Entry Vehicle Design

• Everything
Energy in Orbit

• For 1 kg in a 500 km orbit:
  - Kinetic Energy = 2.9x10^7 J
  - Potential Energy = 4.9x10^6 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

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Gemini Spacecraft Configuration

(Additional notes or text about the Gemini spacecraft configuration could be included here if necessary.)
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

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Graph shows the relationship between altitude (km) and downrange distance (km) for different ballistic coefficients.
Acceleration vs. Altitude

Mars Sample Return

Sensed Deceleration (g's)

Altitude (km)

ParaShield  Ballistic
Maximum Decel vs. L/D

- Ballistic Coefficient (Pa)
- Maximum Deceleration (g's)

Graph showing the relationship between maximum deceleration and ballistic coefficient for different L/D values:

- max G, L/D=.1
- max G, L/D=0
- max G, L/D=.2
Peak Temperature vs. Ballistic Coefficient

- **Peak ParaShield Temperature (°F)**
- **Ballistic Coefficient (Pa)**

![Graph showing the relationship between peak ParaShield temperature and ballistic coefficient.](image)
Entry Temperature vs. Ballistic Coefficient

![Graph showing Entry Temperature vs. Ballistic Coefficient. The graph plots Peak Shield Temp. (°F) on the y-axis against Time since Entry Interface (sec) on the x-axis. There are two curves, one red and one green, indicating different ballistic coefficients. The peak temperature is around 3000°F.](image-url)
Deceleration vs. Temperature

Sensed Deceleration (g's) vs. Stagnation Point Temp (°F)

- ParaShield
- Gemini

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Typical Entry Landing Footprint (L/D=0.23)

![Graph showing typical entry landing footprint with L/D=0.23. The x-axis represents downrange from ballistic impact point in km, ranging from -400 to 1000 km. The y-axis represents crossrange capability in km, ranging from -150 to 150 km. The graph shows the typical ellipse footprint for landing vehicles.]
Lifting Body (X-38)
High Hypersonic L/D Vehicle ("Waverider")
ParaShield Vehicle