BALLUTE ENTRY, DESCENT AND LANDING ON TRITON

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MAJOR TOPICS

- Atmosphere
- Ballute Shape and Size
- Entry Trajectories
- Ballute System Mass
- Landing System Concept
- Approach Accuracy
- Conclusions

ATMOSPHERE

- Data from several star occultations
- Assumes
  - Known Pressure of 2.2 microbar
  - Altitude = 48 km
  - Temperature = 44 K
  - Gas is Nitrogen
  - Pressure follows barometric law –
    - dp = - d•g•dz
    - where p is pressure, d is density,
    - z is altitude
  - Equation of state holds at constant temperature, gravity follows inverse square law.

Altitude, km	Density, kg/m^3
0	6.50E-05
10	5.00E-05
30	2.90E-05
50	1.70E-05
70	9.70E-06
90	5.40E-06
110	3.20E-06
130	1.95E-06
150	1.15E-06
170	7.16E-07
190	4.40E-07
210	2.70E-07
230	1.75E-07
250	1.10E-07
270	7.30E-08
290	4.65E-08
310	3.10E-08
330	1.40E-08
350	9.20E-09

BALLUTE SHAPE AND SIZE

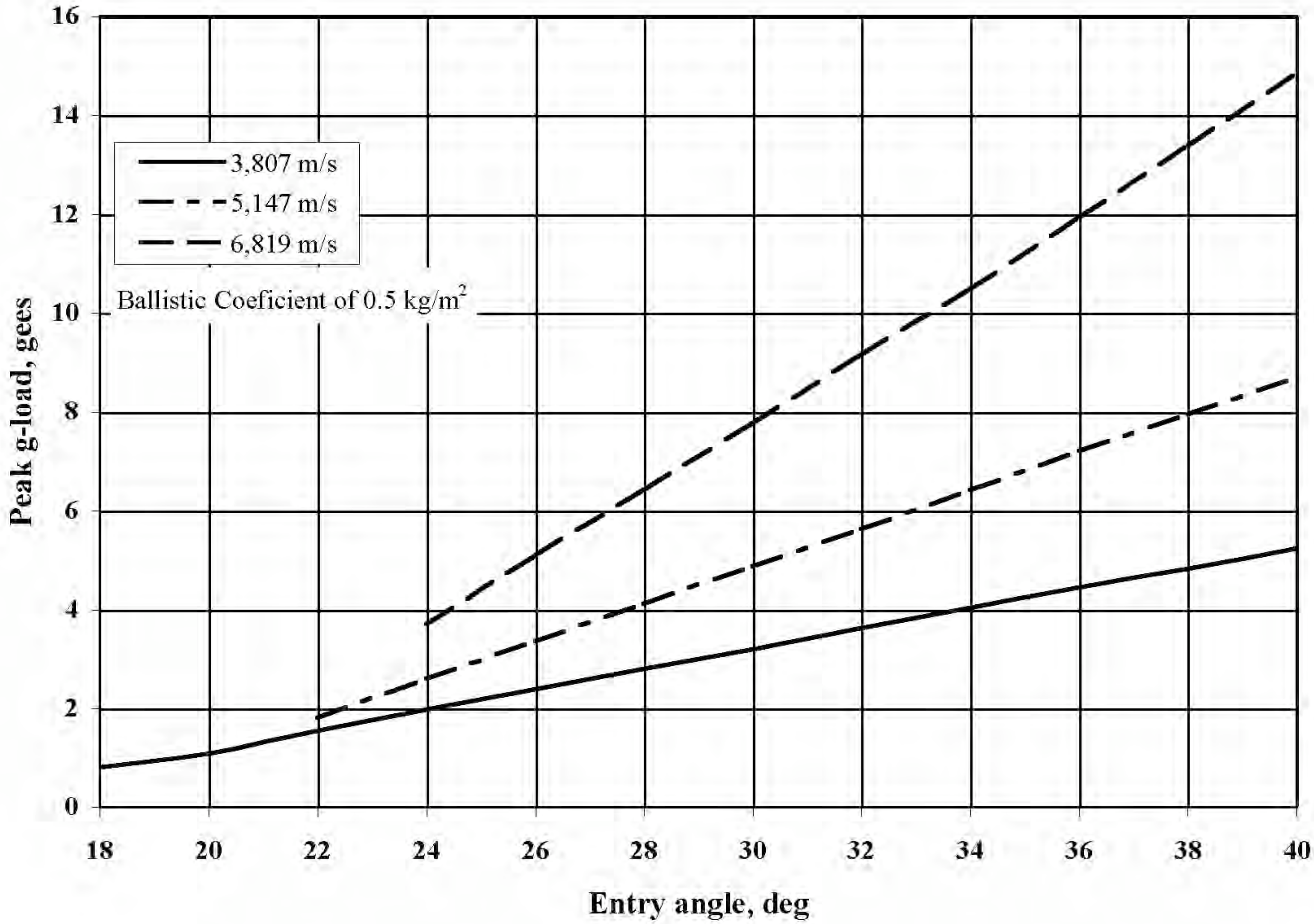
- Spherical Ballute of three sizes given by $B = m/C_dA$, where
  - m is entry mass, assumed to be 300 kg,
  - A is frontal area in m^2 ,
  - C_d is hypersonic drag coefficient assumed to be 0.9, and
  - Ballistic Coeficients, B, of 1.0, 0.5, 0.25 kg/m^2, which results in ballute radii of 10.3, 14.6 and 20.6 m

- Three entry cases examined assuming zero inclination with respect to Triton orbit plane and entry interface at Triton of 300 km altitude.
  - Entry in direction of Triton motion with a Neptune approach speed of 2 km/s resulting in an entry speed of 3807 m/s,
  - Entry against Triton motion with a Neptune approach speed of 6 km/s resulting in an entry speed of 6819 m/s, and
  - Entry from Neptune orbit with an approach speed of 4 km/s resulting in an entry speed of 5147 m/s.

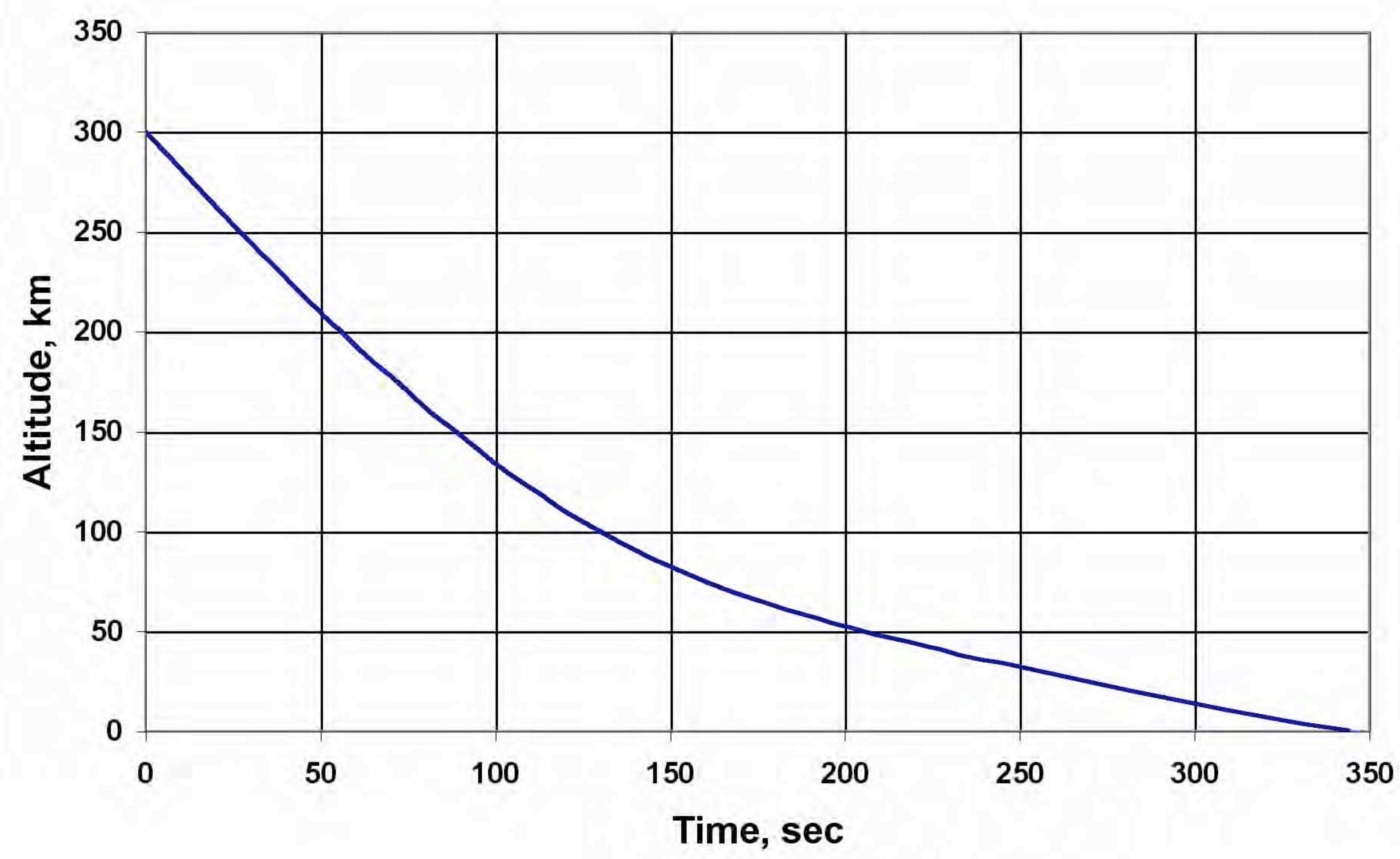
ENTRY TRAJECTORIES

- Trajectories were evaluated for entry angles –18° to –40°
- Some entry conditions result in skip out of the vehicle into Neptune or Triton orbit
  - Shallow flight path angles (>-22°)
  - For some cases of entry speed and ballistic coefficient
- For entry angles steeper than about –40°, the speed relative to the surface and the peak g-load become excessive
- There is an entry corridor corresponding to about 200-550 km in the approach target plane.

PEAK G-LOAD

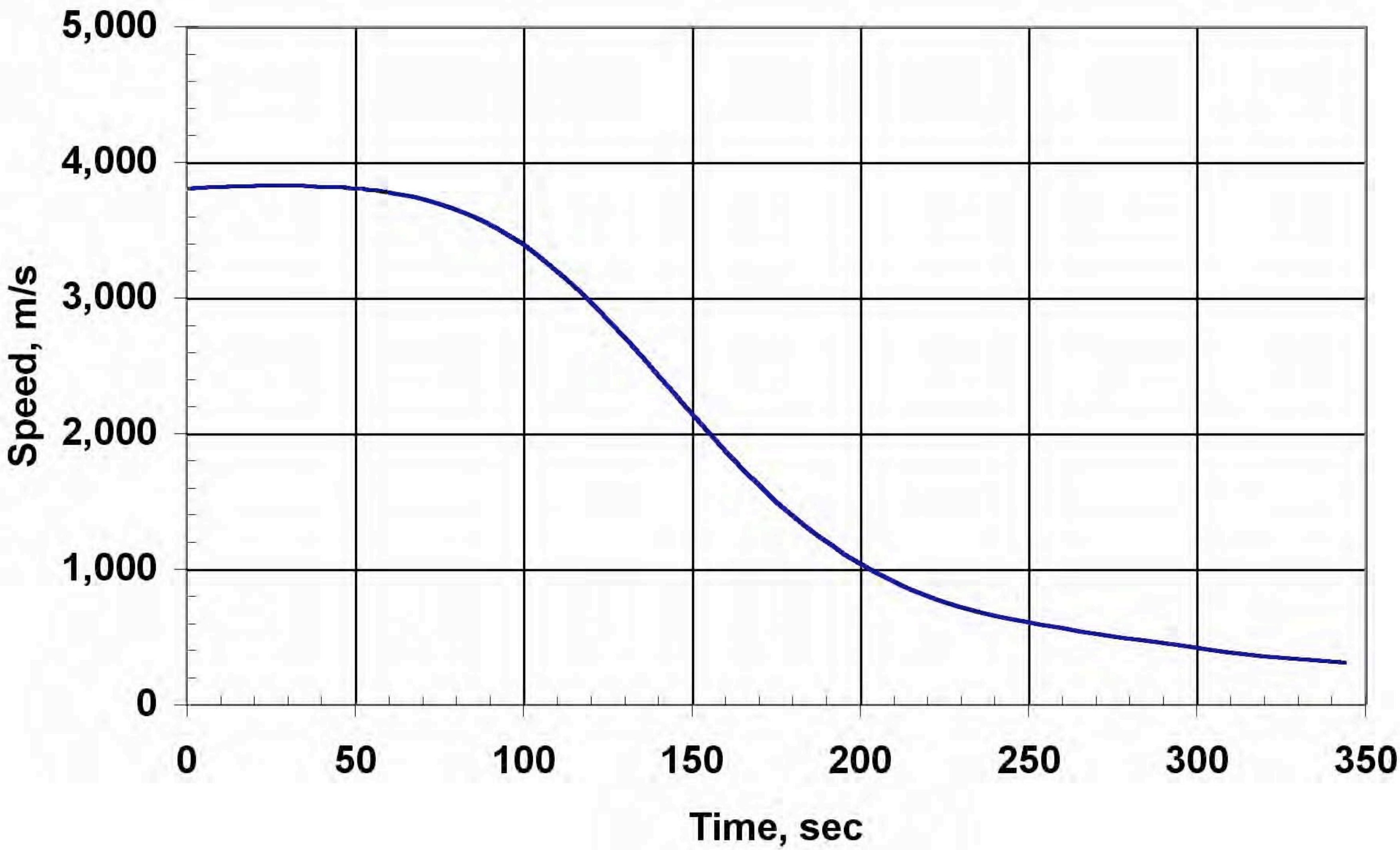

3,807 m/s
5,147 m/s
6,819 m/s
Ballistic Coeficient of 0.5 kg/m²
Peak g-load, gees
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
Entry angle, deg

ALTITUDE

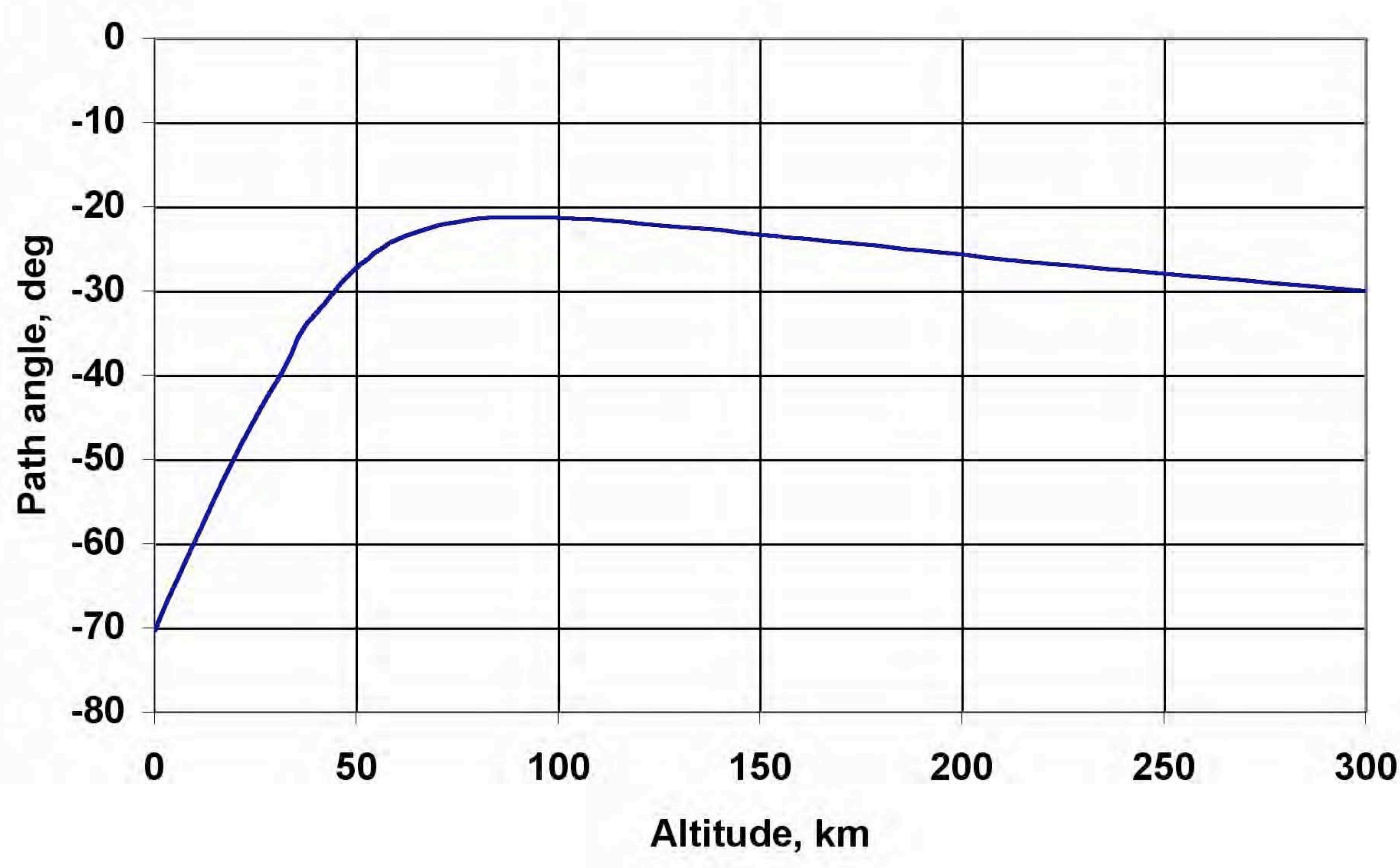


350
300
250
200
150
100
50
0
Altitude, km
0
50
100
150
200
250
300
350
Time, sec

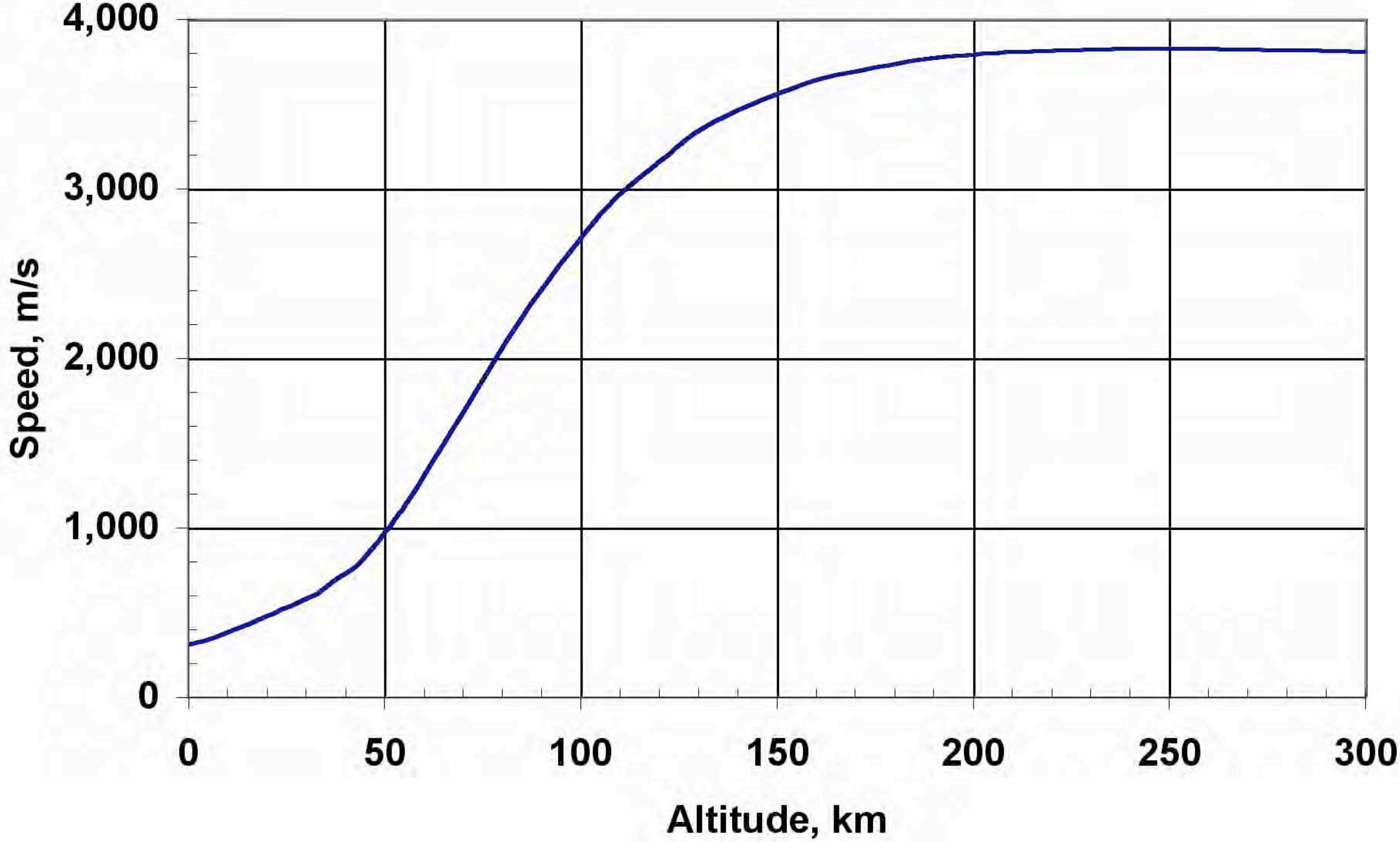
SPEED


5,000
4,000
3,000
2,000
1,000
0
Speed, m/s
0
50
100
150
200
250
300
350
Time, sec

FLIGHT PATH ANGLE



SPEED VS. ALTITUDE



BALLUTE SYSTEM MASS

- **Ballute system mass assumptions**
  - **Ballute film at 10 kg/m^2,**
  - **helium gas at peak stagnation pressure,**
  - **Net or load tapes of PBO to sustain the peak g-load with stress of 56 kgf per area of 1 mm^2, and**
  - **Solid rocket propellant at I_{sp} of 320 s**
- **Ballute system mass is about 60 kg for the three ballute sizes examined**
- **Solid rocket propellant mass dominates for the small ballute, and**
- **Ballute film mass dominates for the large ballute.**

LANDING SYSTEM CONCEPT

- The ballute decelerates the vehicle to a speed of about 200-500 m/s near the surface, at a path angle in the range -40° to -80°

- The ballute is released and a solid rocket or cluster of rockets is fired with radar altimeter control, reducing the speed to near zero

- The vehicle begins to fall under gravity at small speed and nearly vertically

- A set of liquid landing engine thrusters is programmed to perform a soft landing

APPROACH ACCURACY

- The analysis gives an entry angle corridor for a given entry speed and ballute size
- From this we can compute the range of target radius in the target plane or approach plane at infinity
- The range of target plane radius for the entry angle corridor varies from about 200 km to 550 km, which is well within the accuracy of approach navigation

CONCLUSIONS

- **Ballute entry, descent and propulsive landing at Triton appears feasible, assuming an atmosphere consistent with the occultation observations**

- **Peak g-loads are 1-10 gees, peak stagnation pressures are 10 to 100 N/m^2, surface speeds on the ballute are 200 to 500 m/s, and heating rates are small**

- **The entire deceleration and landing system mass (ballute, altimeter and control system) is estimated to be about 100 kg out of the assumed 300 kg entry mass**

- **Navigation to entry appears robust with an approach corridor ranging from 200 to 550 km**