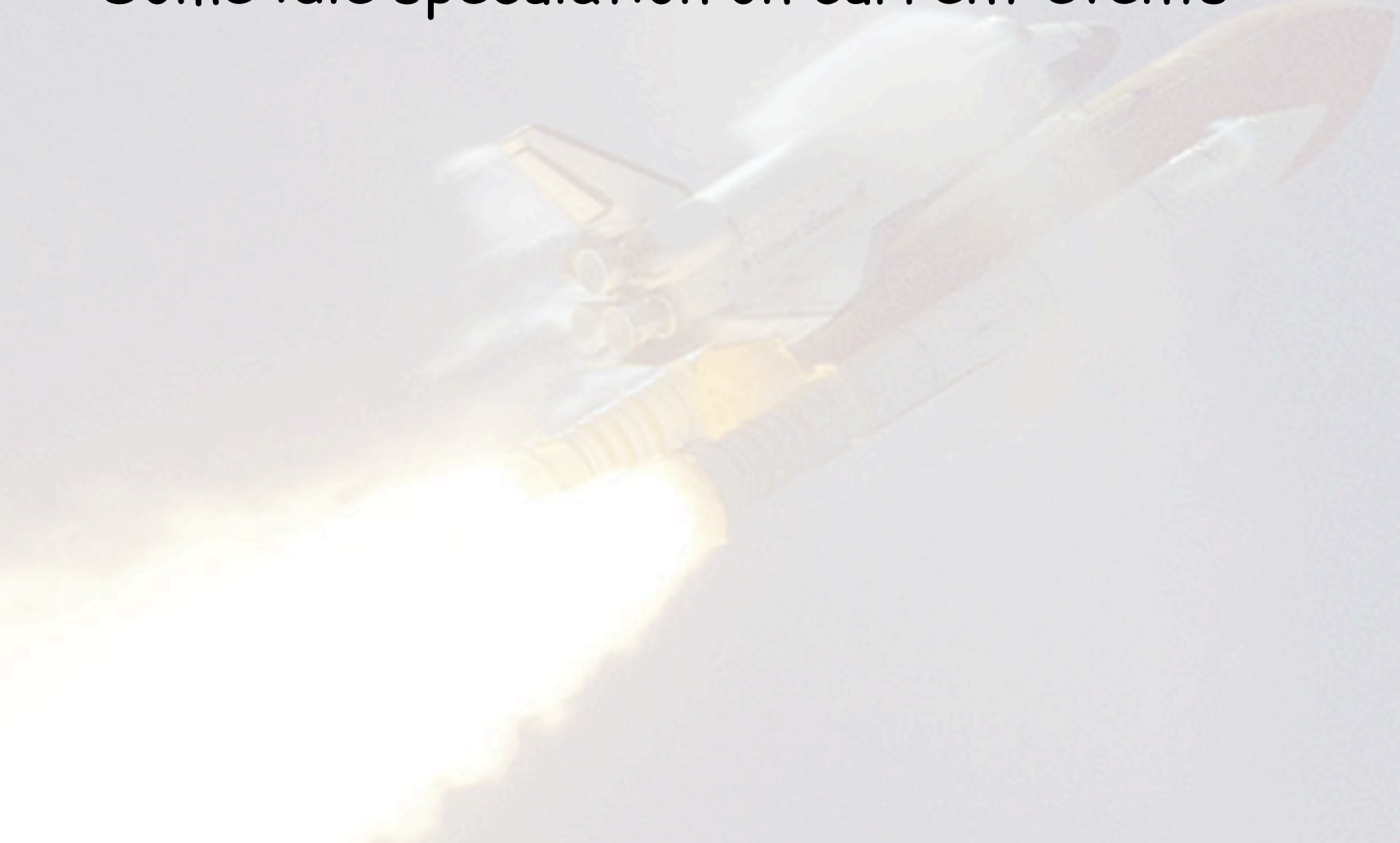


Launch and Entry Vehicles - Wrap-up

- Some idle speculation on current events



Perilous Landings by Soyuz Worry NASA

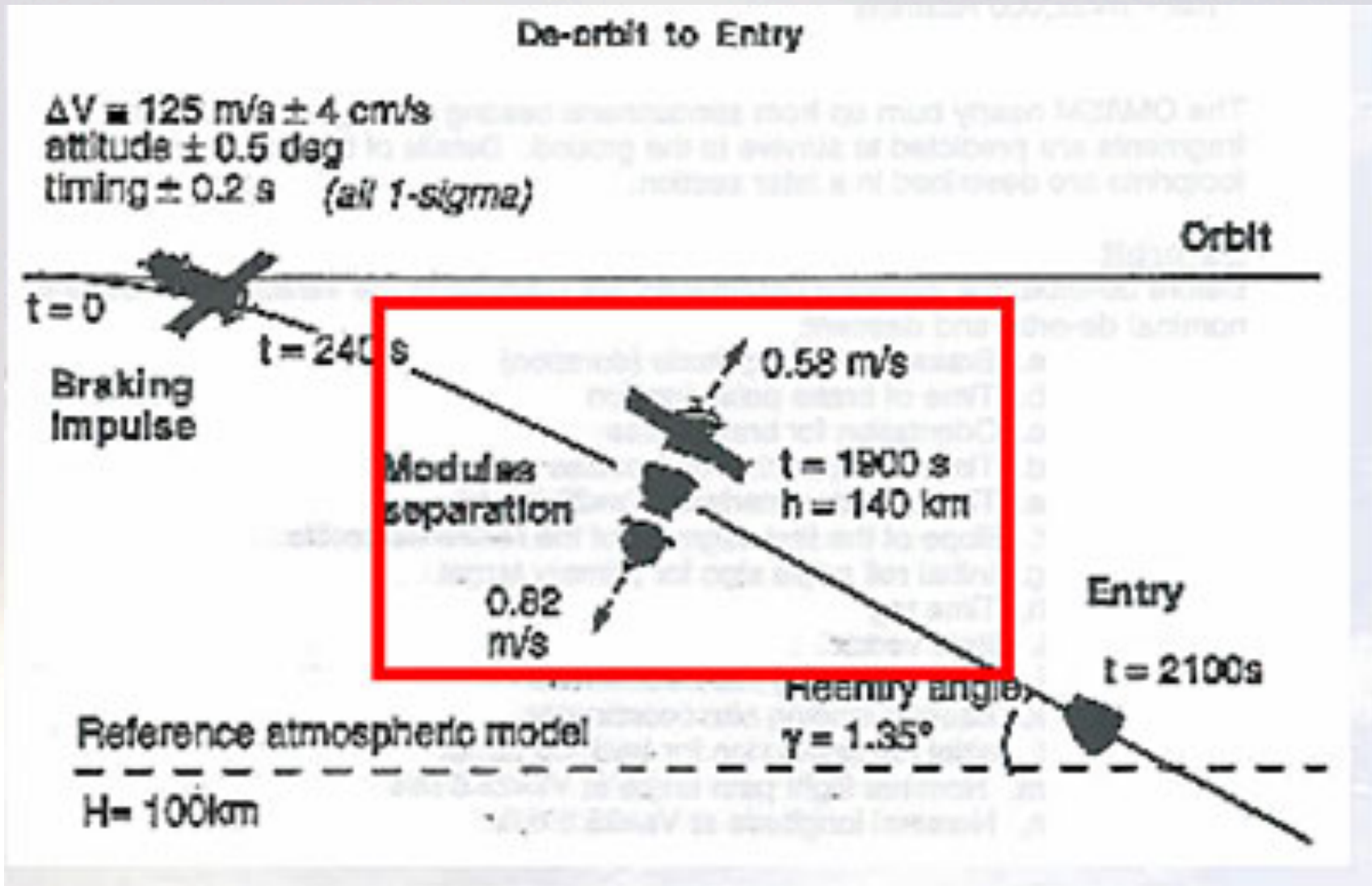
U.S. to Be Dependent on Russian Capsule



Members of the ground crew check the area around the Soyuz capsule. The three astronauts on board, including American Peggy A. Whitson, were uninjured. (By Shamil Zhumatov -- Associated Press)



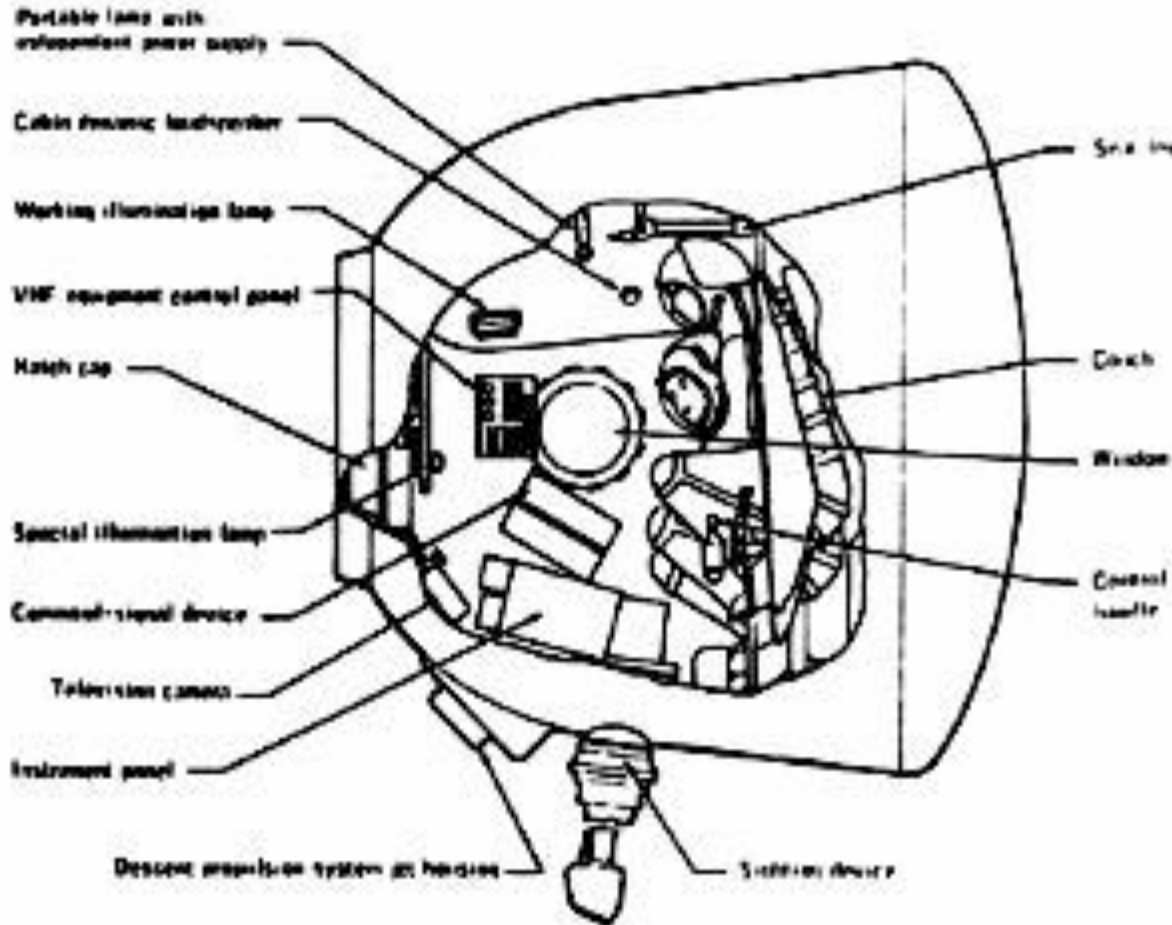
Soyuz Deorbit Milestones



Soyuz 5 Reentry



Soyuz Heat Shield Shape



$$d = 2.2 \text{ m}$$

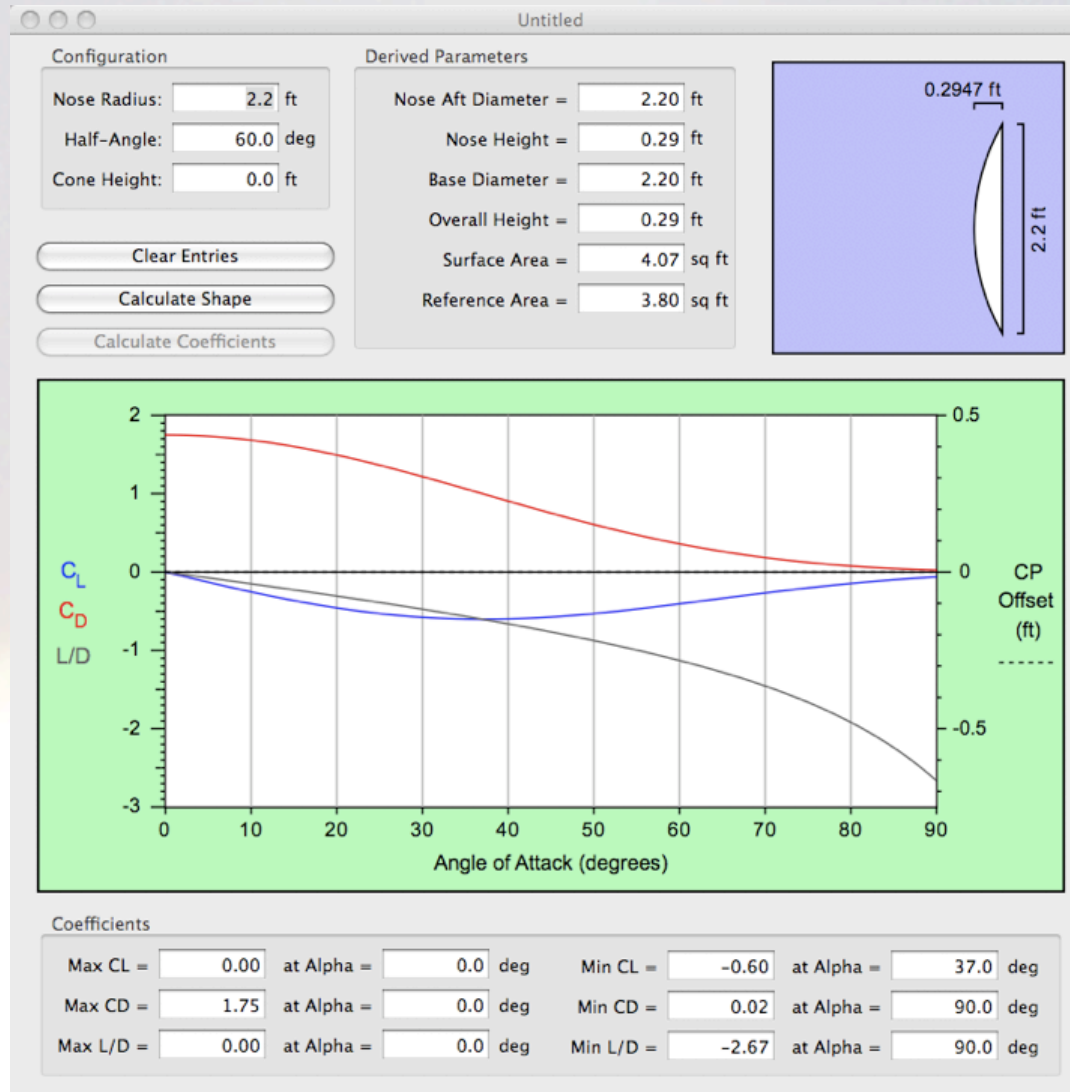
$$\text{depth} \sim 0.3 \text{ m}$$

$$\text{half-angle} \sim 30 \text{ deg}$$

$$R \sim 2.2 \text{ m}$$

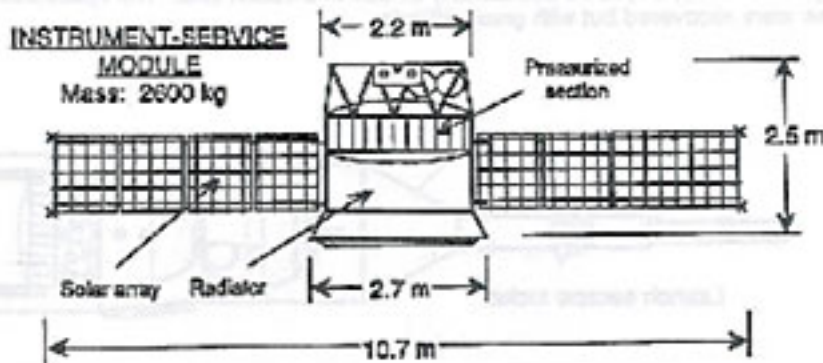
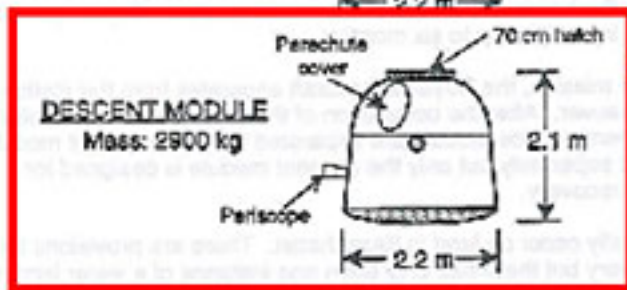
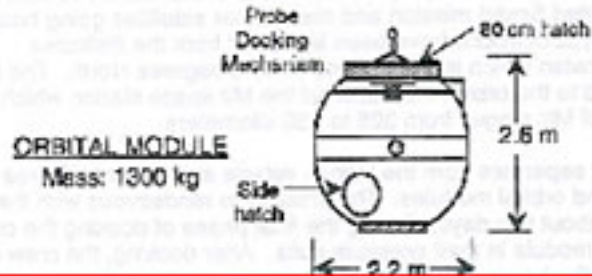


Soyuz Newtonian Aerodynamics



Estimation of Soyuz Entry Parameters

The instrument-service module separates from the descent module following the deorbit maneuver and disintegrates during entry into the atmosphere.



$$c_D \sim 1.75$$

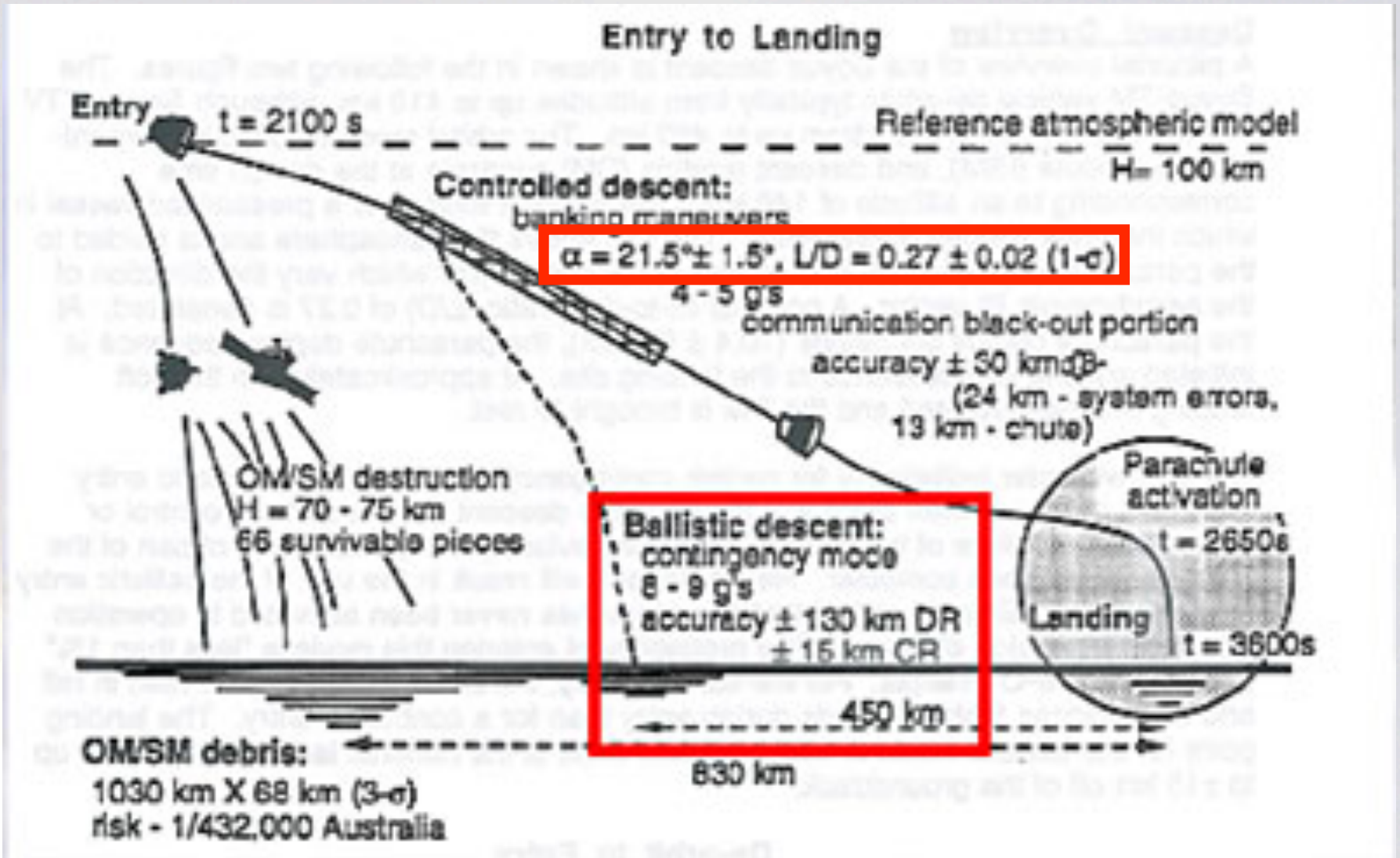
$$A = \pi r^2 = \pi (1.1)^2 = 3.8 \text{ m}^2$$

$$\beta = \frac{2900 \text{ kg}}{(1.75)(3.8 \text{ m}^2)} = 436 \frac{\text{kg}}{\text{m}^2}$$

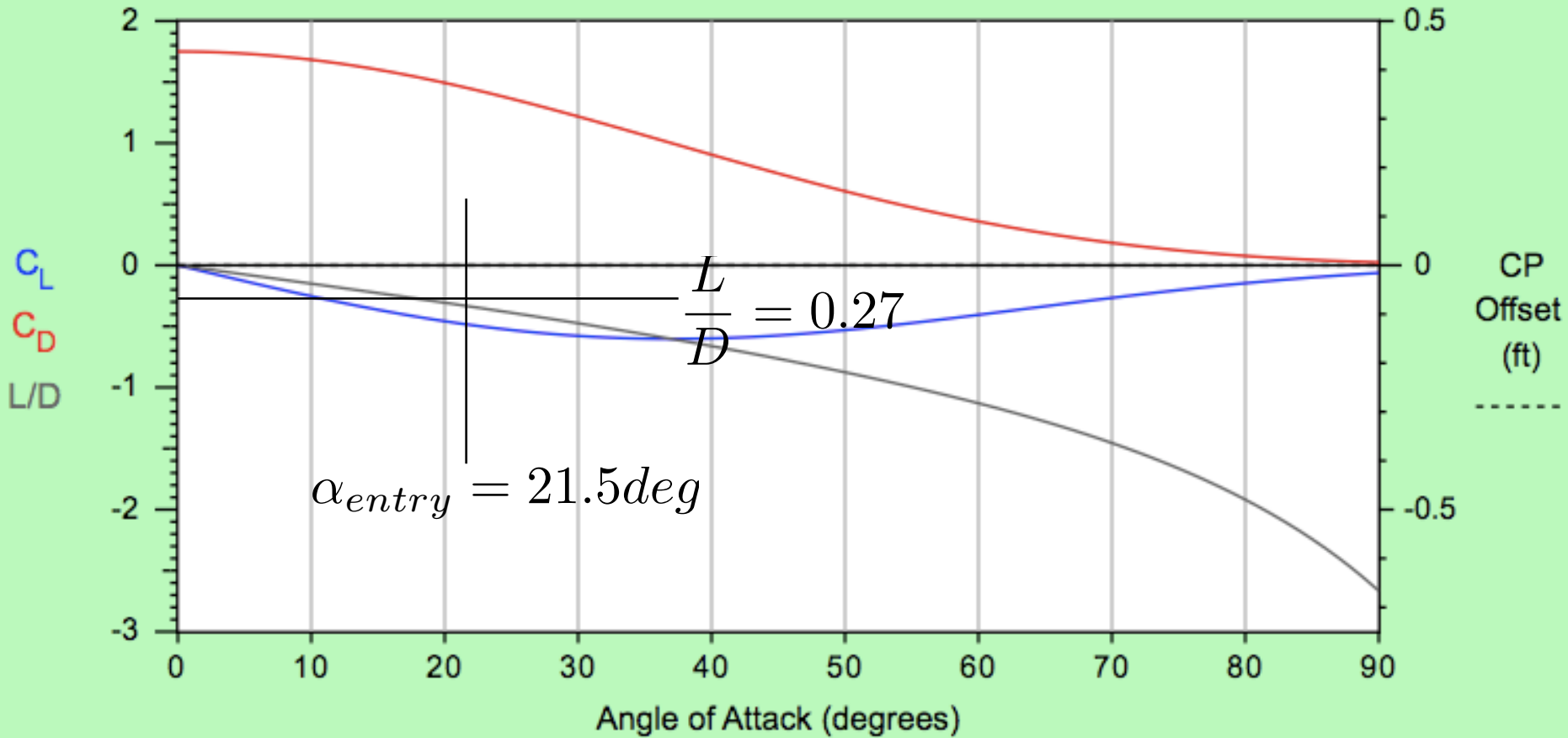
$$\beta = 4270 \text{ Pa}$$



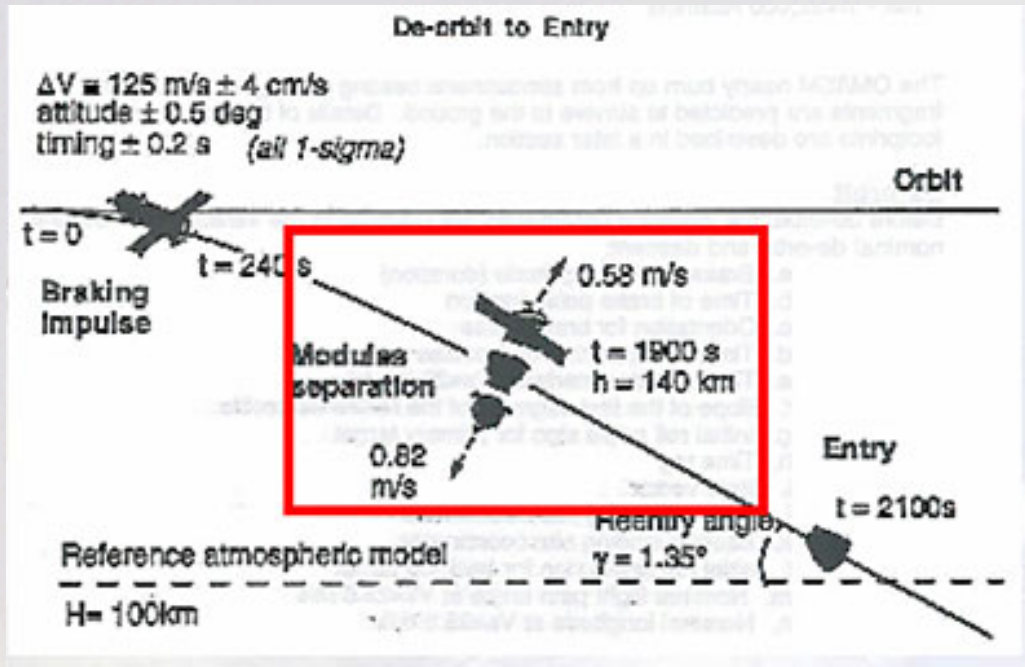
Published Flight Characteristics



Predicted and Published Soyuz Parameters



Soyuz Deorbit Reconstruction



International Space Station

$$r = 6720 \text{ km}$$

$$v = \sqrt{\frac{\mu}{r}} = 7702 \text{ m/sec}$$

$$v_{a,deorbit} = 7577 \text{ m/sec}$$

$$a_{deorbit} = \left[\frac{2}{r_a} - \frac{v^2}{\mu} \right]^{-1} = 6510 \text{ km}$$

$$r_p = 2a - r_a = 6300 \text{ km} \Rightarrow h_p = -78 \text{ km}$$

$$e = \frac{r_a}{a} - 1 = 0.03226$$



Velocity Components in Orbit (continued)

$$\vec{h} = \vec{r} \times \vec{v}$$

$$h = rv \cos \gamma = r \left(r \frac{d\theta}{dt} \right) = r^2 \frac{d\theta}{dt}$$

$$v_r = \frac{r^2 \frac{d\theta}{dt} e \sin \theta}{p} = \frac{he \sin \theta}{p} = \frac{\sqrt{p\mu}}{p} e \sin \theta$$

$$v_r = \sqrt{\frac{\mu}{p}} e \sin \theta$$

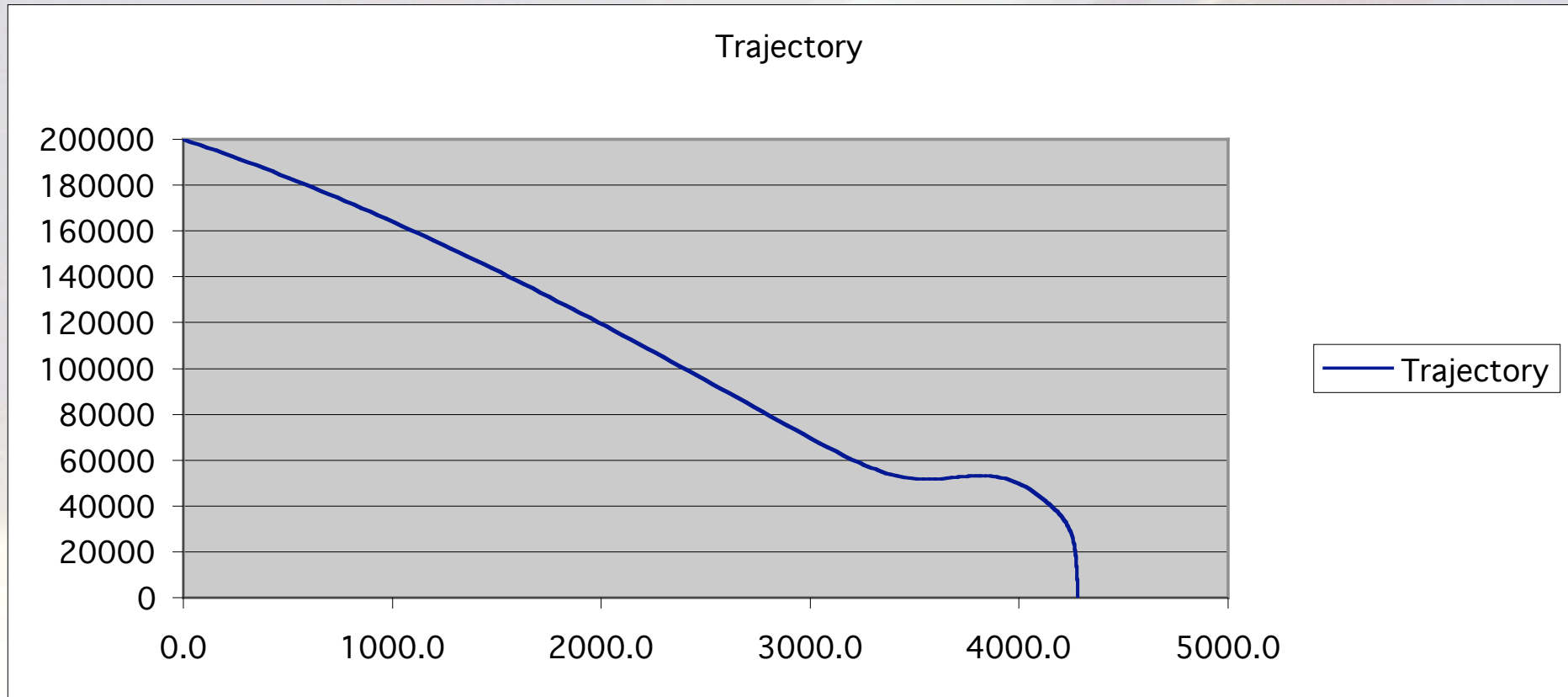
$$v_\theta = r \frac{d\theta}{dt} = r \frac{h}{r^2} = \frac{h}{r} = \frac{\sqrt{p\mu}}{r}$$

$$v_\theta = \sqrt{\frac{\mu}{p}} (1 + e \cos \theta)$$

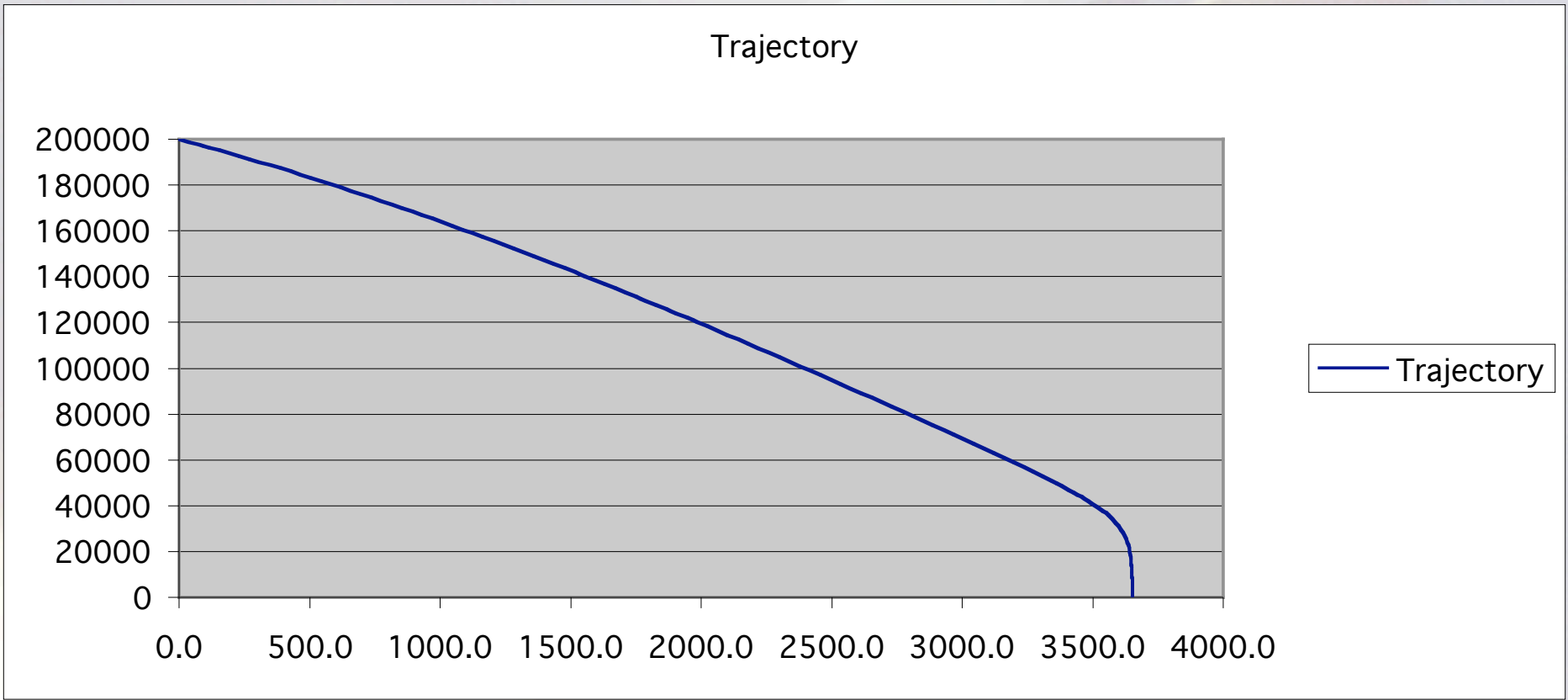
$$\tan \gamma = \frac{v_r}{v_\theta} = \frac{e \sin \theta}{1 + e \cos \theta}$$



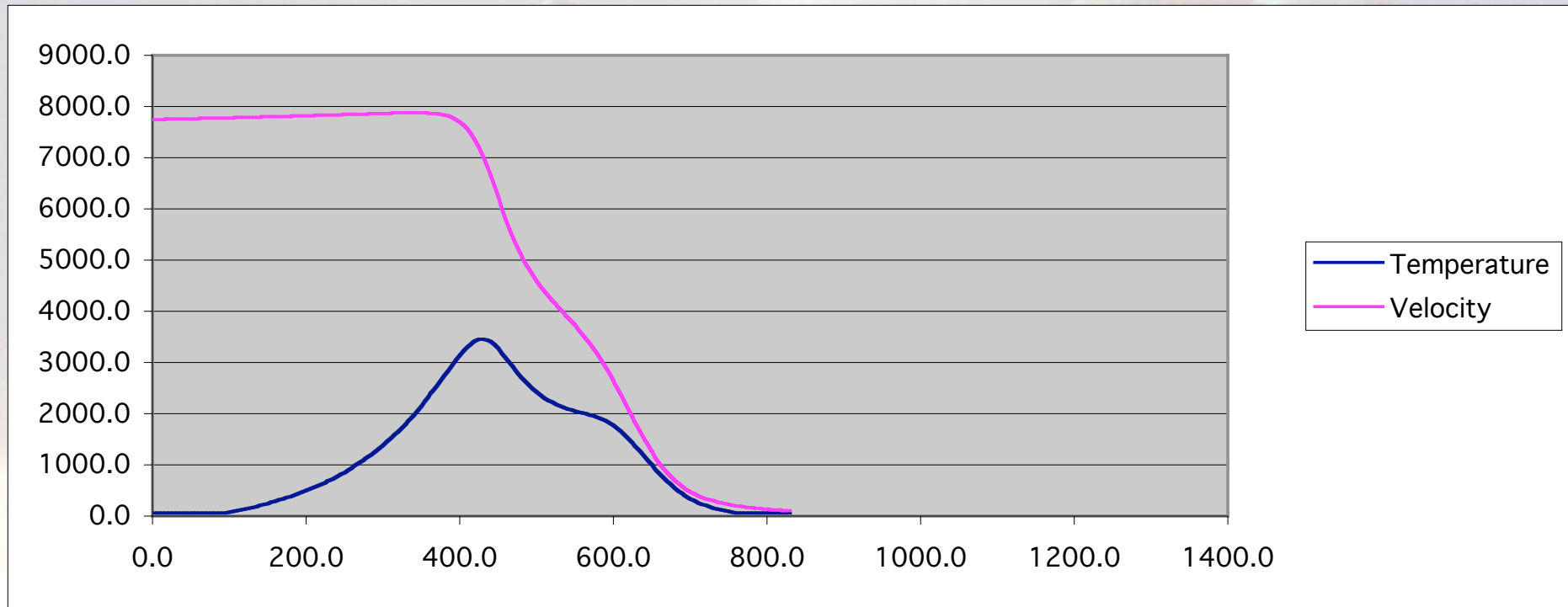
Nominal Entry Trajectory



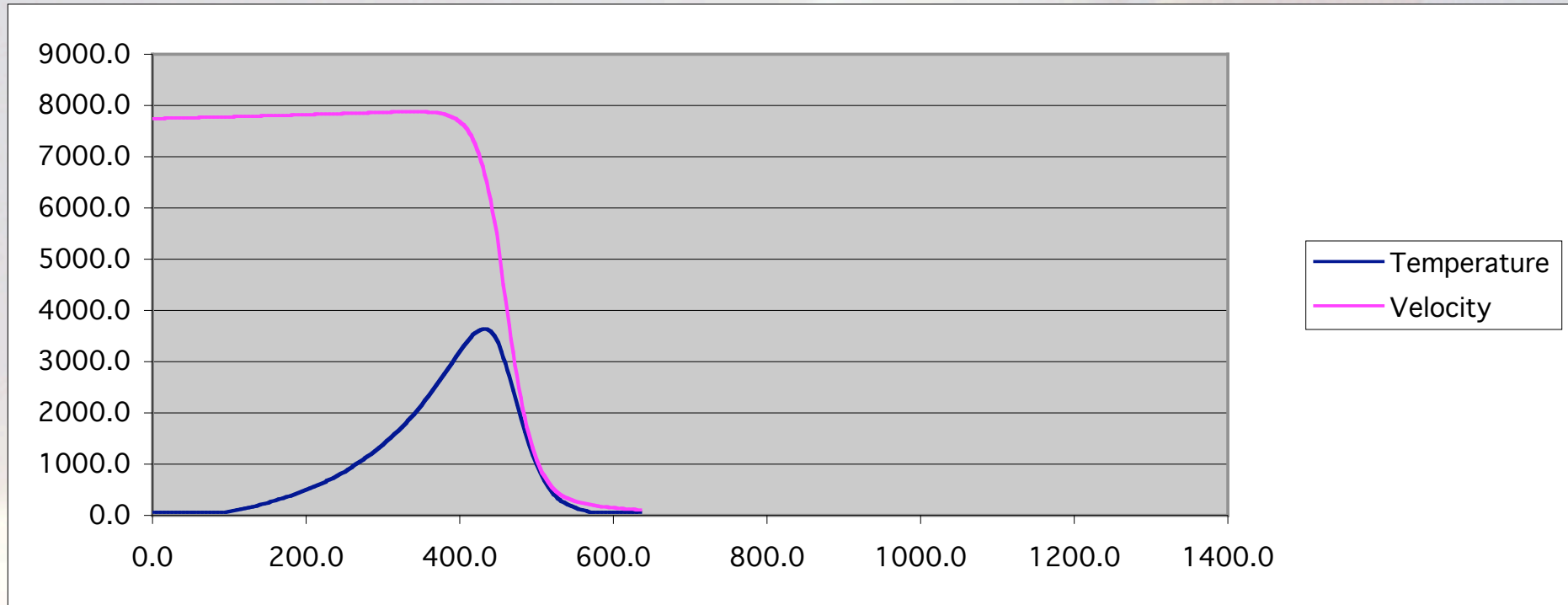
Trajectory (Ballistic Entry)



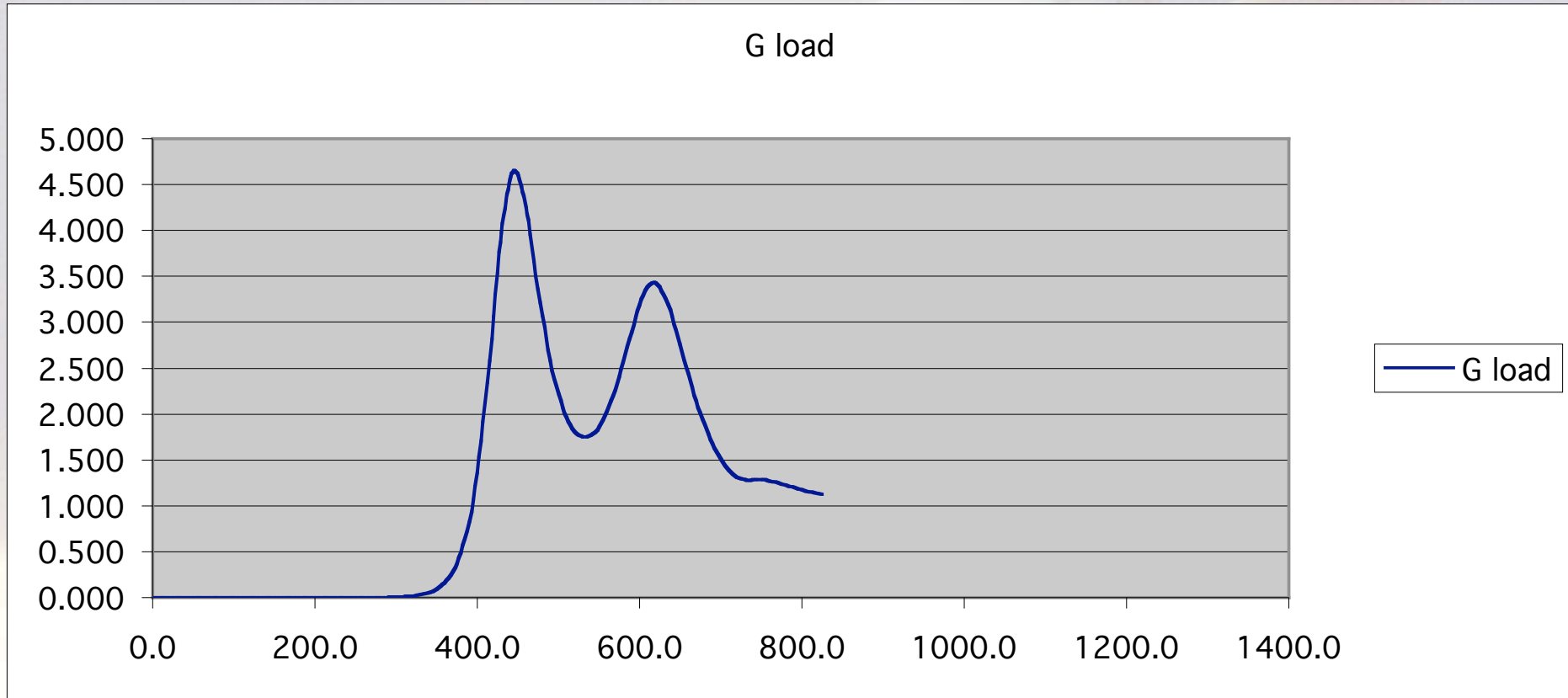
Nominal Entry Heating and Velocity



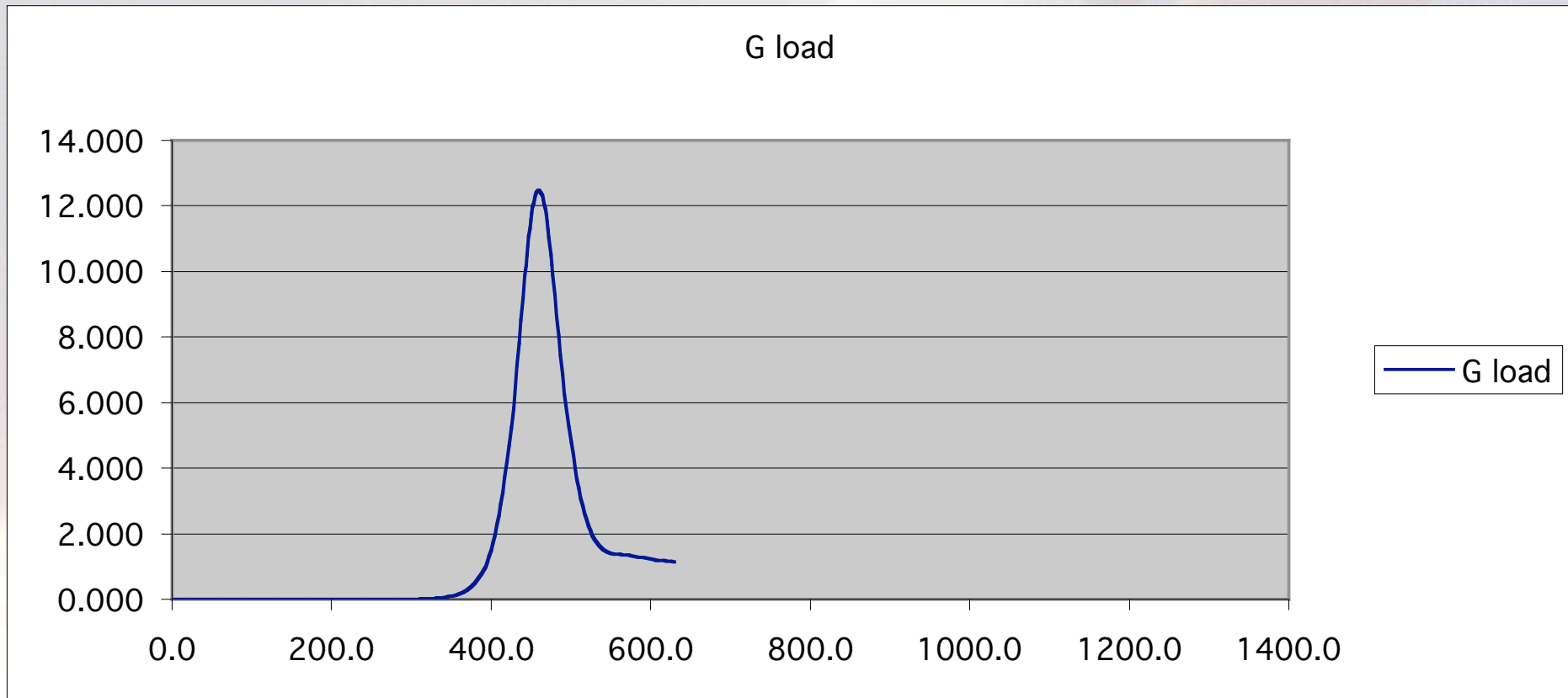
Ballistic Entry Heating and Velocity



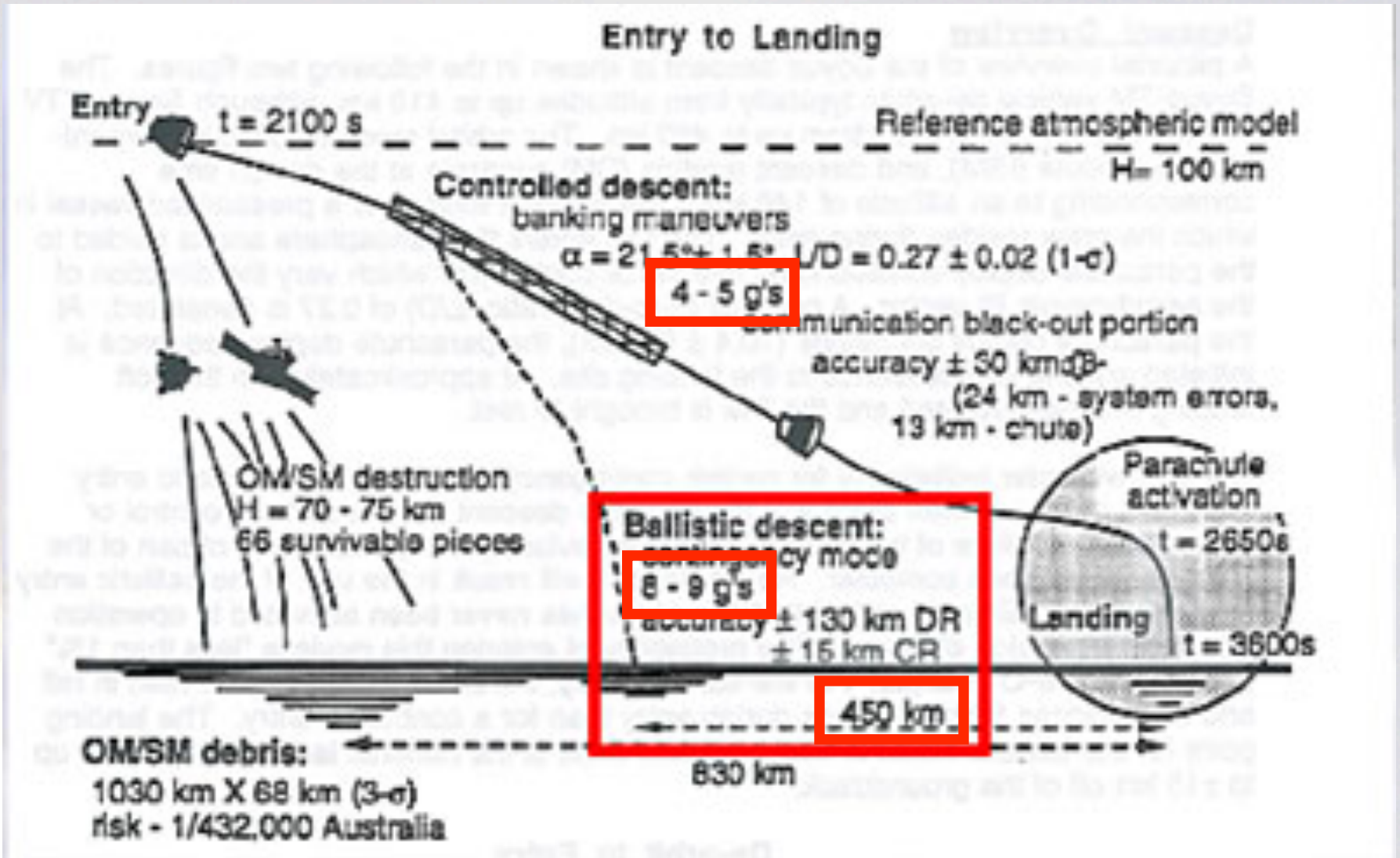
G Loading (nominal entry)



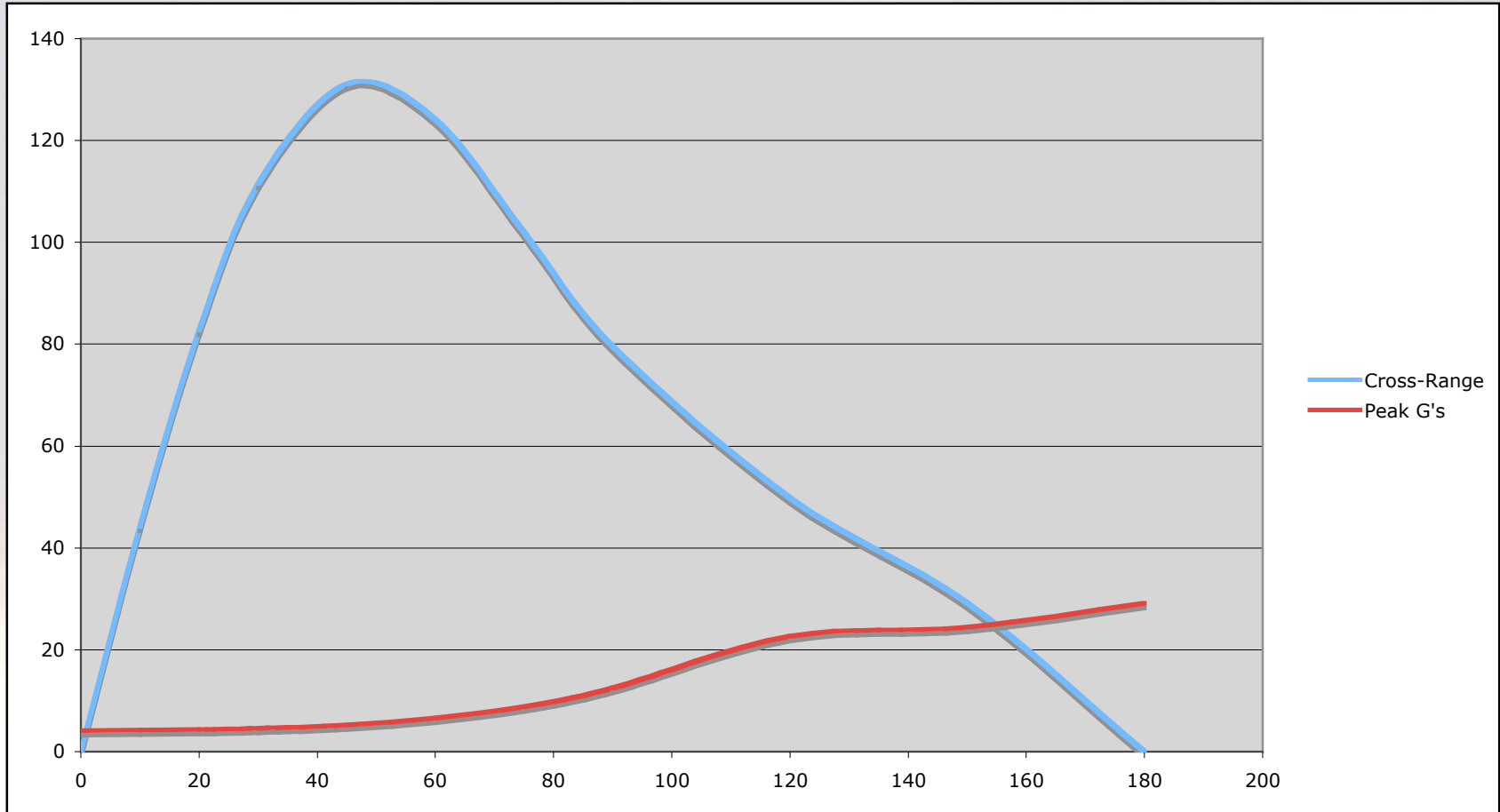
G Loading (Ballistic Entry)



Published Flight Characteristics



Cross-Range and G's vs. Roll Angle



Soyuz Landing Ellipse

