PURDUE UNIVERSITY

A Dual-Use Ballute for Entry and Descent During Planetary Missions

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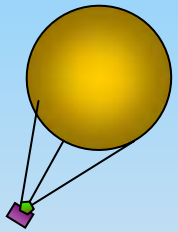

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Attica, Greece
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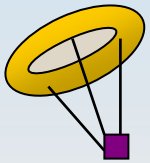

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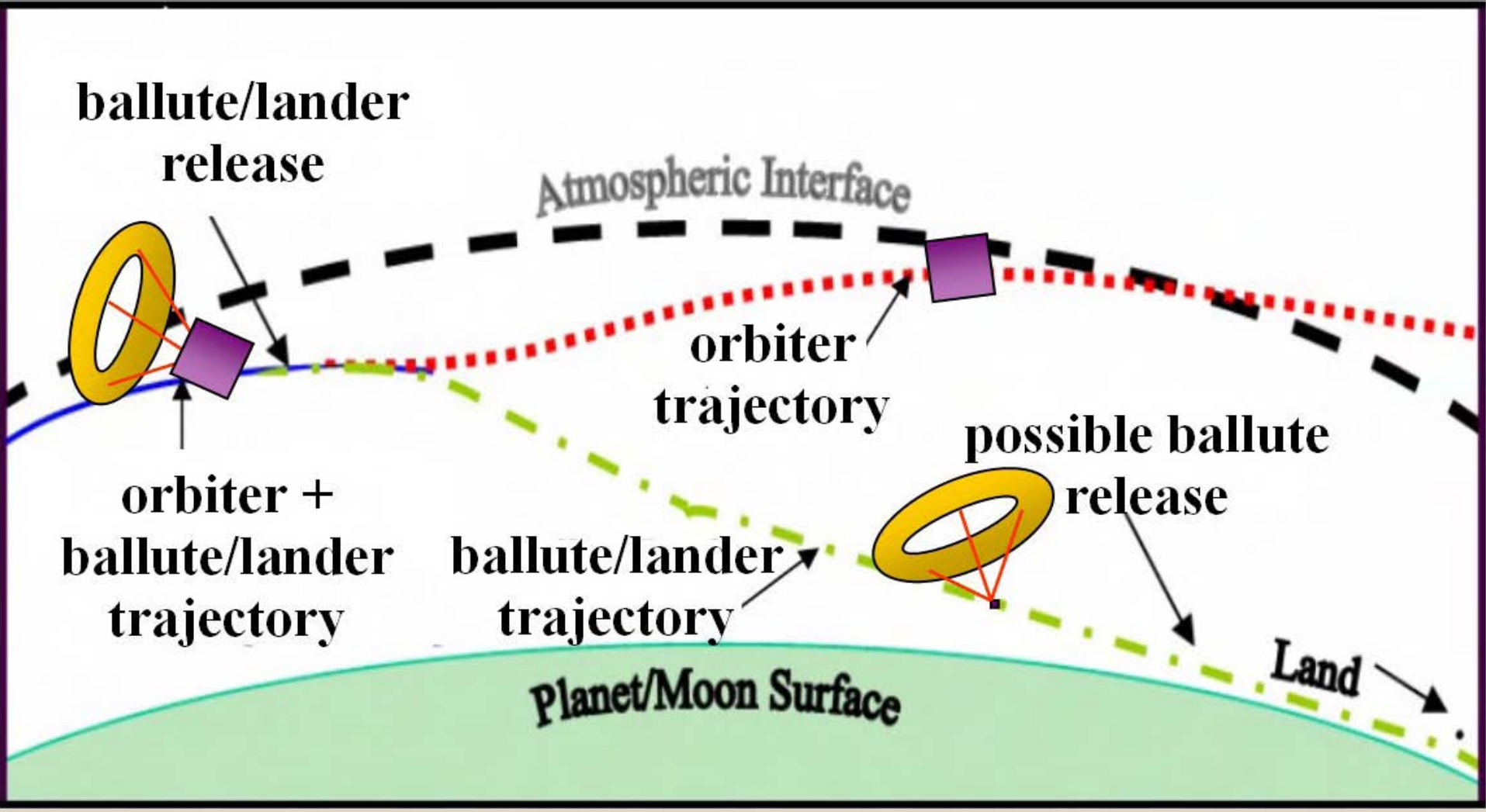
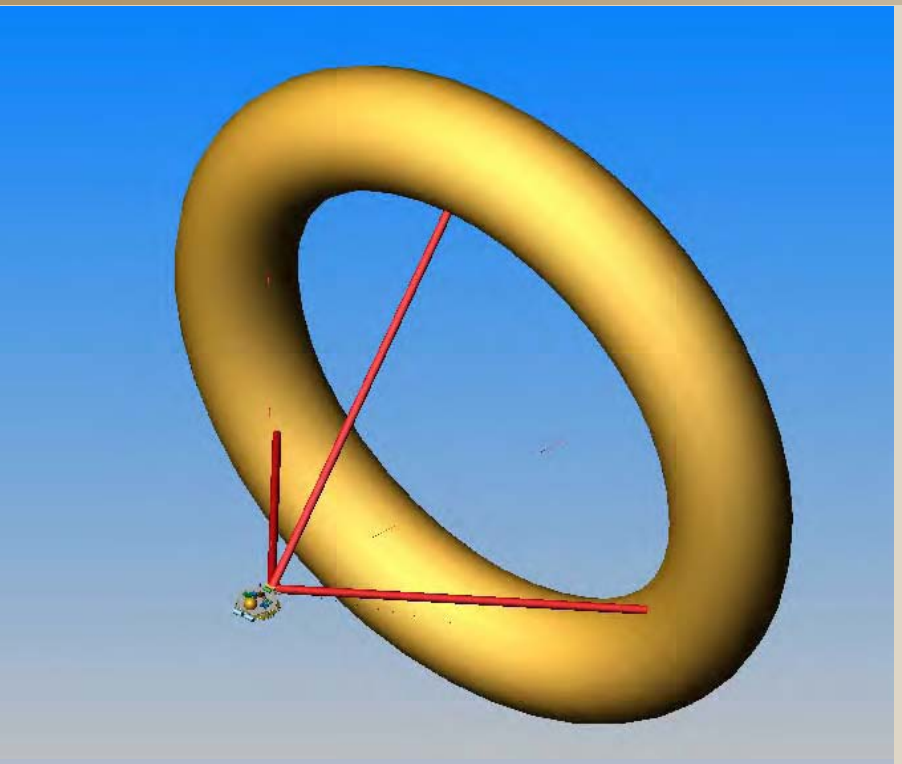
Dual-Use Ballute Concept



Technical Challenges



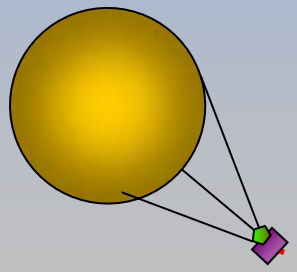
Toroidal Towed Ballute Configuration (Ball Aerospace Concept)

- Shape / configuration
- Heating and material limits
- Packing and storage
- Trajectory robustness
- Flow stability
- Aeroelasticity
- Deployment and inflation
- Tether design (for towed ballutes)

Parameters

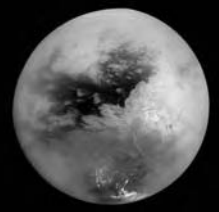
for Dual-Use Ballute Simulations at Mars, Titan and Neptune

Parameter	Orbiter	Ballute/Lander
m	400 kg	100 kg
C_D	1.37	1.37
A	2 m^2	750 m^2
R_n	0.8 m	15.5 m



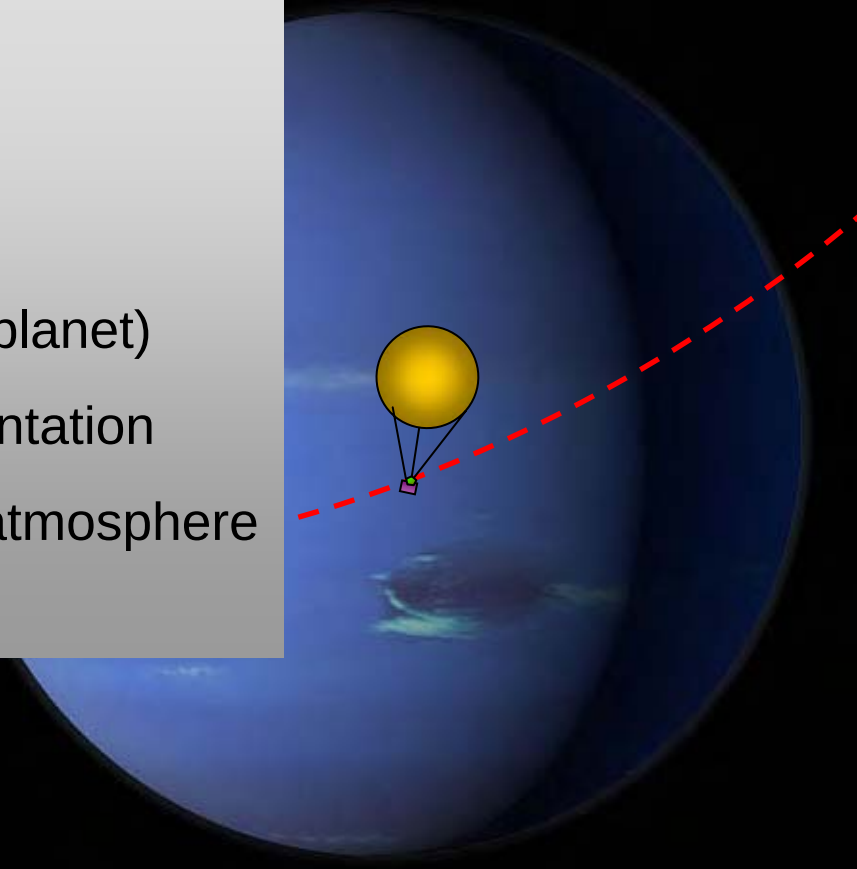
Target Body	Entry Speed (km/s)
Mars	5.75
Titan	6.5
Neptune	23.6

HyperPASS

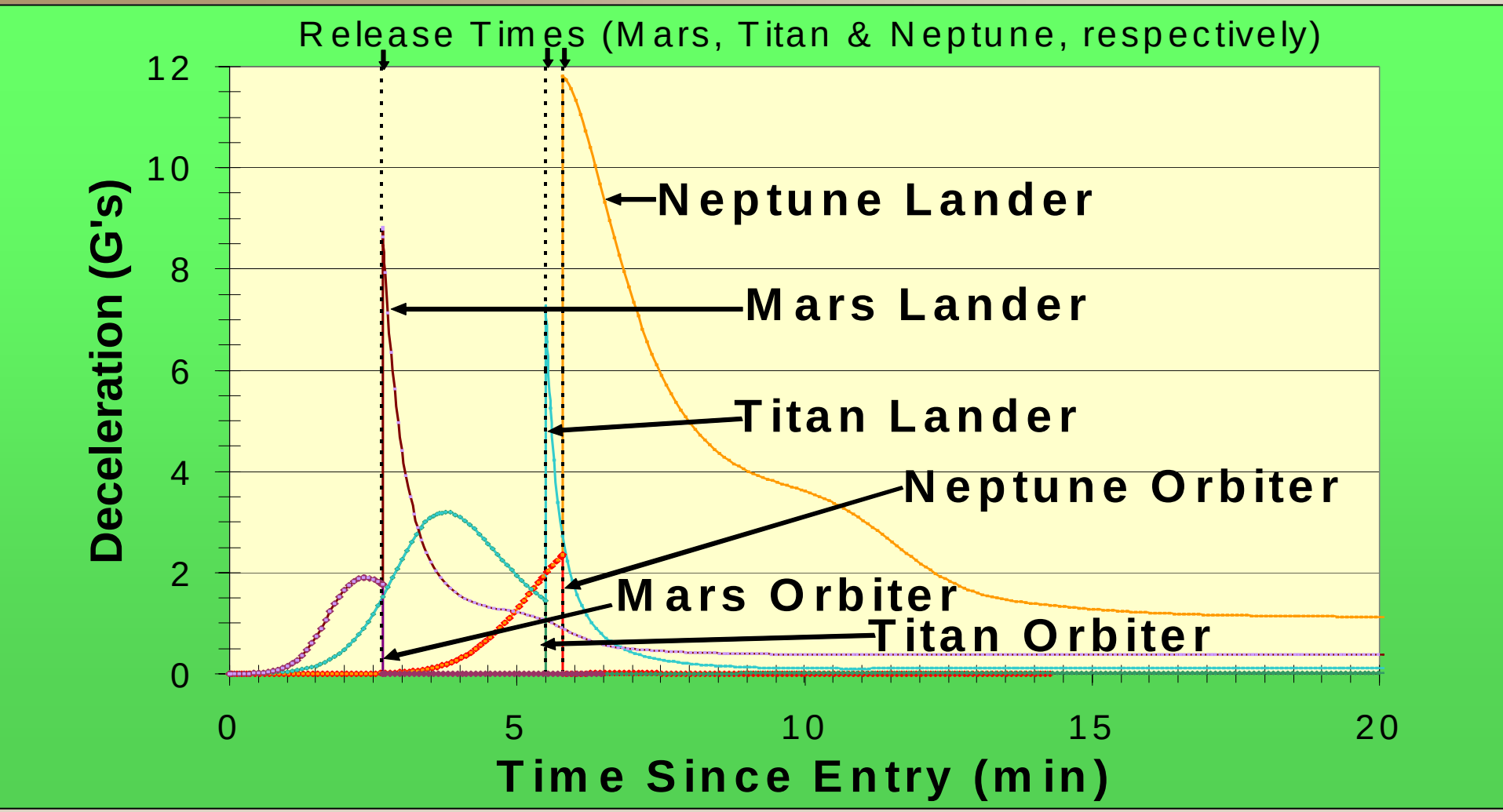


Modeling Assumptions:

- Spherical planetary body
- Inverse-square gravity field
- Rotating atmosphere (with planet)
- Point-mass vehicle representation
- Exponentially interpolated atmosphere
- Constant drag coefficient



Deceleration



Heating Rates

- **Stagnation-Point**

$$Q_{stag} = \frac{C\rho^{Nstag} v^{Mstag}}{\sqrt{R_n}}$$

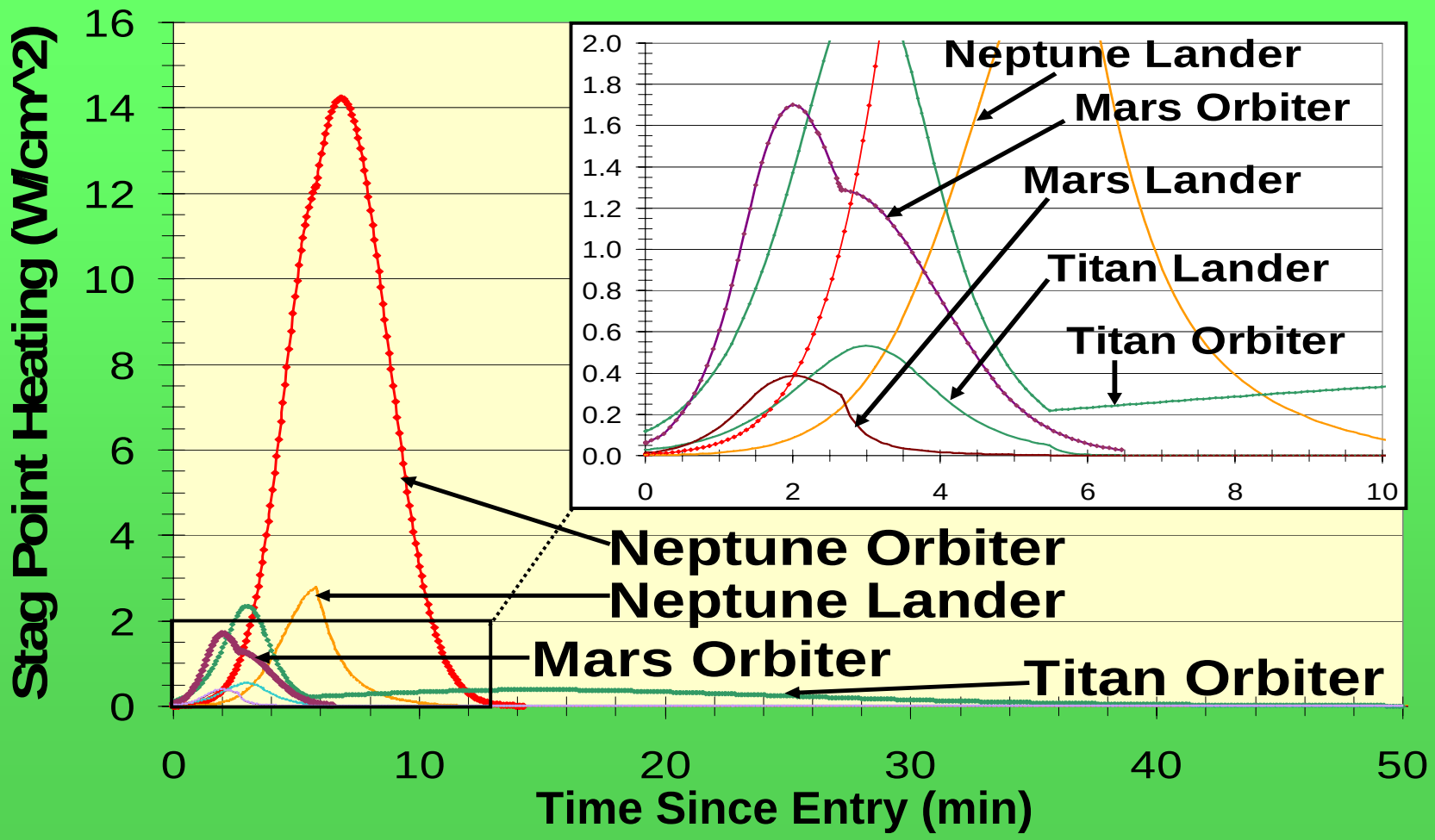
- **Free Molecular**

$$Q_{fm} = \frac{1}{2}\rho v^3$$

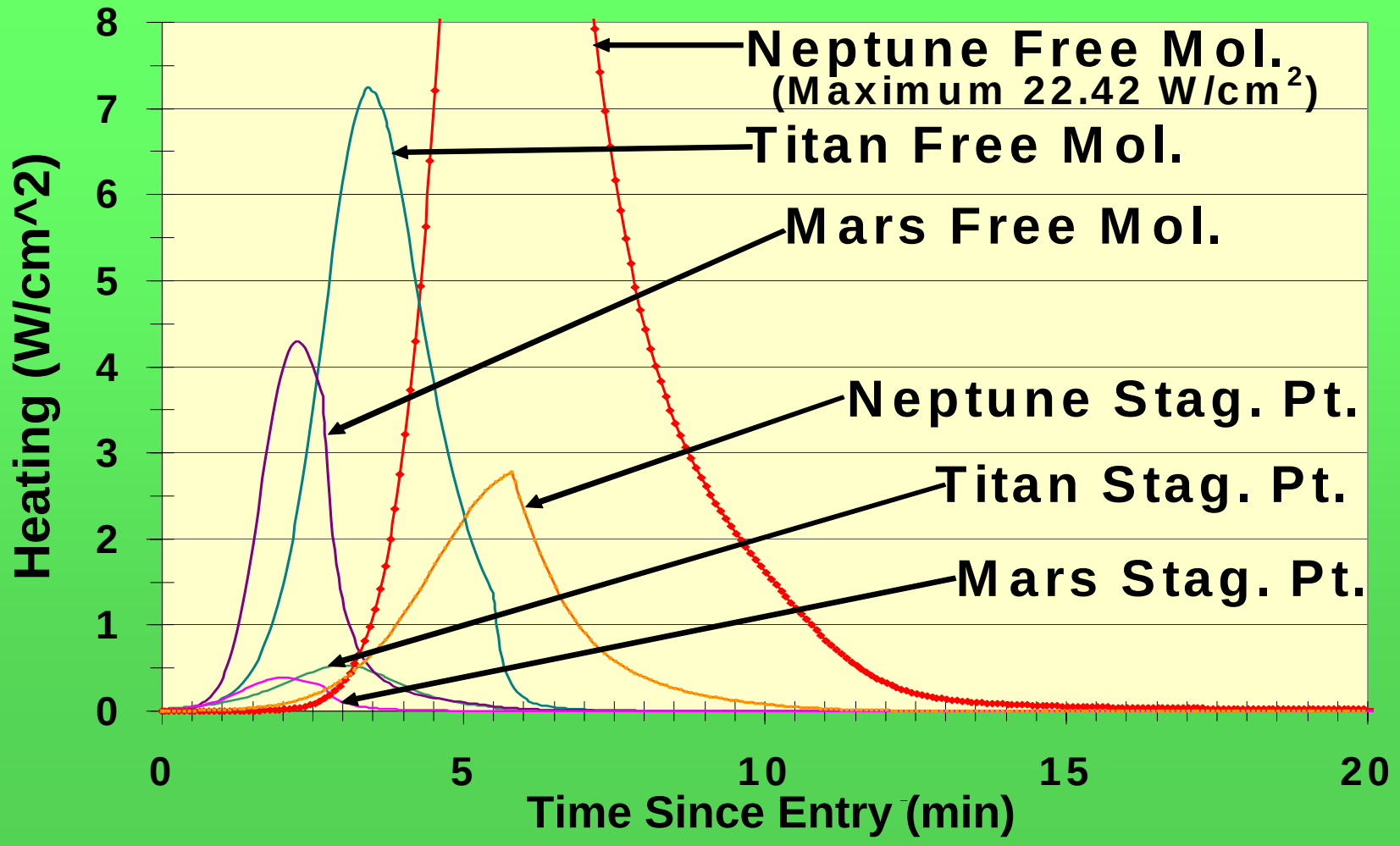
Goal:

$$Q \leq 3 \ W/cm^2$$

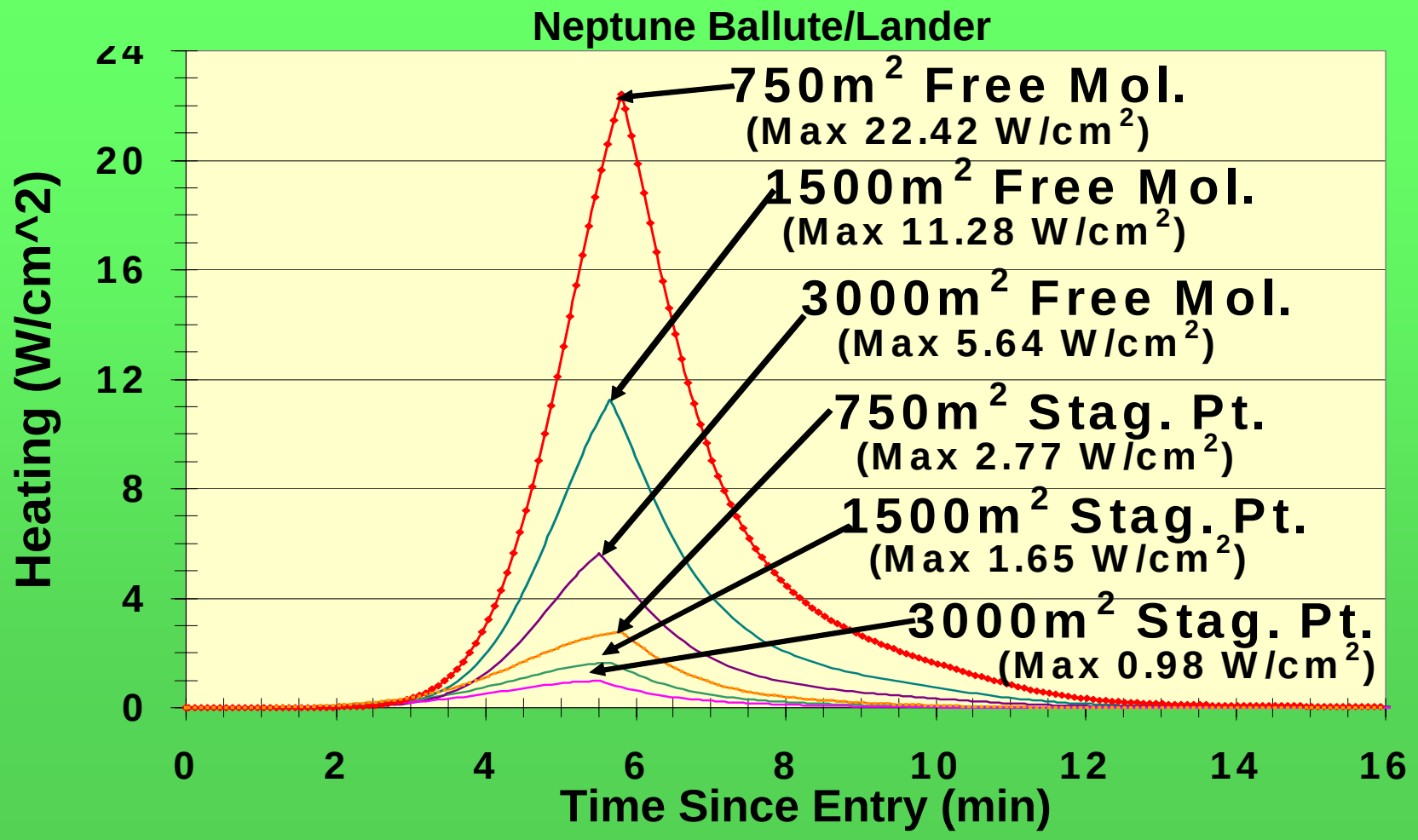
Stagnation-Point Heating Rate



Heating Comparison for Ballute/Lander

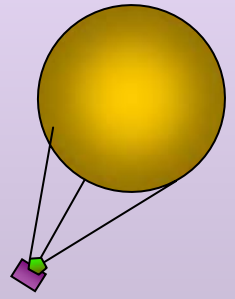


Ballute Area Comparison

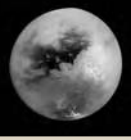
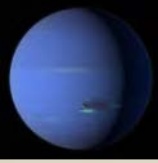


Conclusions

- Efficient in delivering payloads to the surface of Titan and Mars
- Applications at Neptune will require a larger area-to-mass ratio
- Offers a significant new technique and tremendous advantages for exploration of the Solar System

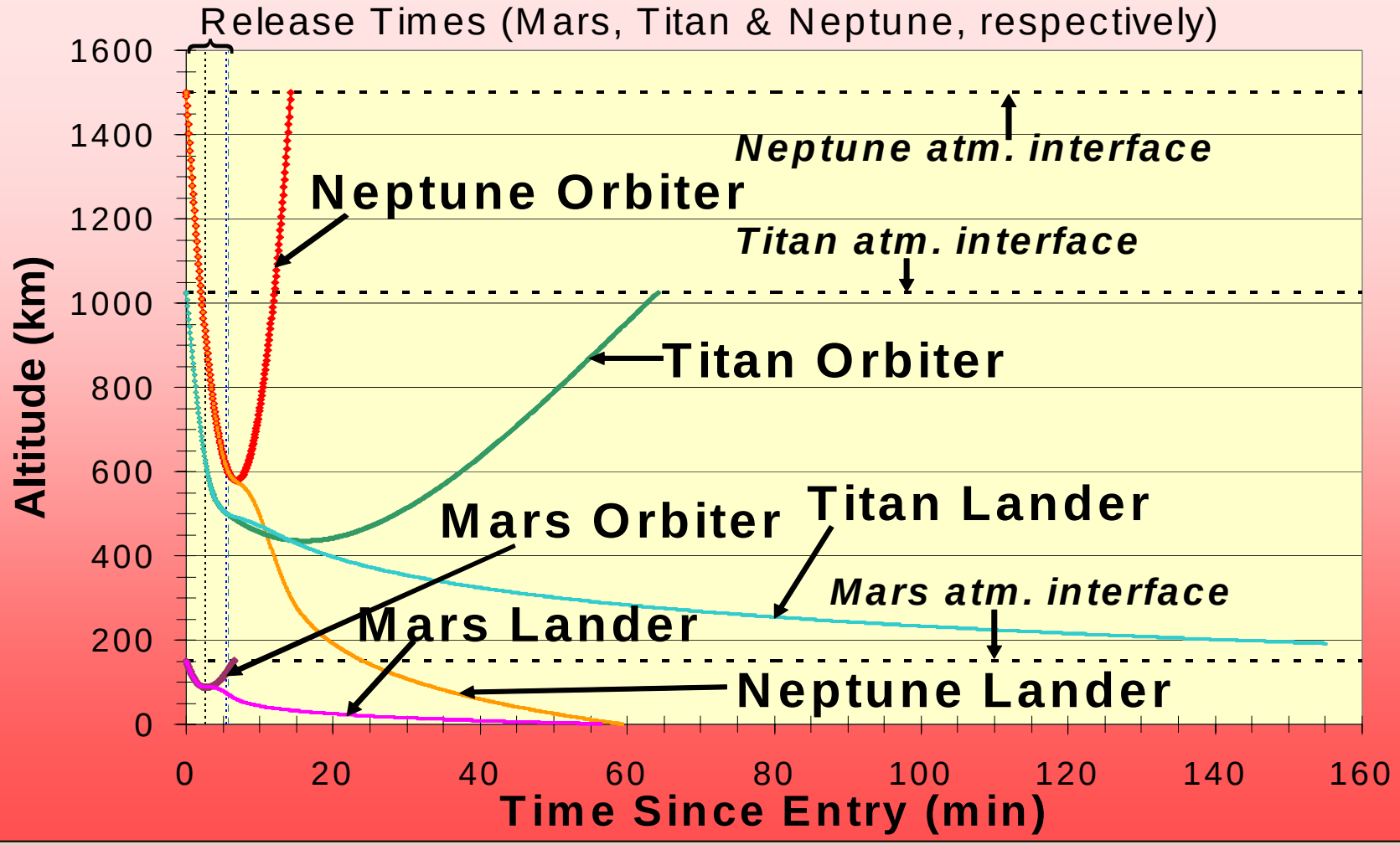


Entry and Target Conditions

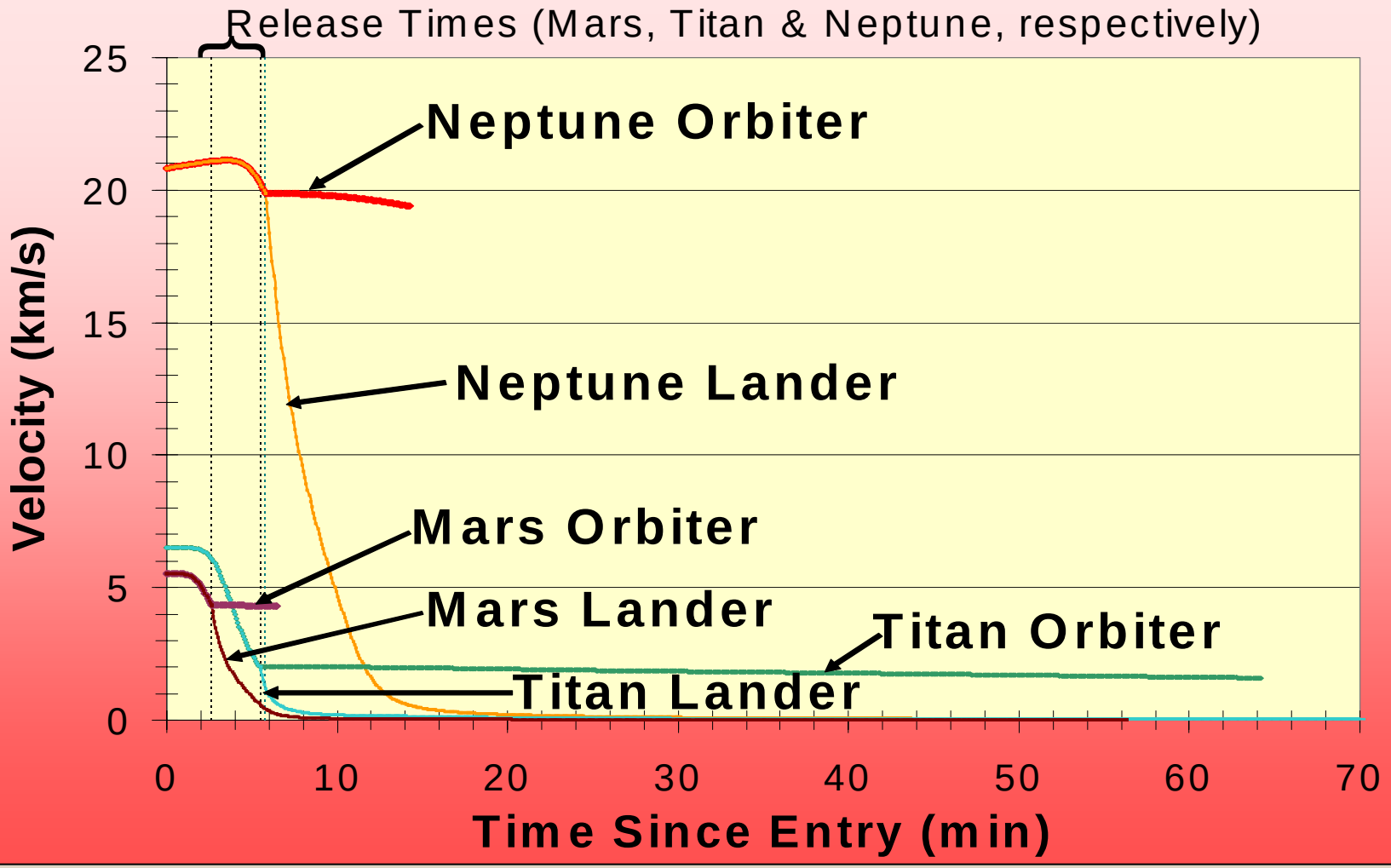



Condition	Mars	Titan	Neptune
Entry/Exit Altitude, km	150	1025	1500
Inertial Entry Speed, km/s	5.75	6.5	23.6
Inertial Entry FPA, deg	-8.49	-30.50	-11.10
Target Apoapsis Altitude, km	16685	1700	430,000

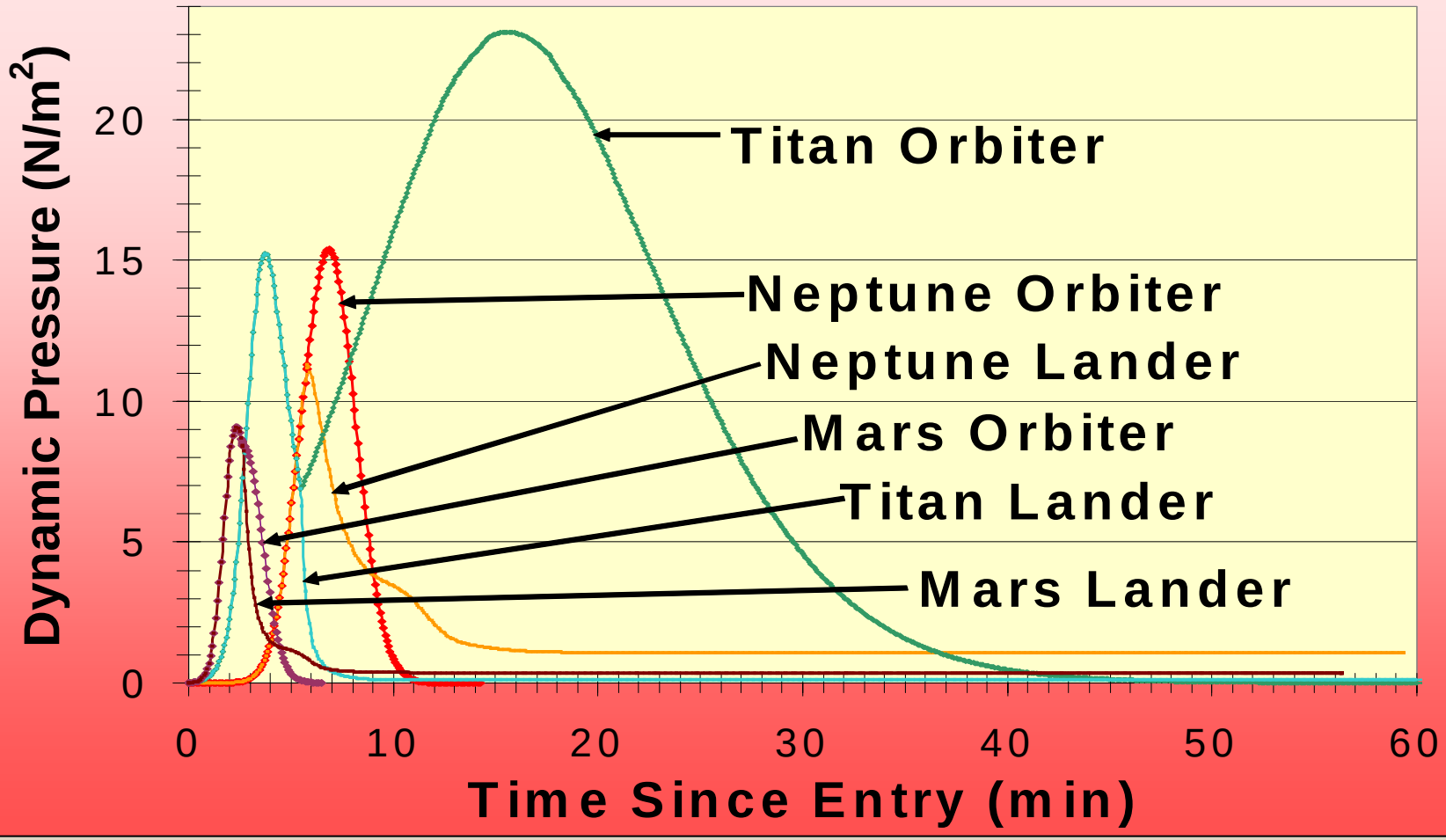
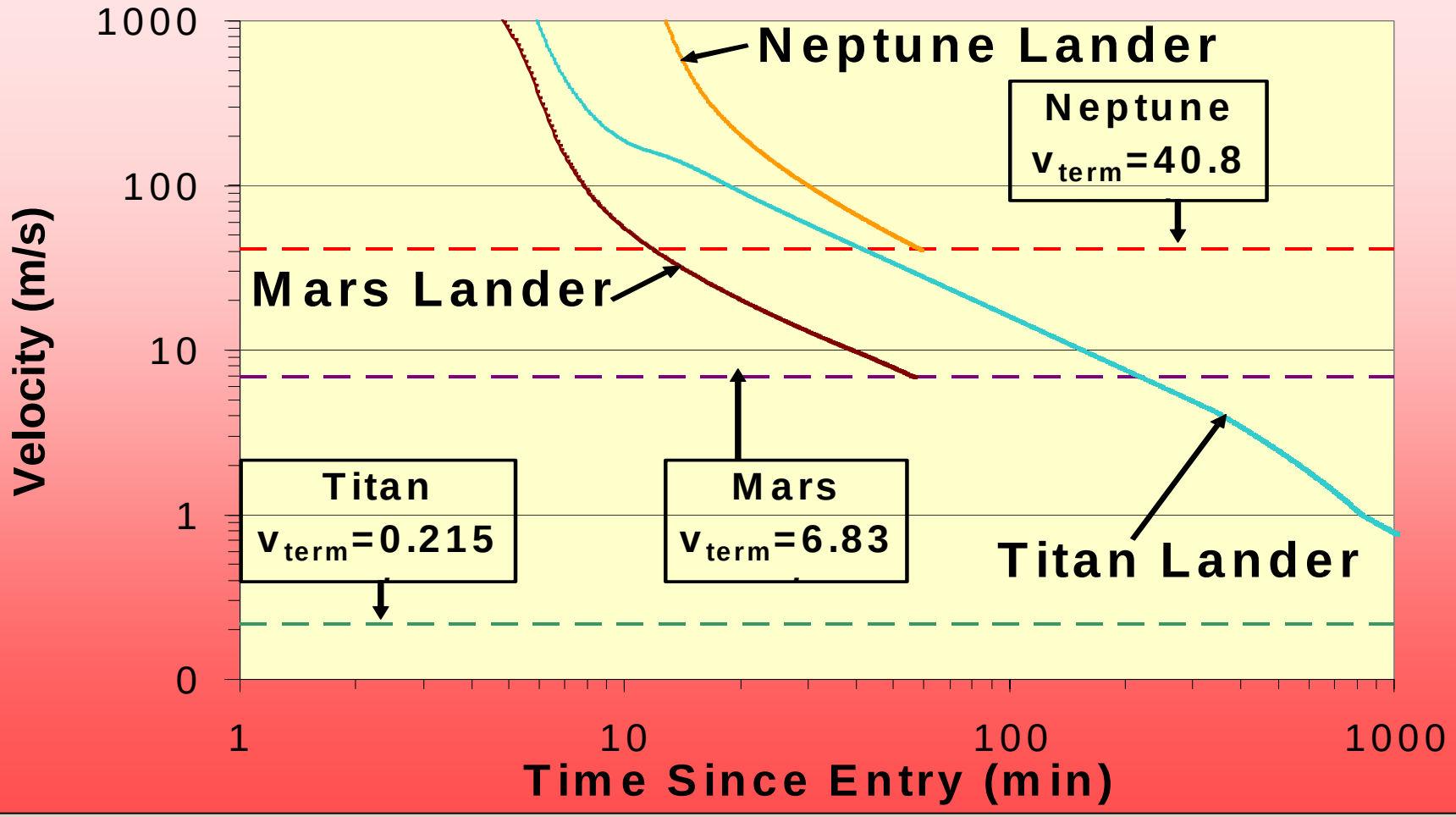
Altitude


Release Times (Mars, Titan & Neptune, respectively)
Neptune atm. interface
Neptune Orbiter
Titan atm. interface
Titan Orbiter
Titan Lander
Mars Orbiter
Mars atm. interface
Mars Lander
Neptune Lander
Altitude (km)
Time Since Entry (min)
0
200
400
600
800
1000
1200
1400
1600
0
20
40
60
80
100
120
140
160

Velocity


Release Times (Mars, Titan & Neptune, respectively)
Neptune Orbiter
Neptune Lander
Mars Orbiter
Mars Lander
Titan Orbiter
Titan Lander
Velocity (km/s)
25
20
15
10
5
0
0
10
20
30
40
50
60
70
Time Since Entry (min)

Dynamic Pressure



Terminal Velocity