ADEPT

Venus Entry Options

Venus Upper Atmosphere Investigations
Science and Technical Interchange Meeting (STIM)
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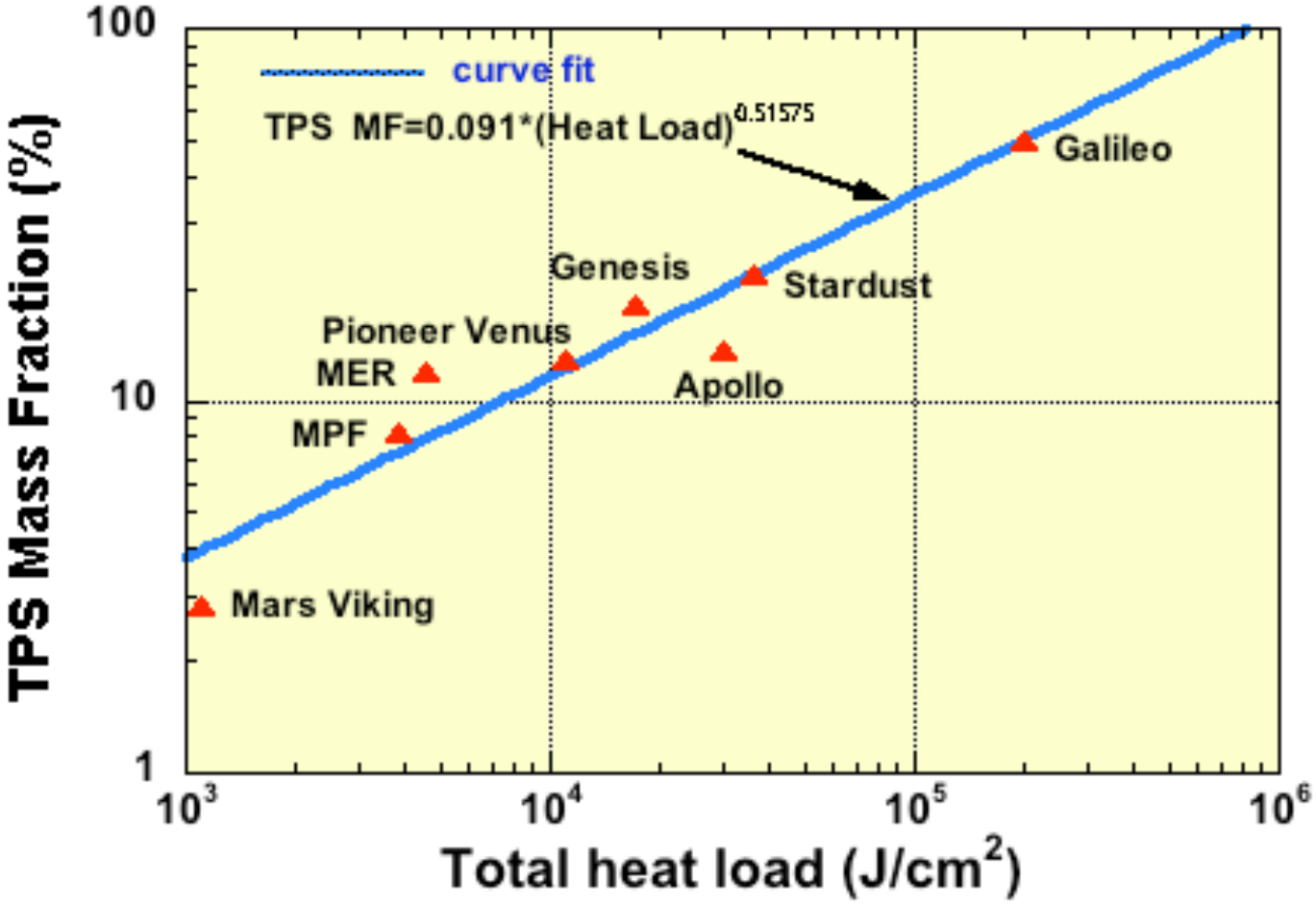
Characteristics of the Entry Problem

ADEPT

- **Entry velocity**
  - Driven by interplanetary trajectory
- **Entry angle**
  - Must be high enough to avoid skip-out
  - Affects latitude that can be reached
- **Ballistic coefficient**
  - Design choice, constrained by packaging
- **Heating rate**
  - Constrains material selection
- **Heat load**
  - Drives thermal protection thickness
- **Deceleration**
  - Drives payload structural requirements

TPS Mass Scales with Heat Load



From Laub and Venkatapathy

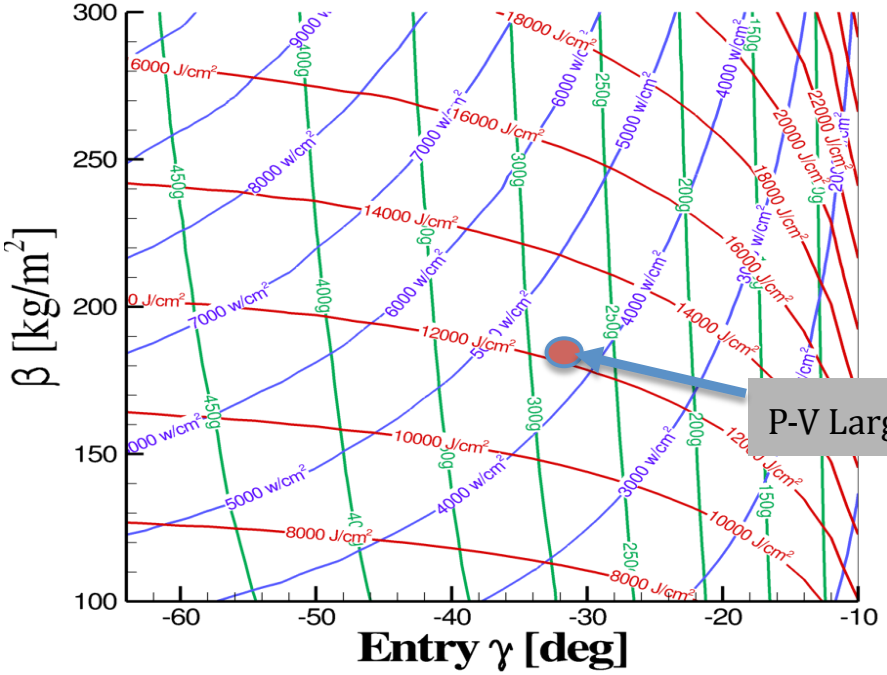
Entry Environments for Previous Missions

ADEPT

β = 600

Venera 4, 5, 6

Venera/Vega



P-V Large Probe

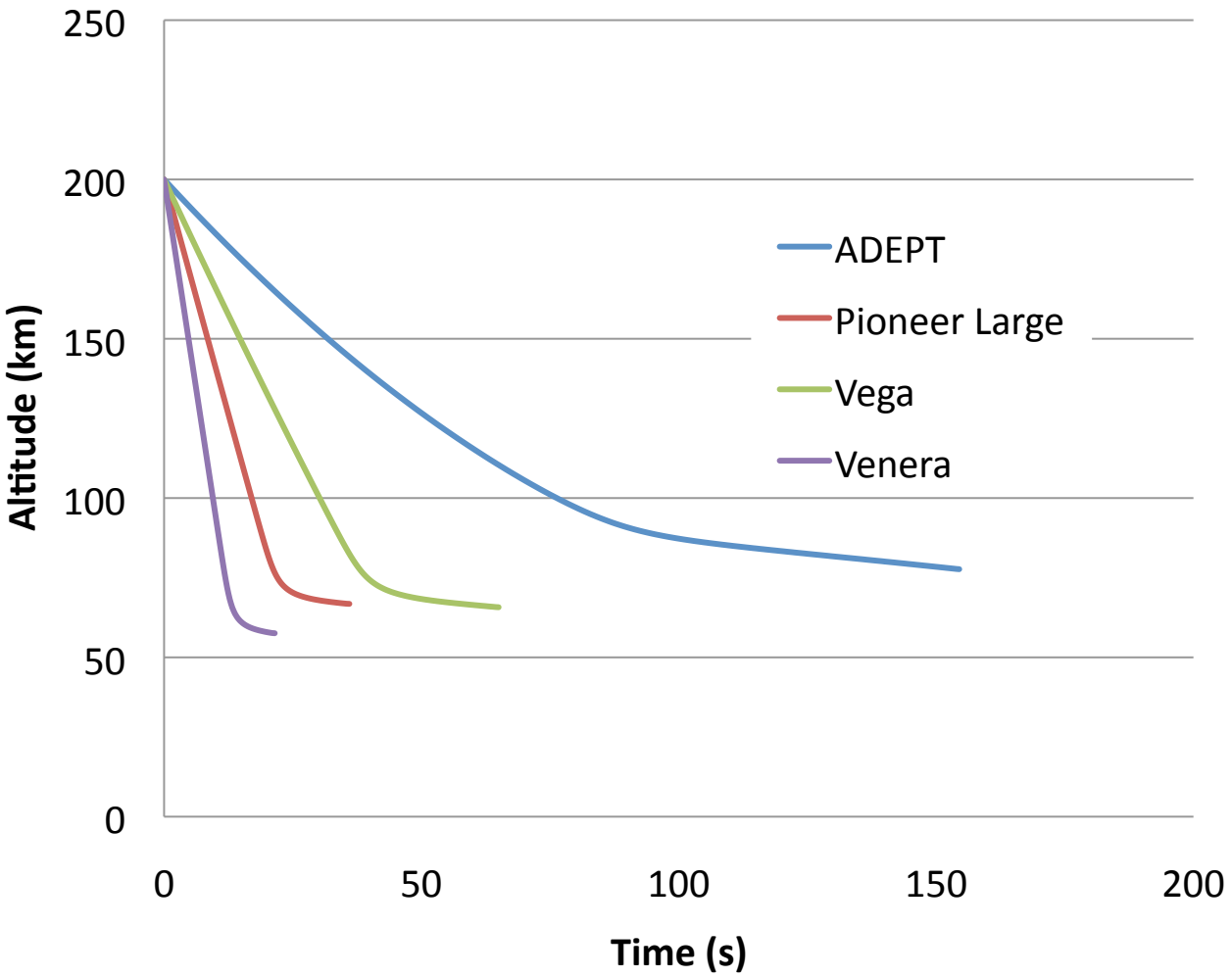
Entry Performance

ADEPT

Entry Vehicle Class	Ballistic Coefficient	Entry Angle	Peak deceleration (g's)	Peak heat flux (kW/ cm2)	Total heat load (kJ/ cm2)	TPS mass fraction (%)
Venera	600	-70	435	14	23.6	>23
Vega	400	-18	140	3.4	19.5	23
Pioneer Large	200	-32	265	3.2	9.9	13
ADEPT	50	-9	45	0.4	8.5	~12 (estimated)

All cases assume V=11.2 km/s
Cases are representative, not matching actual mission conditions

Venus Entry: Time to Mach 1

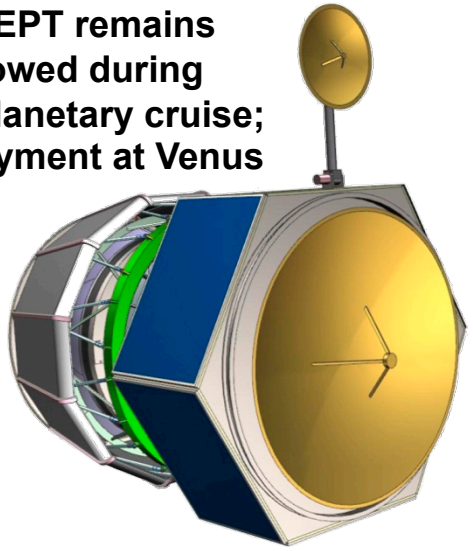


Adaptive Deployable Entry and Placement Technology

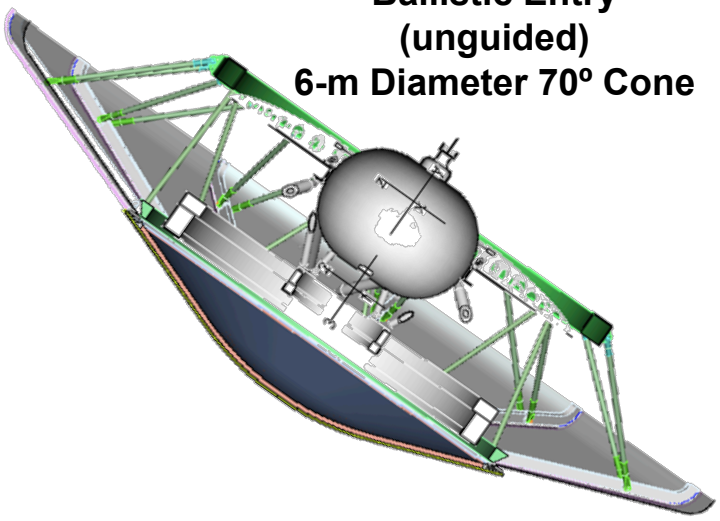
ADEPT-VITaL Key Facts	
Launch Vehicle	Atlas V 551
Launch Date	29 May 2023
Entry Date	29 September 2024
Entry Flight Path Angle	-8.25º
Entry Velocity	10.8 km/s
Entry Azimuth Angle	171.0º
Peak G-load (nominal)	30 G
Peak G-load (3σ)	46 G

Atlas V 551 Launch

ADEPT remains stowed during Interplanetary cruise; Deployment at Venus

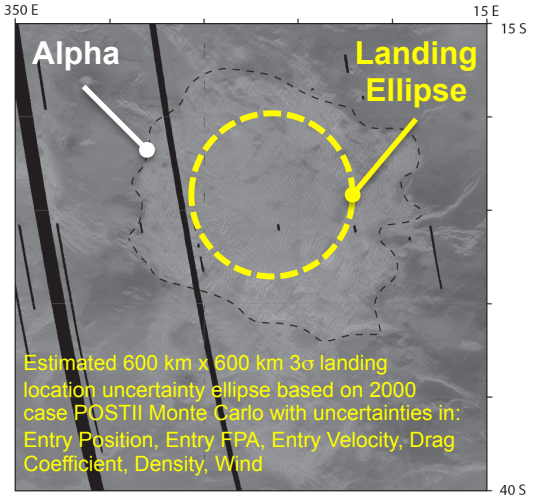


Ballistic Entry (unguided) 6-m Diameter 70º Cone

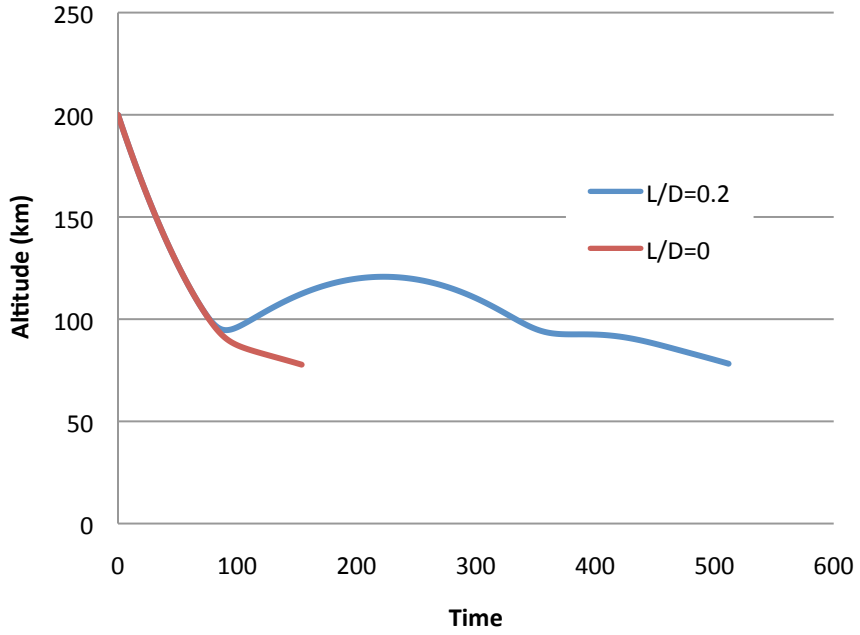


Subsonic parachute for ADEPT separation and VITaL Lander release

Landing in Alpha region



Any benefit from lifting entry?

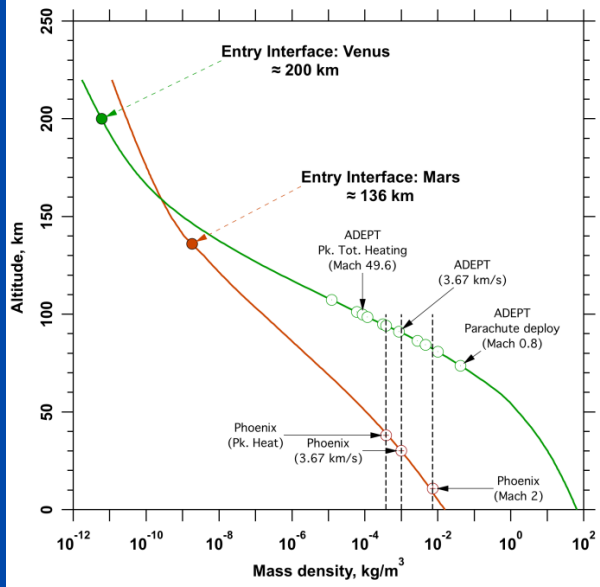


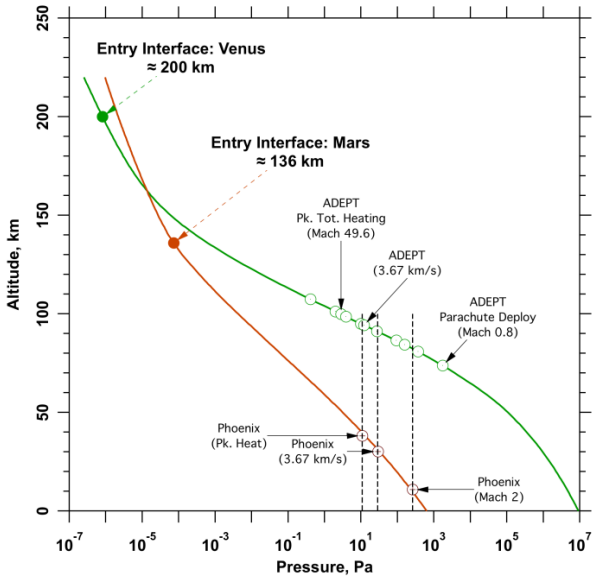
Targeting accuracy

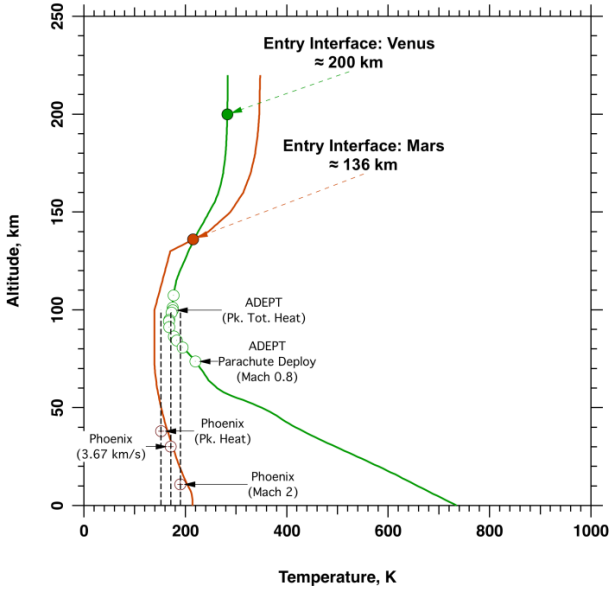
Cross range

	Ballistic Coefficient	Entry Angle	Peak deceleration (g's)	Peak heat flux (kW/ cm2)	Total heat load (kJ/ cm2)
ADEPT Ballistic	50	-9	45	0.4	8.5
ADEPT L/ D=0.2	50	-9	25	0.35	13.5

Deployment Environment: Venus and Mars







UAV design experience from Mars may be relevant for Venus

Summary

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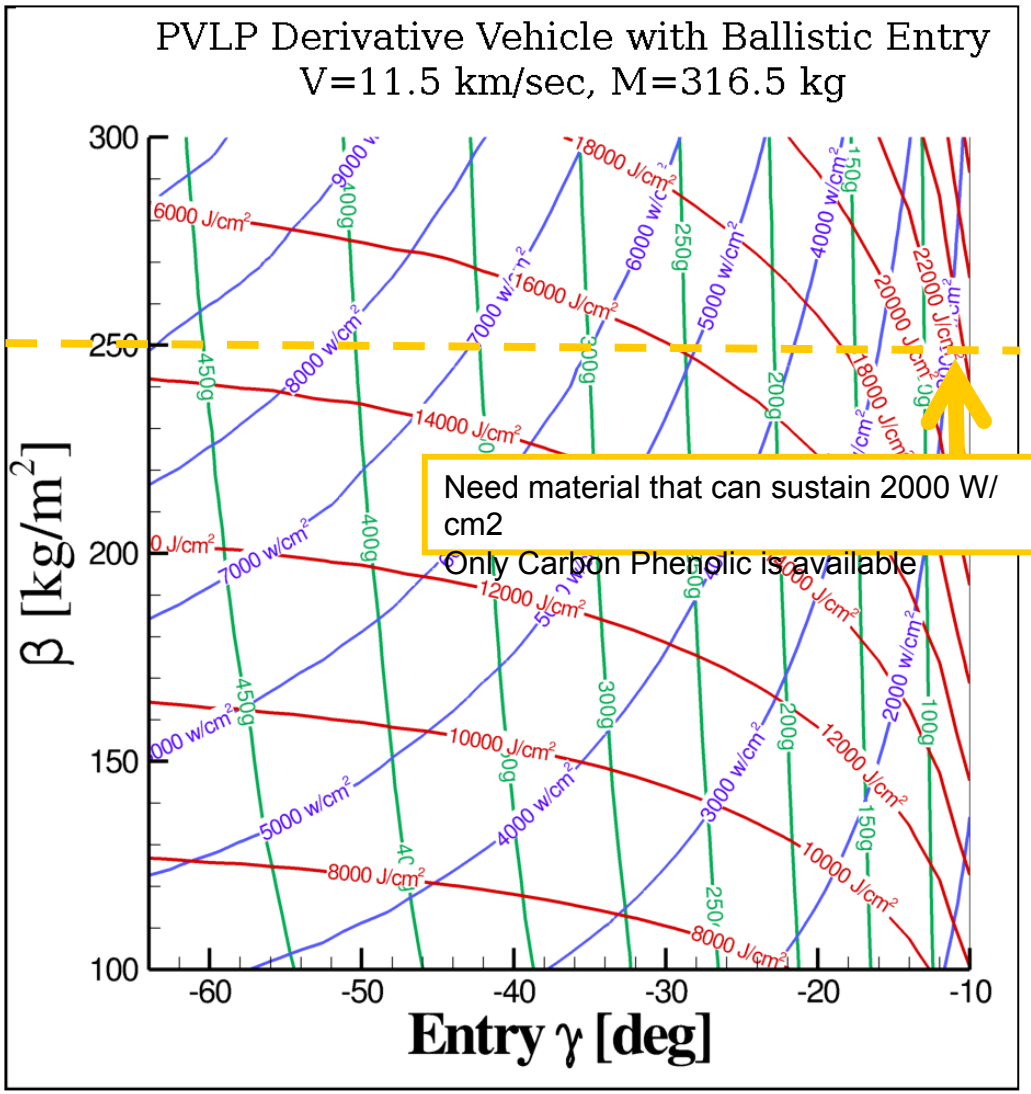
- **Vega provides existence proof for entry capability for balloons**
  - Requires Carbon Phenolic or equivalent
- **More mass efficient solutions are available**
  - Pioneer Venus has similar altitude for M=1
    - More mass efficient, higher peak deceleration
  - ADEPT decelerates higher, with much lower peak deceleration
    - Opportunity for unfolding UAVs
    - Technology development is in progress
- **Lifting entry adds complexity without obvious benefit**

BACKUP

Engineering Challenges for High-Speed Atmospheric Entry – Venus Example

ADEPT

- **For rigid aeroshell**
  - Size constrained by launch shroud
  - Entry mass constrained by launch vehicle throw capability
  - Ballistic coefficient ~ 250 kg/m²



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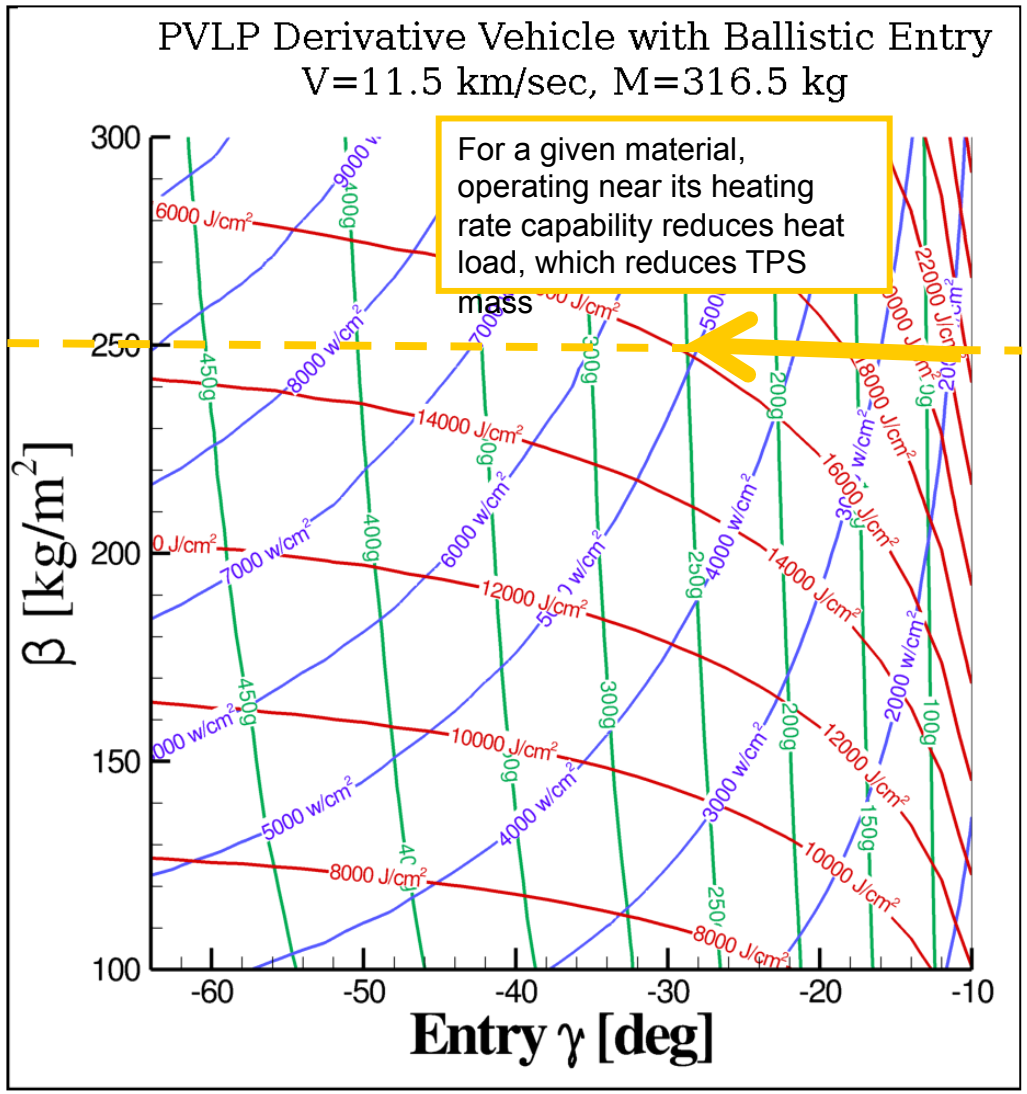

Engineering Challenges for High-Speed Atmospheric Entry – Venus Example

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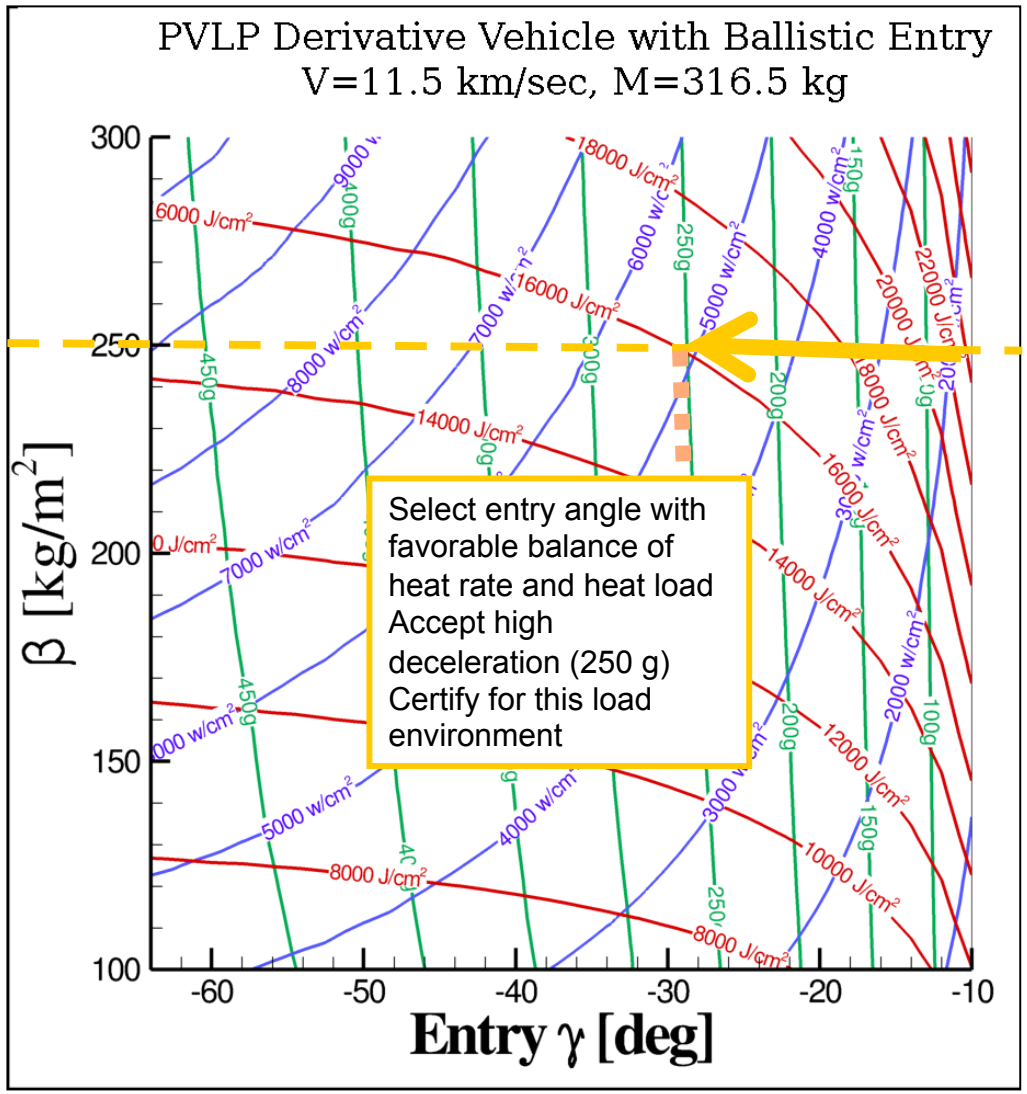
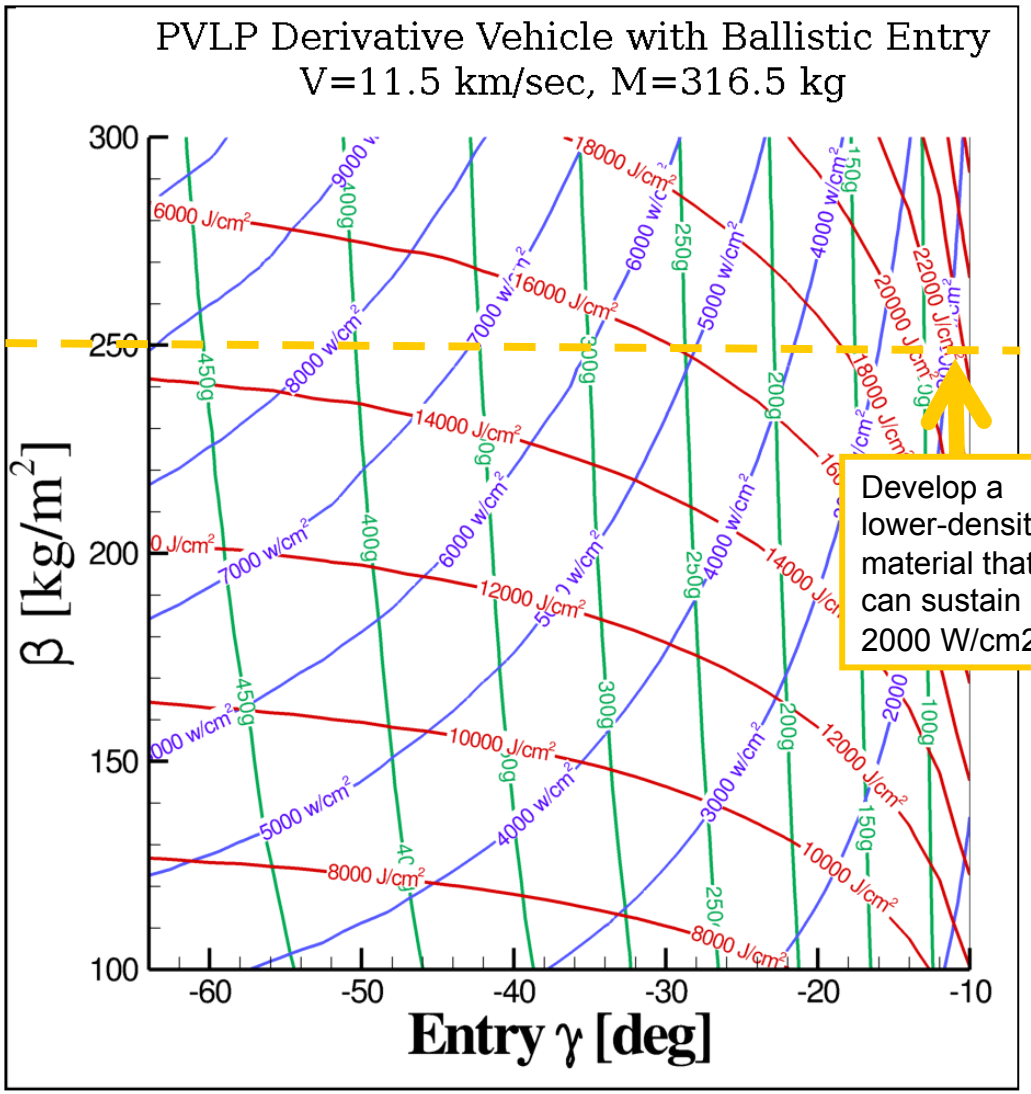


Opportunity for High-Speed Atmospheric Entry – Venus Example

ADEPT



Operate at a lower ballistic coefficient

Develop a lower-density material that can sustain 2000 W/cm2

Opportunity for High-Speed Atmospheric Entry – Venus Example

ADEPT

- Assume ballistic coefficient can be lowered 10 x