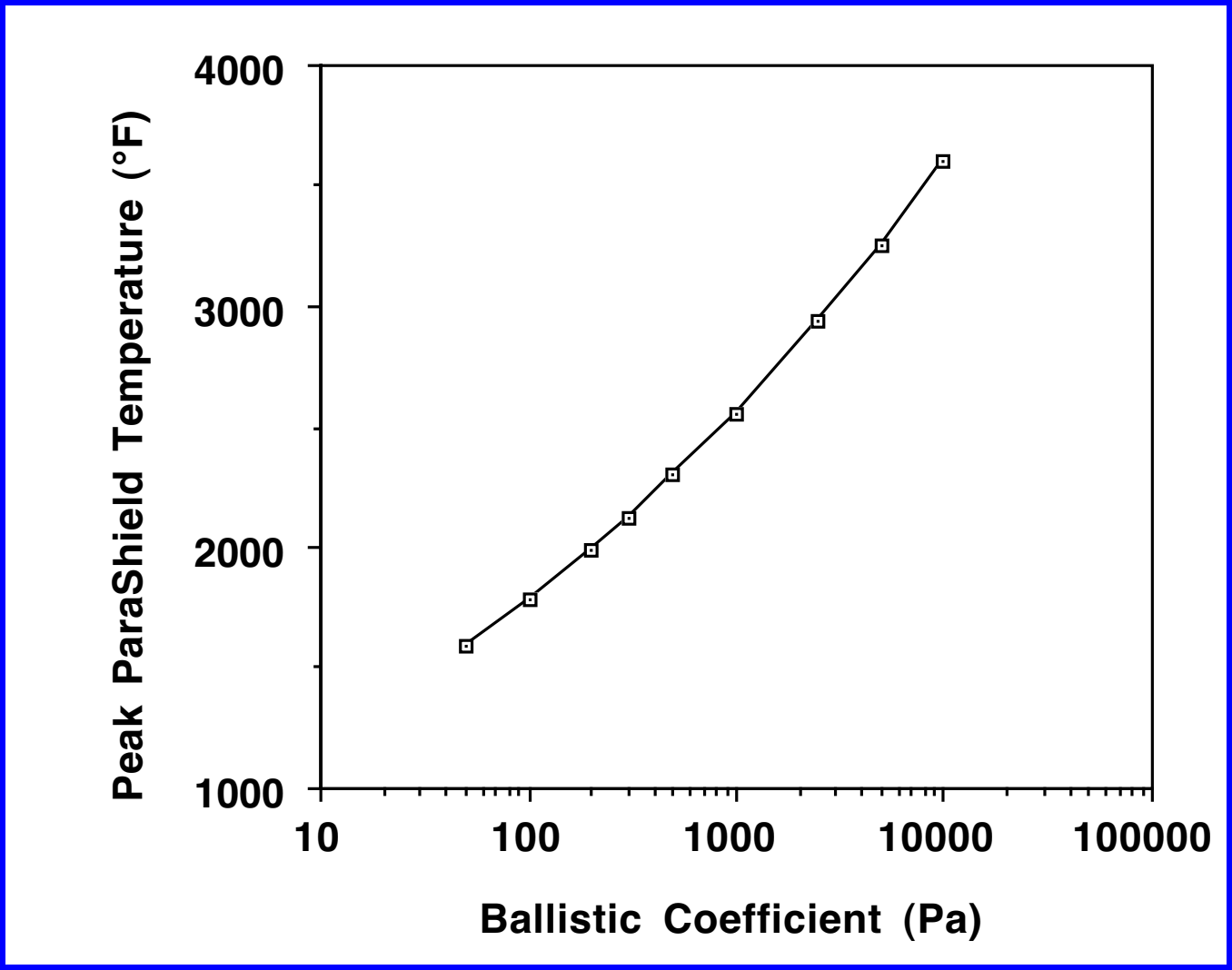
# Acceleration vs. Altitude



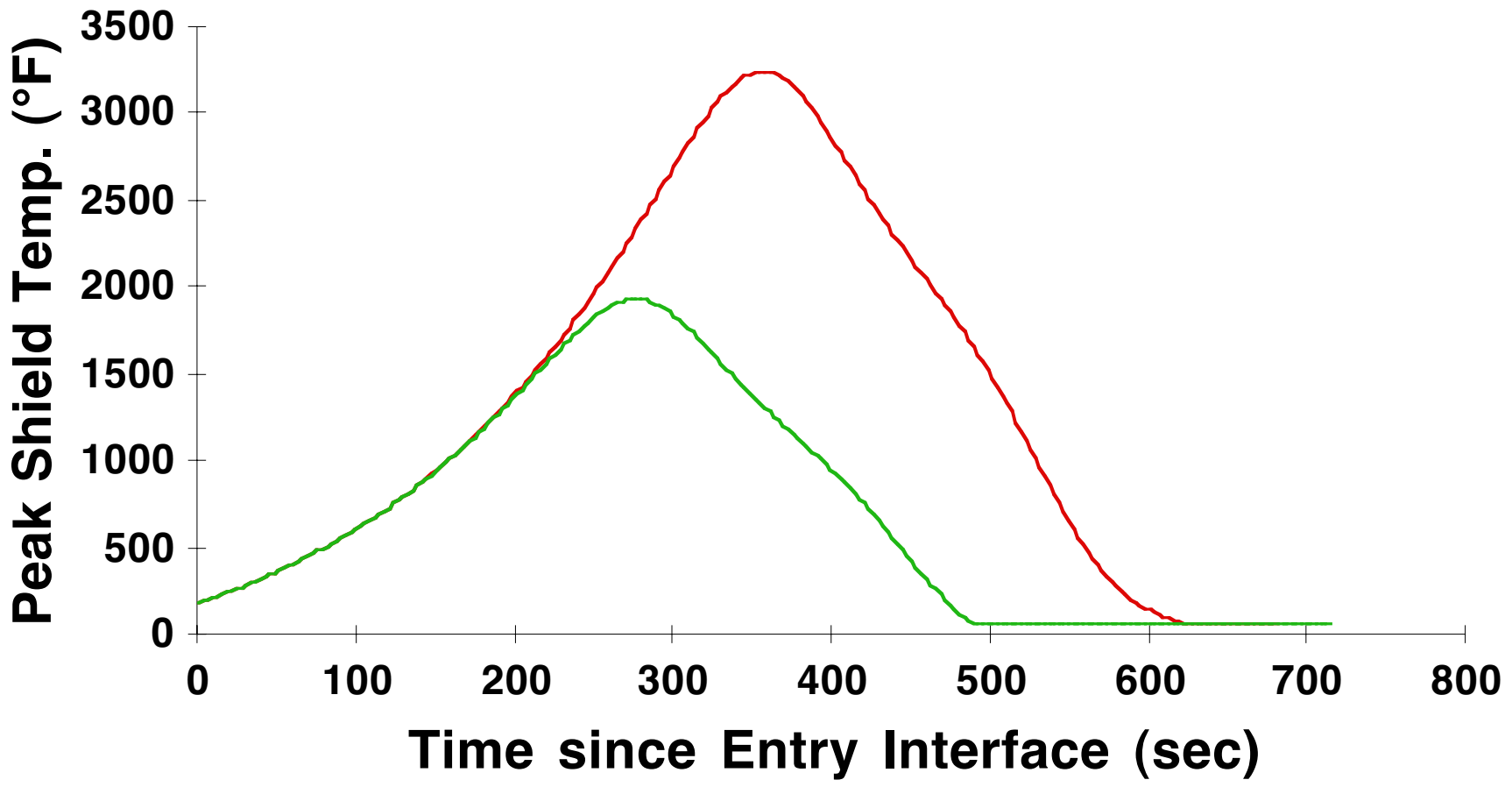
# Maximum Decel vs. L/D



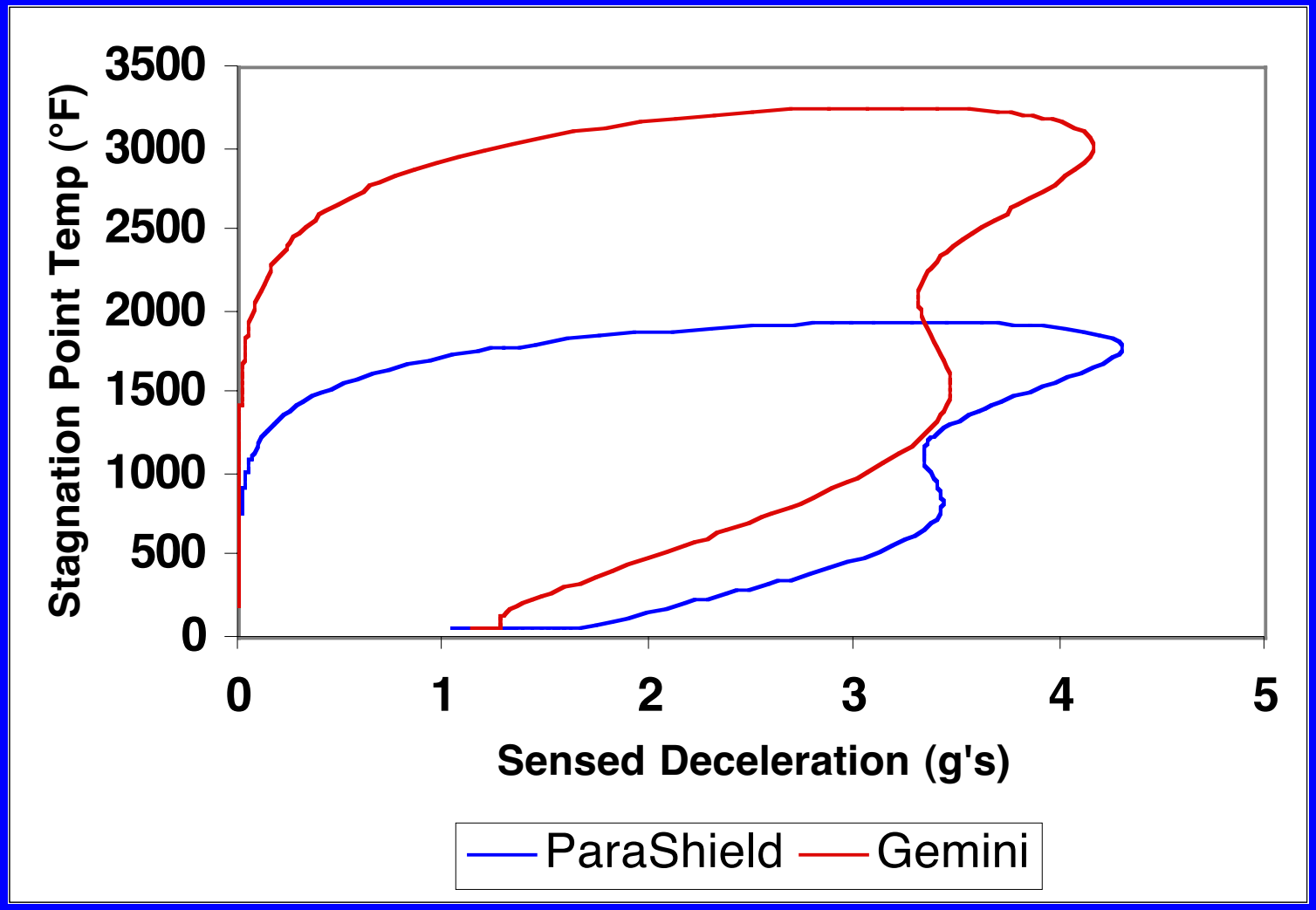
# Peak Temperature vs. Ballistic Coefficient



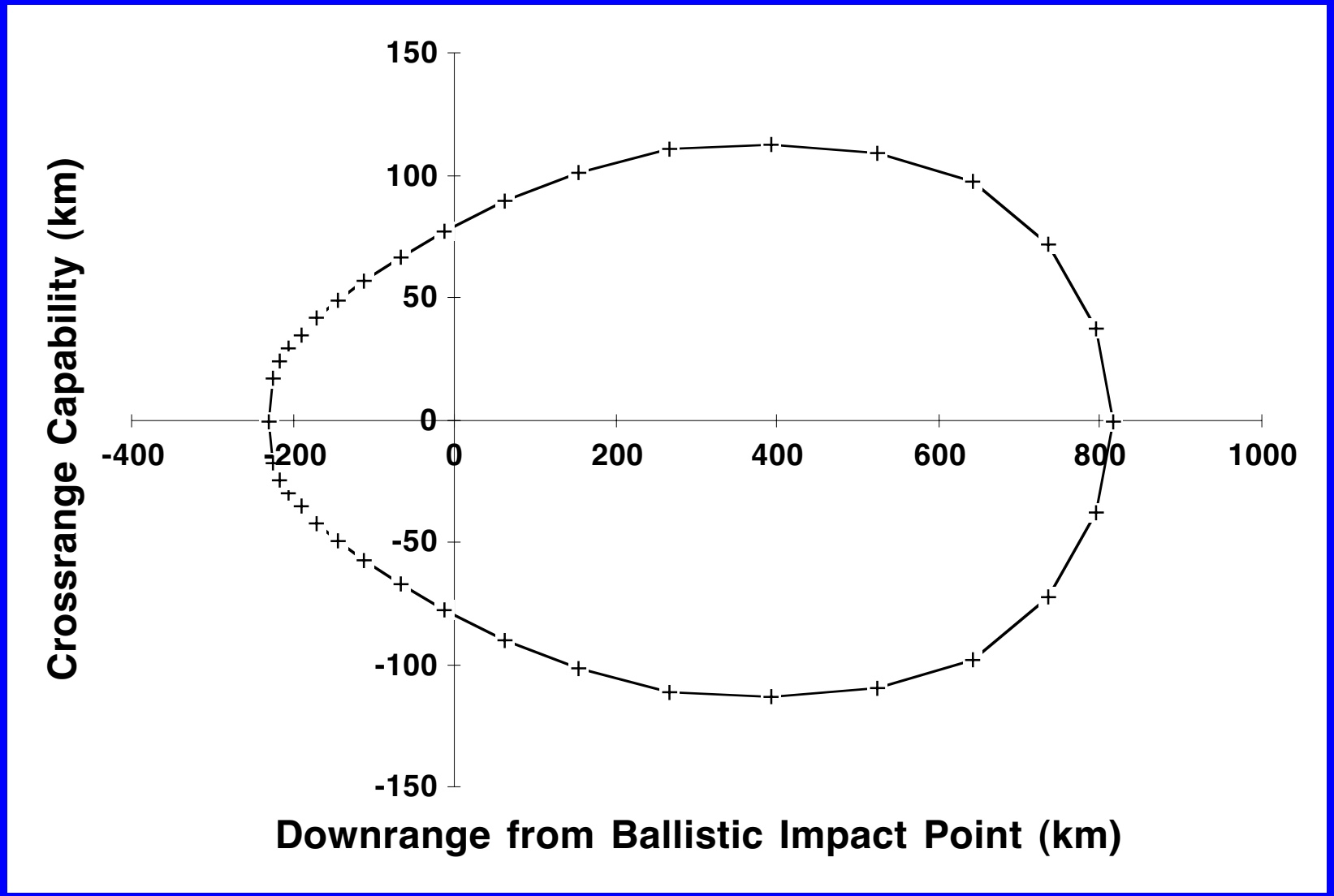
# Entry Temperature vs. Ballistic Coefficient



# Deceleration vs. Temperature

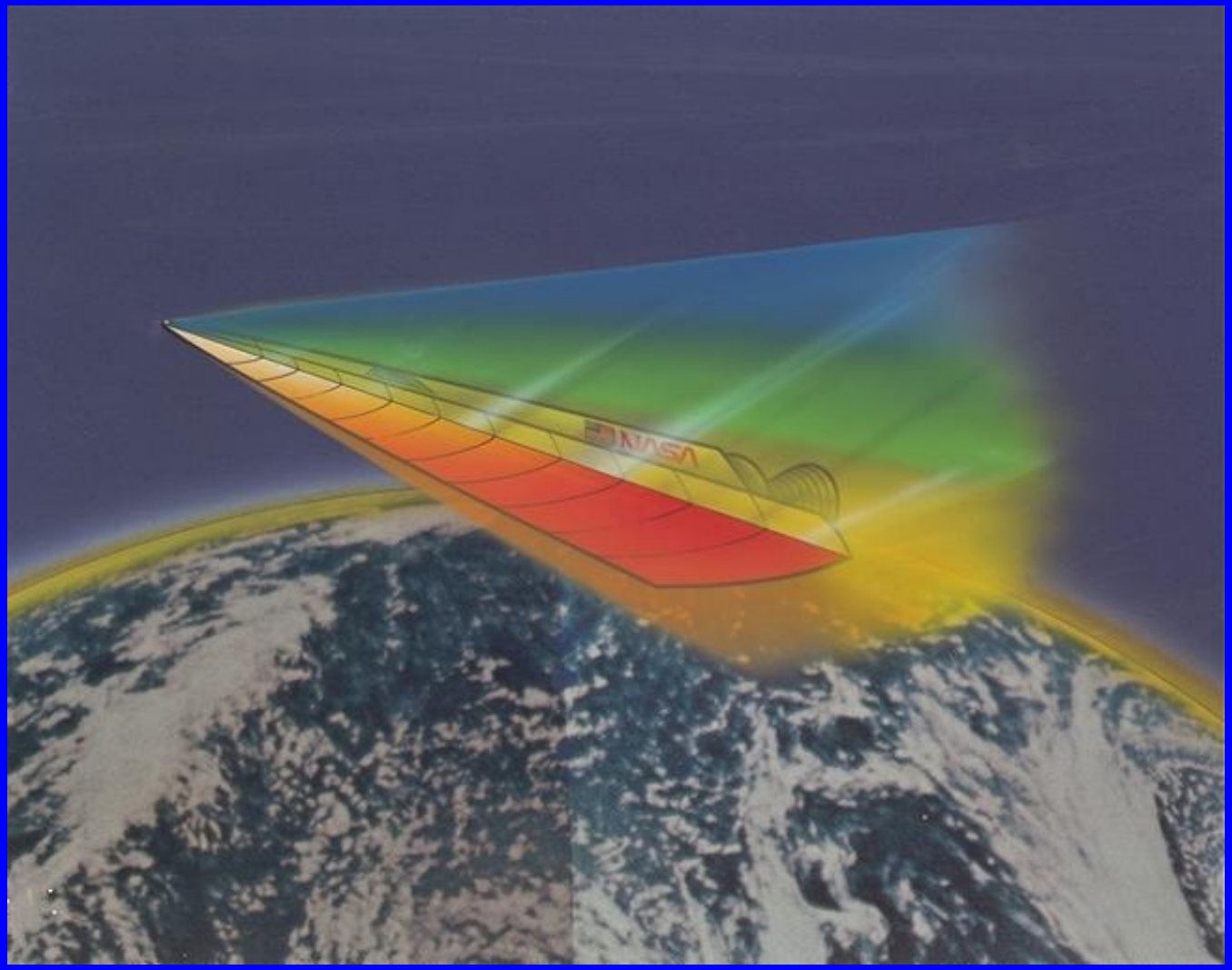


# Typical Entry Landing Footprint (L/D=0.23)



# Lifting Body (X-38)

# High Hypersonic L/D Vehicle ("Waverider")



# ParaShield Vehicle