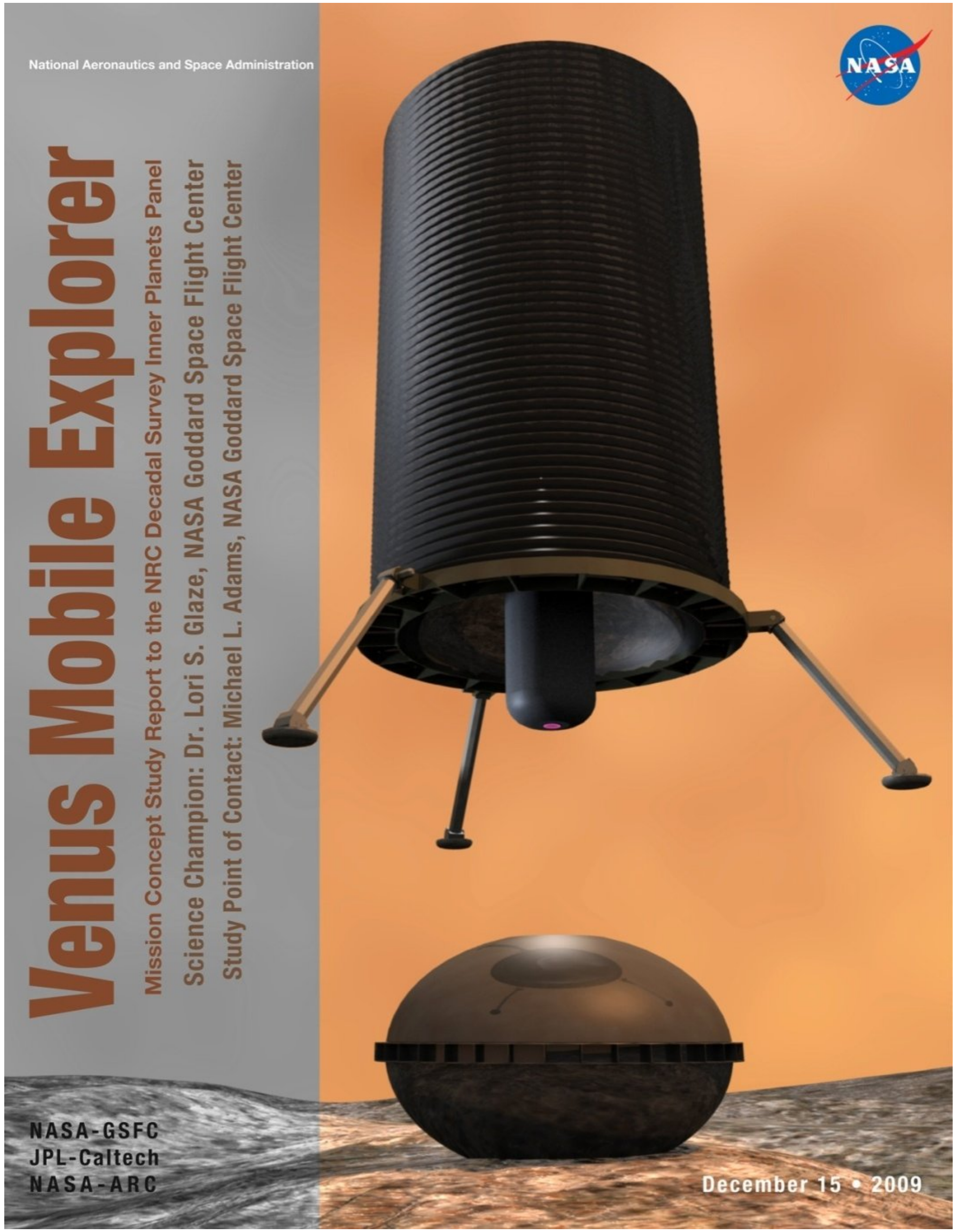
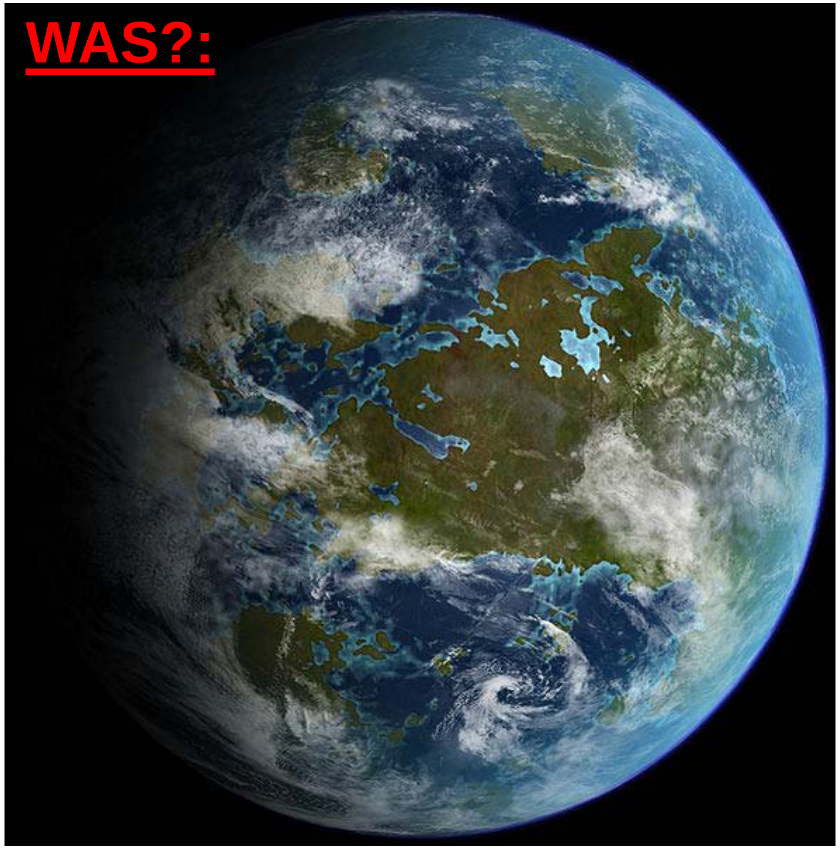
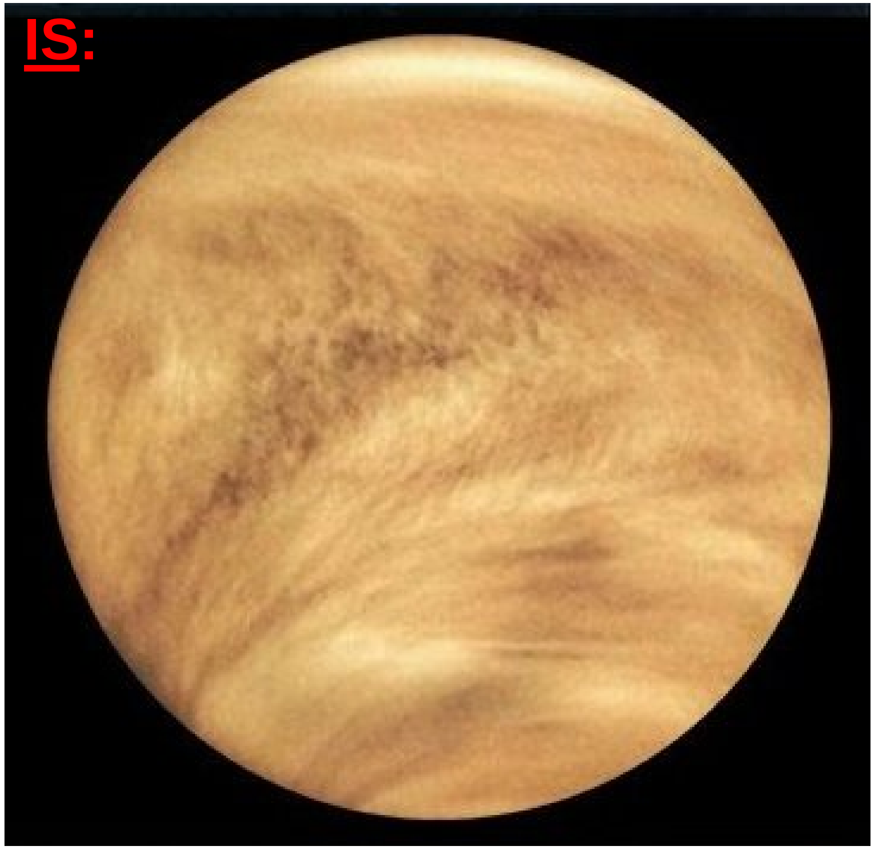


Venus Mobile Explorer (VME): A Mission Concept for the National Research Council Planetary Decadal Survey

L Glaze, C Baker, M Adams, M Amato, T Balint, A Jones, G Karpati, G Marr, S Tompkins, E Venkatapathy, T White

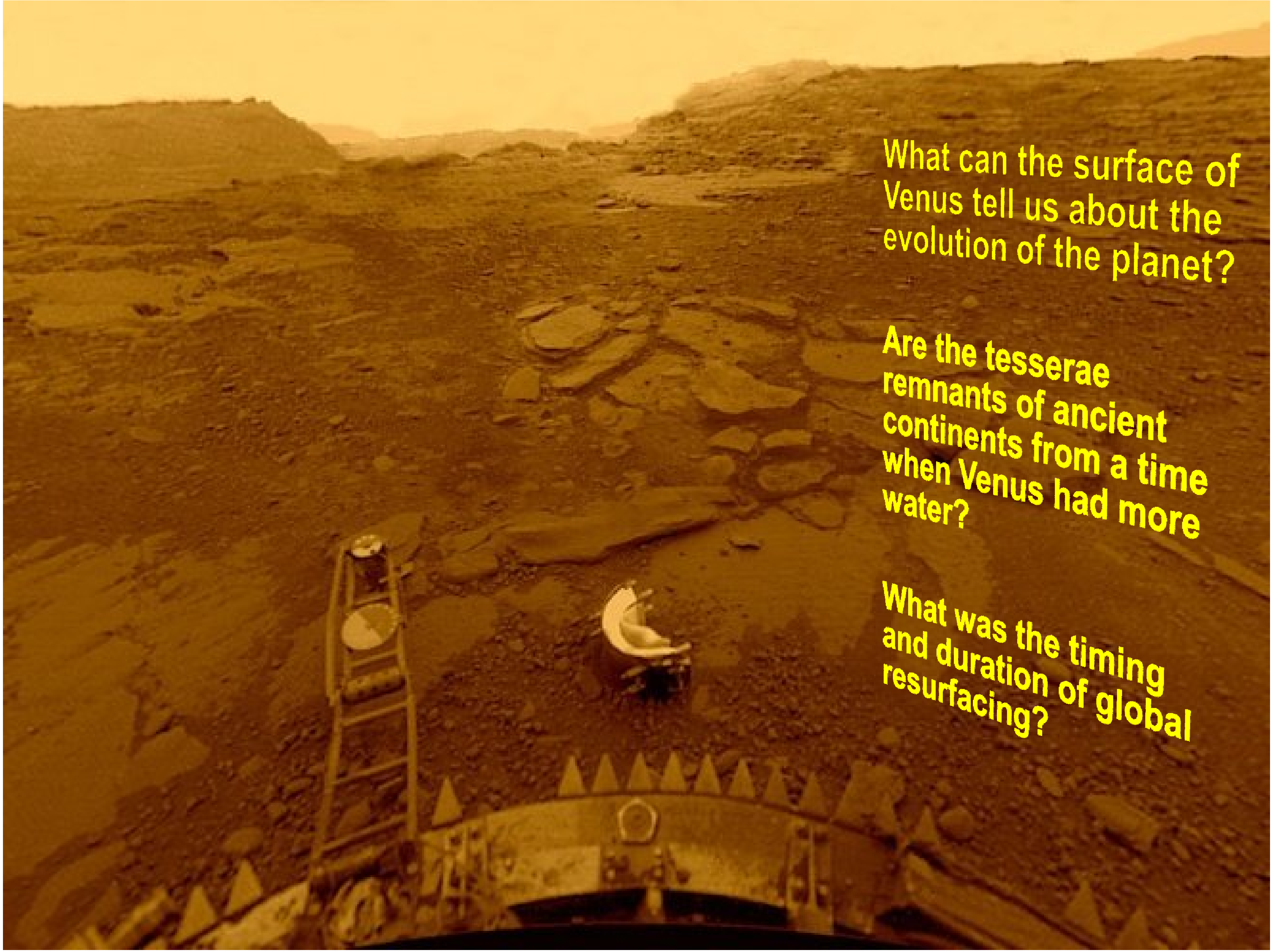
(NASA GSFC, JPL, ARC)





Venus is so similar to Earth in size and composition, one would expect a lot of water there, yet it is virtually absent.

Models for the loss of the water involve the runaway greenhouse effect on Venus.


What can the surface of Venus tell us about the evolution of the planet?
Are the tesserae remnants of ancient continents from a time when Venus had more water?
What was the timing and duration of global resurfacing?

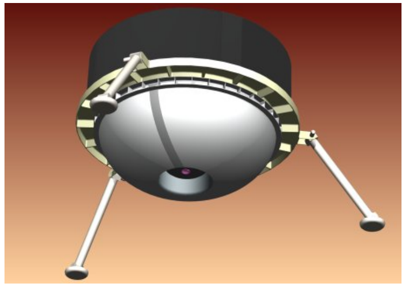
2010 Decadal Survey
Inner Planets Panel (IPP)

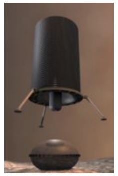
- Requested 3 Venus New Frontiers class mission concept studies:
  - Venus Mobile Explorer (VME) (this talk + T. Balint poster)
    - In situ atmospheric chemistry
    - Surface chemistry and mineralogy in two locations
    - Aerial imaging survey
  - Venus Intrepid Tessera Lander (VITaL) (C. Baker poster)
    - Same as Decadal Venus In Situ Explorer (VISE) mission, but must land in a tessera
    - In situ atmospheric chemistry
    - Surface chemistry and mineralogy
    - Descent imaging
    - Rugged lander must survive plausible range of surface conditions
  - Venus Climate Mission (VCM) (hot off the press)
    - Provide constraints for General Circulation Models from extreme greenhouse atmosphere
    - 4-D In situ (balloon/probes) chemical and physical measurements of atmosphere

VME Study Objectives

- Assess feasibility of a Venus mission with:
  - surface, or near surface, mobility
  - realistic operational lifetime
  - meaningful surface science at two or more independent locations separated by several kilometers
  - budget comparable to a New Frontiers cost envelope.

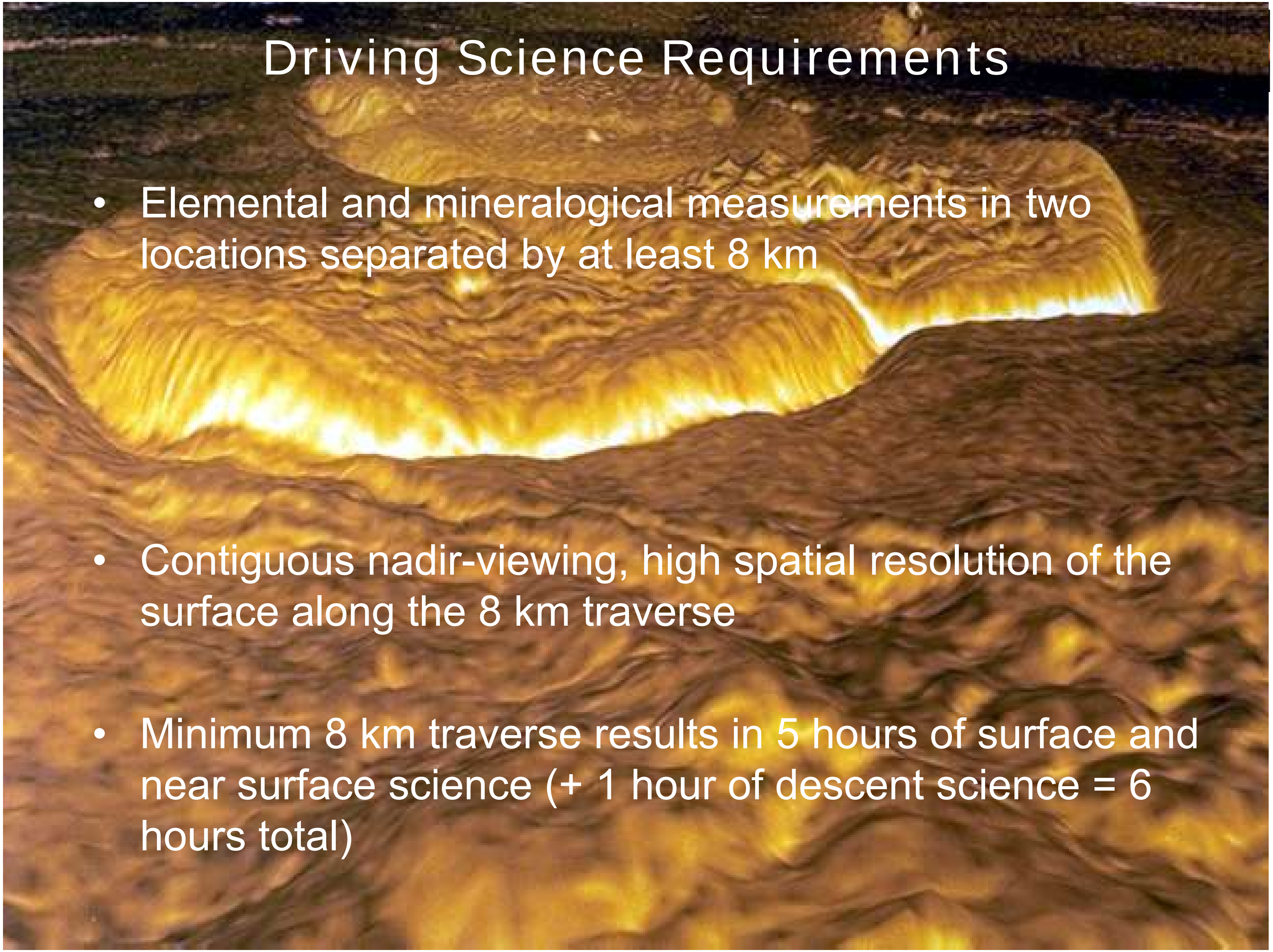
- The IPP was particularly interested in:
  - The metallic bellows mobility concept
  - Use of Radioisotope Power System for power/cooling (not explored because inappropriate for near-surface Venus conditions)





VME Science Traceability

Science Objective	Measurement	Instrument	Functional Requirement
Determine whether Venus has a secondary atmosphere resulting from late bombardment and the introduction of significant outer-solar system materials, including volatiles	Measure Noble gas isotopes	Mass Spectrometer	In situ sample of atmosphere (1 bulk sample on descent)
Characterize major geologic units in terms of major elements, minerals in which those elements are sited, and isotopes	Identify mineralogy and elemental chemistry of surface rocks in ≥ 2 surface locations (separated by x km)	Raman/LIBS	Land in ≥ 2 locations; ~ 1 m path-length for observation; stable platform for measurement duration
Characterize the morphology and relative stratigraphy of surface units	Near IR observations along a transect ≥ 10 km in length, at < 5 m spatial resolution	Near-infrared (~1.1 micron) imager	Position of imager to image the surface, platform stability for clear images
Determine the rates of exchange of key chemical species (S, C, O) between the surface and atmosphere	Measure trace gases in the near surface atmosphere	Mass Spectrometer; Tunable Laser Spectrometer	In situ sampling of atmosphere as functions of altitude and time [f (z, t)]
Place constraints on the size and temporal extent of a possible ocean in Venus's past	Measure D/H ratio in atmospheric water	Mass Spectrometer; Tunable Laser Spectrometer	In situ sampling of atmosphere [f (z, t)]
Characterize variability in physical parameters of the near surface atmosphere (pressure, temperature, winds, radiation)	Temperature, Pressure, winds	Temperature, pressure, accelerometers, Ultra-Stable Oscilator	In situ measurements of T/P, communication with orbiter for Doppler winds
Measure ambient magnetic field from low- and near-surface elevations	Detection of existence or absence of magnetic signal	Magnetometer	Must be able to detect surface "signal" above payload "noise"



Driving Science Requirements

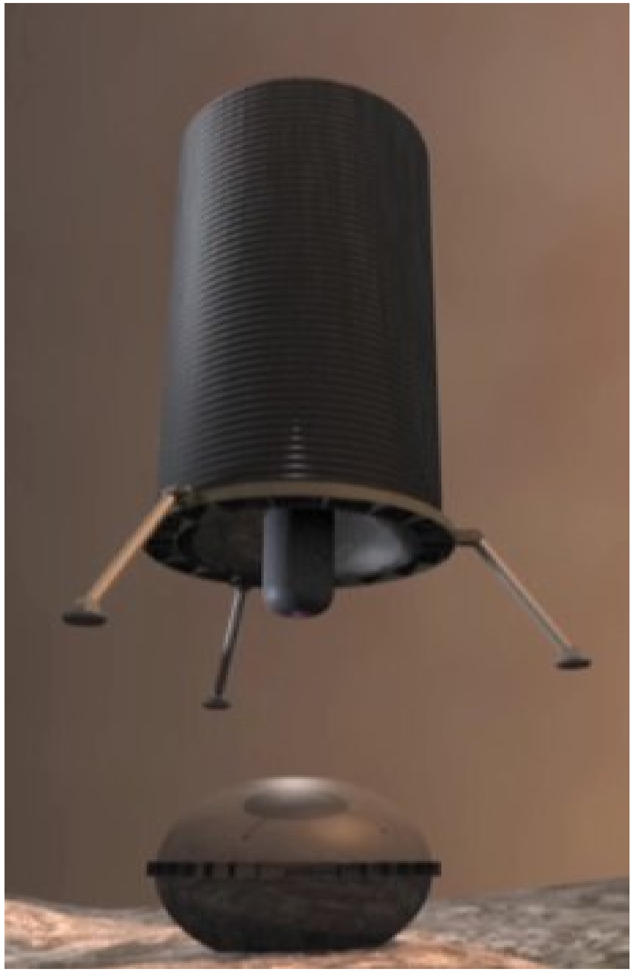
- Elemental and mineralogical measurements in two locations separated by at least 8 km

- Contiguous nadir-viewing, high spatial resolution of the surface along the 8 km traverse

- Minimum 8 km traverse results in 5 hours of surface and near surface science (+ 1 hour of descent science = 6 hours total)

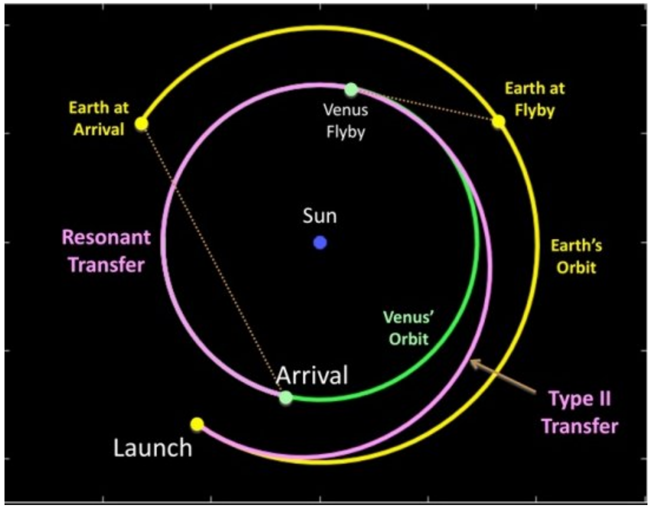
Venus Mobile Explorer (VME)
Key attributes

- 1 hour descent science
  - Evolution of the atmosphere
  - Interaction of surface and atmosphere
  - Atmospheric dynamics
- 5 hours of surface and near-surface science
  - Physics and chemistry of the crust
- Aerial mobility to access 2 surface locations



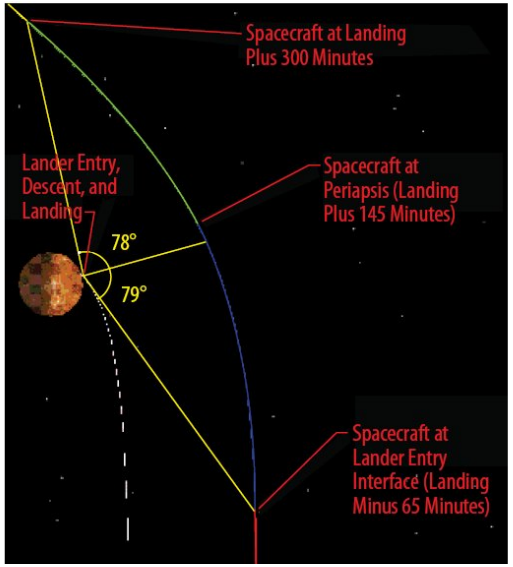
Nominal Mission Scenario

Launch on an Atlas V 551 (short fairing) in May 2023

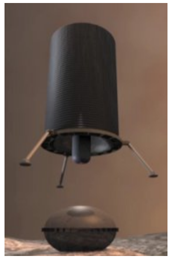


Type II trajectory to Venus

Venus fly-by October 2023



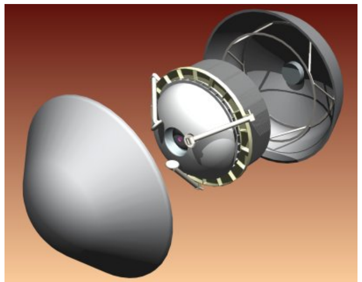
Landed science mission February 2024



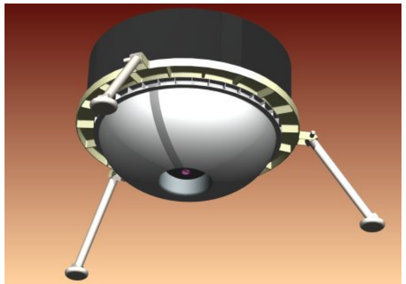
VME Strawman Science Instrument Complement

	Mass (kg)	Power (watts)	Volume (cm)	Data Volume	TRL/Heritage
Neutral Mass Spectrometer (NMS)	11	50	26 x 16 x 19	2 kbps	6-7 MSL/SAM
Tunable Laser Spectrometer (TLS)	4.5	17	25 x 10 x 10	3.4 kbps	6-7 MSL/SAM
Raman/Laser Induced Breakdown Spectroscopy (LIBS)	6.0	6.7	CCD & preamps: 19 x 14 x 19, Optical Head: 08 x 07 x 10, Electronics: 08 x 10 x 40	1.5 Mb/sample	4/ExoMars
Near-IR Imager	1.8	12	17 x 09 x 09	1.65 Mb/image	6/Venus Flagship
Magnetometer	1.0	1.0	20 x 10 x 10	0.1 kbps	6/Various
Atm Structure Investigation (ASI)	2.0	3.2	10 x 10 x 10	2.5 kbps (descent) 0.25 kbps (surface)	6/Venus Flagship

Entry flight System

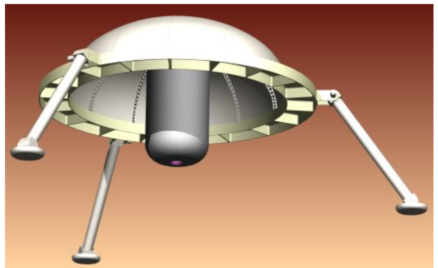


Lander Descent



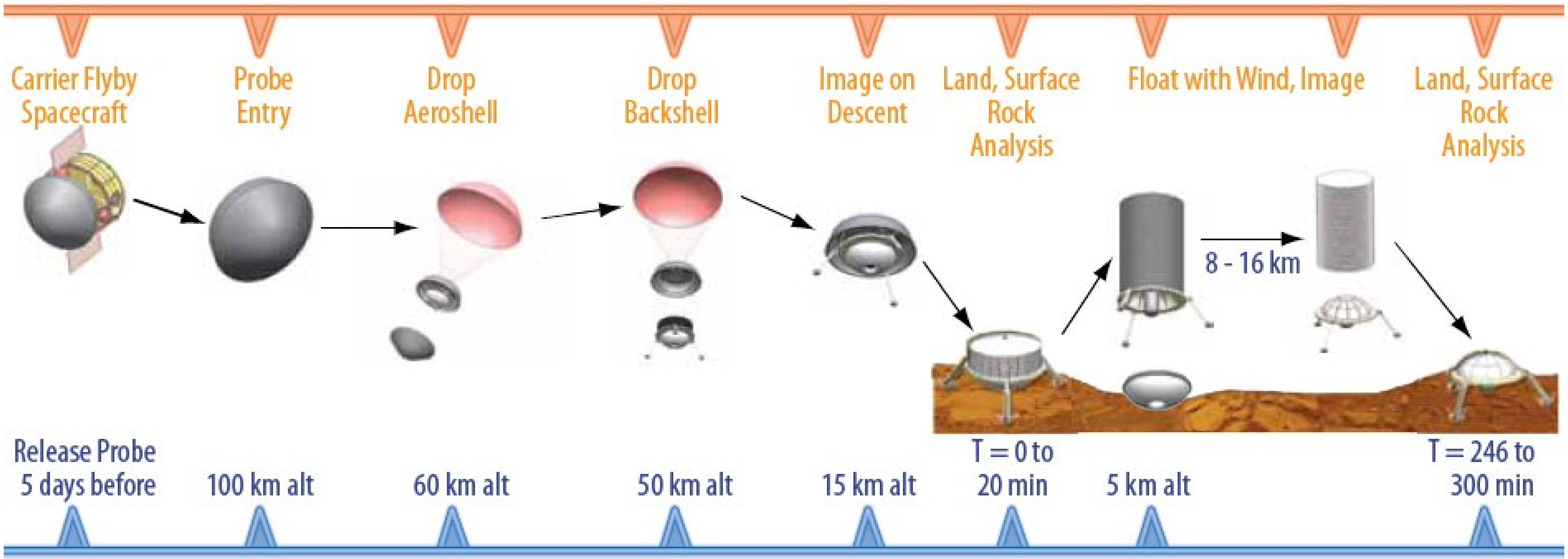
Post-inflation Ascent

Final Descent

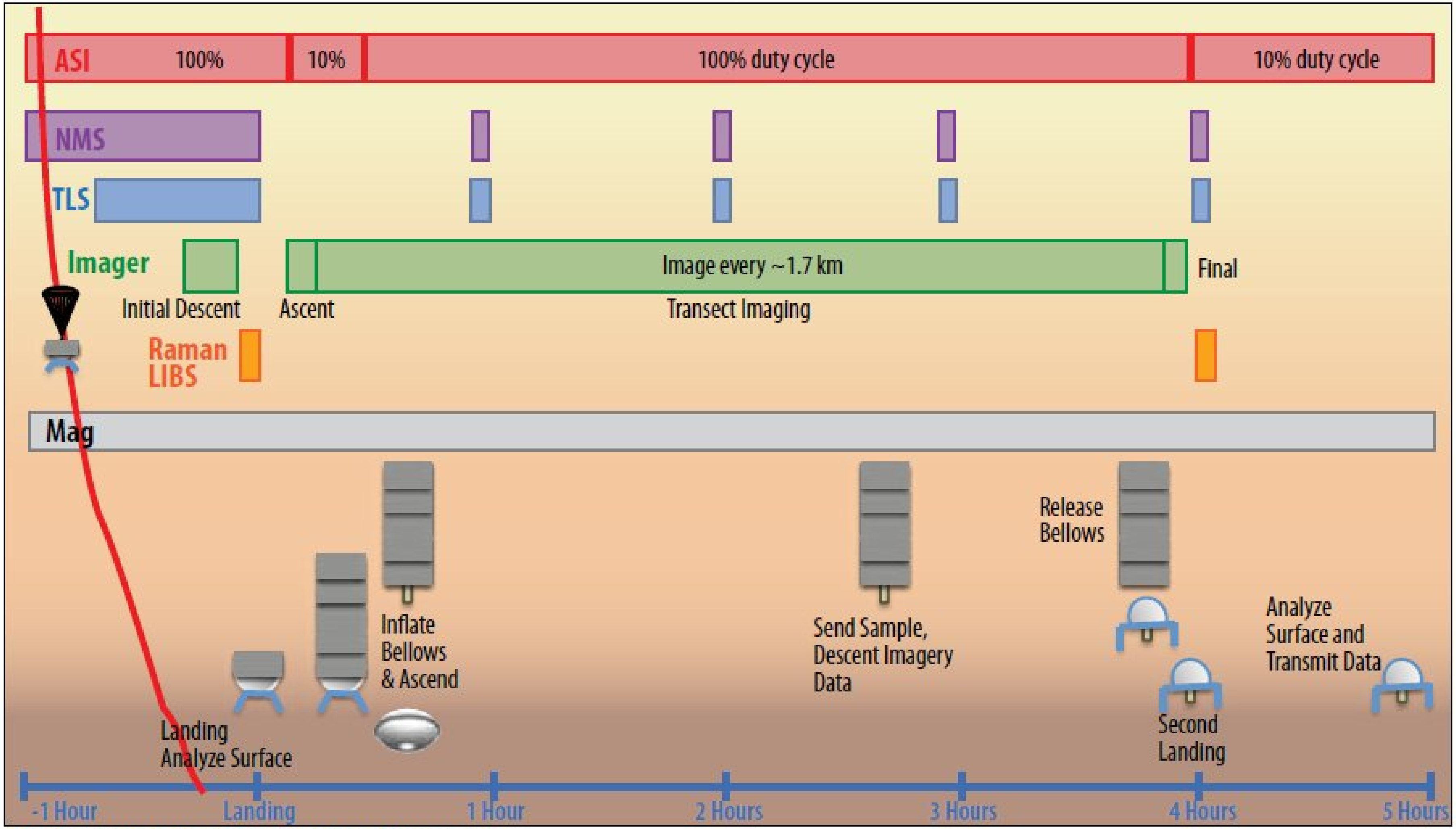


VME Concept of Operations

5 Hour Near-surface Lifetime

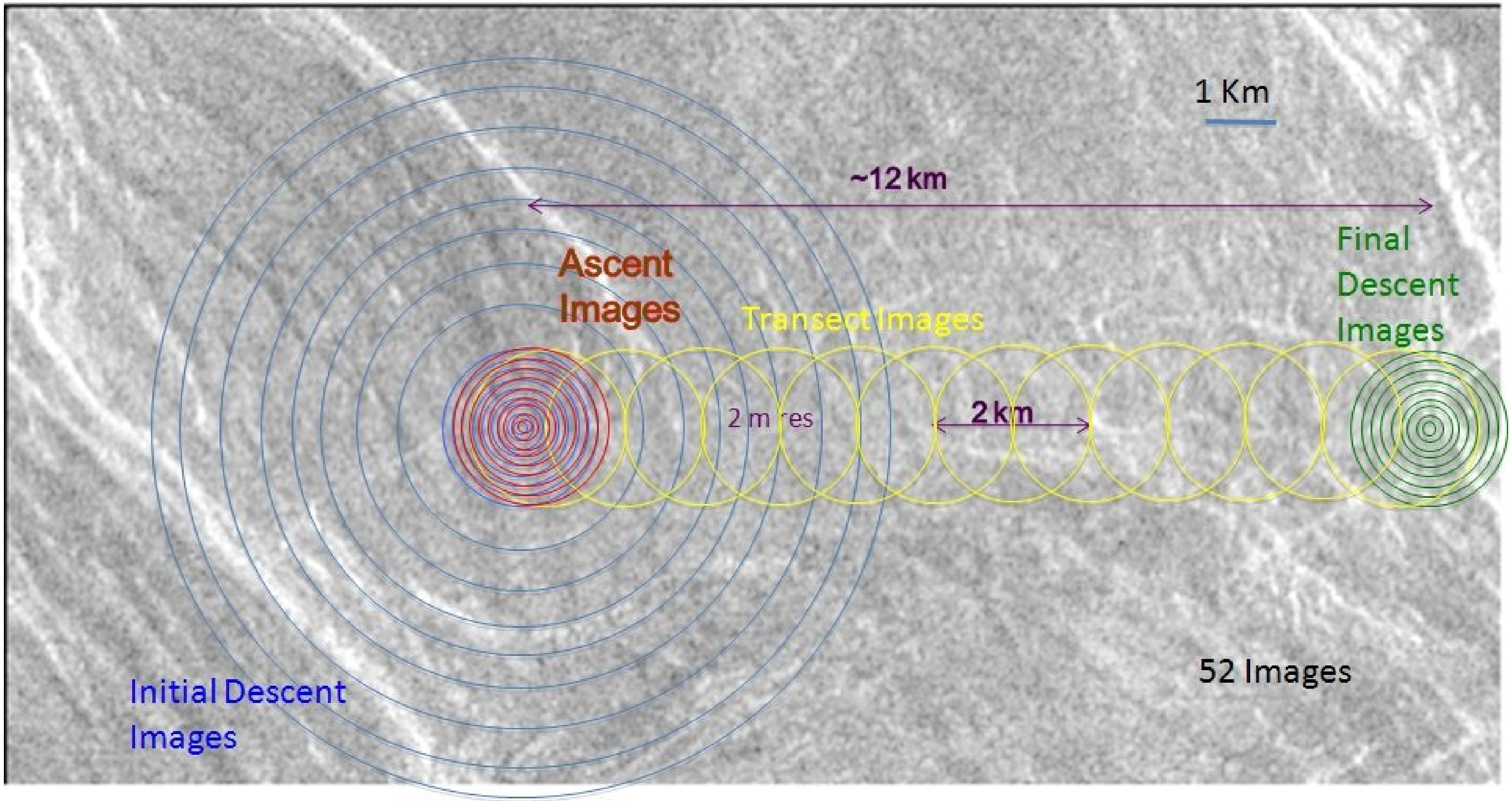


VME communicates with Spacecraft throughout science mission



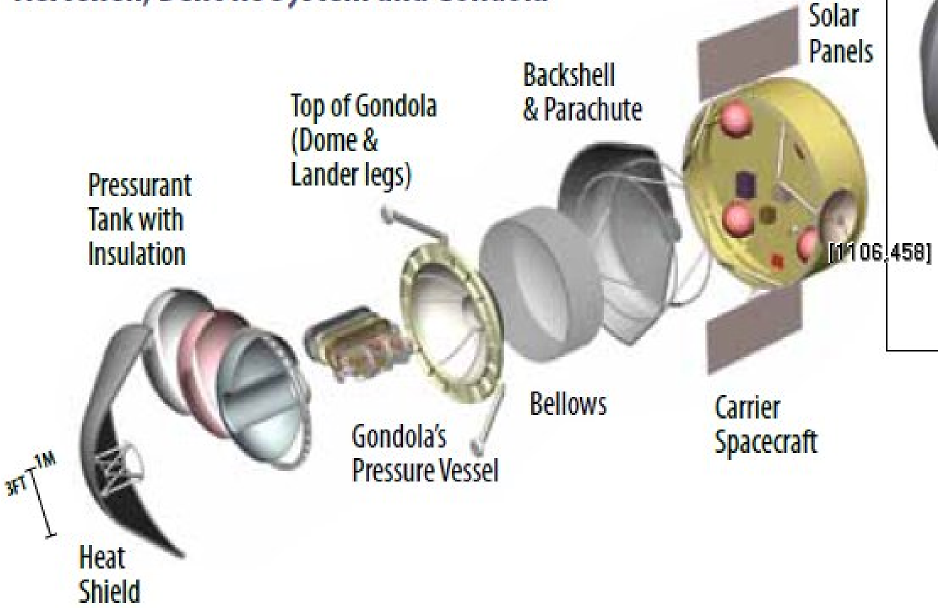
ASI = Atmospheric Structure Investigation; Mag = Magnetometer

Nominal 12 km traverse provides contiguous imaging at (context for Raman/LIBS), and between, two surface locations

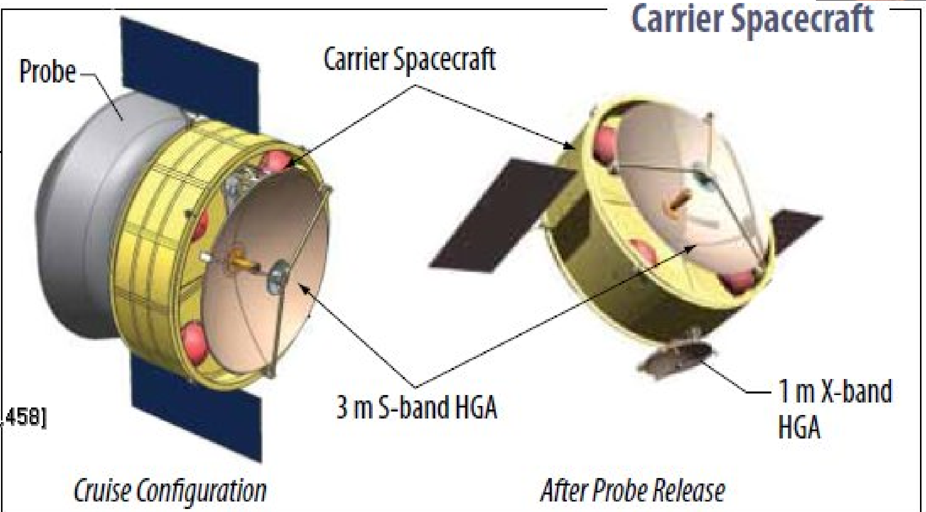


Carrier Spacecraft w/ Lander

Exploded view of Carrier Spacecraft, Aeroshell, Bellows System and Gondola



Carrier Spacecraft



1 kg instrument mass:

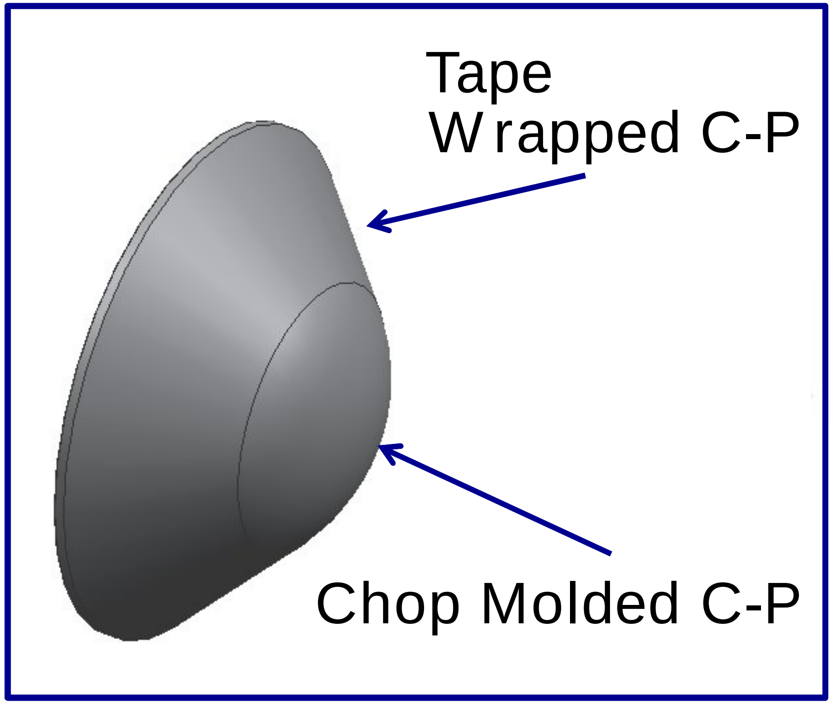
→5 kg structure (drives bellows mass, aeroshell mass)

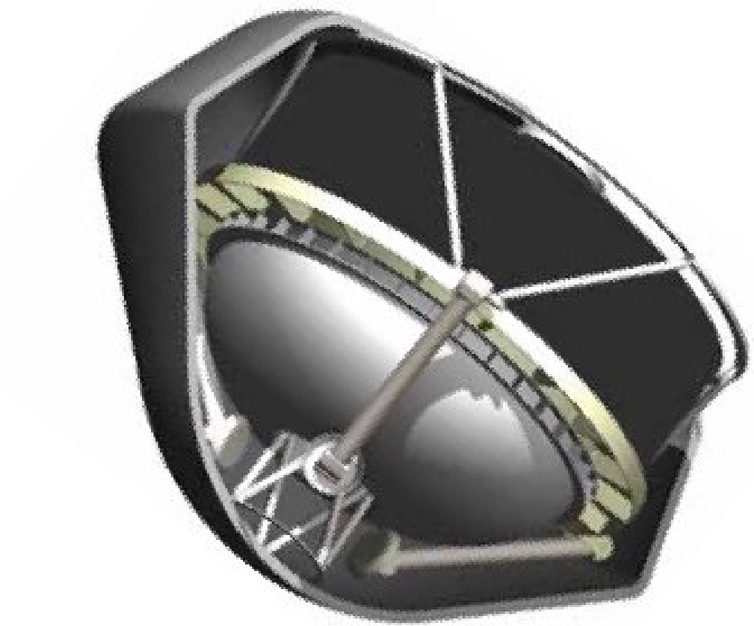
→50 kg launch mass

Mass Rackup:

Item	CBE (kg)	Composite Mass Growth Allow. (%)	Max Expected Mass (kg)
Lander	**1390**	30%	**1782**
Lander Science Payload	31	30%	41
Lander Subsystems	469	30%	609
Mechanical/ Structure	270	30%	351
Mechanisms	51	30%	66
Thermal	113	30%	147
Other	34	30%	44
Bellows	890	30%	1132
Aeroshell	**876**	30%	**1139**
Spacecraft	846	30%	1100
Satellite (S/C + Probe) Dry Mass	3112	30%	4021
Propellant Mass	366	1%	370
Satellite Wet Mass	3478		4390
LV Throw Mass available to lift Wet			5141
Mass Margins			
LV Limited Max Wet Mass [kg]			5141
Propellant in LV Limited Max [kg]	428	3%	441
LV Limited Max Dry Mass [kg]			4700
Project Margin (Wet Mass Growth, MEV to LV Limit) [kg]			751
Wet Mass Growth (Wet Mass Growth, MEV to LV Limit) [%]			17%
Total Possible CBE Dry Mass Growth			1234
Total Possible CBE Dry Mass Growth [%]			35.5%

Pioneer Heritage Aeroshell by Ames



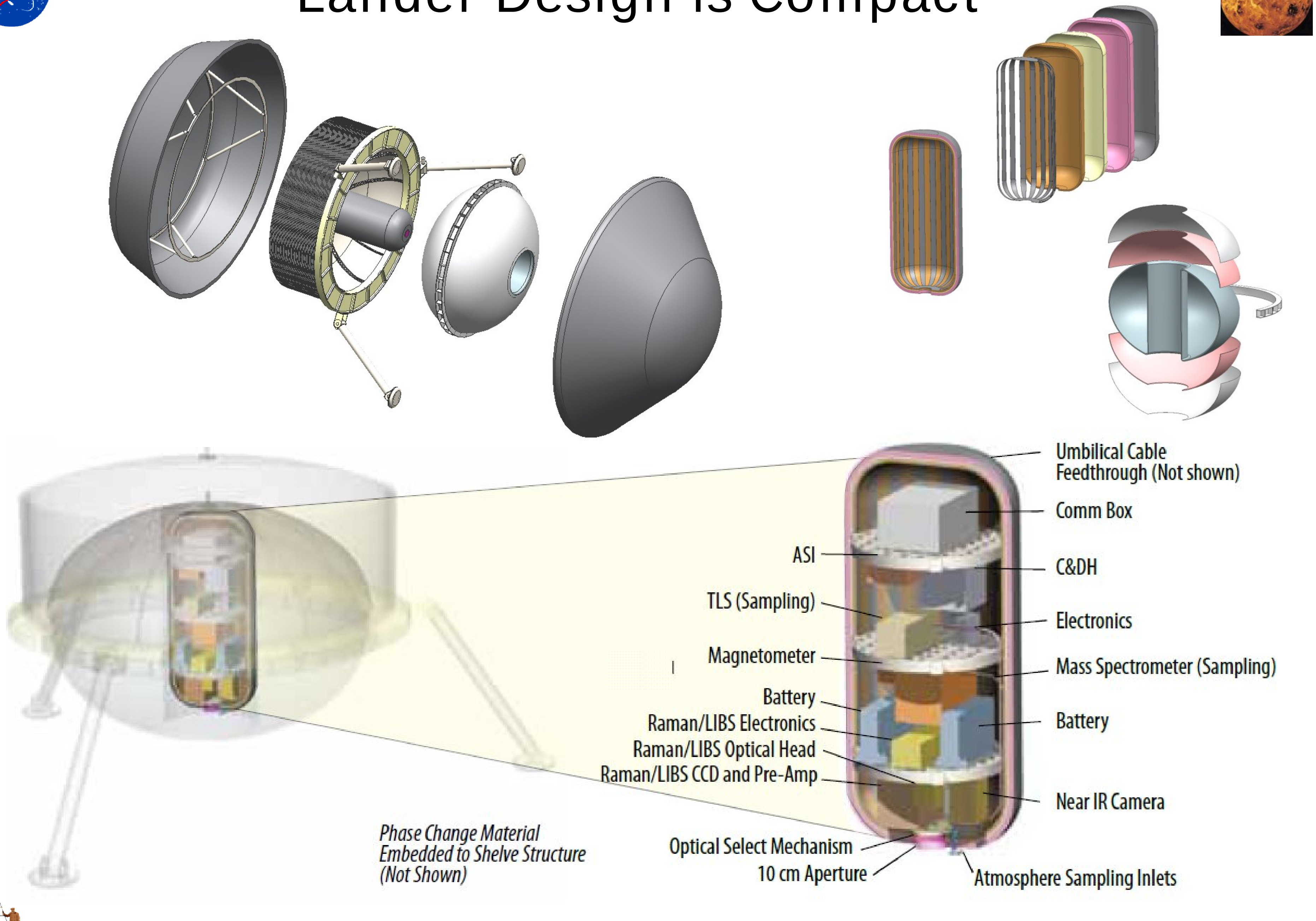


[redacted]ameter

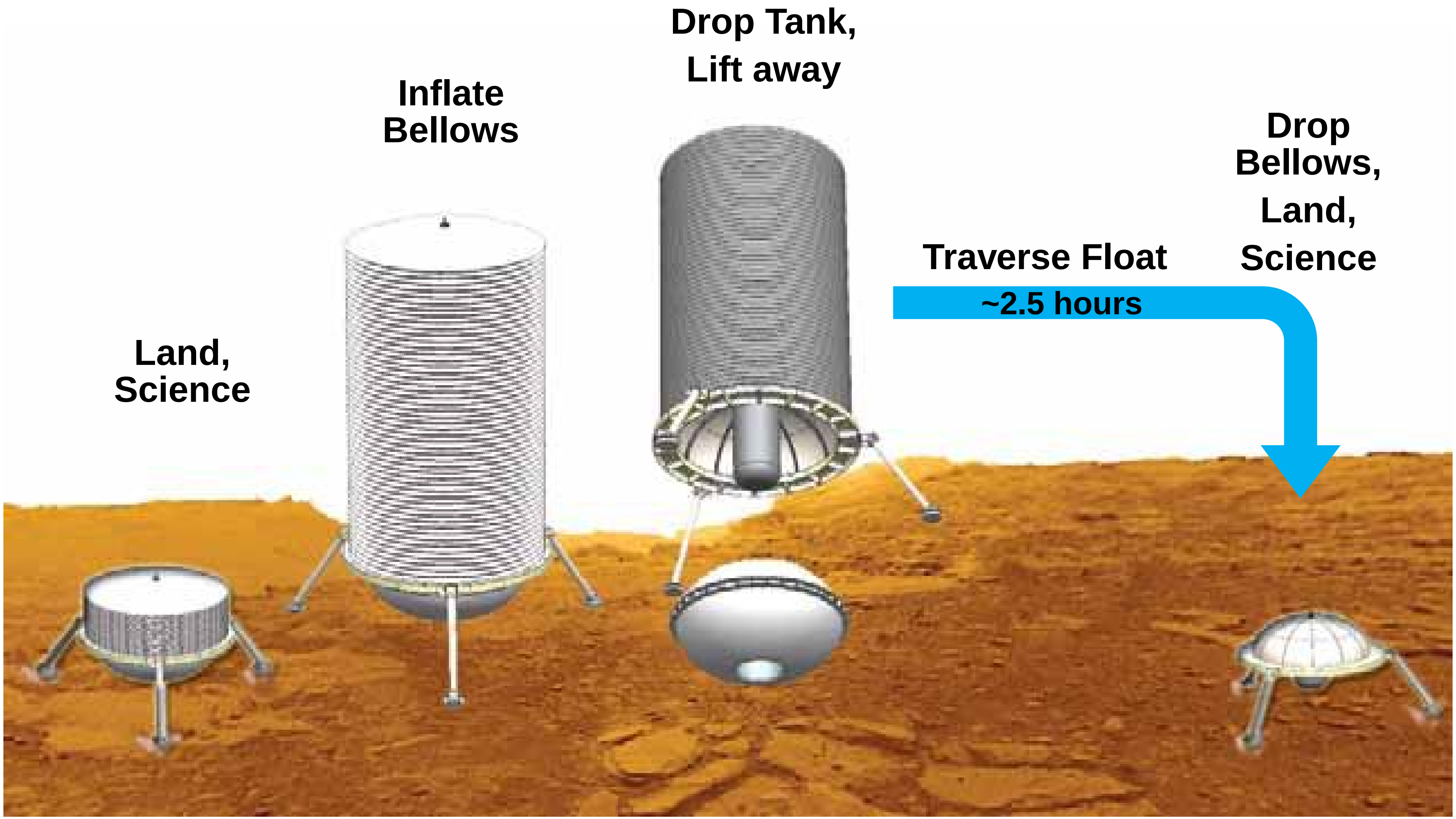
- •Fabrication process needs to be re-qualified
- •Heritage precursor material in hand at Ames
- •Enough precursor for the large VME aeroshell

(Raj Venkatapathy discussing in Friday session)

Lander Design is Compact

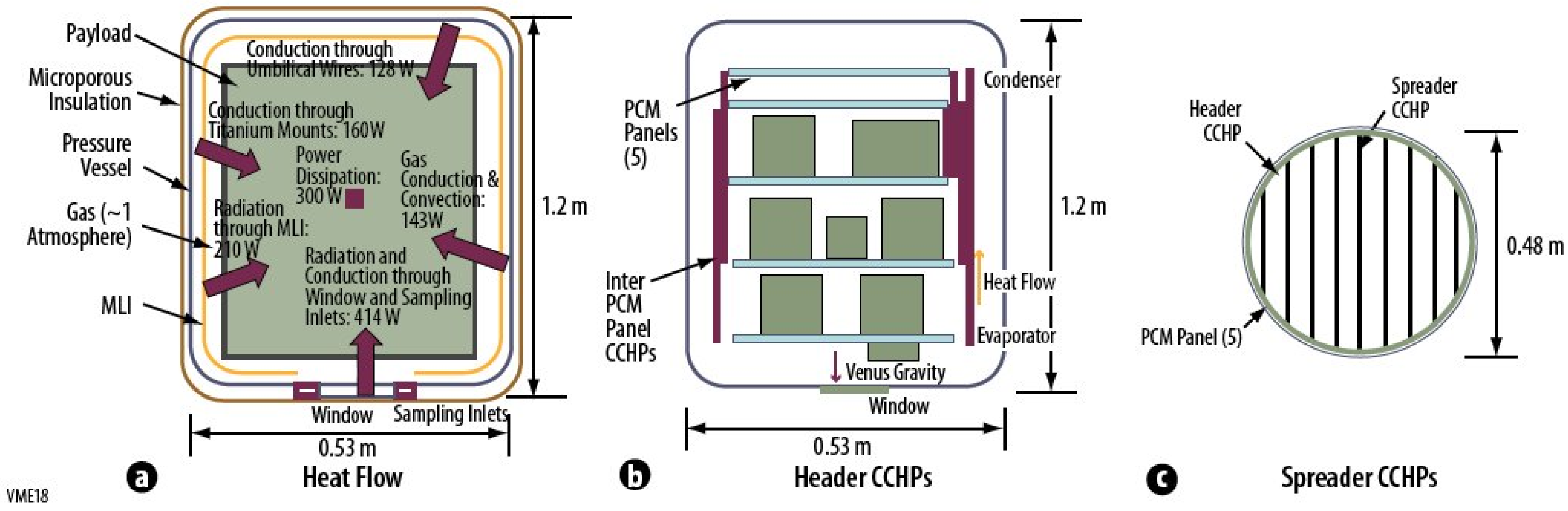


Aerial Mobility Provided by Bellows System (T. Balint poster)

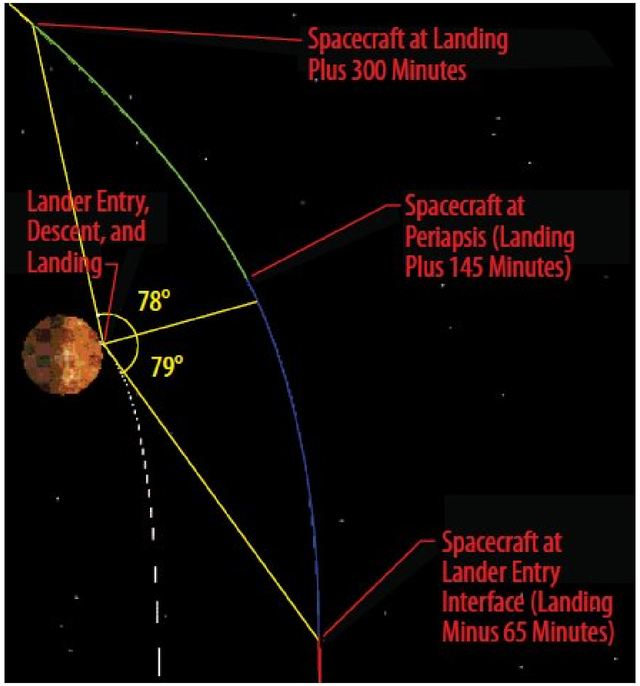


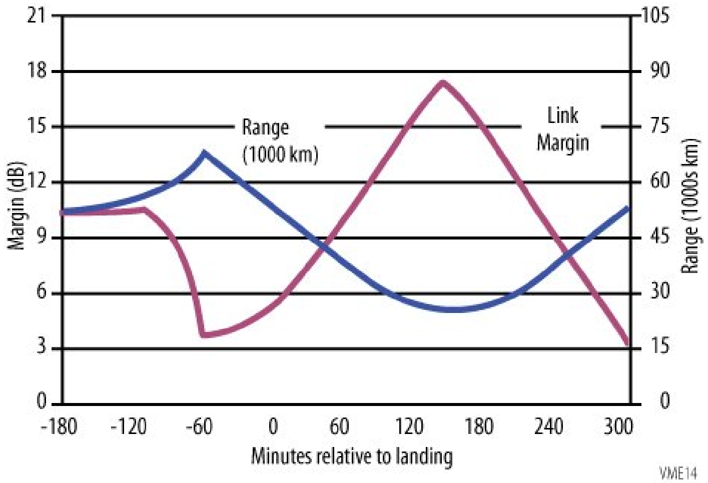
Pressure Vessel Thermal Control

- Thermal Environment is controlled with Phase Change Material (PCM), Constant Conductance Heat Pipes (CCHPs), and Multi-Layer Insulation (MLI)

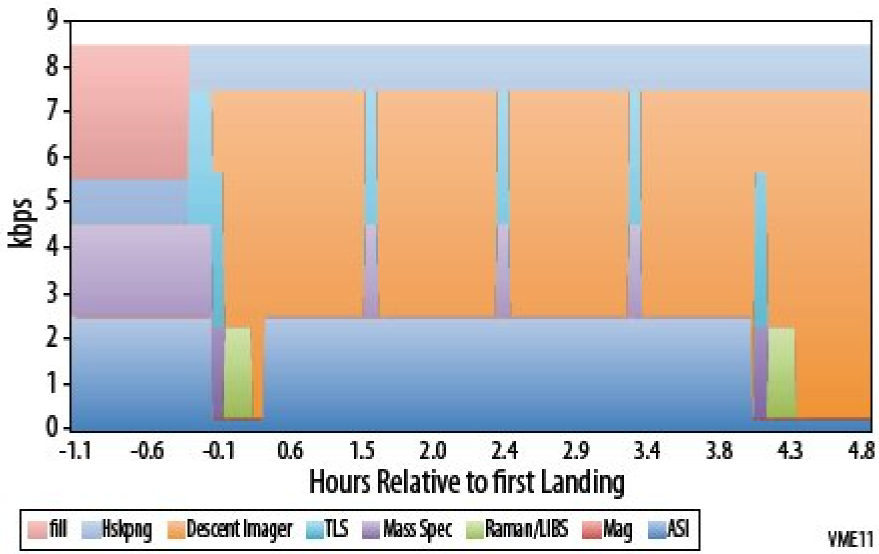


Communications



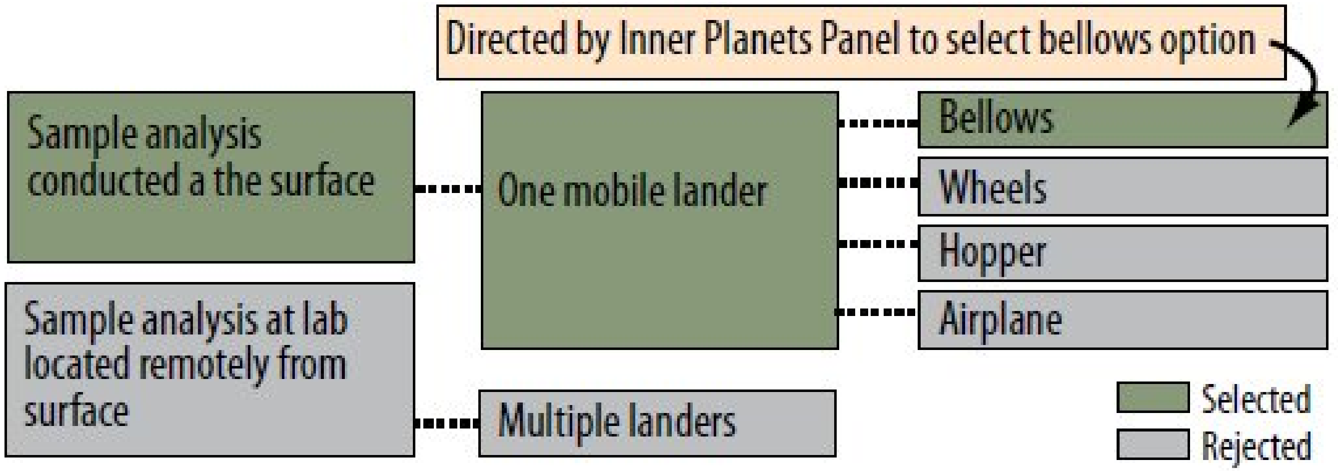


- VME transmits at a constant rate (8.5 kbps) for 7 hours (1 hour prior to entry, 1 hour descent, 5 hours on/near surface
- Minimum 3dB margin
- Total data uplinked to carrier is ~200 Mbits



Architecture Trades

- Desire to better understand the cost and capabilities of the bellows concept contributed to its selection for more detailed study.
- Prototype bellows had been tested by JPL at Venus surface temperatures (but not pressures or composition).
- Sizing of the system to provide buoyancy to a surface lander had not been done
- Original motivation for bellows was for sample return
- This system can only be inflated once – limits surface access to two locations.



Concept Maturity Level (CML)

- Venus surface and near-surface mobility concepts were assessed as CML 2 or lower:
  - Had been studied to determine feasibility, but no architecture trade studies that evaluated detailed cost, risk, or performance
- The concept described here brings the metallic bellows Venus mobility concept to CML 4:
  - Preferred design point
- Please see Tibor Balint poster for more details on the bellows design.

Key Risks

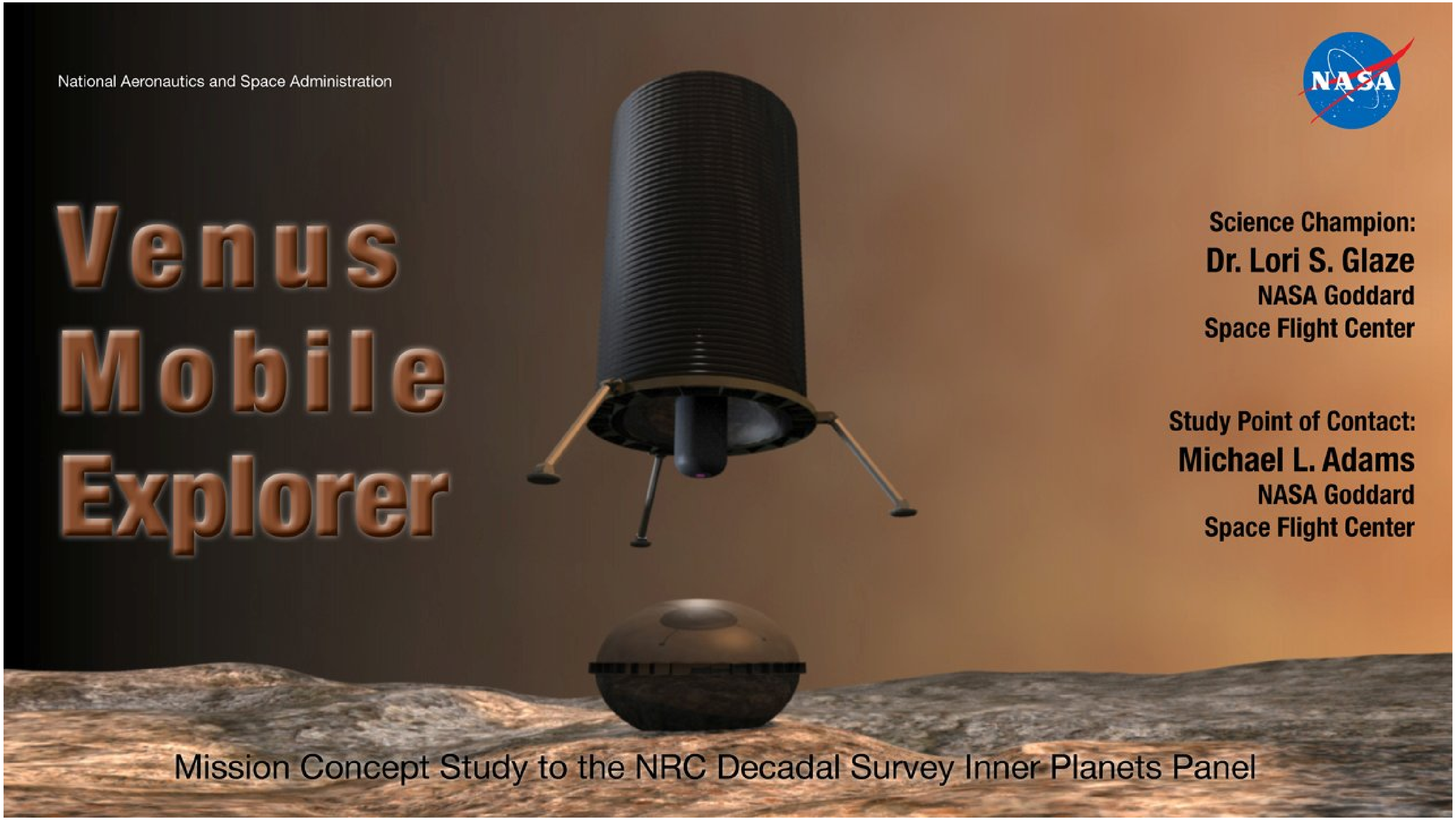
- Bellows concept development
  - Helium tank – large titanium, toroidal shape
  - Valves – Venus surface activation
  - Multiple mechanisms
  - Critical timing of events for operations – precise timing required
- Safe landing
  - beyond scope of this study, some mass allocated
- Full scale Venus environment test facilities
  - no known test facility can accommodate the bellows system
  - Costs for development of such a facility not included in study
- Raman/LIBS calibration under Venus surface conditions

VME Cost Estimate

- Estimated cost for the VME concept is in the low-end Flagship cost range (beyond New Frontiers)
- Assumed:
  - remote sensing technique for surface chemistry and mineralogy can be demonstrated
  - Appropriate test facility will be ready, paid for outside of VME
  - Considerable progress through internal research and development studies prior to Phase-A
  - Mission-specific targeted development would start at the beginning of Phase –A (not typical for New Frontiers)
  - 6.5 years for Phases B-D (long for New Frontiers, Flagship?)
- Needs substantial development to bring this concept into New Frontiers class mission category

Conclusions

- Metallic bellows aerial mobility system is technically feasible and within reach with today's technology
- VME offers the most credible approach for Venus near-surface mobility with a single flight system.
- Extended near surface survival (thermal, power) would allow much longer aerial traverse – mass trade with bellows
- RPS is currently not an option for Venus surface environment
  - Even with technology development, will be too heavy for mobile platforms
- VME can address many high priority Decadal science objectives within the Low End Flagship cost range
- Final report is available upon request from the National Research Council


National Aeronautics and Space Administration
Venus Mobile Explorer
Science Champion:
Dr. Lori S. Glaze
NASA Goddard Space Flight Center
Study Point of Contact:
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NASA Goddard Space Flight Center
Mission Concept Study to the NRC Decadal Survey Inner Planets Panel

Back up

Venus Science Questions for NASA New Frontiers Program (<$1B, PI-led missions)

- 2003 Planetary Decadal Objectives for Venus:
  - Understand the physics and chemistry of Venus’ atmosphere, especially the abundances of its trace gases, sulfur, light stable isotopes, and noble gas isotopes;
  - Constrain the coupling of thermochemical, photochemical, and dynamical processes in Venus’ atmosphere and between the surface and atmosphere to understand radiative balance, climate, dynamics, and chemical cycles;
  - Understand the physics and chemistry of Venus’ crust;
  - Understand the properties of Venus’ atmosphere down to the surface and improve our understanding of Venus’ zonal cloud-level winds;
  - Understand the weathering environment of the crust of Venus in the context of the dynamics of the atmosphere and the composition and texture of its surface materials; and
  - Look for planetary scale evidence of past hydrological cycles, oceans, and life and for constraints on the evolution of the atmosphere of Venus