Team Blue

VEnus

Lander and

Orbiter for

Characterising the

Interior and

TEctonics

Presentation Outline

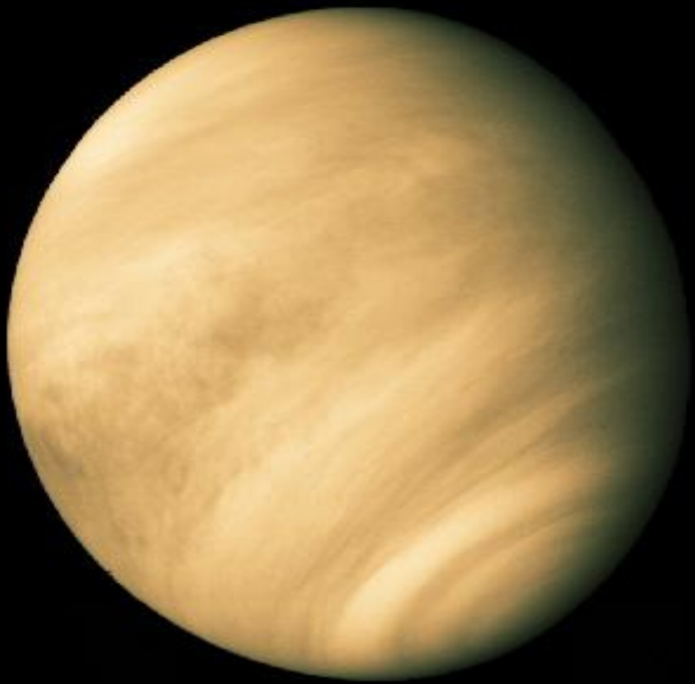
1. Overview
2. Science & Mission Objectives
3. Instruments Overview
4. Spacecraft and Subsystems Design
5. Orbit Configuration
6. Analyses
7. Summary

Similarities to Earth

Mass	4.87×10^{24} kg	5.97×10^{24} kg
Equatorial radius	6052 km	6378 km
Mean density	5243 kg/m^3	5514 kg/m^3

Differences to Earth

- Optically opaque atmosphere (96% CO_2)
- High surface temperature (737 K)
- High air pressure (92 bar)
- No active magnetic field
- Extensive resurfacing 1 Ga ago



http://ircamera.as.arizona.edu/NatSci102/NatSci102/lectures/venus.htm

Previous Missions to Venus

Venera lander

Pioneer-12 (1978):
- topography, radio thermal emission, surface roughness

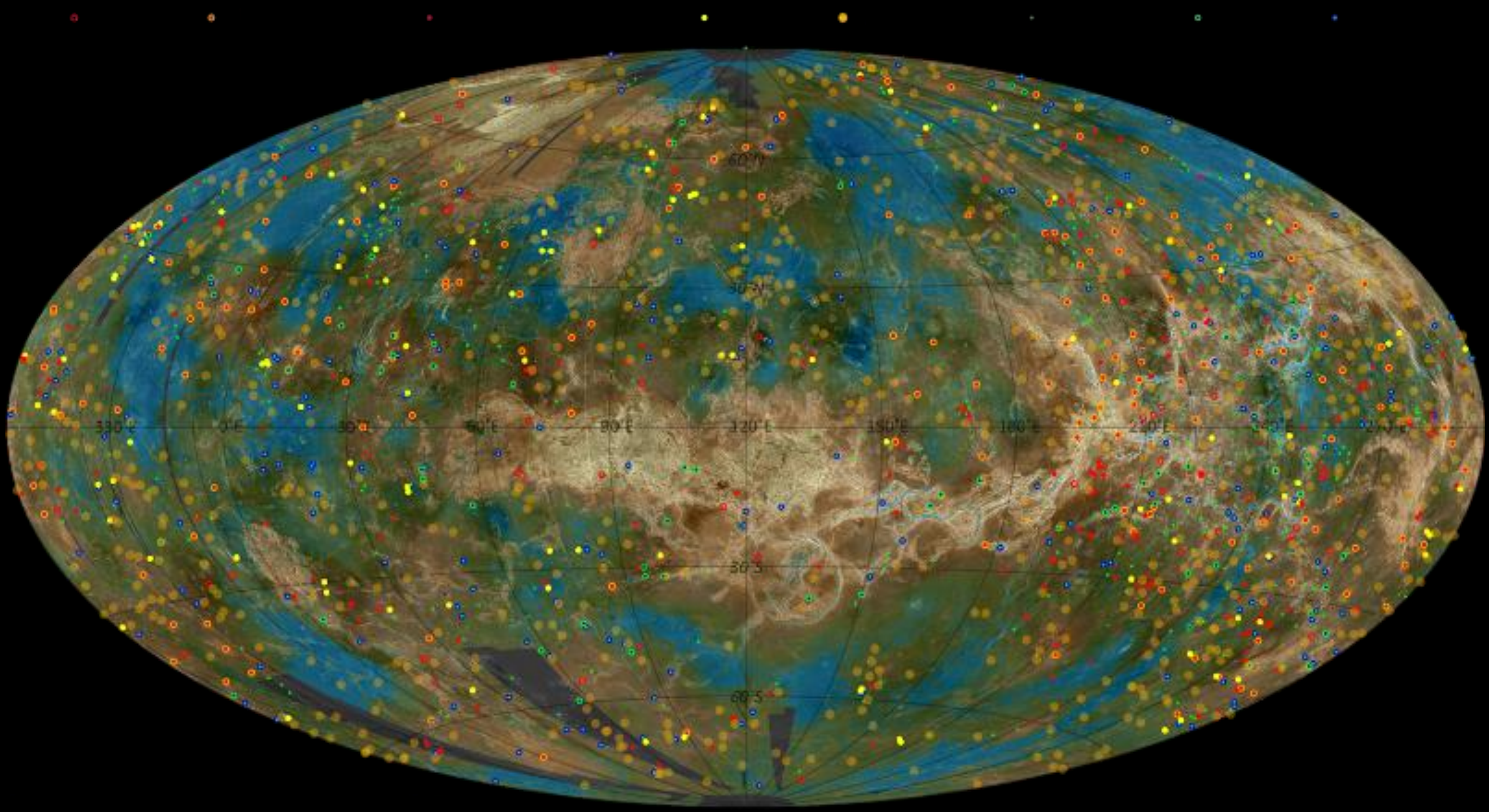
Venera-15 & 16 (1983):
- extensive lava fields, shield volcanoes, ridges and coronae

Magellan (1989):
- radar surface imaging, topography , gravity field

Venus Express (2005):
- long term observation of the Venusian atmosphere
  (active volcano?)

Magellan

Venus Tectonics: current knowledge

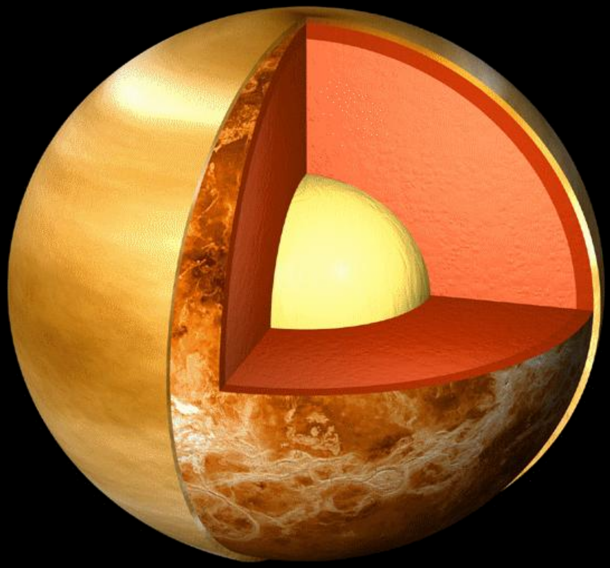


Richard Chail (2014), Venus Geophysics

Venus Tectonics: desired knowledge

Elevation and gravity models exist but no hard information on

- dynamic processes
- tectonic processes

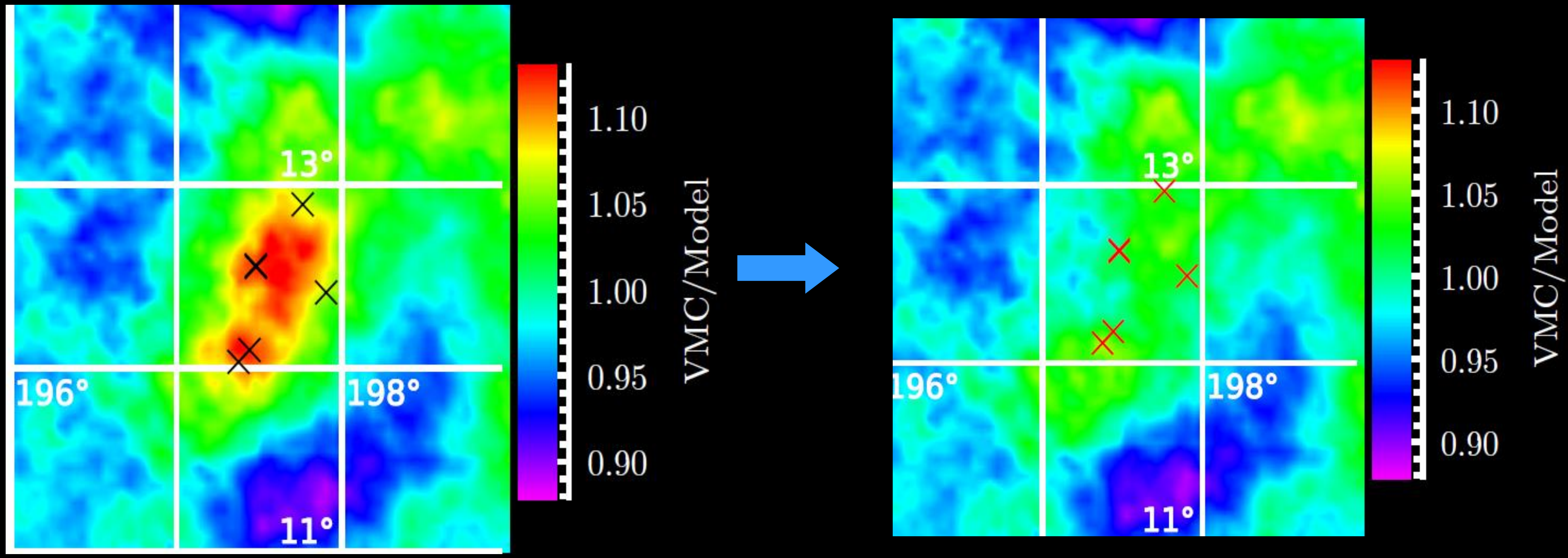


Scarcity of knowledge about surface and interior of Venus

- chemical composition of surface/interior
- structure of the interior (core-mantle-crust)
- venusian libration and moment of inertia

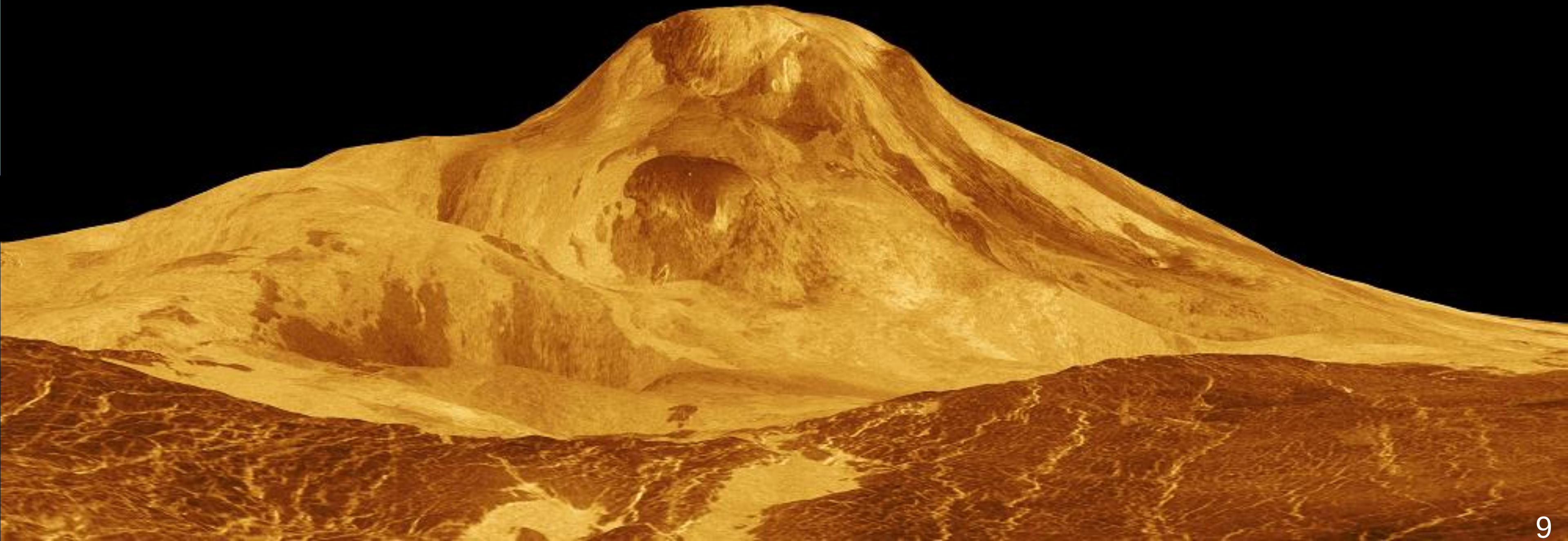
Recent Discoveries

Hints of ongoing activity



Comparison of data ratios to model with and without lava flows

Science and Mission Objectives



Mission statement

Investigating our twin planet by satellite and in-situ measurements will provide us a unified scenario of terrestrial planet formation and the past and the evolution of Earth.

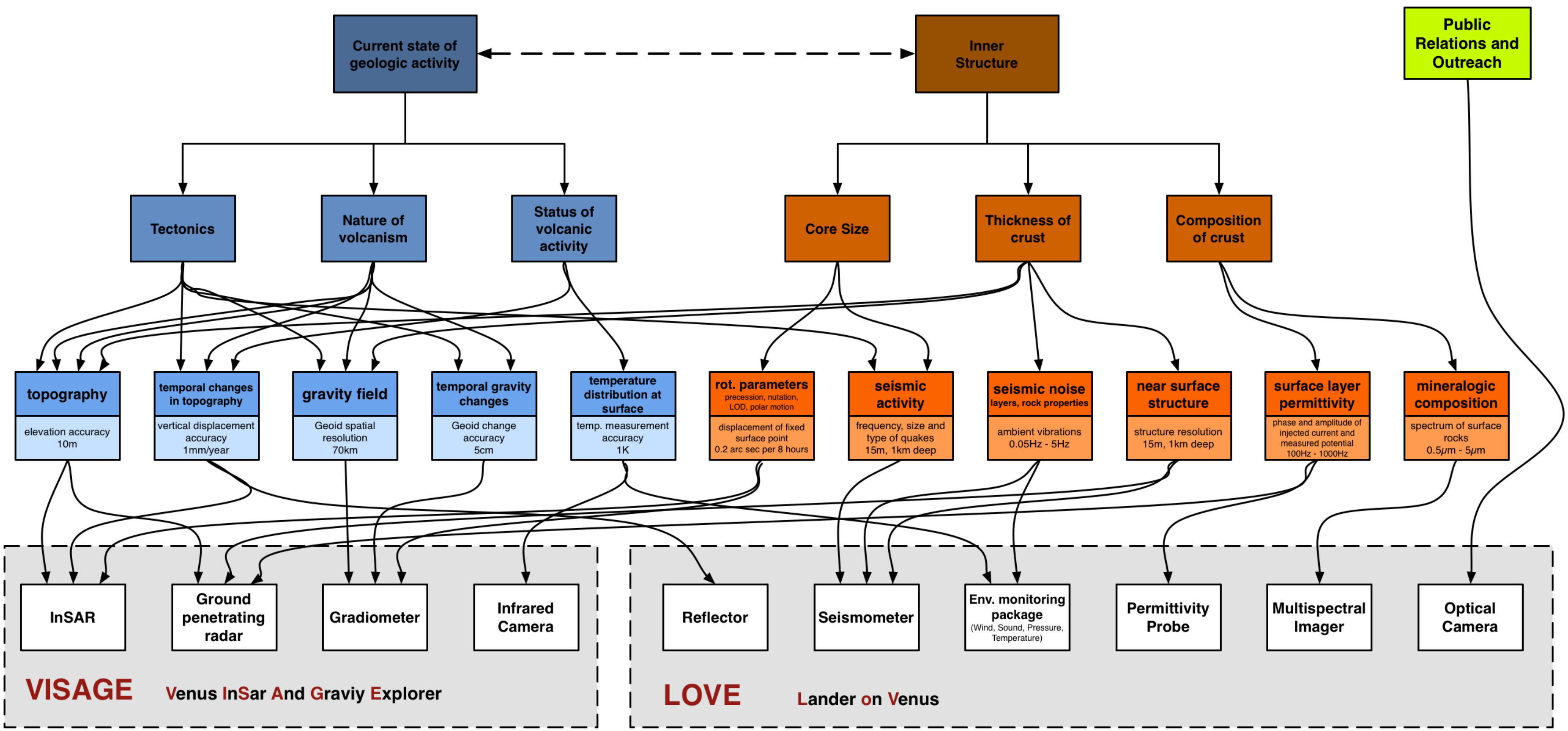
Primary

Studying the **near-surface** geological activity will deepen our knowledge on the current status of Venus' evolution and tectonics and improve our understanding of the dynamics of Earth-like planets.

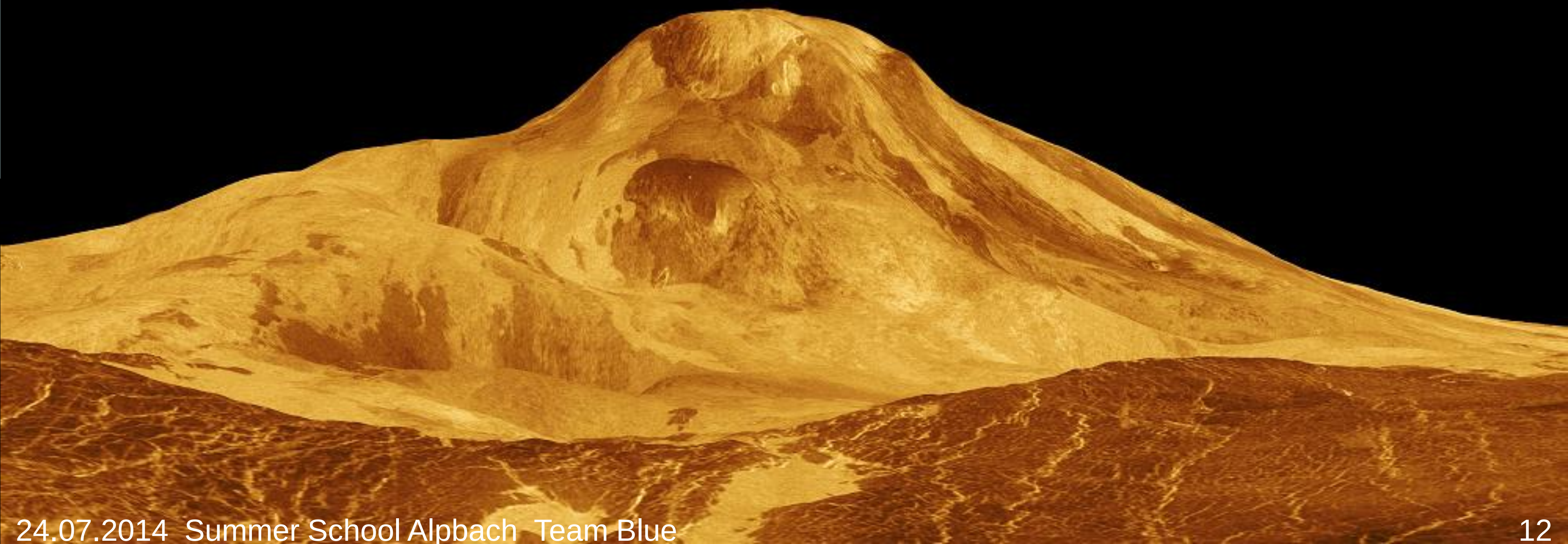
Secondary

The **interior structure** will allow us to substantially understand terrestrial planet interior dynamics and planetary and solar system formation.

Mission Requirements

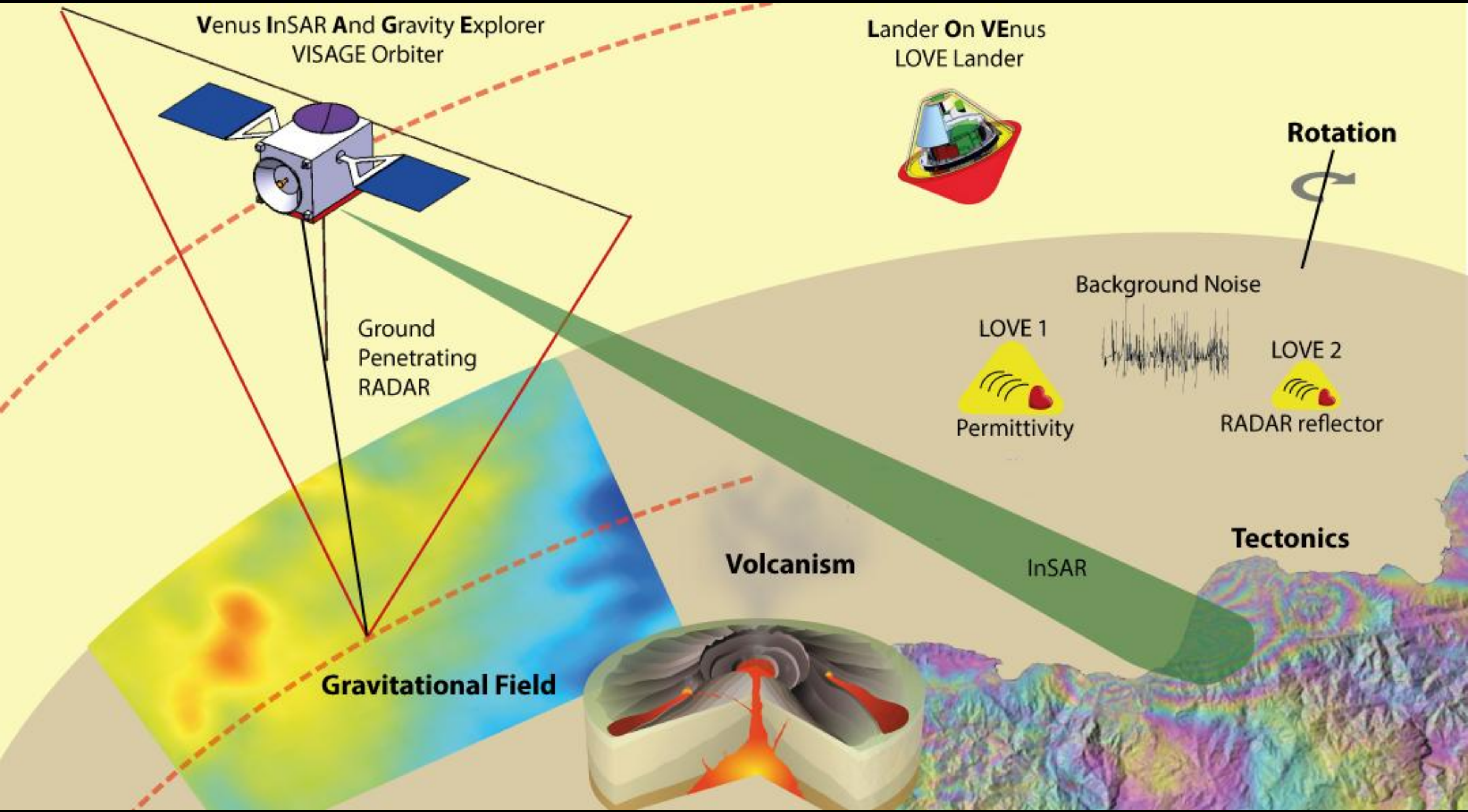


Instrument Overview

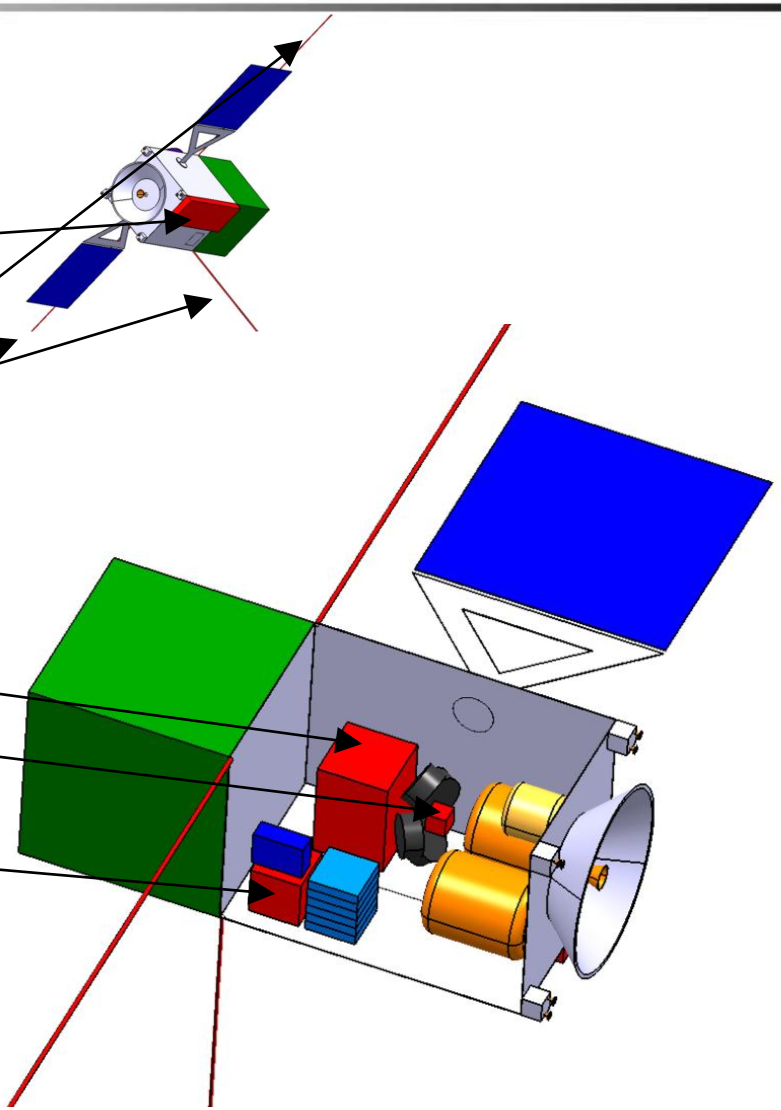


Measurement and Instruments

VELOCITÉ comprises two constituents:



VISAGE Instruments Overview



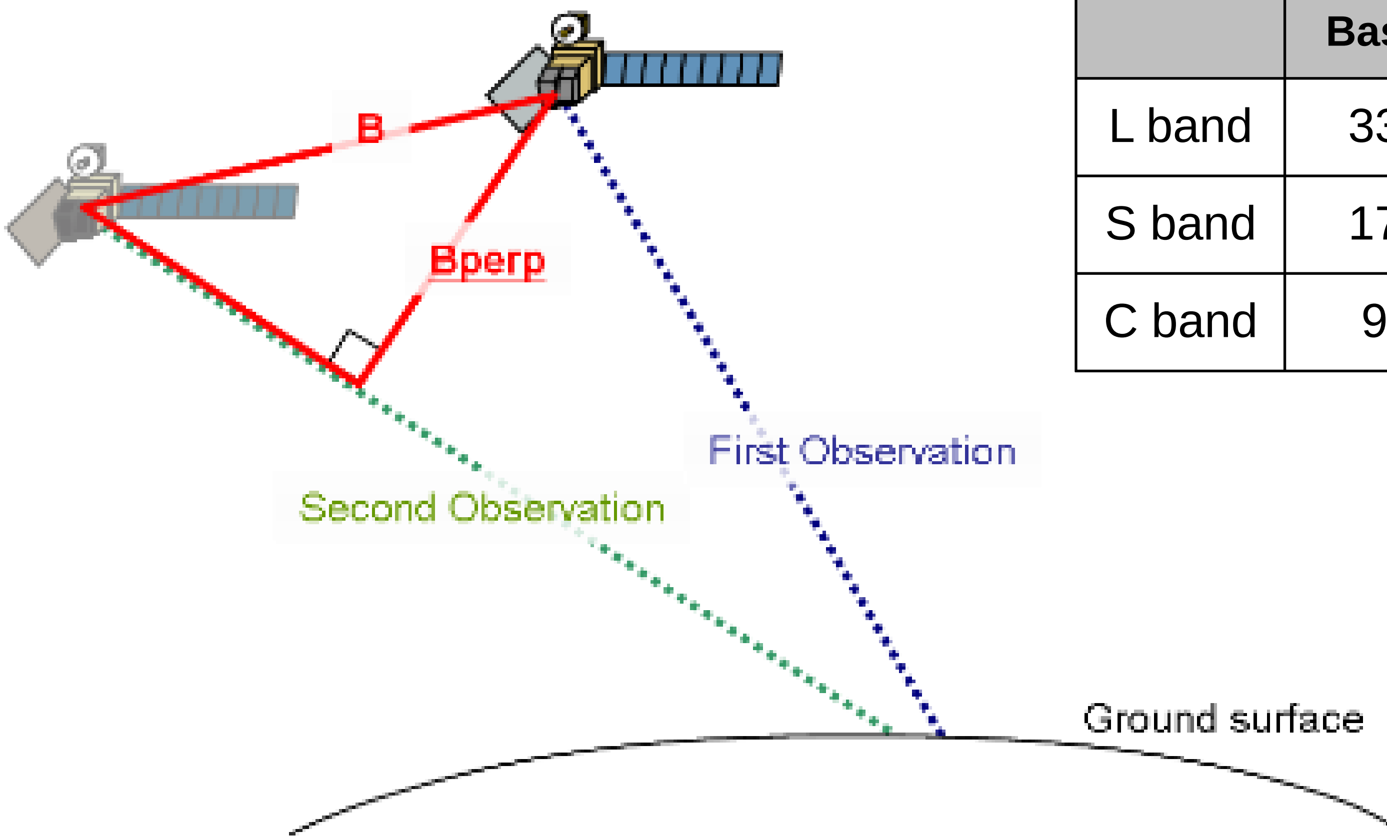
InSAR

Ground Penetrating Radar

Gravity Measurement System
- Gradiometer
- Accelerometer

Infrared Camera

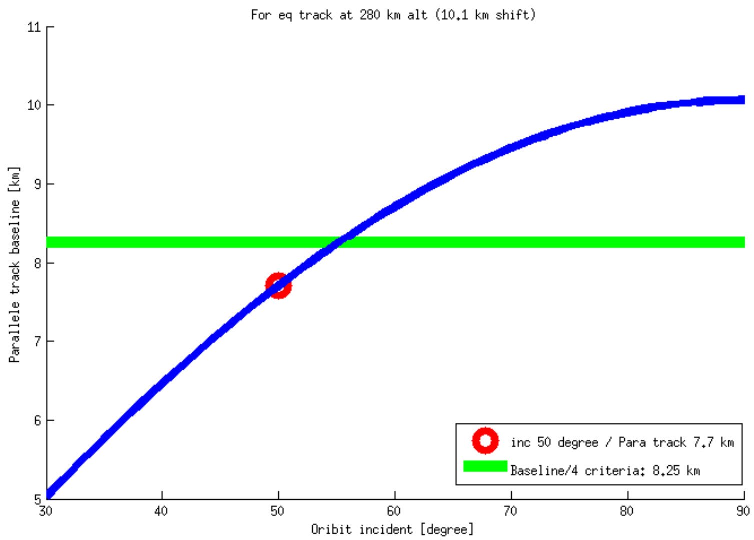
InSAR Theoretical Constraints

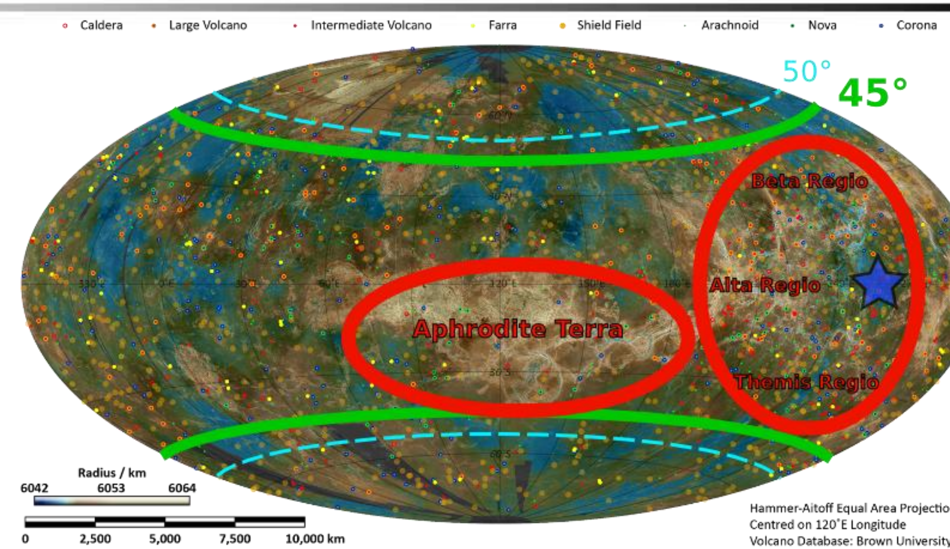


	Critical Baseline	Critical Baseline / 4
L band	33 km	8.3 km
S band	17 km	4.3 km
C band	9 km	2.3 km

Wieczorek 2007, Gravity and Topography of the Terrestrial Planets

Orbiter: InSAR Design Drivers





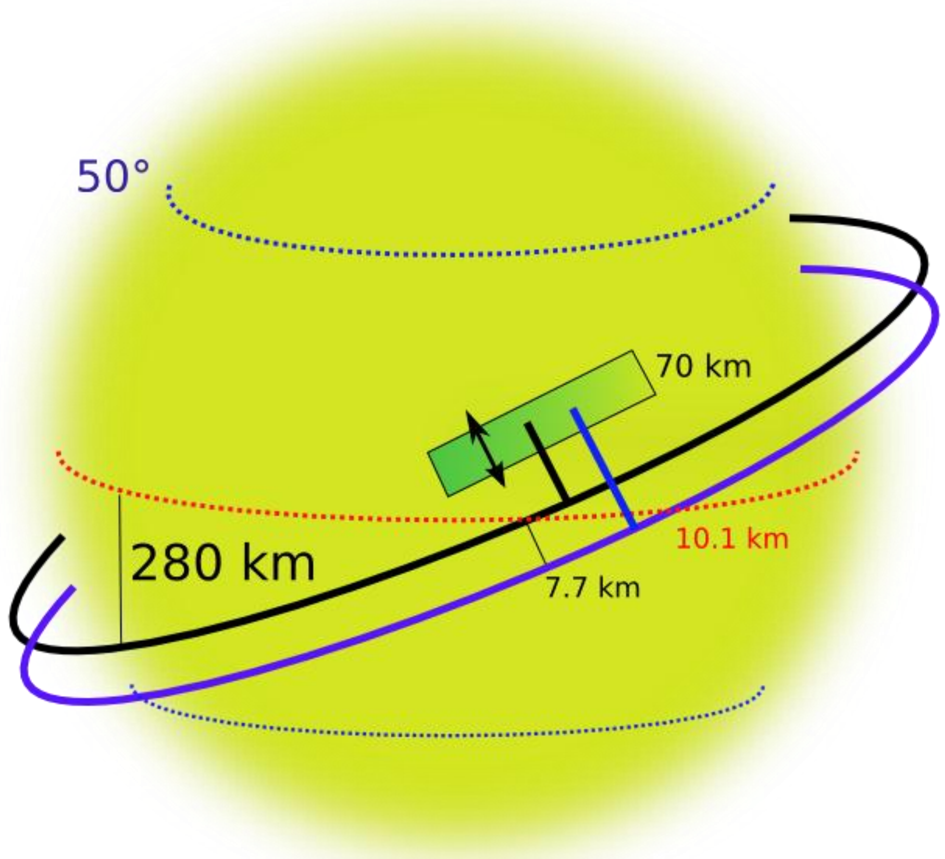
Richard Chail (2014), Venus Geophysics

orbit inclination → technical requirement: 55 deg

minimum desired potential surface coverage yields 45 deg inclination

trade-off yields 50 degrees

Orbiter: InSAR Fact Sheet



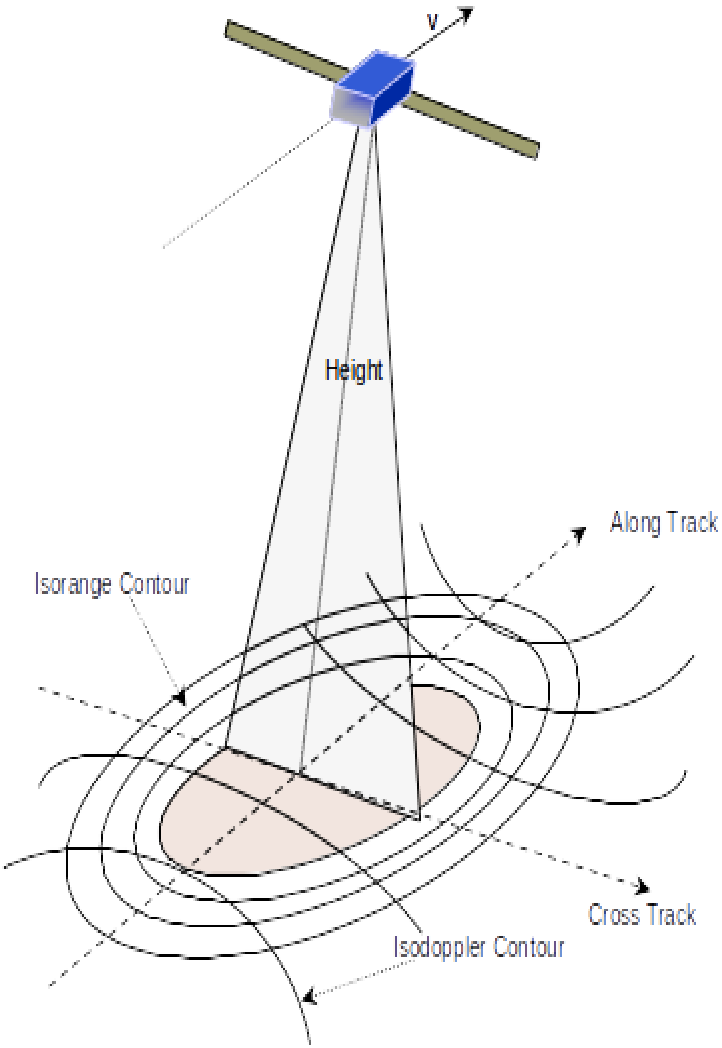
Right and left looking to measure displacement in both directions.

Constraints on the orbit for the InSAR acquisition:

Height orbit	280 km
Time orbit	92.6 min
Shift per orbit	10.1 km
Orbit inclination	50°
Critical baseline	7.7 km
Range angle	25 °
Swath	70 km

(Critical baseline in L band to do InSAR: 8.3 km)

Orbiter: Penetrating Radar

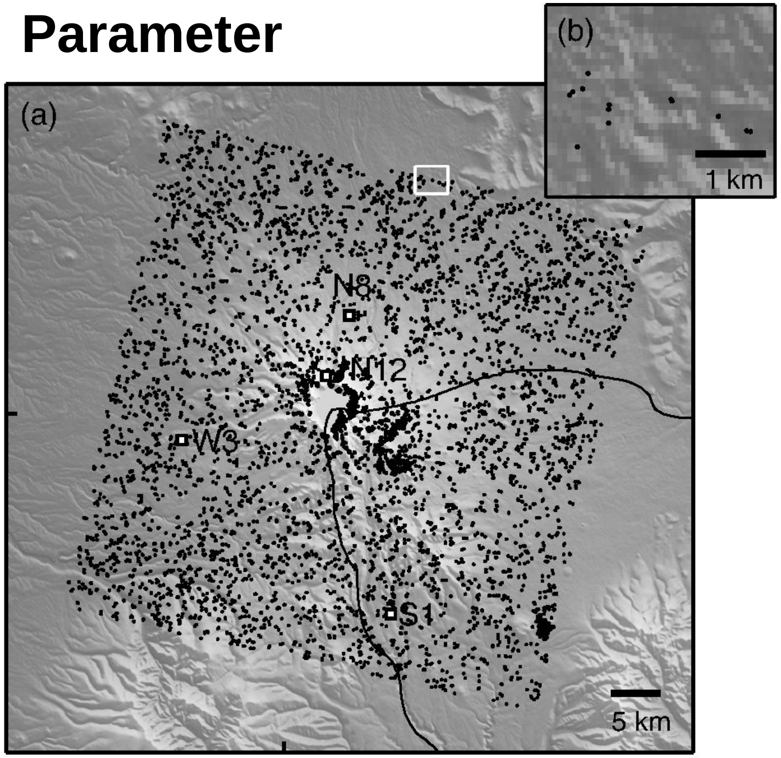


Constraints on the orbit for the antenna:

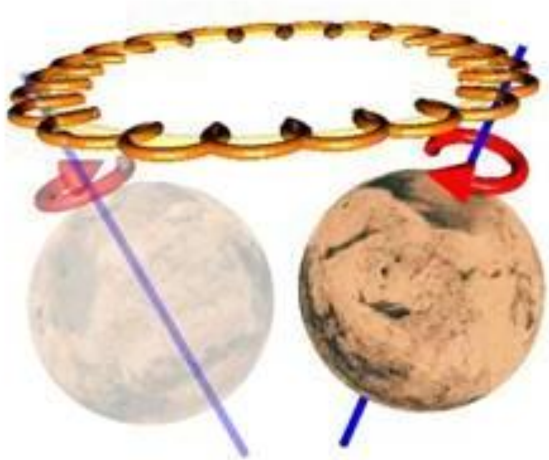
Resolution	15 m
Depth	1000 m
Booms	2 x 10m
Carrier frequency	20 Mhz
Pulse	85 µs
Repetition frequency	700 Hz
RF Power peak	10 W
Mass	20 kg

Orbiter: Persistent Scatterers

Rotation Parameter



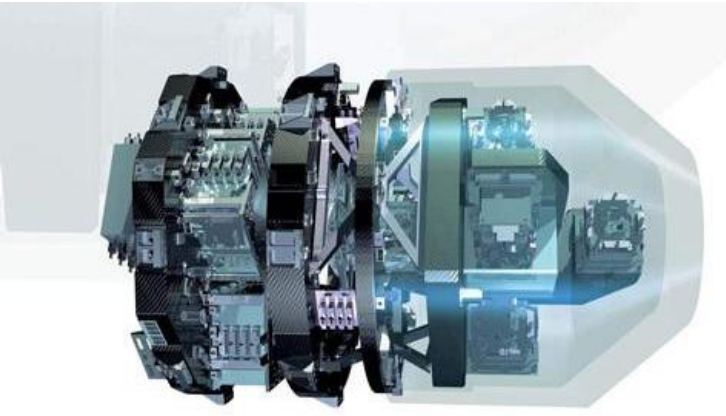
Persistent scatterers for PSInSAR solutions



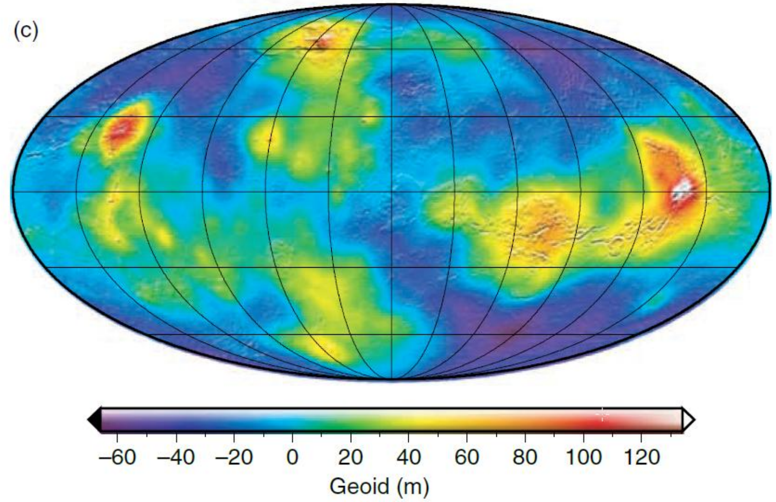
http://astarmathsandphysics.com/

- length of day
- polar motion
- precession
- nutation
- moment of inertia
- planet’s interior

Orbiter: Gradiometer

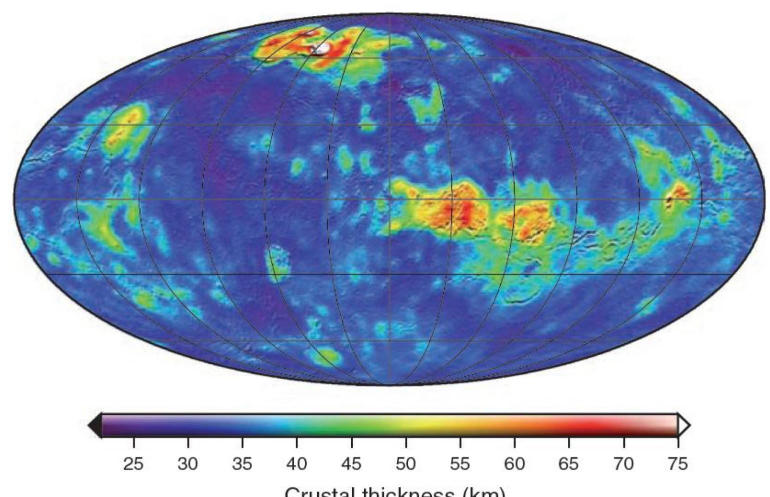


GOCE instrument from : http://www.dlr.de/dlr/



The **static** and **time-variable gravity field** will be obtained from:

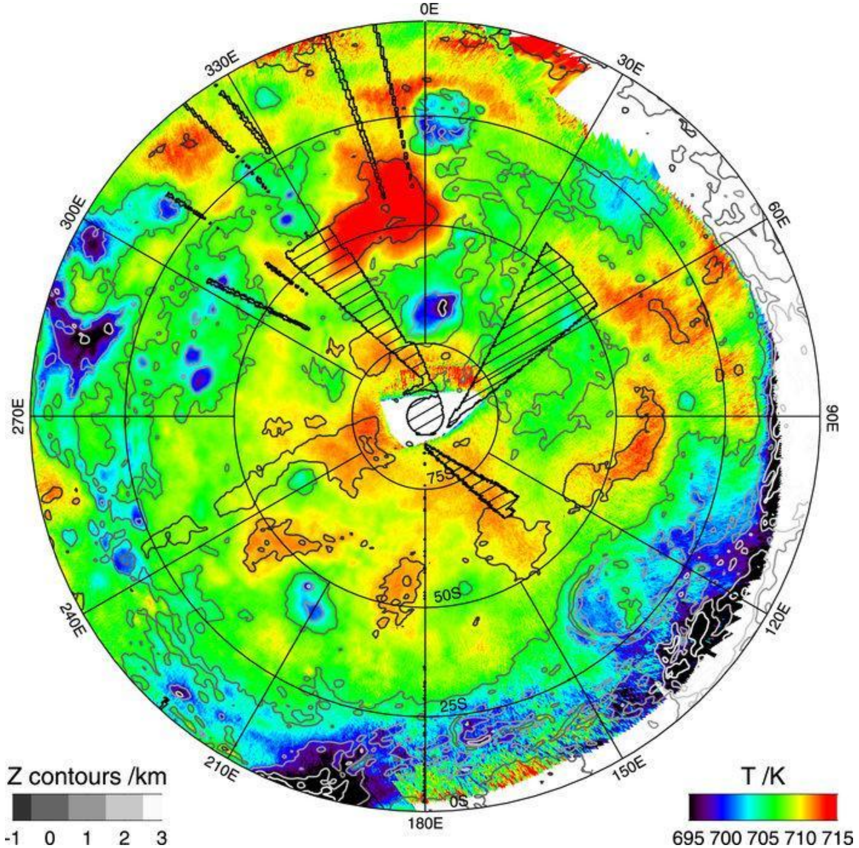
- orbit perturbations supported by an accelerometer (for low-degree spherical harmonic coefficients)
- gradiometer (for high-degree spherical harmonic coefficients)



Wieczorek 2007, Gravity and Topography of the Terrestrial Planets

Orbiter: Infrared Camera

The **surface temperature** distribution will allow investigating active eruptions and volcanic activity.



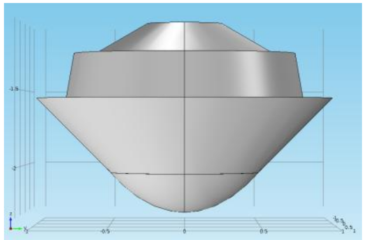
Temperature map of the north pole of Venus from :
http://www.esa.int/

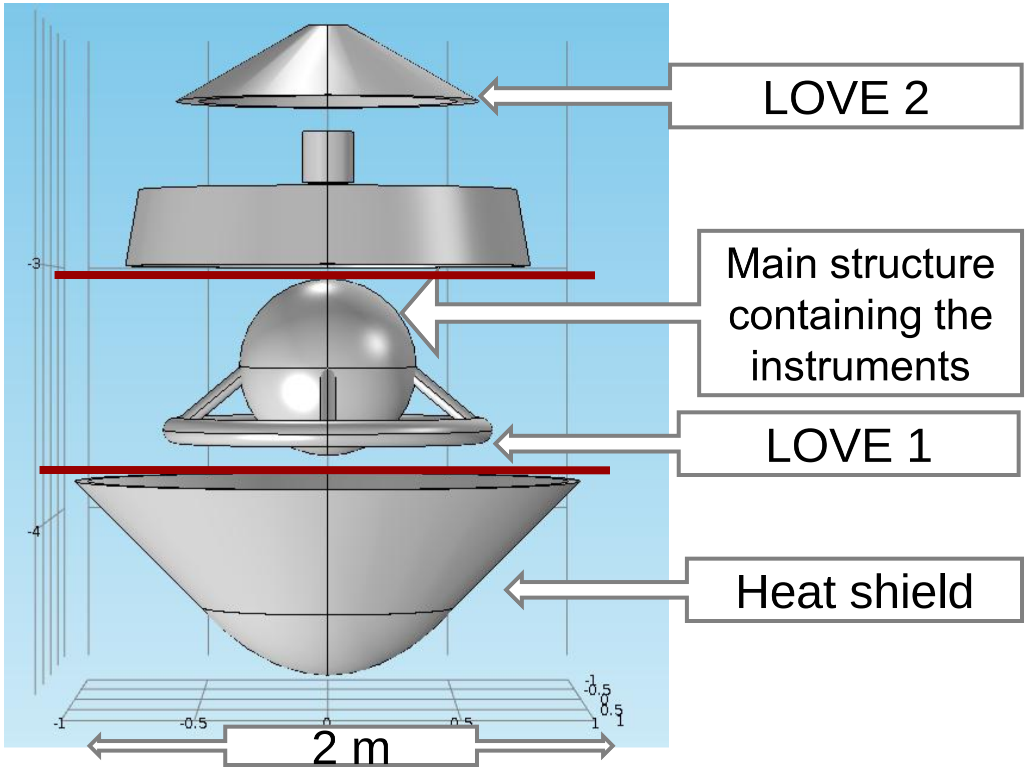
LOVE Instruments Overview

- **LOVE 1**
- 1. Seismometer
- 2. Multispectral Camera
- 3. Permittivity Probes
- 4. Environment monitor
- 5. Radar Reflector

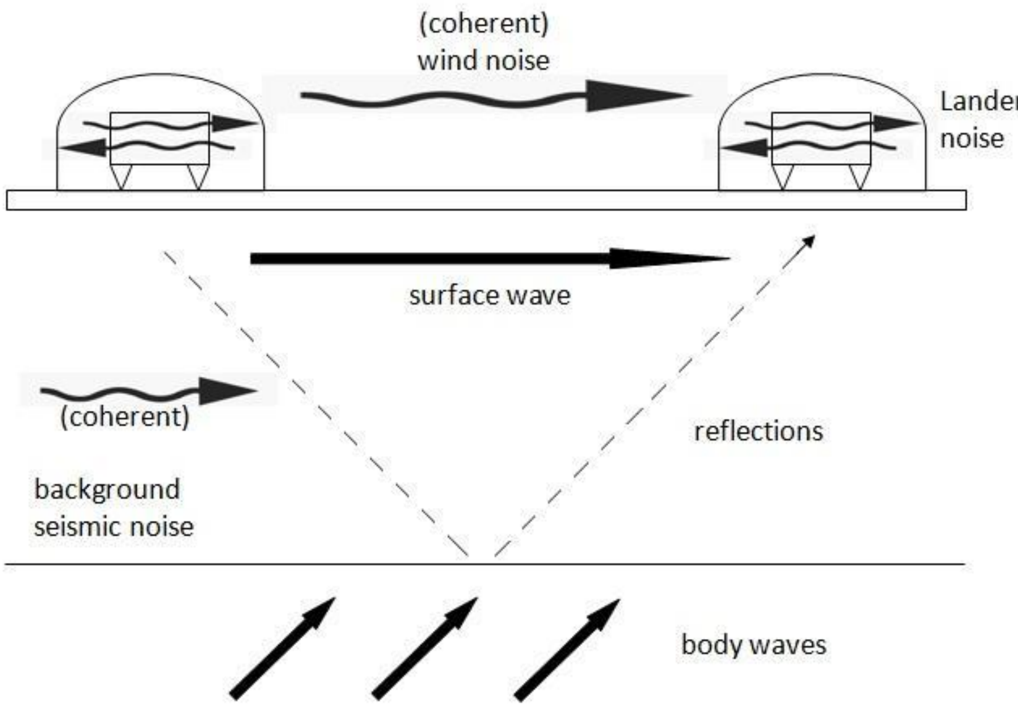
- **LOVE 2**

1. Seismometer
2. Radar Reflector





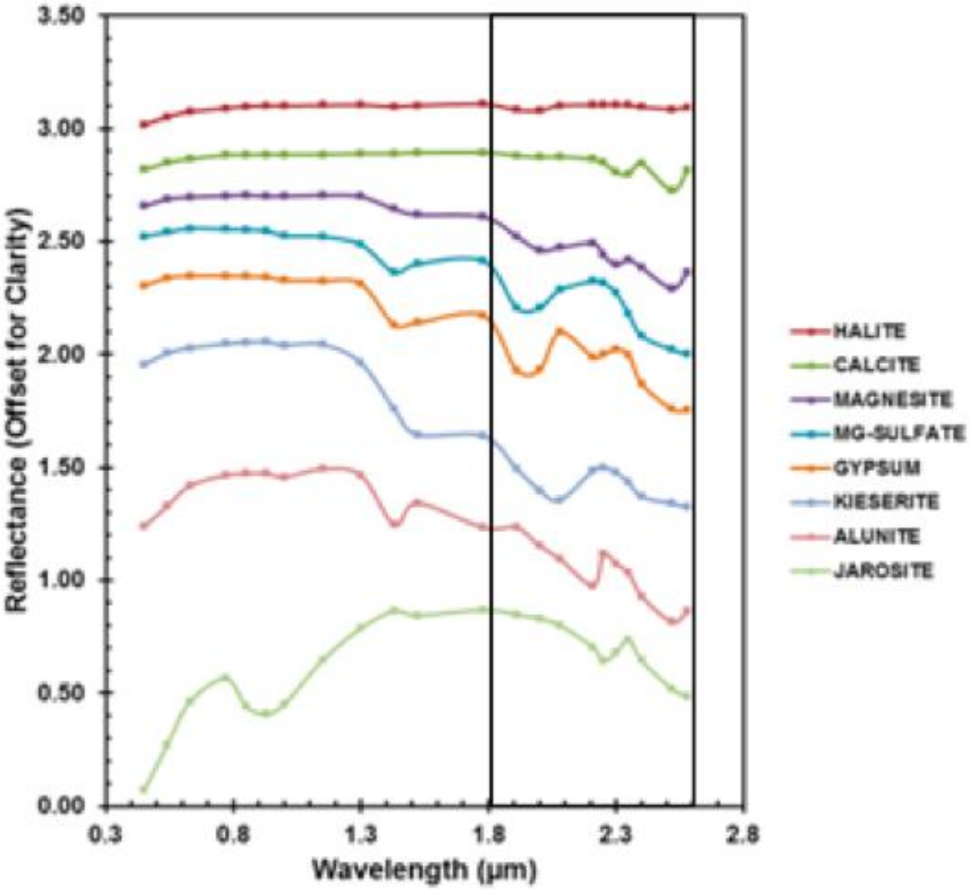
Lander: Seismometers (Network)



Correlation of two seismometers show

- **coherent background signals/noise** (wave velocity)
- seismic activity (Inclination, slowness)

Lander: Multispectral Imager

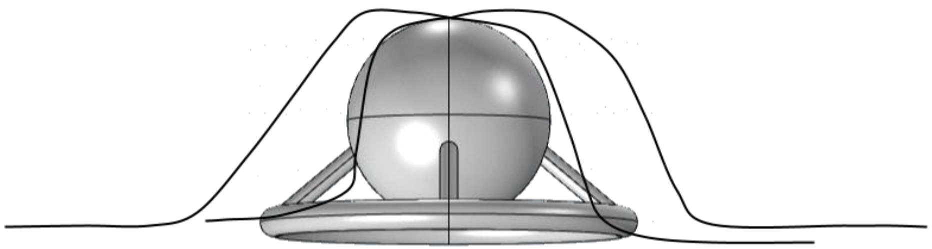


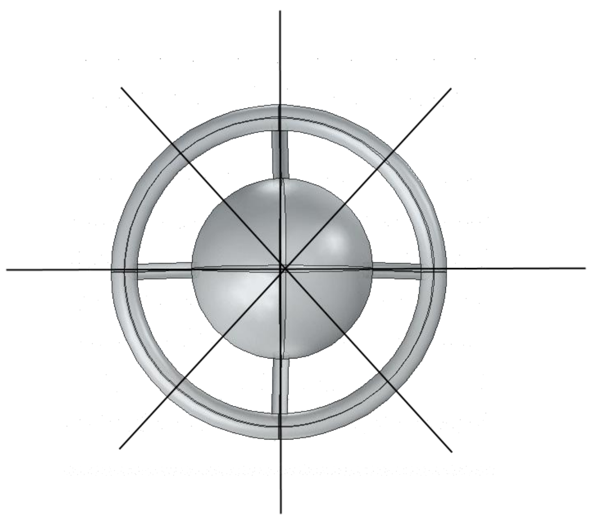
Example of spectrum

Measurement of actively generated spectrum of the landing site to infer mineralogical composition.

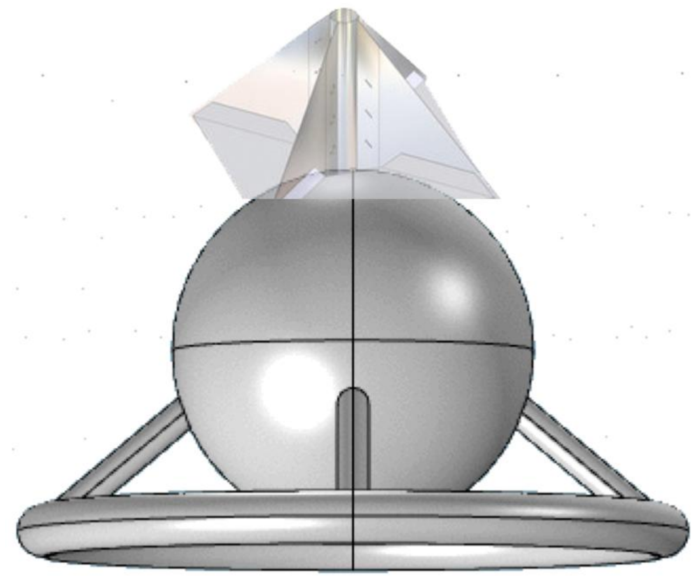
Lander: Reflector System

Iron hair option





Umbrella option

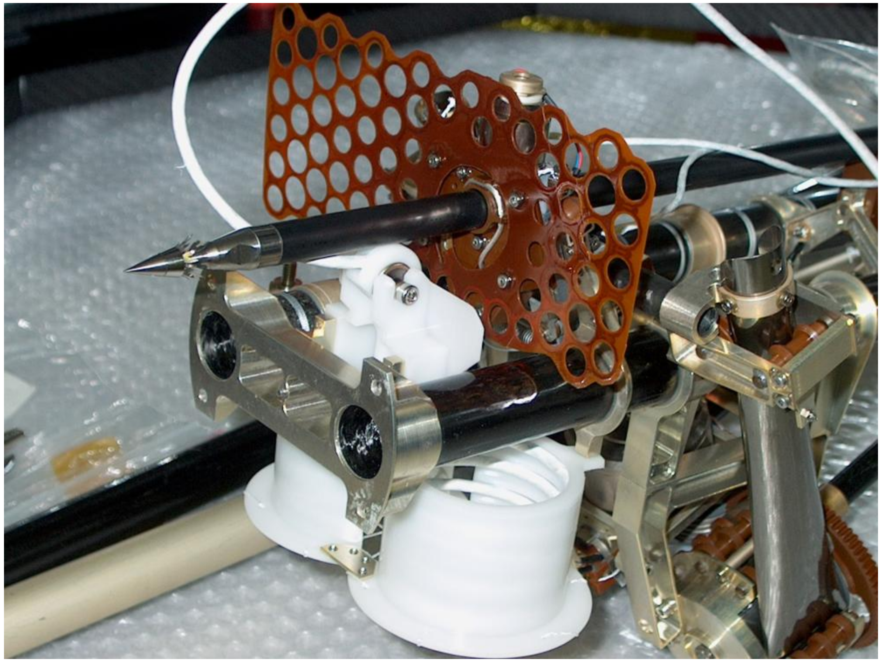


Both systems can easily be tested in Earth-like environment

Lander: Permittivity Probe

- **Permittivity Probe**
- Heritage from the Philae Lander

Properties of PP	
Sounding frequency	0.01 to 10 kHz
Receiving frequency	20 up to 40 kHz
Mass	270 g
Power	≤ 320 mW



PP electrode located on the MUPUS pin on the philae Lander

- Mutual quadrupole array technique
- Study depth: ca. 2 m

Lander: Additional Systems

Environmental Monitor,
heritage from the curiosity rover

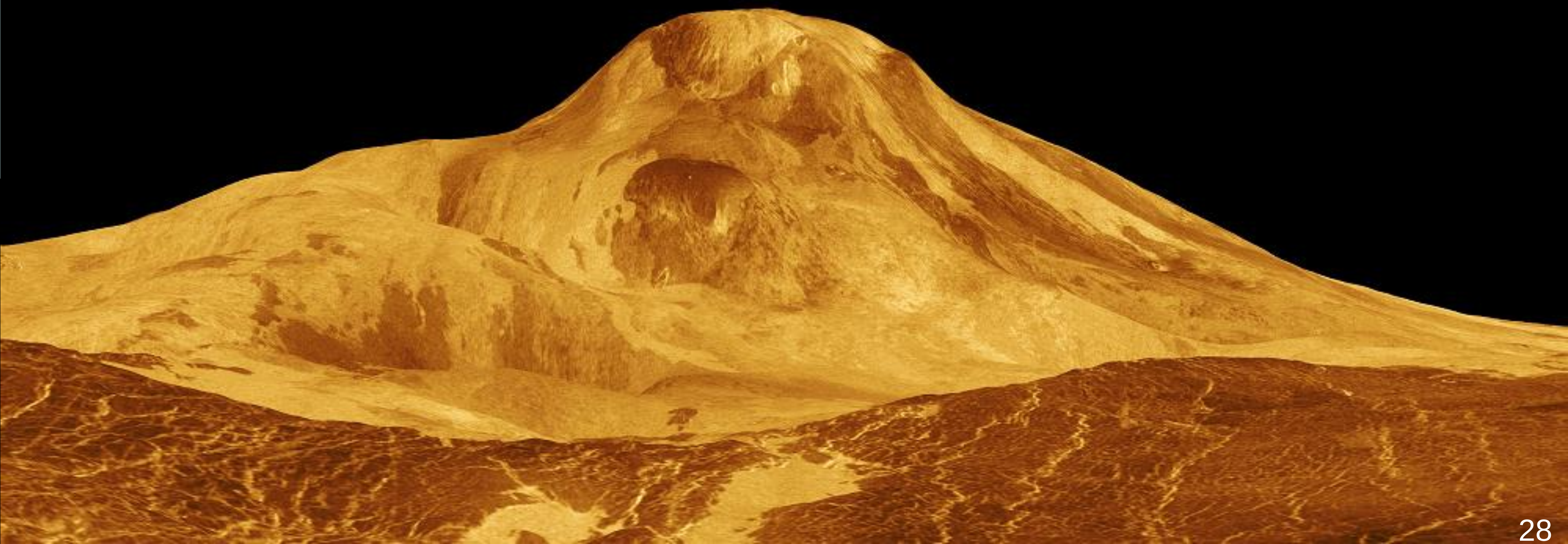
- temperature
- pressure
- wind speed
- acoustic sound

Camera

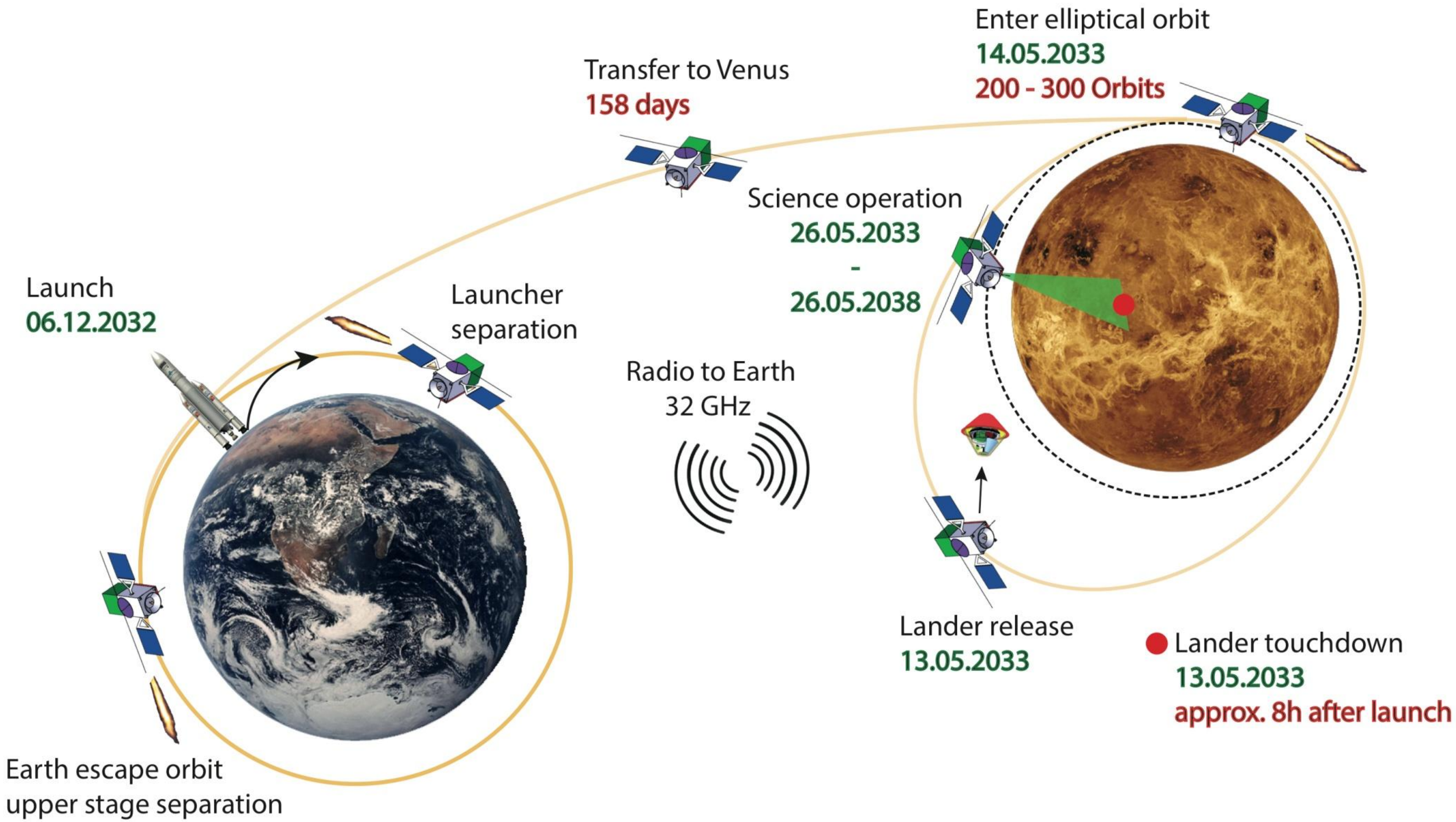
will take pictures of the descent and on the surface (resolution 4 Mpixels)

(REMS: T*he Environmental Sensor Suite for the Mars Science Laboratory Rover, Gómez-Elvira et al, 2012*)

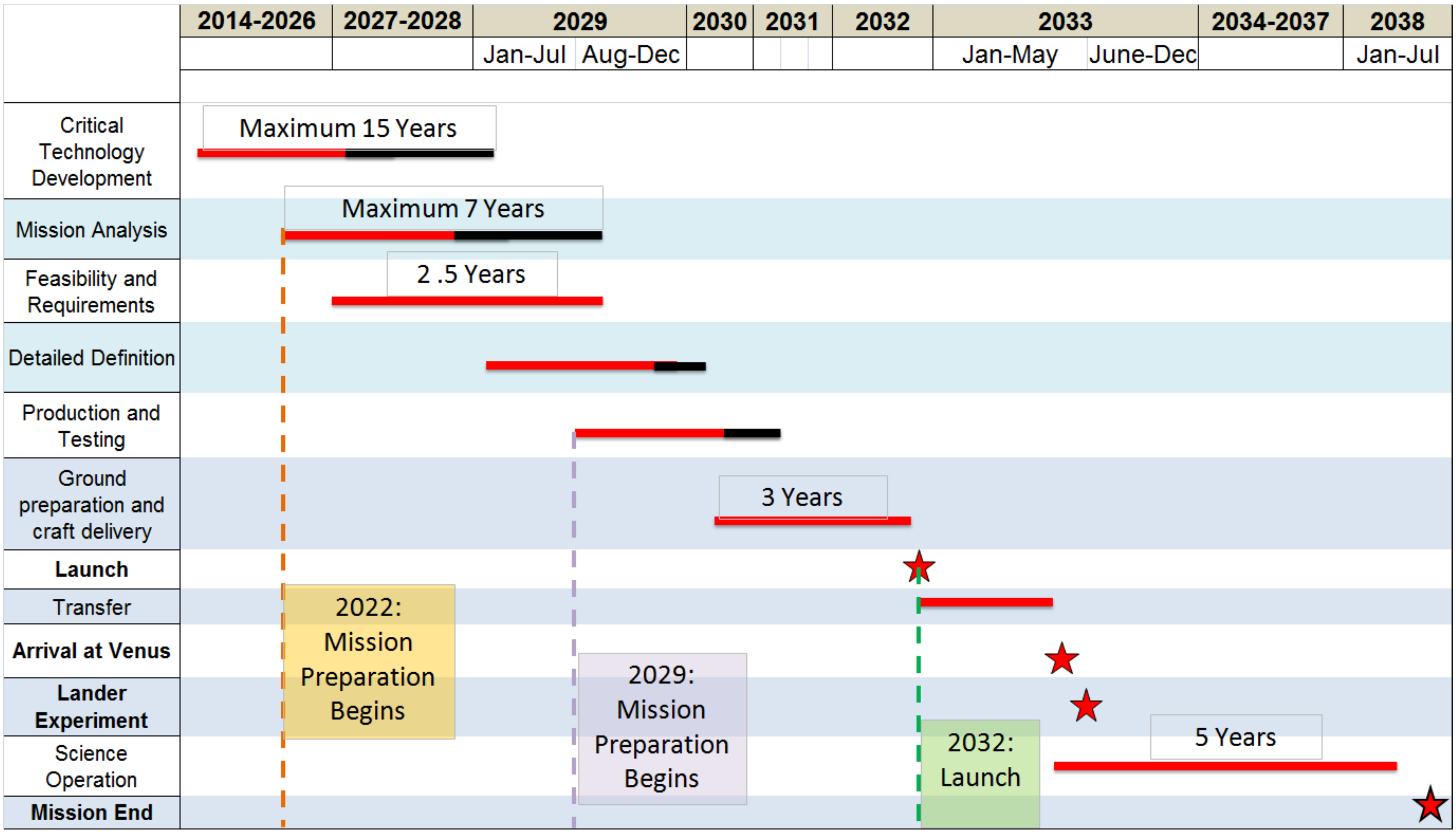
Timeline



Mission Timeline (1/3)



Mission Timeline (2/3)

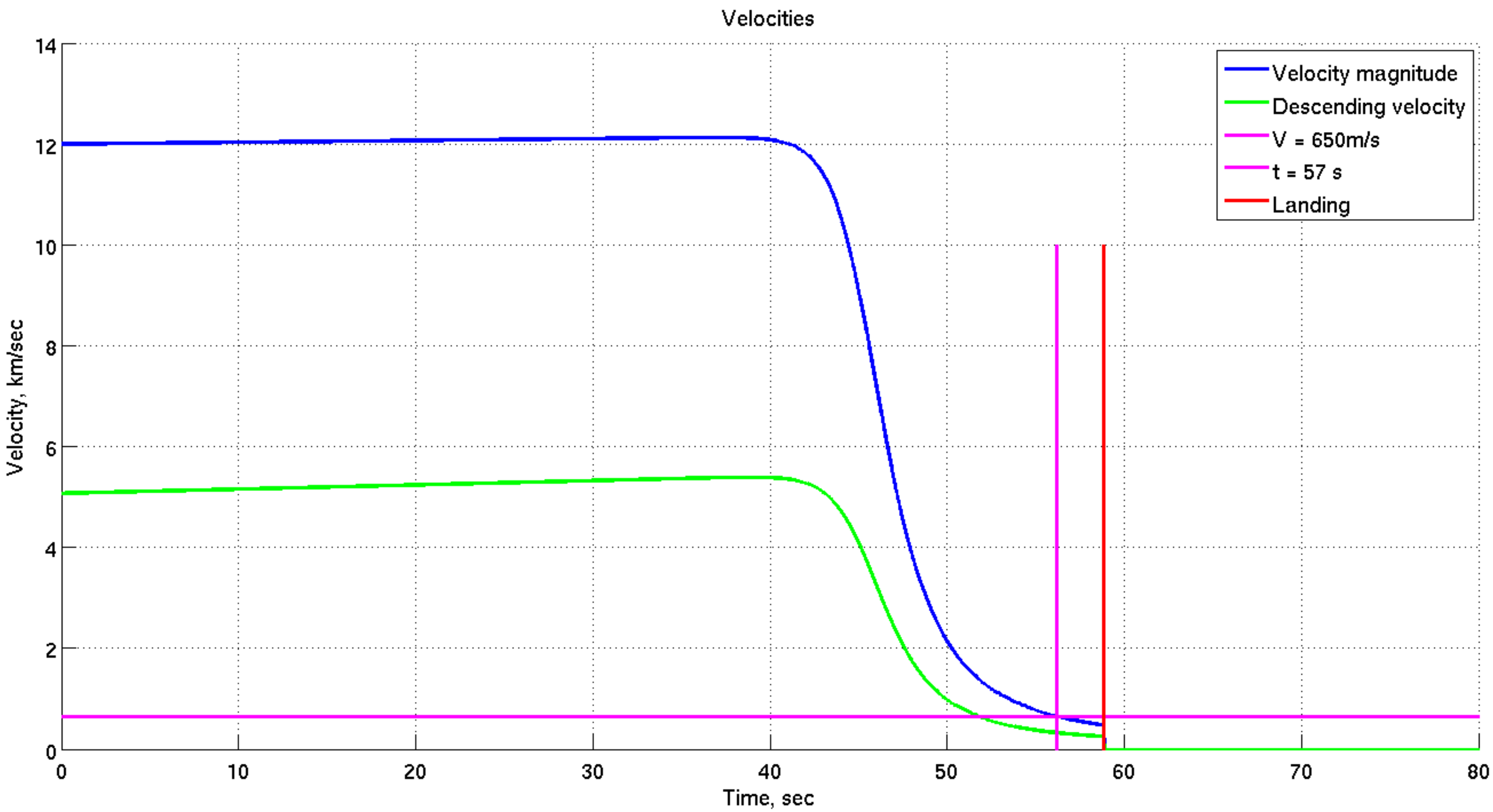


Launch: 6th December 2032

Mission Timeline (3/3)

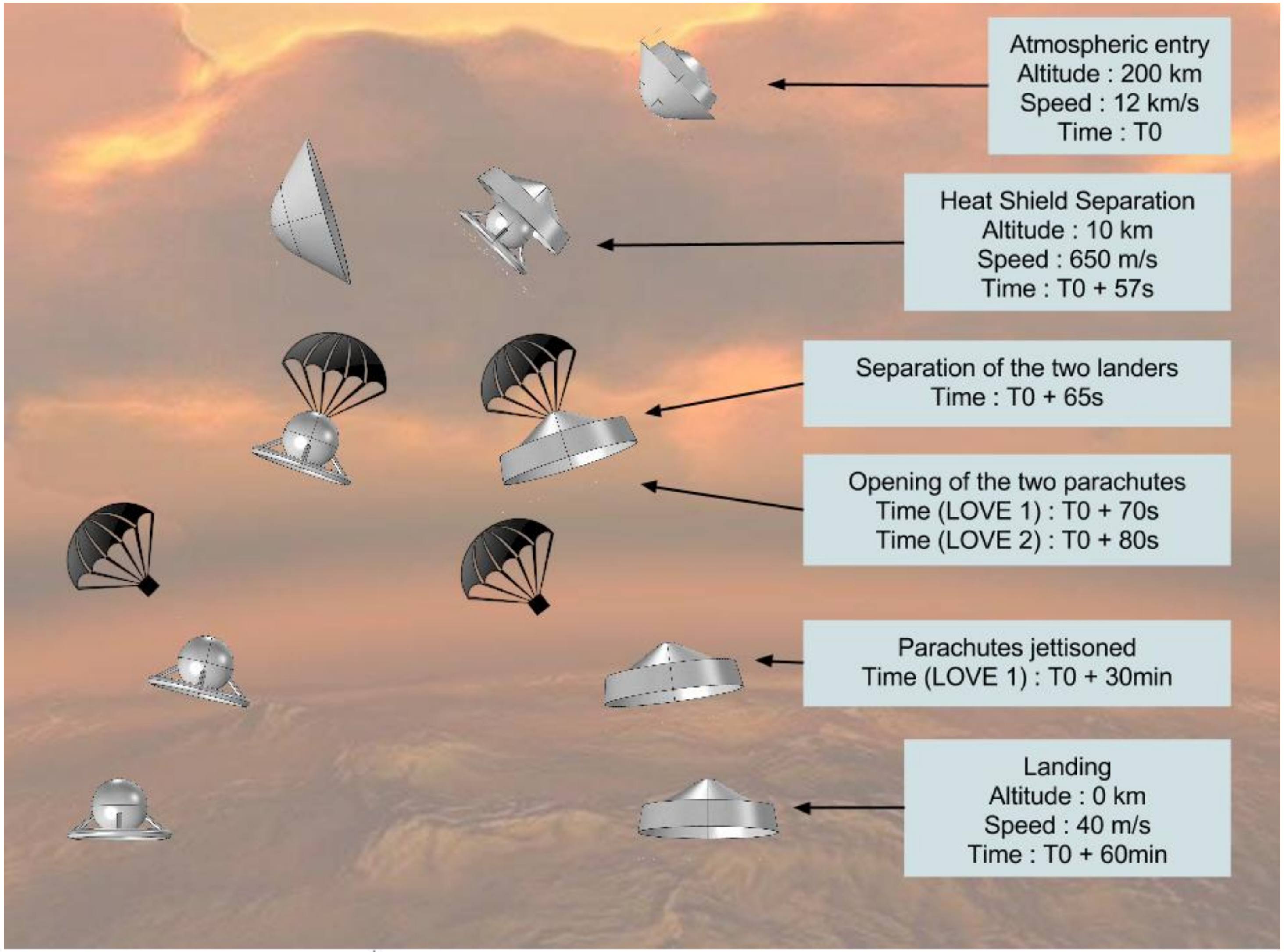
	2032		2033				2035	2034 - 2037	2038	
	6 Dec	7-31 Dec	Jan-Apr	1-12 May	13 May	14 May-Dec			Jan - 26 May	27. Mai
Launch										
LEOP										
Transfer										
Lander Separation										
Lander Touchdown										
Lander Science Operation										
Aerobraking										
Science operation										
EOL										

EDL of LOVE



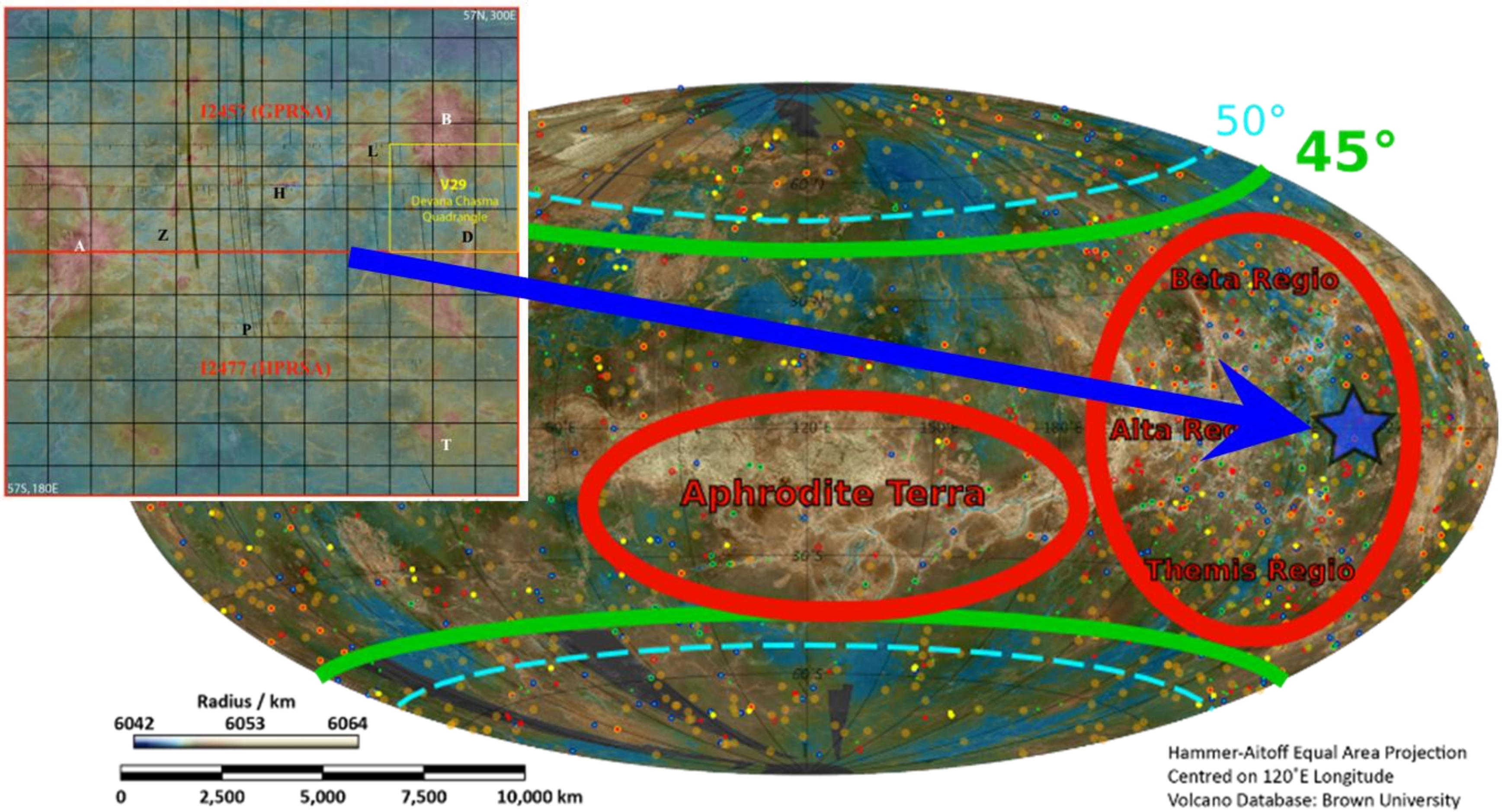
Separation of the heat shield, speed inferior to Mach 2 Allowing parachute deployment

EDL of LOVE



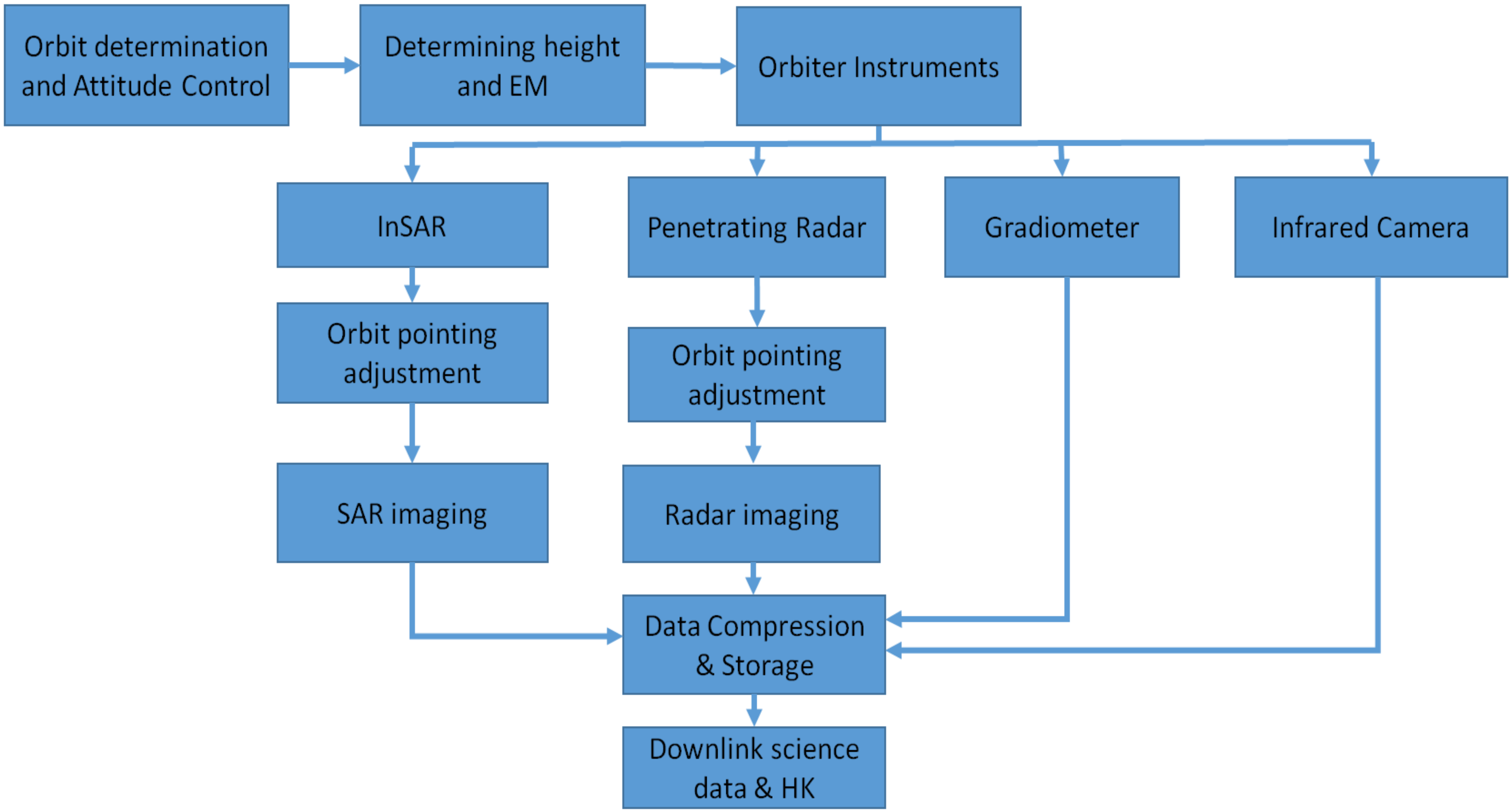
Atmospheric entry
Altitude : 200 km
Speed : 12 km/s
Time : T0
Heat Shield Separation
Altitude : 10 km
Speed : 650 m/s
Time : T0 + 57s
Separation of the two landers
Time : T0 + 65s
Opening of the two parachutes
Time (LOVE 1) : T0 + 70s
Time (LOVE 2) : T0 + 80s
Parachutes jettisoned
Time (LOVE 1) : T0 + 30min
Landing
Altitude : 0 km
Speed : 40 m/s
Time : T0 + 60min

Where to land?

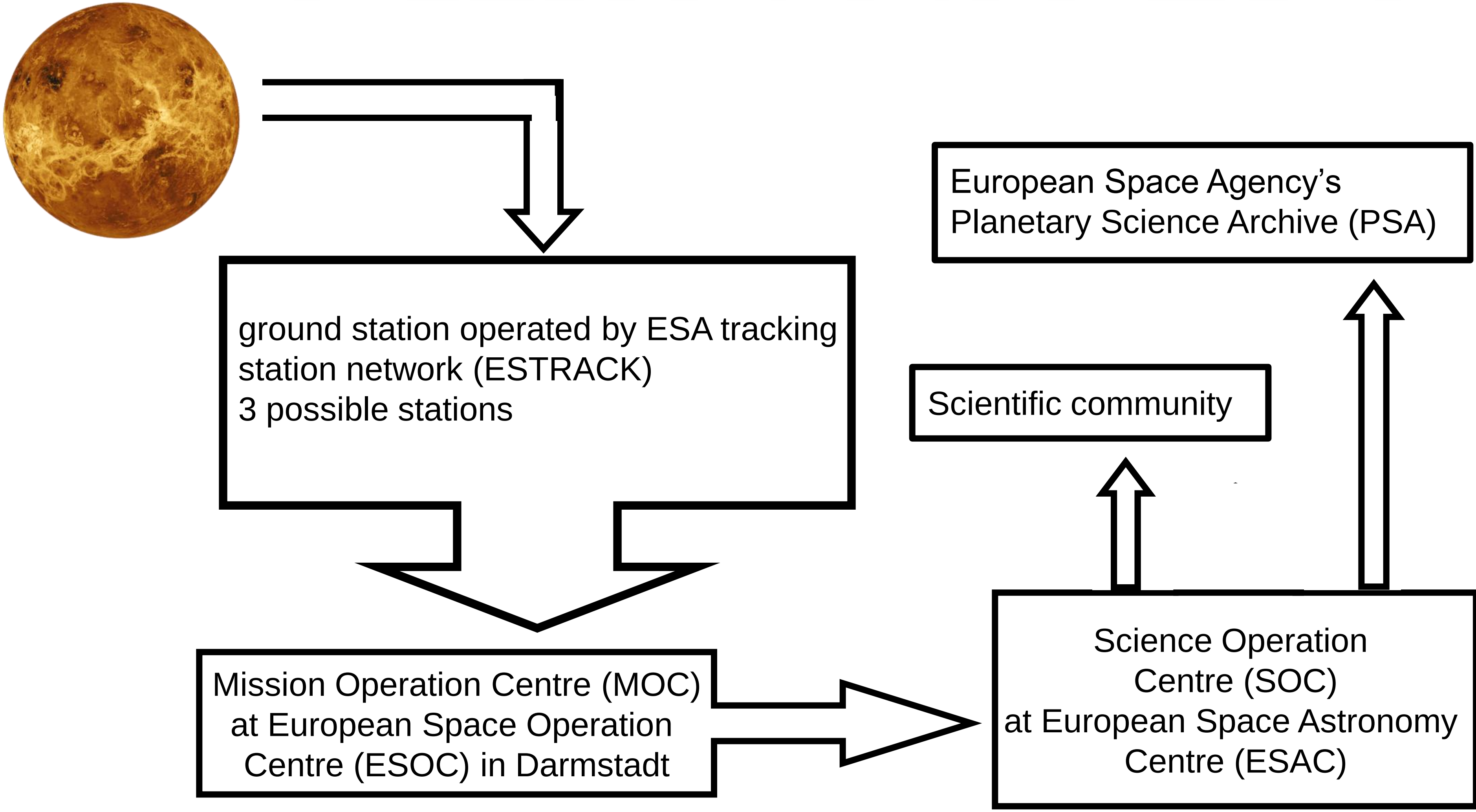


GEOLOGIC MAPPING OF THE BETA-ATLA-THEMIS (BAT) REGION OF VENUS: BATTING A THOUSAND? Bleamaster III et al.

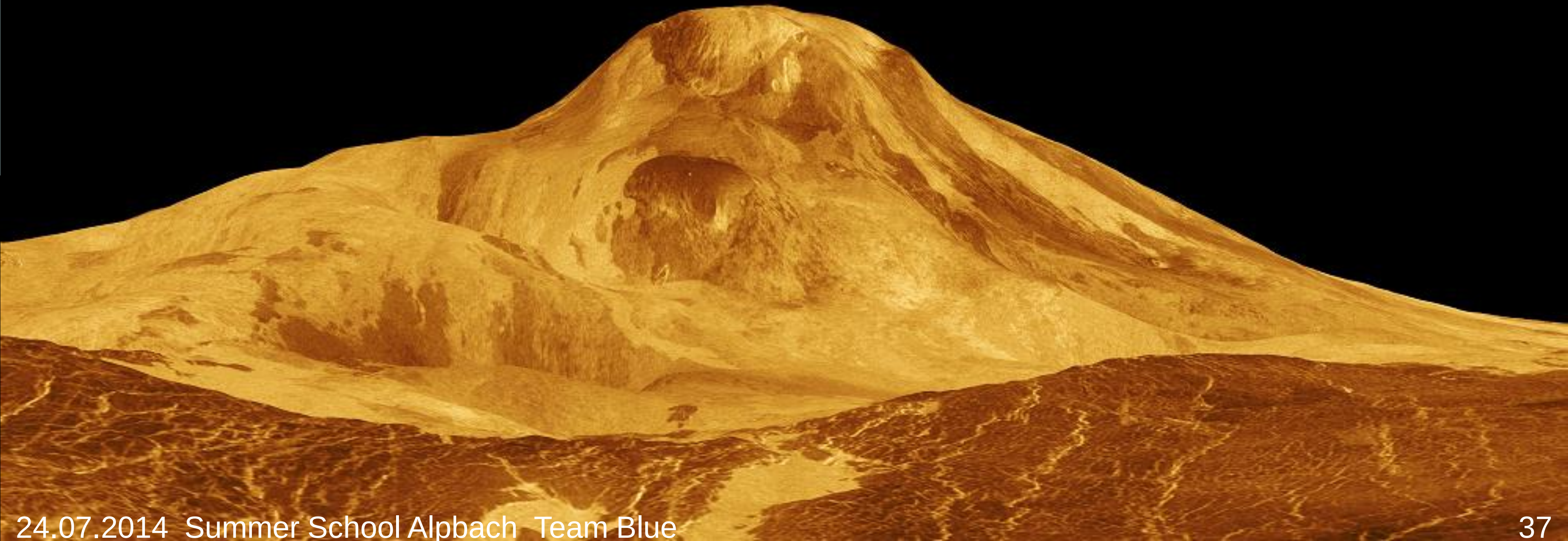
Data Acquisition Mode



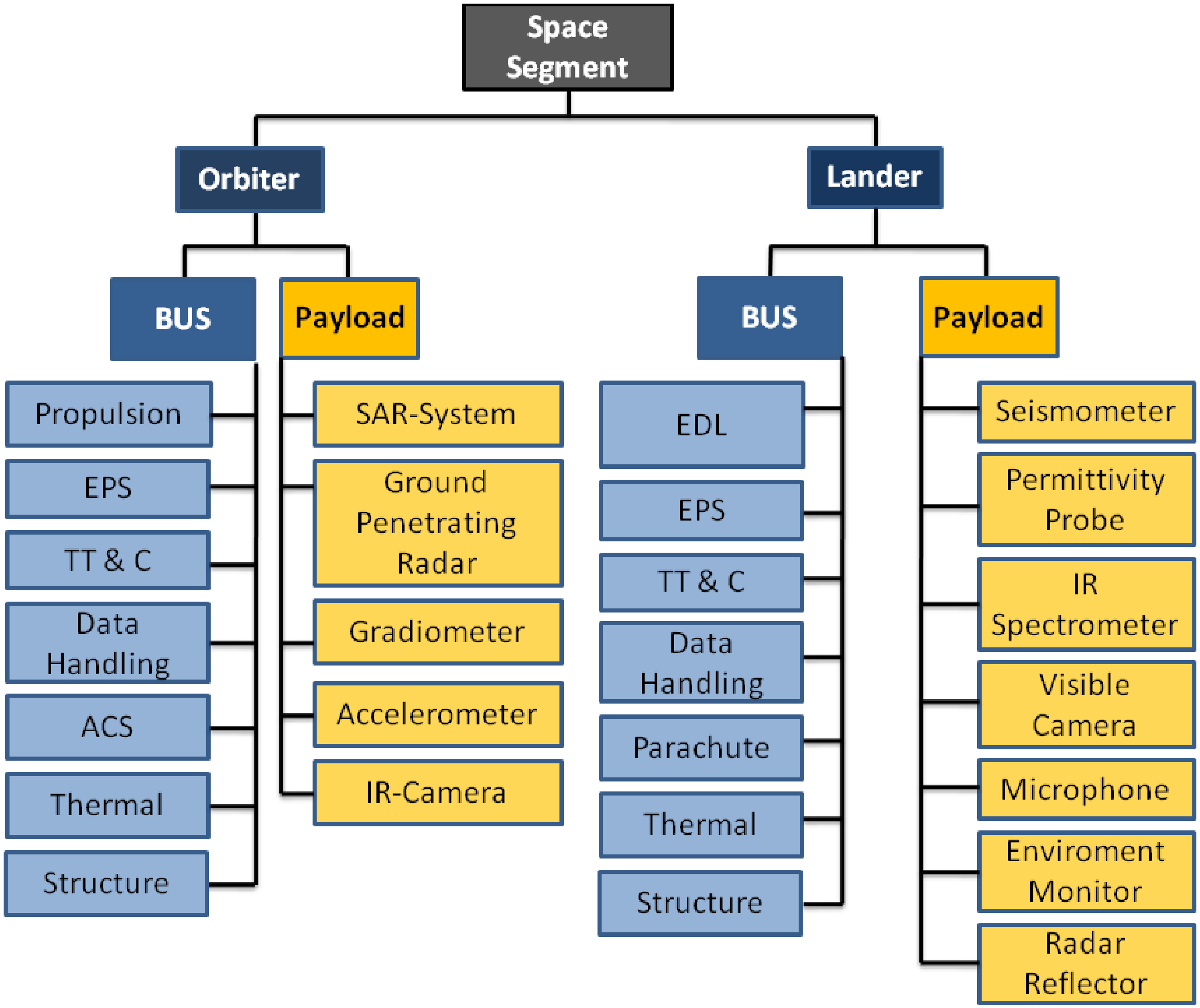
Ground segment and operation



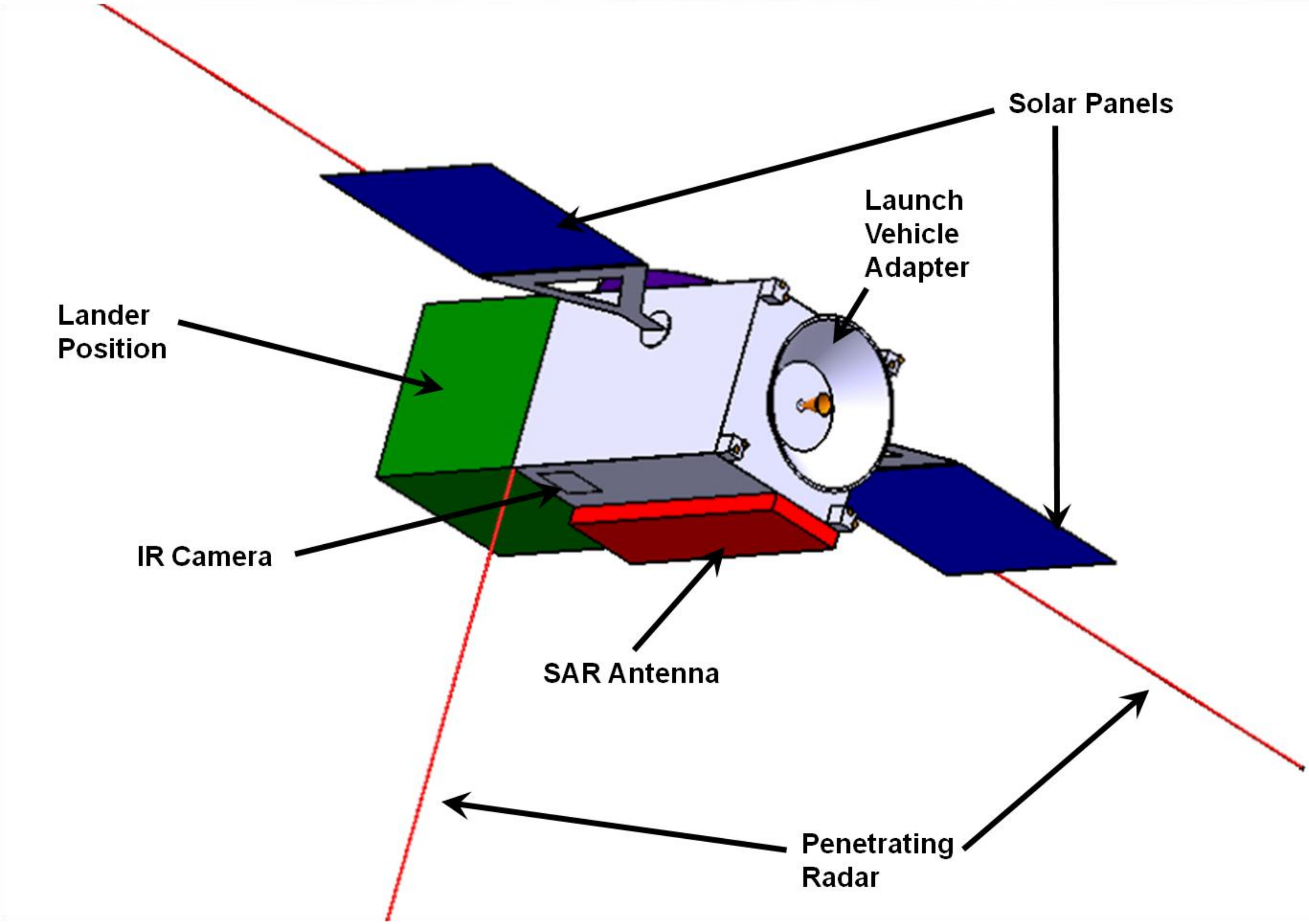
Mission overview



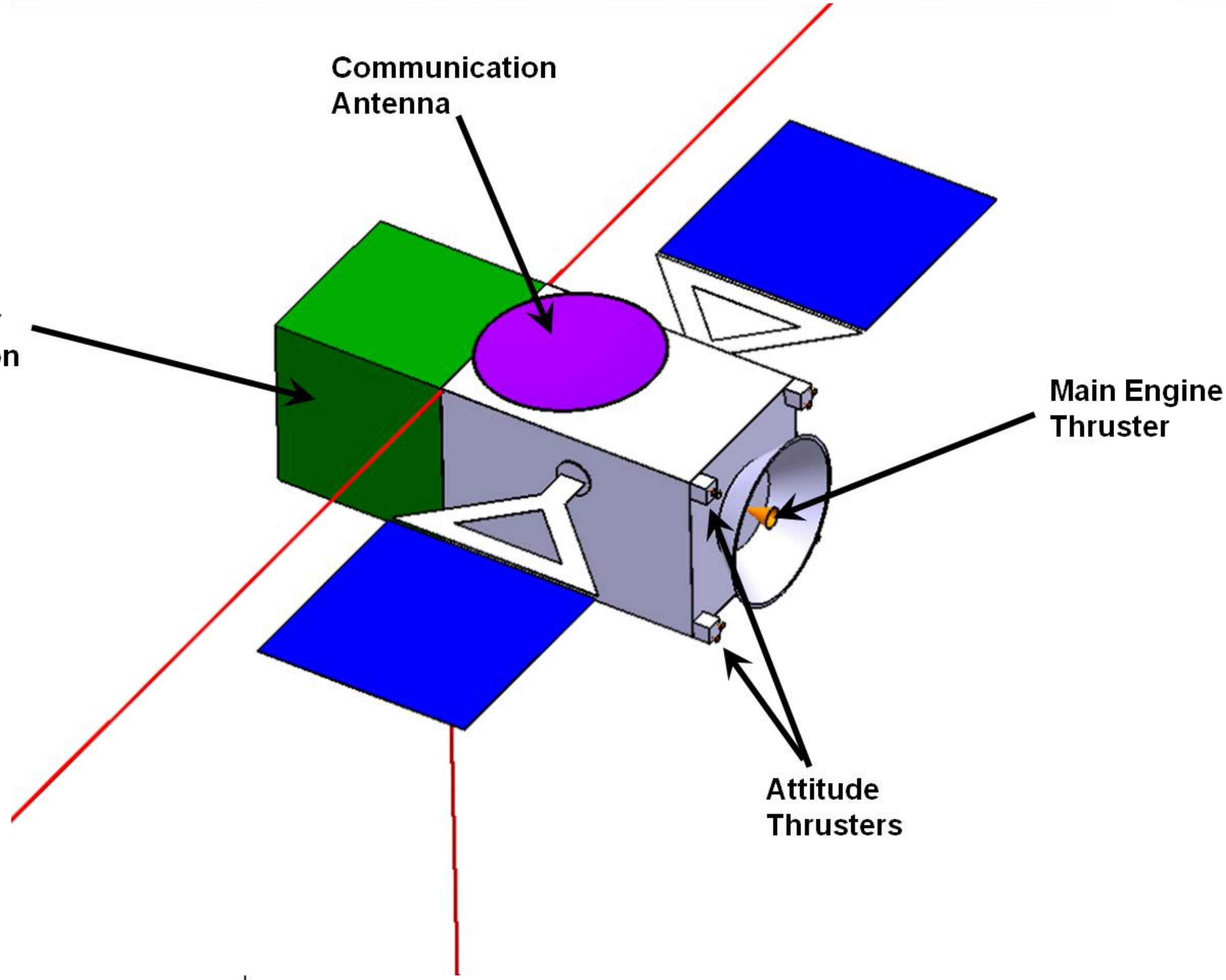
Product Tree



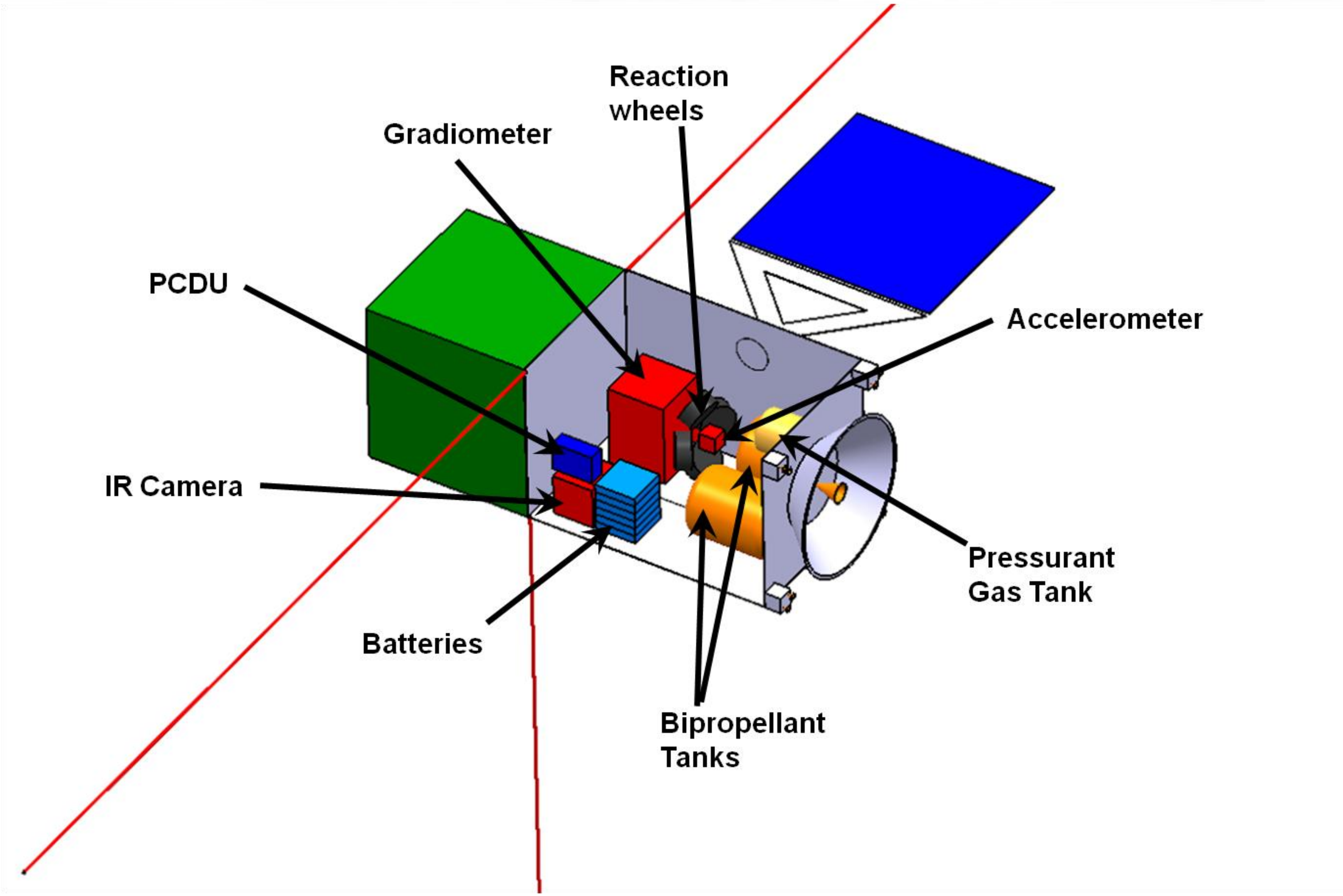
System Arrangement (1/3)



System Arrangement (2/3)



System Arrangement (3/3)



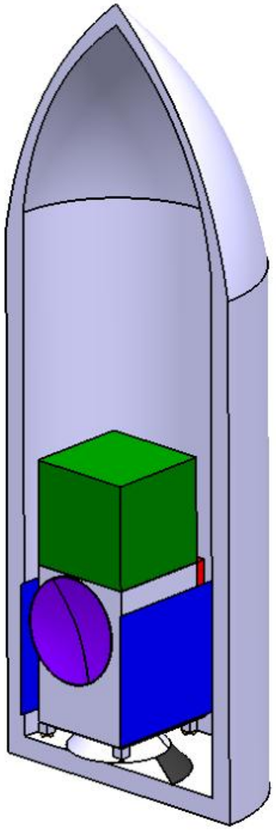
Launcher

Ariane 5 ECA single payload configuration

• 10.5 tons into GTO which is approximately 4.5 tons for deep space
• High reliability and high performance
• Total cost for single launch: 175M€

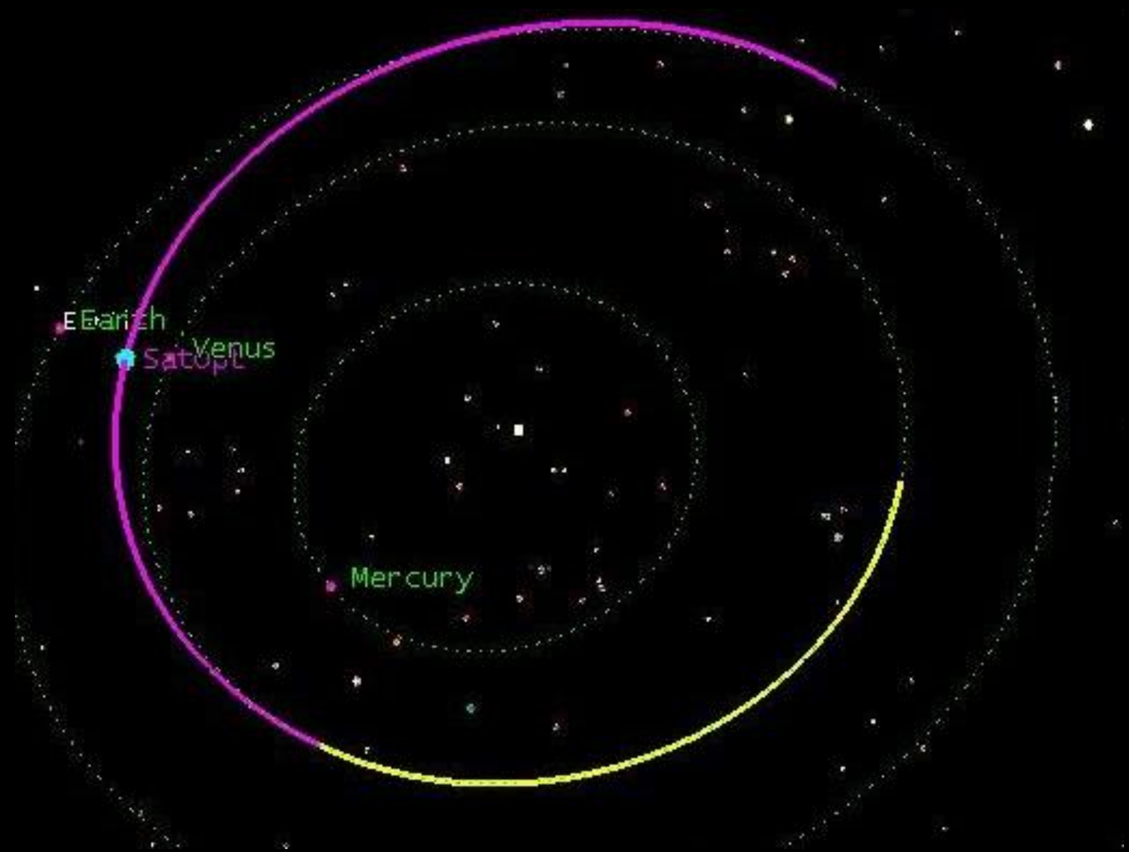
Ariane 5 ME (possible alternative)

• 12 tons into GTO
• Under development: qualification flight estimated for 2018



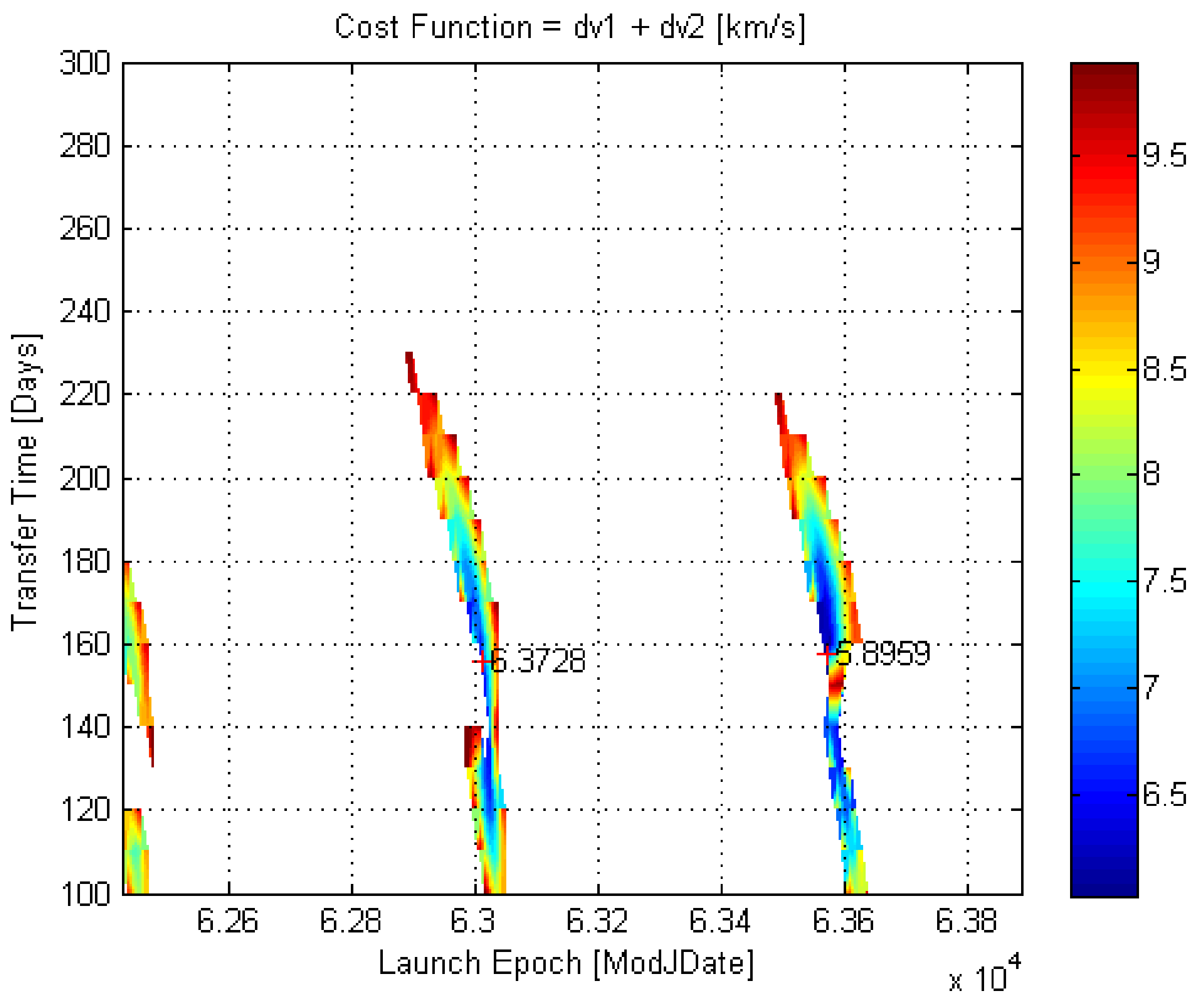
VELOCITÉ inside Ariane 5 ECA Fairing

Orbit and maneuvers



Origin - destination	Earth - Venus
Transfer type	Hohmann transfer
Required delta v	5.895862 km/s
Transfer time	157.8 days
Launch window	+/- 2 days

Pork chop diagram



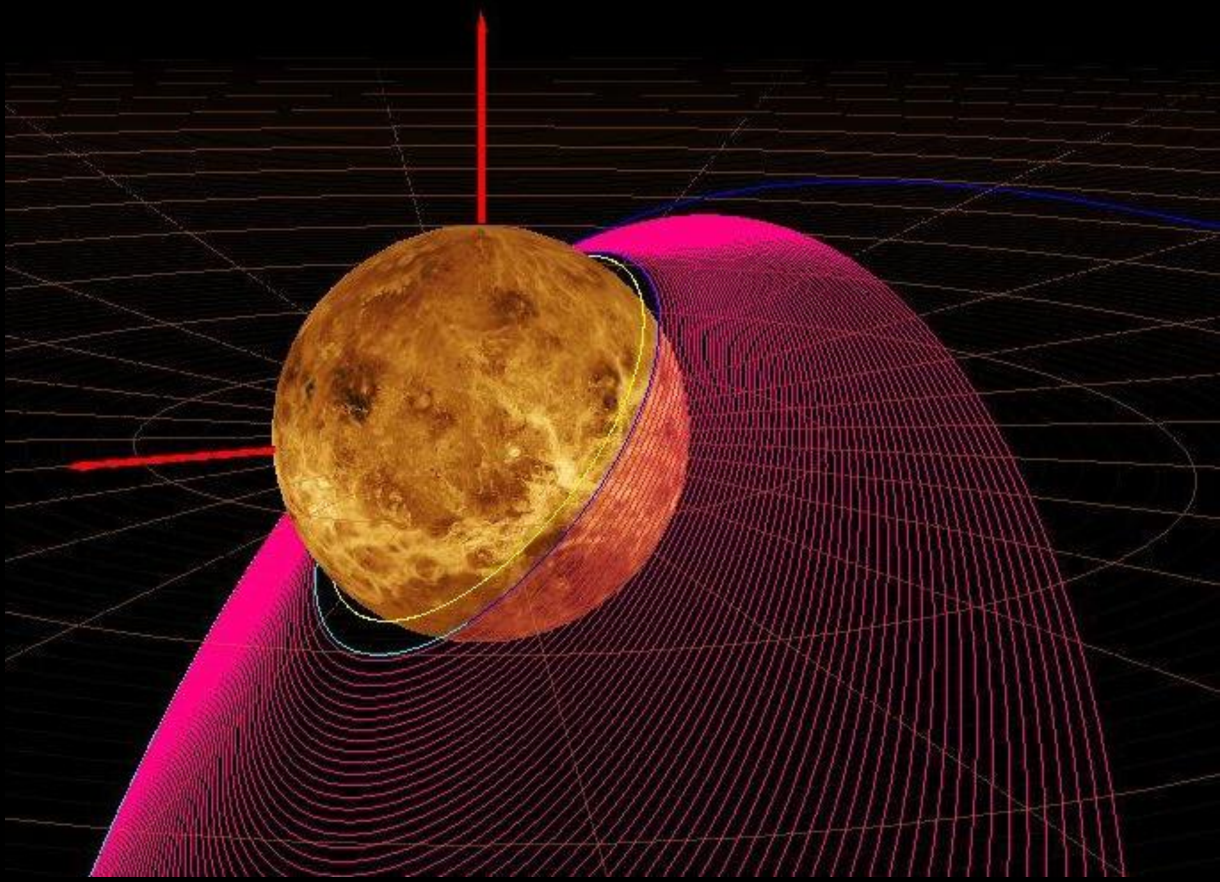
Variations of the deltav requirements as a function of the launch epoch.

Orbit insertion

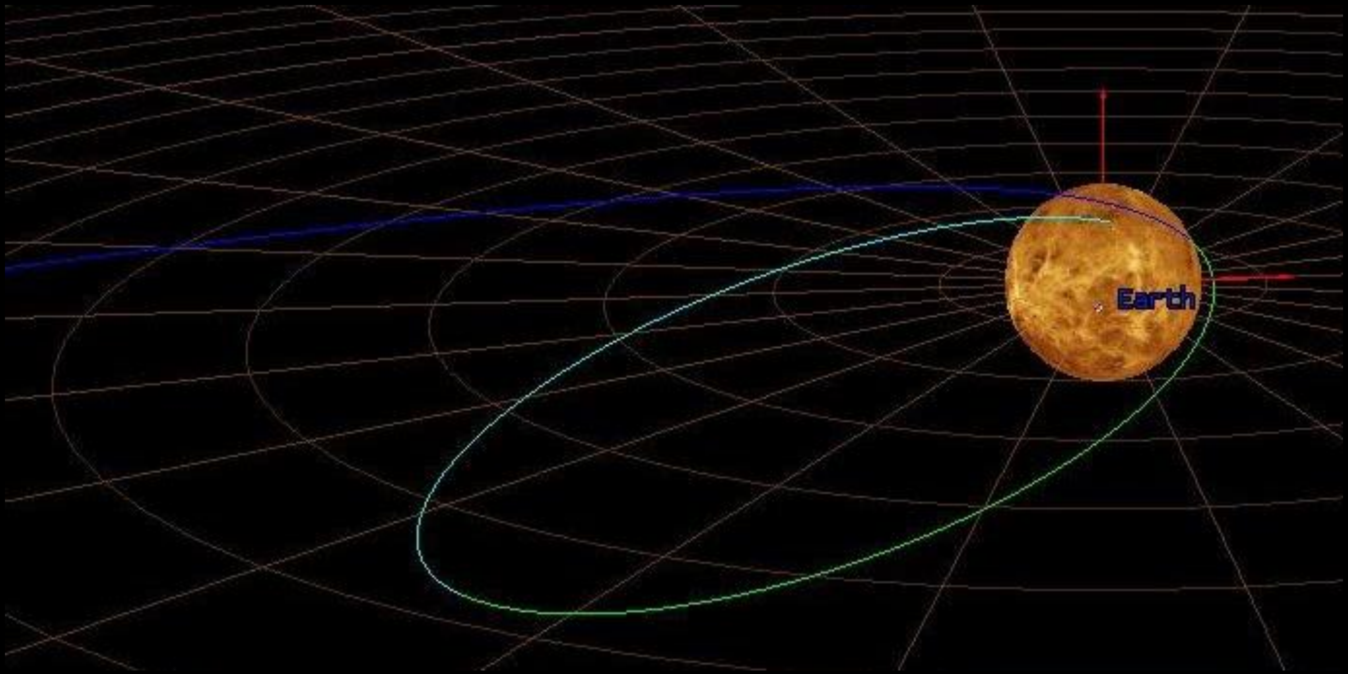
B plane

Insertion into Venus' gravity field:

- correction maneuvers are made to enter with an inclination of 50° to match the future orbit.
- periapsis from 200km to 400km depending on atmospheric density. A brake maneuver is then performed.



Lander deployment

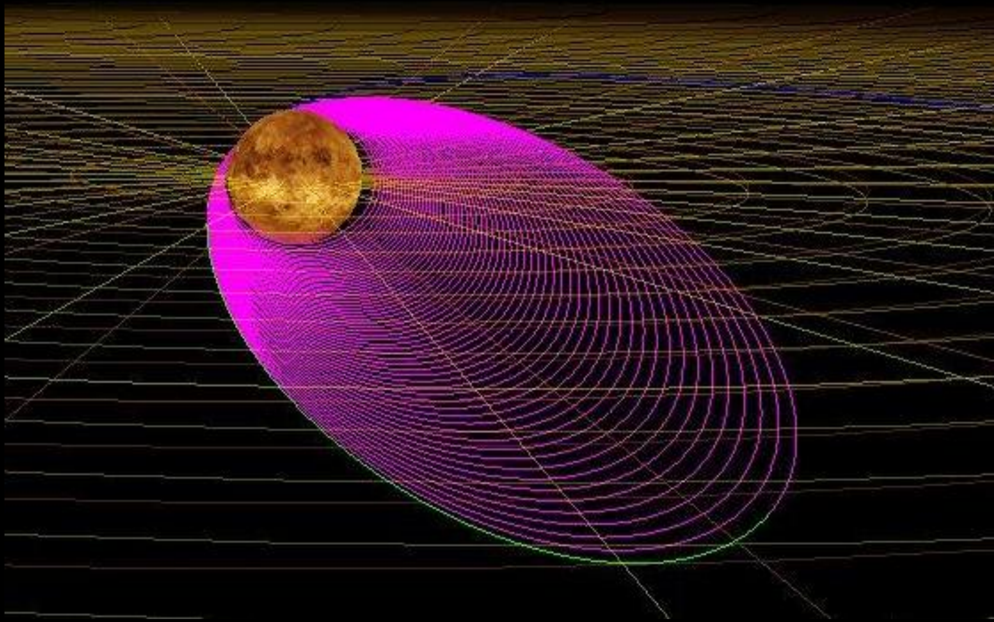


- Lander separation after orbit inserting
- Landing site selected, so that Earth is visible and communications can be performed

Aerobraking

Manoeuvre using atmospheric drag in order to reduce the speed at periapsis and therefore lower the apoapsis.

- Fuel-efficient
- Long lasting maneuver
- Duration: 3-9 months (large uncertainties in atmosphere density)
- ablative mass efficient material for thermal protection

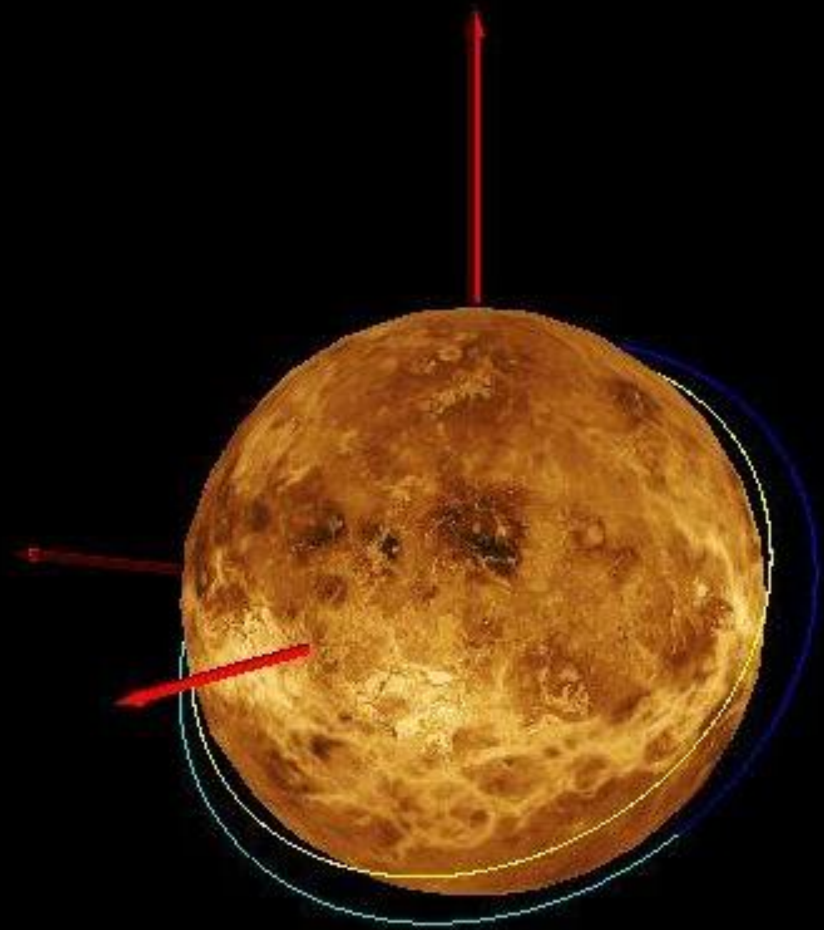


Science orbit insertion

Additional orbit maneuvers after aerobraking:

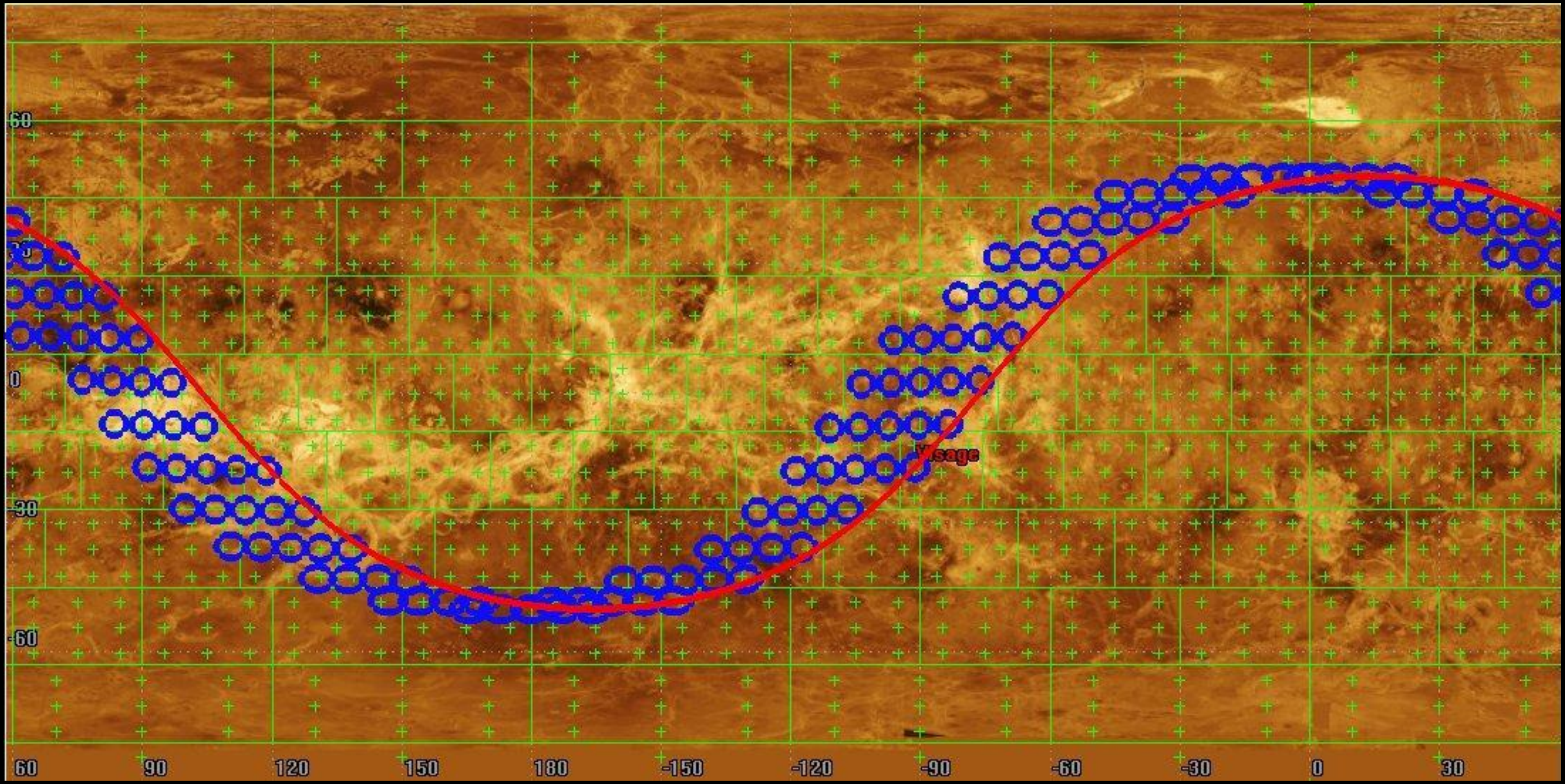
- Raising the pericentre
- Circularise the orbit at the pericentre

- Target orbit:
  - Inclination: 50°
  - Eccentricity: 0
  - Altitude: 280km



Science Orbit

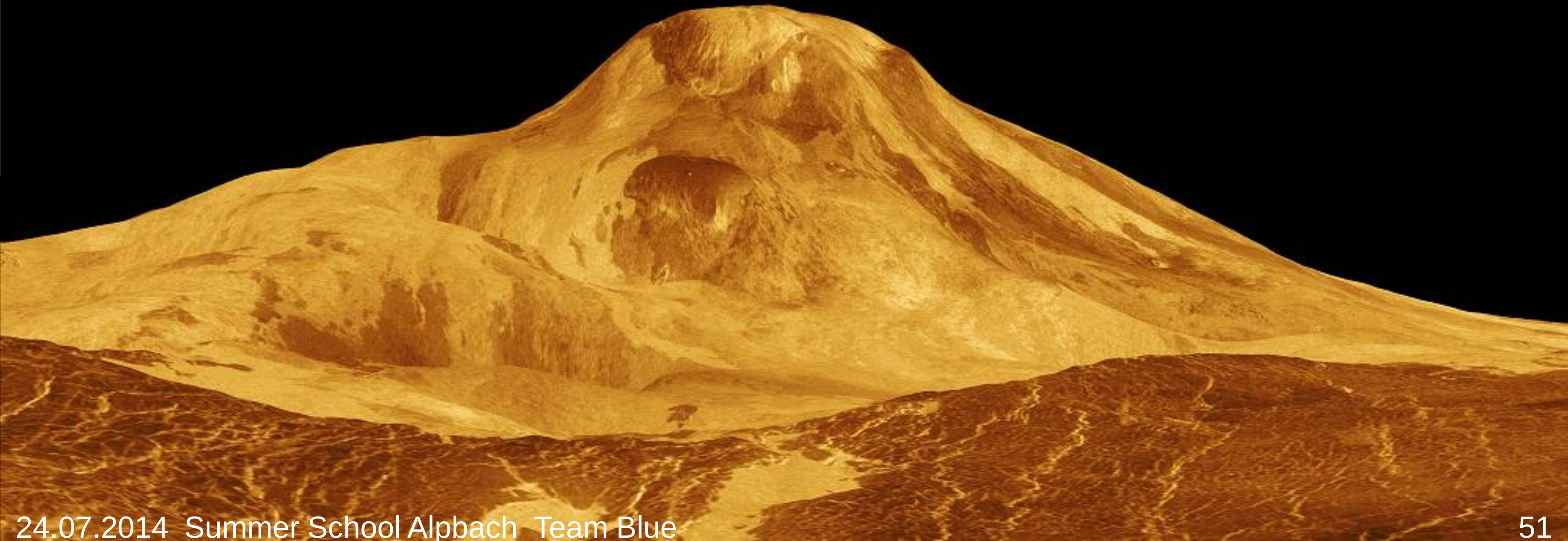
Ground Track of a sample orbit on Venus.



Delta V budget

Maneuver	Delta V (km/s)	Fuel consumption(kg)
Leaving LEO parking orbit (performed by Launcher upper stage) from Ariane 5	3.18	-----
Entering B plane	0.01	15.25
Entering elliptic orbit (break at closest approach)	0.93	1184.15
Separation	0.1	65
Set periapsis (unnecessary aerobrake works perfectly)	0.1	65
Set circular orbit (unnecessary aerobrake works perfectly)	0.3	262.15
Total for VISAGE	**1.1-1.5**	**1250 - 1600**

Spacecraft Design



Systems with heritage Orbiter

Subsystem/component	Used on
Propulsion system	Venus Express/ Mars Express
Reaction Wheels	Venus Express
Star tracker	GOCE
Coarse Sun and ground detector	GOCE
Li ion batteries	Venus Express/ Mars Express
PCDU*	Huygens
OBDH**	Rosetta
Separation mechanism	Cassini/Huygens
Thermal	Venus Express

* Power Conditioning and Distribution Unit
** On Board Data Handling

Systems with heritage Lander

Subsystem/component	Used on
Seismometer	InSight Mission
Permittivity probe	Rosetta Philae Lander / Huygens probe
IR-Spectrometer	Mars Express
Li ion batteries	Venus Express / Mars Express
Separation mechanism	Huygens probe
Environmental probe	Curiosity Rover
Thermal	Vega Missions
OBDH*	Rosetta Philae Lander

* On Board Data Handling

Propulsion System - Orbiter

Fuel	MMH
Oxidant	Mixed oxides of nitrogen with 3% MON-3
Number of thrusters	1 main engine, 8 RCS engines
Thrust (main engine)	~ 416 N
Thrust (RCS engines)	Approx. 10 N
Specific impulse	~ 317 s
Pressurant gas	He
Tank pressure	267 bar (high pressure tank), 20 bar (tank pressure of the oxidant/fuel tanks)

Attitude Control System - Orbiter

Star Tracker

- 2 x ASC (used on GOCE) provided by TU Denmark
- Mass each: 1 kg
- Power each: 2 x 8 W
- Dimension each: 10x10x10 cm Unit + 5 x 5 x 5 cm Camera
- Accuracy: 1 “

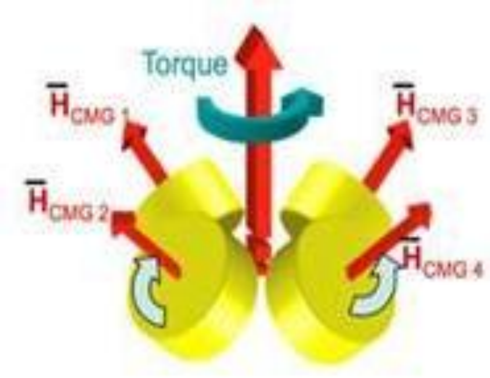
http://home.lu.lv

Sun Detector and Coarse Ground Detector

- 6 x Sensors (used on GRACE/CHAMP) provided by Atri
- Accuracy: 5 - 10 °

Reaction Wheels

- 4 reaction wheels as used on Venus Express
- 12 Nms angular momentum at max 6000 rpm

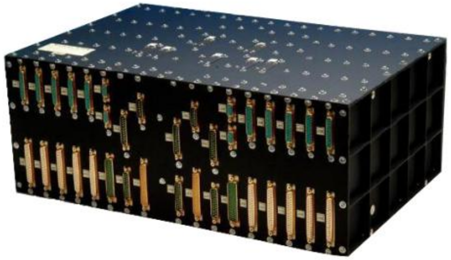


EPS - Orbiter

Power distribution unit	PCDU Medium Power by Thales Aliena Space
Power-supply voltage	28 V
Solar cells Provider	Spectrolab
Cell structure	GaInP2 / GaAs / Ge
Efficiency	28.3 %
Solar array size	**10 m²**
Provided power at Venus	4621,21 W
Batteries provider	ABSL
Battery type	Rechargeable Li-ion batteries
Power of one battery pack	24 Ah
Number of battery packs	6

Li-ion battery by ABSL

Solar cells by spectrolab

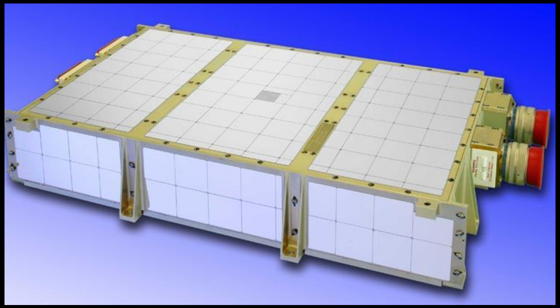


PCDU by Thales Aliena Space

Radiation and Thermal

- Kapton multi-layer insulation’ composed of 23 layers
- Radiators
- optical solar reflectors (OSRs)
- sulphuric anodisation on the launch-vehicle adapter (LVA) ring’s external surface
- additional heaters for missions early cruise phase and eclipse
- H/W designed to withstand total radiation dose of 20krad (1mm case thickness)

Multi Layer Insulation



optical solar reflectors

Separation Mechanism - Lander

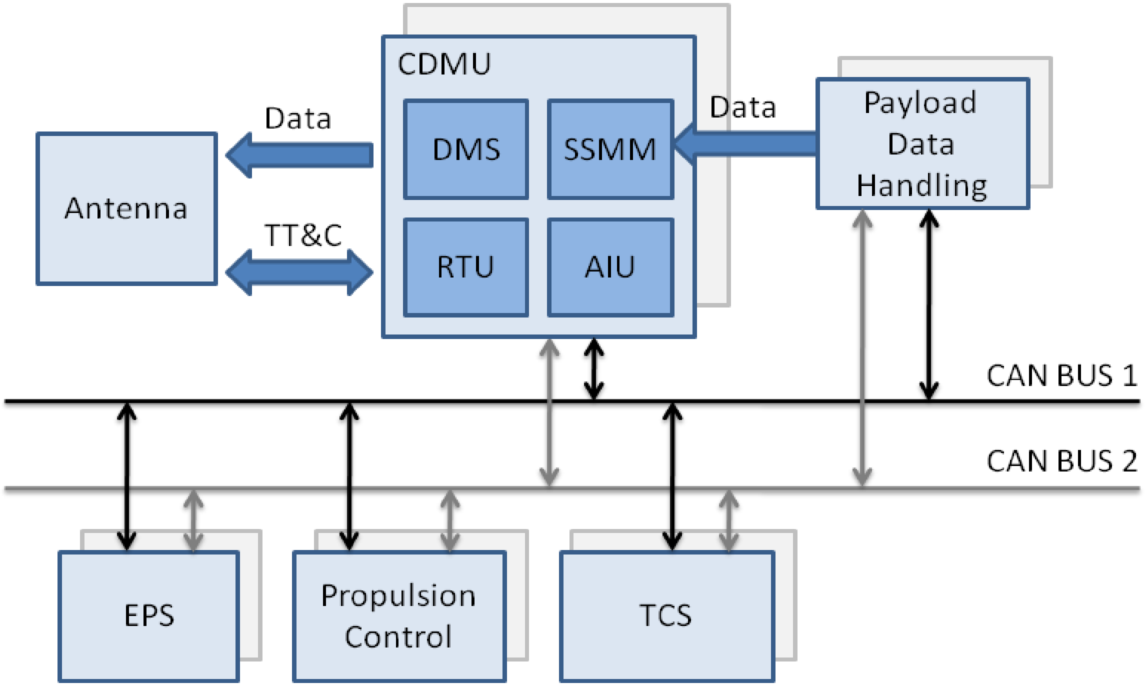
Separation mechanism as used on the Cassini Huygens mission:

Spin rate	5 - 10 rpm
Total mass	30 - 40 kg
Axial velocity relative to the spacecraft	0.3 m/s + 25 % - 10 %

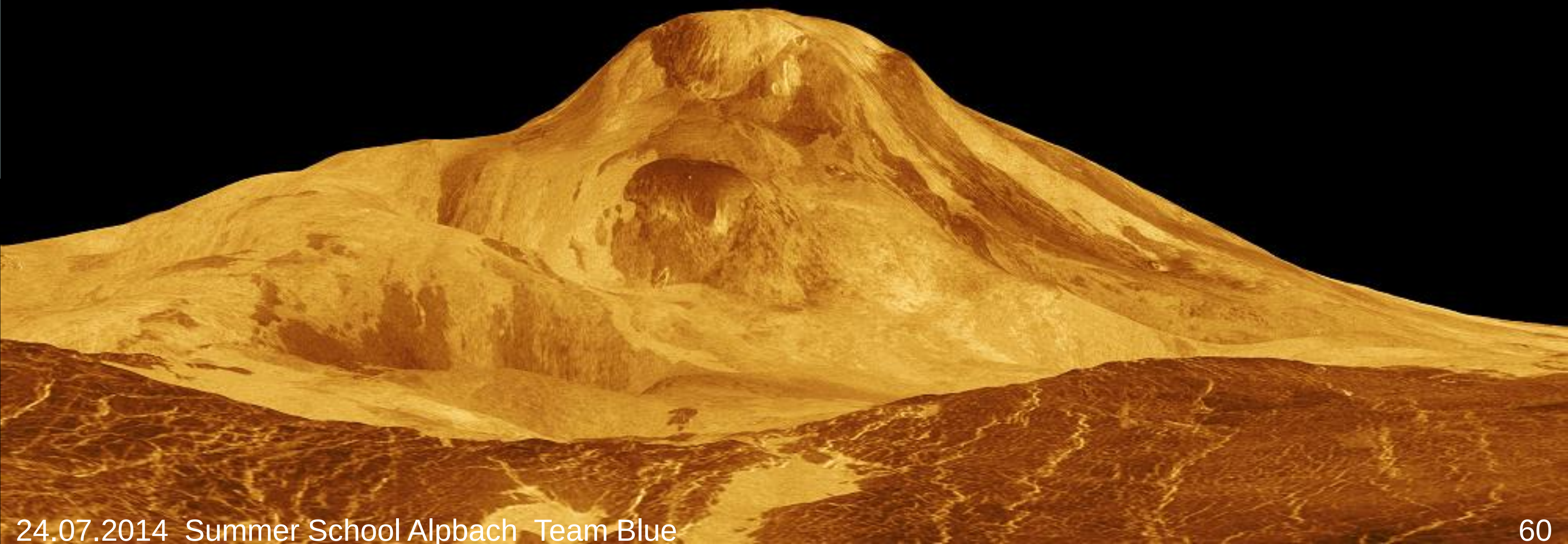
http://www.swissworld.org/en/science/space_research/probing_planets/

Data Handling - Orbiter

- two Control and Data Management Units (CDMUs)
  - constitute the Data Management System (DMS)
  - a Remote Terminal Unit (RTU)
  - an AOCS Interface Unit (AIU)
  - a 1 TB Solid-State Mass Memory (SSMM)
- Caesium Clock



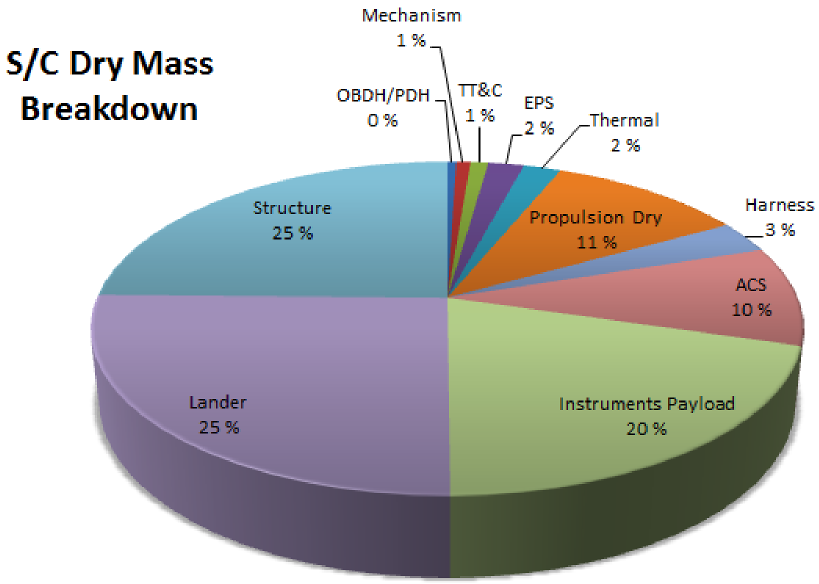
Budgets

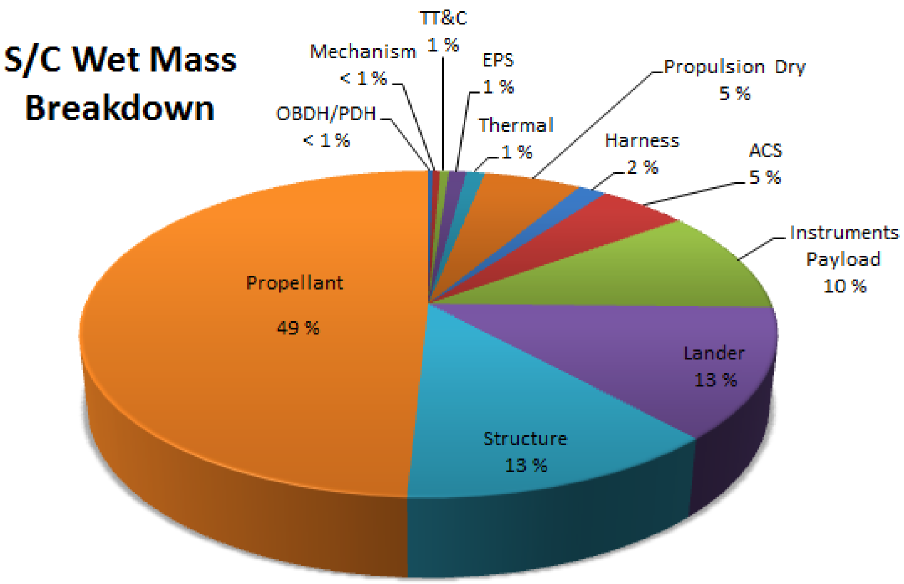


Mass Budget

Subsystem	Nominal Mass (kg)	Margin (%)	Mass with Margin (kg)
SAR (Payload)	300	20	360
Gradiometer (Payload)	180	10	198
Ground-penetrating radar (Payload)	20	10	22
IR Camera (Payload)	20	10	22
Structure (20% of dry mass)	228,2	20	273,8
Mechanisms	35	20	42
TT&C	60	20	72
ACS	90	15	103,5
OBDH/PDH	20	10	22
EPS	60	10	66
Thermal	75	20	90
Propulsion	200	10	220
Lander	323	20	387,6
Harness (5%)	70	0	70
Total dry mass with margin			**1948,9**
Total dry mass with extra margin (15%)			2241,2
Propellant	1600	5	1680
ACS Propellant	100	100	200
Launch Mass			**4121,2**

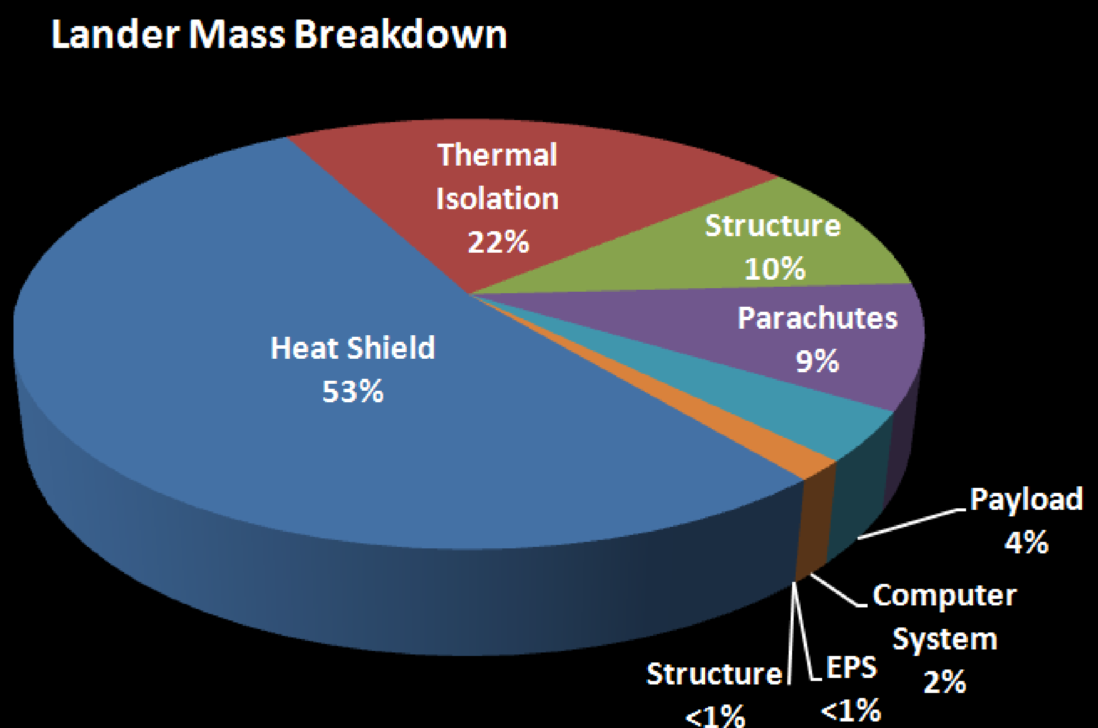
Mass Breakdown





Mass Budget - Lander

Subsystem	Mass [kg]
Payload	12
Structure	32
Communications	2
Thermal Isolation	70
Heat Shield	170
Parachutes	30
EPS	2
Computer system	5
Total mass	323
20% marginTotal mass with	**387,6**



Power Budget - Orbiter

Subsystem	Peak Power Consumption (W)	Margin	Duty Cycle	Power Consumption with margin (W)
SAR (Payload)	870	20	0,03	31,32
Gradiometer (Payload)	100	20	1	120
Ground-penetrating radar (Payload)	10	20	1	12
IR Camera (Payload)	20	20	0,92	22,17
TT&C	200	20	0,16	39,13
Deployment	5	10	0,00	0,00
ACS	200	10	0,09	19,13
OBDH/PDH	20	5	1,00	21,00
EPS	120	5	1,00	126,00
Thermal	30	10	0,00	0,00
Propulsion	50	20	0,05	3,26
Total power with margin	1840			394,02
Total power with extra margin (20%)	2208			472,82

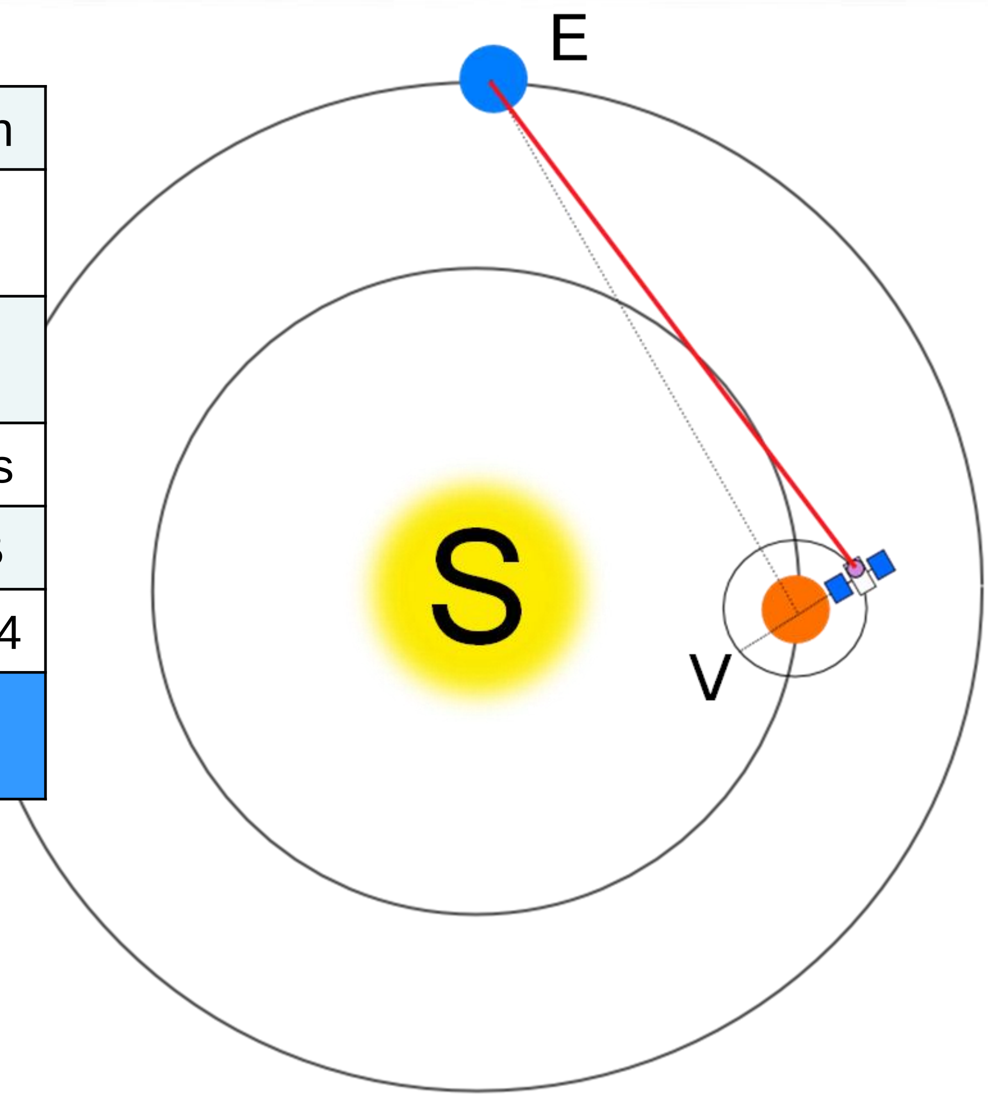
Link Budget - Orbiter

Frequency	32 GHz (Ka-Band)
Range	2.533×10^8 km = 1.7 AU
Power Transmitter	50 W
Transmitter Antenna Diameter	2 m
Receiver Antenna Diameter	35 m
Nominal Data Rate	400 kbps

Subsystem	Data Bit Rate (Kb/s)	Duty Cycle	Data per orbit (kB)
SAR (Payload)	6,64	0,03	1099,584
Gradiometer (Payload)	0,996	1	5497,92
Ground-penetrating radar (Payload)	0,249	1	1374,48
IR Camera (Payload)	0,415	1	2290,8
TT&C	0,5	0,163	450
Total			**85702,272**

Link Budget - Orbiter

Time orbit	92.6 min
Communication time / orbit	41 min
Instrument data transfer /orbit (85%)	35 min
Communication / day	10,500 s
Data transfer / day	500 MB
Synodic period	567 / 584
Instrument mean data transfer / orbit	46 MB



Link Budget – Orbiter Instruments

(46 MB / orbit = 8,300 B/s on average)

			Average Time used	Average orbite use	Average coverage
InSAR	**80 %** (6,640 B/s)	High Res (15m/pix)	5.4 s	0.01 %	37 km x 70 km
		Med Res (50m/pix)	1 min	0.9 %	410 km x 70 km
		Low Res (100m/pix)	3.5 min	3.5 %	1,640 km x 70 km
Ground Penetrating Radar	**12 %** (996 B/s)	Sounder	10 min	0.1 %	4,150 km x 1 km
		Altimeter	92.6 min	100 %	37,800 km
IR Camera	**5 %** (415 B/s)	Low Res (1km/pix)	92.6 min	100 %	37,800 km
Gradiometer	**3 %** (249 B/s)	High Res (1km/pix)	92.6 min	100 %	37,800 km

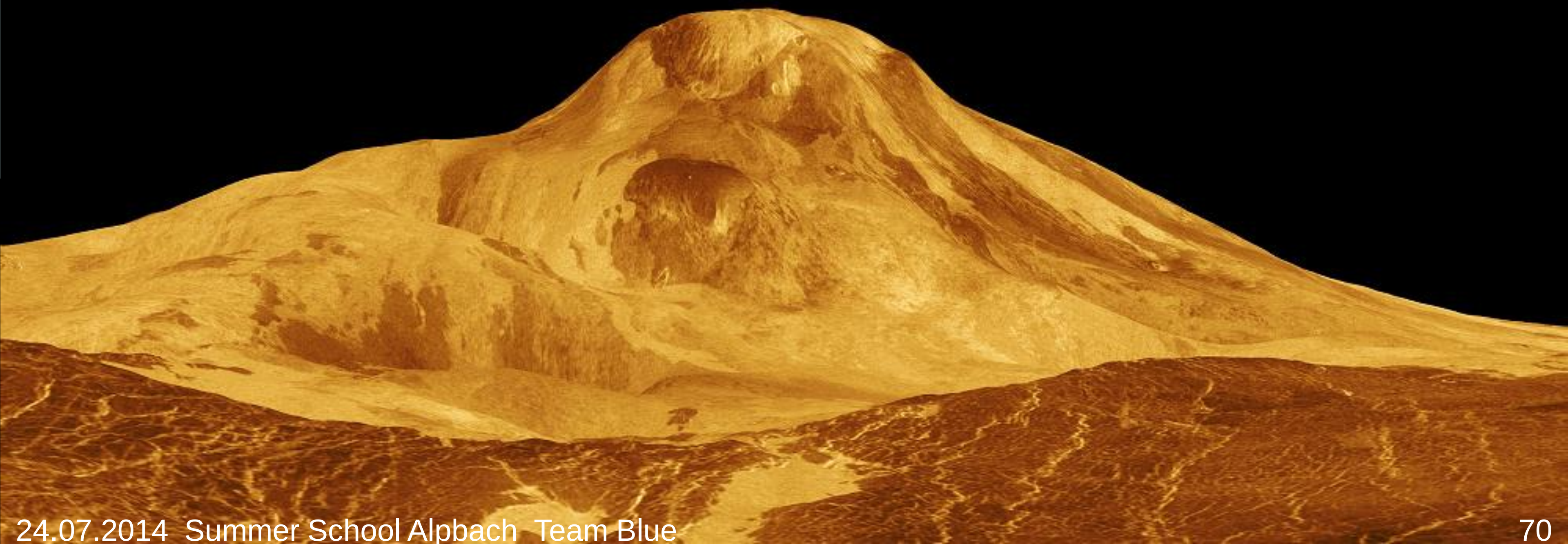
Link Budget - Lander

Frequency	2.5 GHz (S-Band)
Range	2.533×10^8 km = 1.7 AU
Power Transmitter	20W
Transmitter Antenna Diameter	0.5 m
Receiver Antenna Diameter	DEEP SPACE NETWORK 70 m ARECIBO OBSERVATORY 300m
Nominal Data Rate	5 kbps
Maximum possible Data Rate	50 kbps

Data Budget

Subsystem	Data Bit Rate (kB/s)	Duty Cycle	Data per orbit (kB)
SAR (Payload)	6,64	0,03	1099,6
Gradiometer (Payload)	0,996	1	5497,2
Ground-penetrating radar (Payload)	0,249	1	1374,5
IR Camera (Payload)	0,415	0,92	2290,8
TT&C	0,5	0,16	450
Total			48892,8

Analyses



Technology Readiness Level Components

ORBITER	
Component	**TRL**
InSAR	6
Ground-penetrating radar	6
Gradiometer	6
Accelerometer	9
IR-Camera	9
Lander Separation Mechanism	7
Subsystems	5-9

LANDER	
Component	**TRL**
Parachutes	5
Seismometer	4
Permittivity Probe	4
IR Spectrometer	4
Visible Camera	9
Microphone	4
Environment Monitor	9
Radar Reflector	4
Heat Shield	5
Separation Mechanism	3

Risk Analysis

ECSS-M-ST-80C

Probability					
A = 5	5	10	15	20	25
B = 4	4	8	12	16	20
C = 3	3	6	9	12	15
D = 2	2	4	6	8	10
E = 1	1	2	3	4	5
	I = 1	II = 2	III = 3	IV = 4	V = 5

Severity

Risk Assessment

SPACECRAFT		
TT&C	D5	10
OBDH	D5	10
EPS	D5	10
Thermal	D5	10
Structure	E5	5
ACS	E5	5
Propulsion	E5	5
Payload - Lander	E1-B3	1-12
Payload - Instruments	E2-C4	2-12

LANDER		
Parachute	B3	12
IR Spectrometer	C3	9
Heat Shield	D4	8
Seismometer	D3	6
Radar Reflector	E4	4
Separation Mechanism	E3	3
Environment Meter	E3	3
Permittivity Probe	E2	2
Visible Camera	E1	1
Microphone	E1	1

Preliminary Cost Analysis

MISSION COST BREAKDOWN	
TYPE	**€M**
Technology Development	100
Launcher	175
Spacecraft	330
Lander	350
MOC + SOC	140
Management	80
Contingency (15 %)	135
SUBTOTAL	1310
Payload	300
TOTAL	**1610**

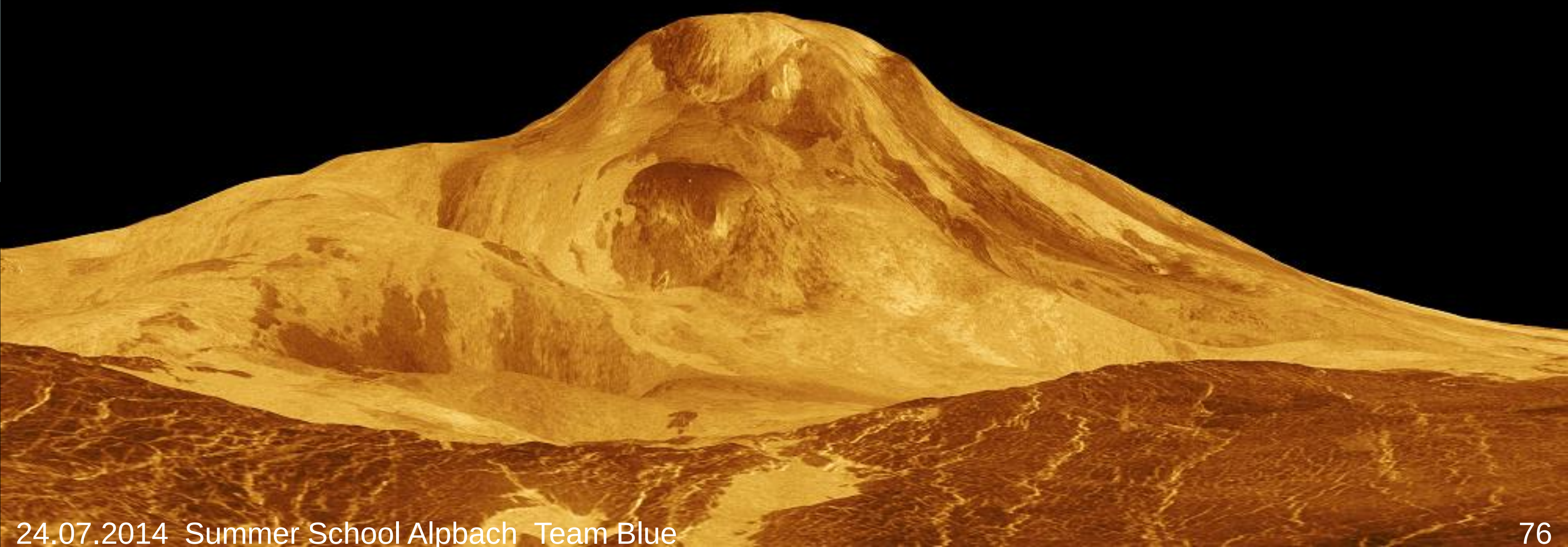
Planetary Protection

Venus: Class II

www.spaceagenda.com

COSPAR Planetary Protection Policy (2005), COSPAR/IAU Workshop on Planetary Protection

Summary



Mission Summary

VELOCITE is designed to enhance our understanding of geological processes on Venus' surface and interior.

The main selected technology (InSAR, gravity field determination, lander system) will constrain of the upper and interior structure of Venus.

R&D work required to raise technology readiness adequate levels.

design analyses give confidence that the mission can be conducted within the identified cost and schedule constraints

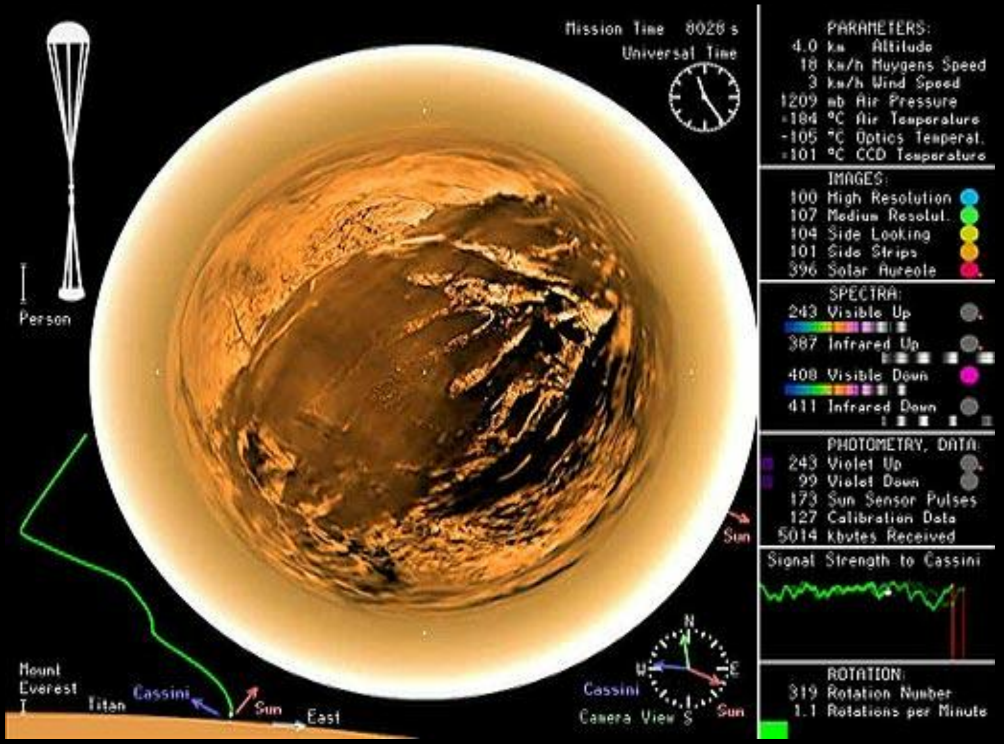
Risk understood and managable

Outreach and Education

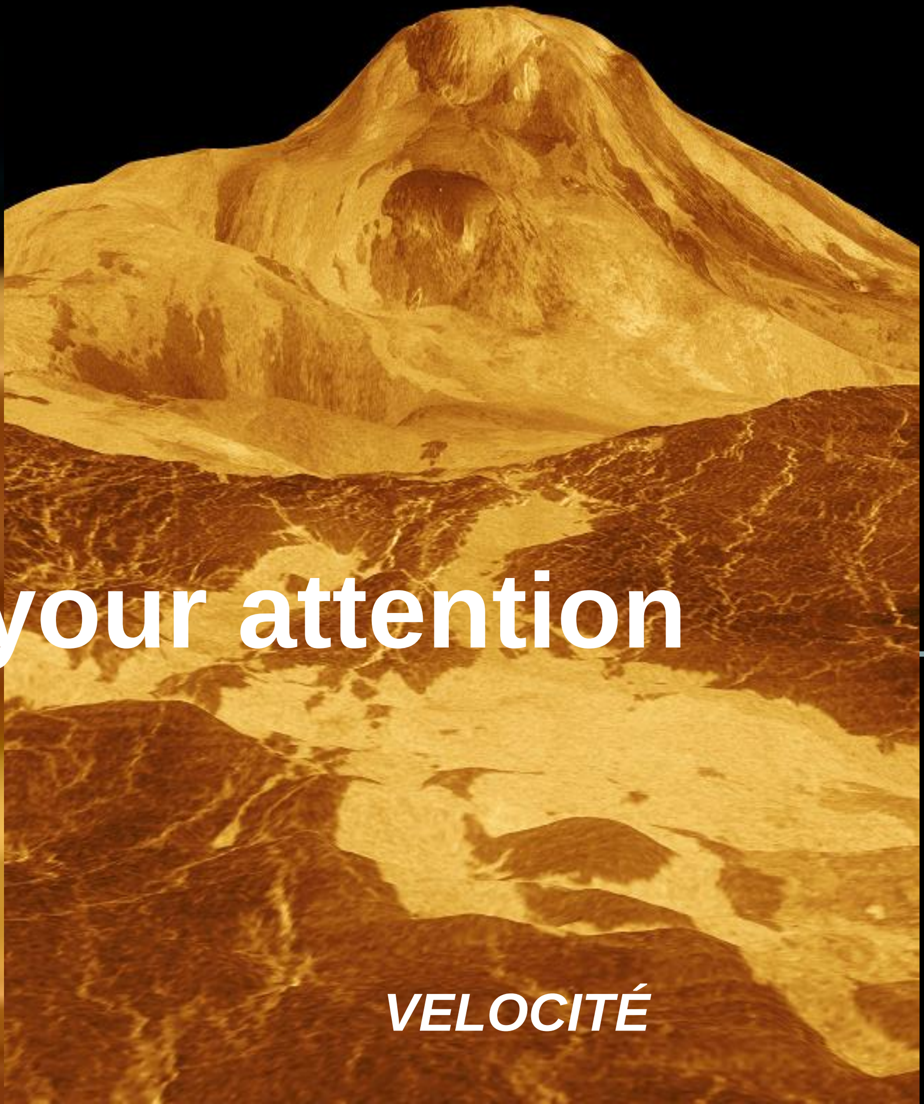
Outreach
Two instruments specifically built for outreach, a microphone and a camera.

Use
Possible understanding of the future of our Earth

Education
Create interest in a planet that is not well known
Example of school project : Why are Earth and Venus so similar and so different at the same time ?
Generally a better understanding of how other planets are like

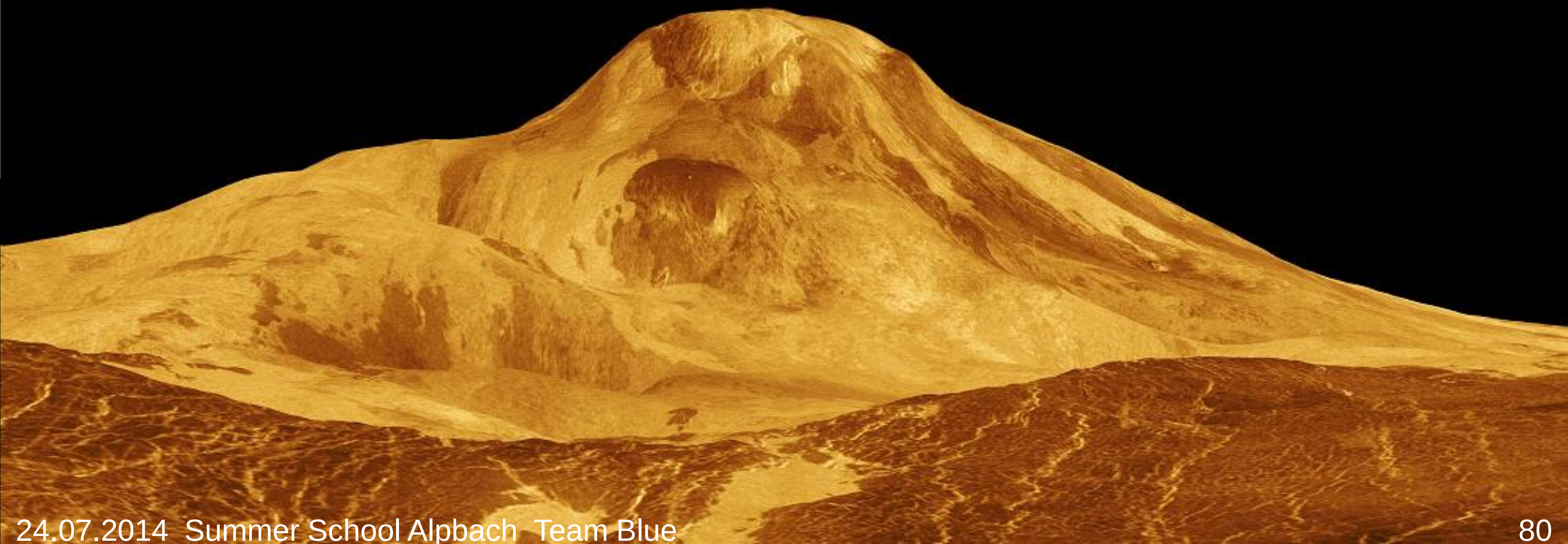


VELOCITÉ



Thank you for your attention

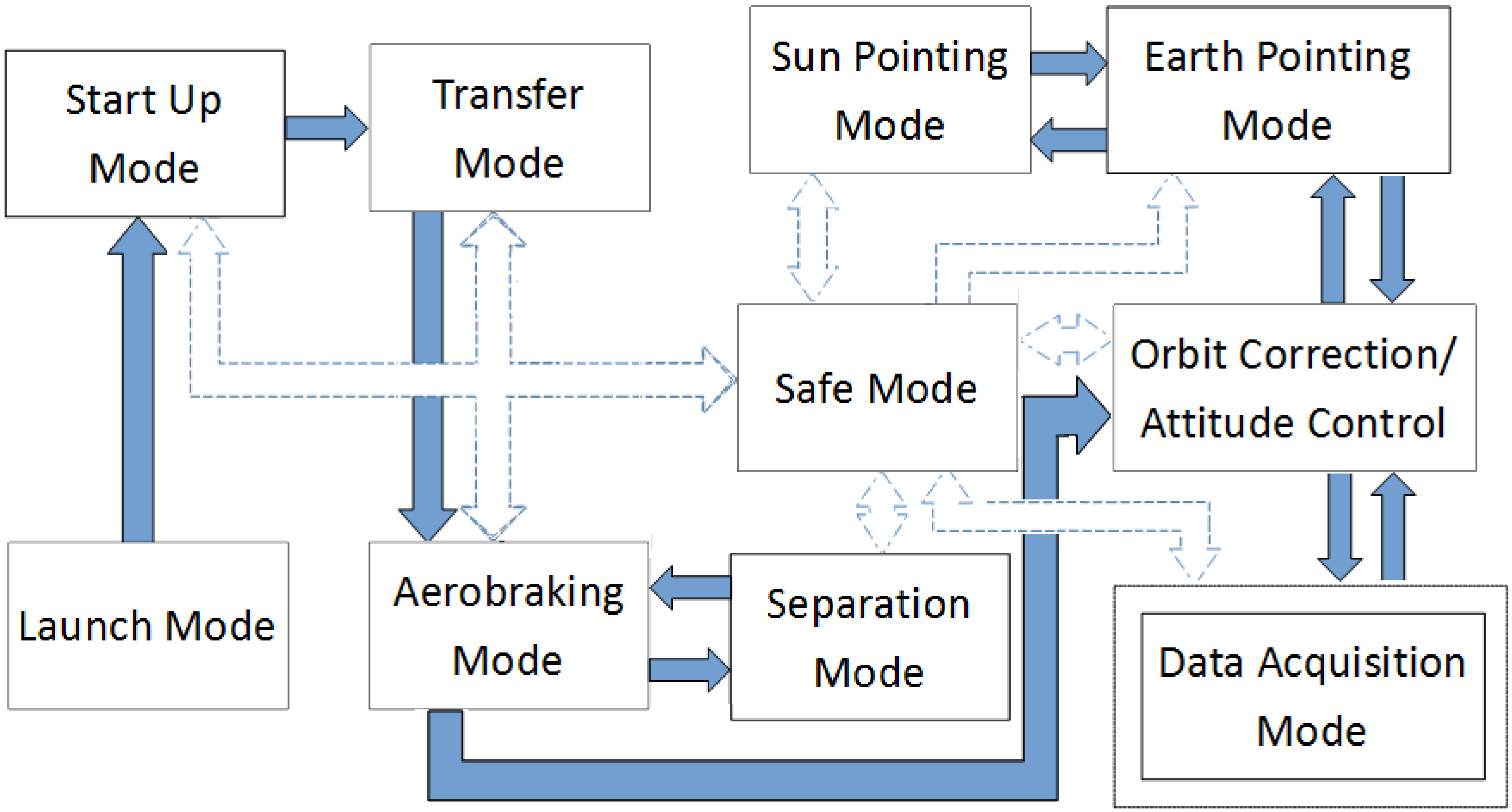
Questions?



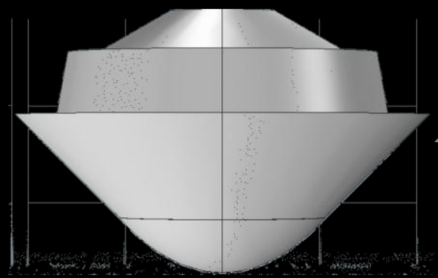
What are we going to learn?

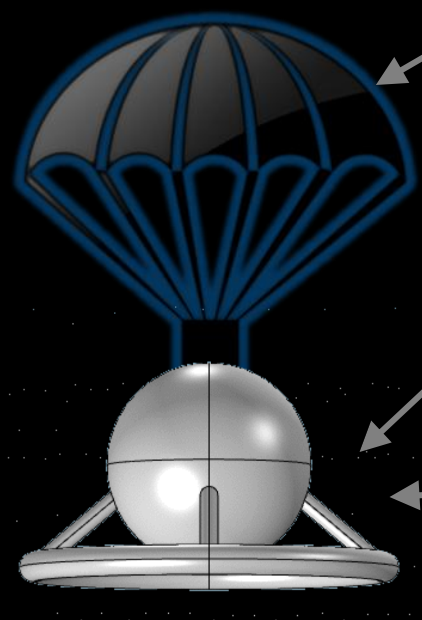
Current knowledge	With VELOCITÉ
Scarcity of knowledge about venusian interior	Remarkable knowledge about the interior
Scarcity of knowledge about tectonic activities	Hard evidence for tectonic and volcanic dynamics
NO DATA	Surface displacements of 1 cm accuracy
NO DATA	Polar motion and length of day variations of sub-daily sampling, moment of inertia
Static gravity field with up to d/o 40 (signal above the noise) from Magellan	Static gravity field up to d/o 260
NO DATA	Temporal variations of gravity field
NO DATA	Variations of crustal thickness
NO DATA	Crustal displacements due to severe atmospheric conditions
NO DATA	Answers for the questions: where do we come from and where are we going to?

Operational Modes



Description of the Lander





Descent

Max heat flux : 60 Mw/m²

Material used : - Carbon-Phenolic

Parachute

Needs to resist high temperature

Material used : Zylon PBO (resists up to 600°C)

Landing

Speed of 40m/s

Material used : - Honeycomb structure

Structure used : - Circular hollow tube

On the surface

T ~ 730 K and P ~ 92 bar

Material used : - Titanium alloy

- Phase changing materials

- Low thermal conductivity materials

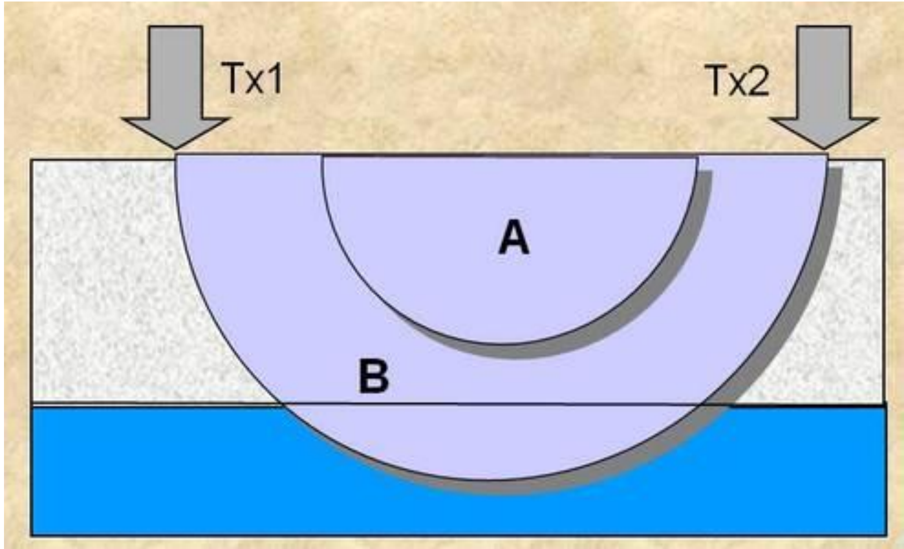
Mission Challenges!

- Orbit control
- Data volume
- Communications/data transfer to Earth
- Minimising the effect of solar radiation pressure and other non-gravitational perturbations on gradiometer and satellite orbit
- Co-ordination and deployment of modules
- Durability of the Lander
- Funding!

Wieczorek 2007, Gravity and Topography of the Terrestrial Planets

Measurement principles - Surface Permittivity

Permittivity Probe defines electrical rock properties (calibration PR & water content)
Quadrupole configuration:
Inject AC-current (Amplitude/Frequency) into the surface
Measure potential distribution



Wieczorek 2007, Gravity and Topography of the Terrestrial Planets

What is the current status of the planet's geologic activity?

Science Objective	Mission Objective	Measurement Requirements
Presence of **active tectonics**?	Measure temporal **dynamics**	3D displacement accuracy of 1 cm
	Measure the **topography**	Elevation accuracy of 10 m
	Improve the current knowledge about the static **gravity field** and determine temporal variations of the gravity field	Accuracy of C20 of 1.0E-11 Gravity field expansion up to degree 250 of spherical harmonics, i.e., with spatial resolution of 70 km Geoid change with an accuracy of 5 cm
Status and nature of the planet's **volcanic activity**?	Measure the **near surface** structure	15 m resolution up to 1 km deep
Presence of **current** volcanic **activity**?	Map the **temperature** distribution of the **surface**	Temperature measurements to accuracy of 1 K

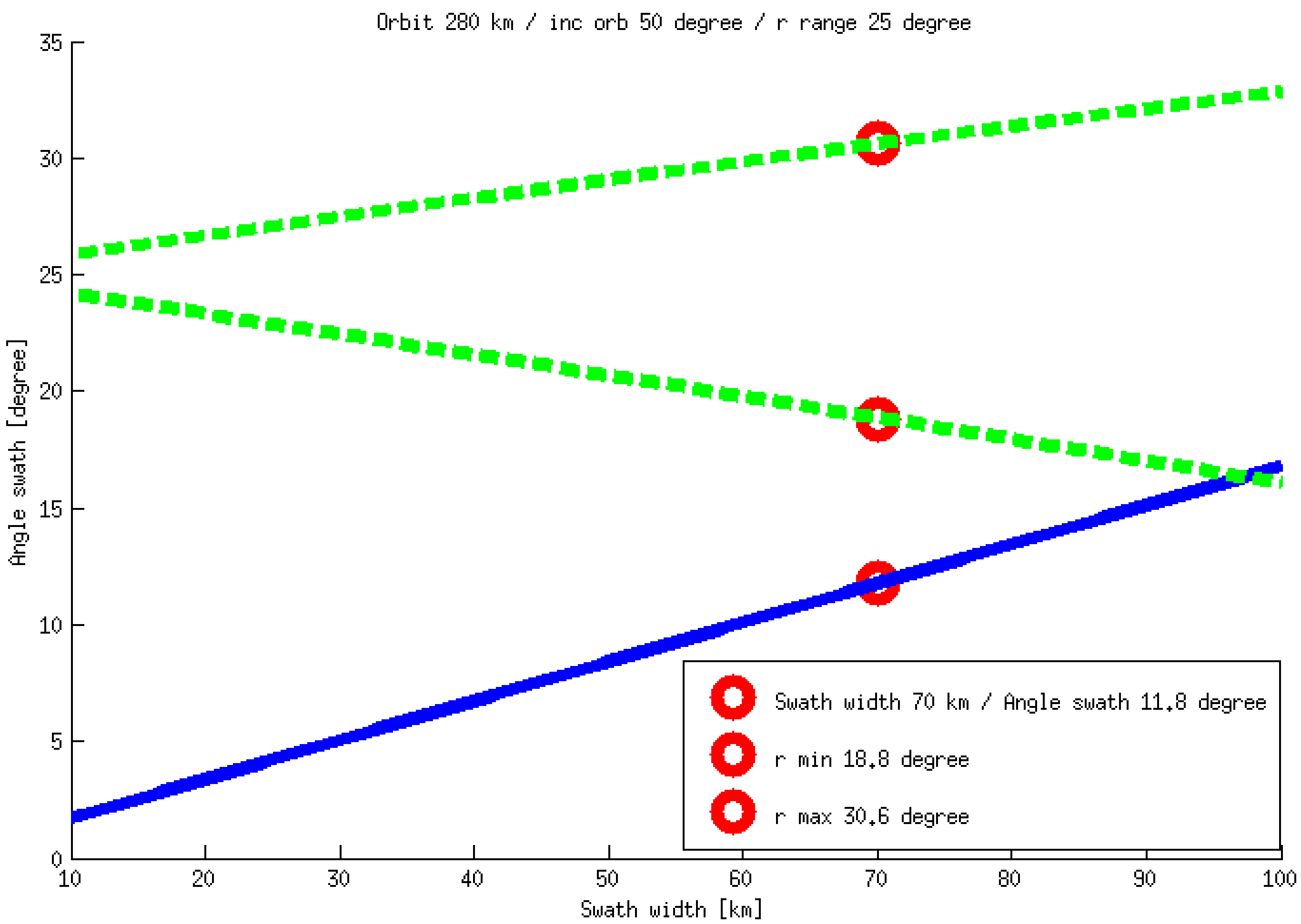
Wieczorek 2007, Gravity and Topography of the Terrestrial Planets

What is the inner structure of the planet?

Science Objective	Mission Objective	Measurement Requirements
What is the size and structure of the **upper layer**?	Measure the planet's **seismic** activity and **noise**	0.05 - 5 Hz
	Measure the **seismic** parameters of the most **upper layers**	0.05 - 5 Hz
What is the structure of the **interior**?	Determine the **rotational parameters** of the planet: precession, nutation, Length of day, polar motion	Accuracy of C20 of 1E-11 0.2 arc second on the surface with the temporal resolution of 8 hours
Composition of the upper layer?	Determine the complex **permittivity** of the near surface layer	Phase and Amplitude of injected current and measured potential (10 frequencies from 100 to 10 000 Hz)
	Determine the **composition** of the surface (mineralogy)	Spectrum of surface rocks (0.5 µm - 5.2 µm)

Wieczorek 2007, Gravity and Topography of the Terrestrial Planets

InSAR Swath Width Requirement

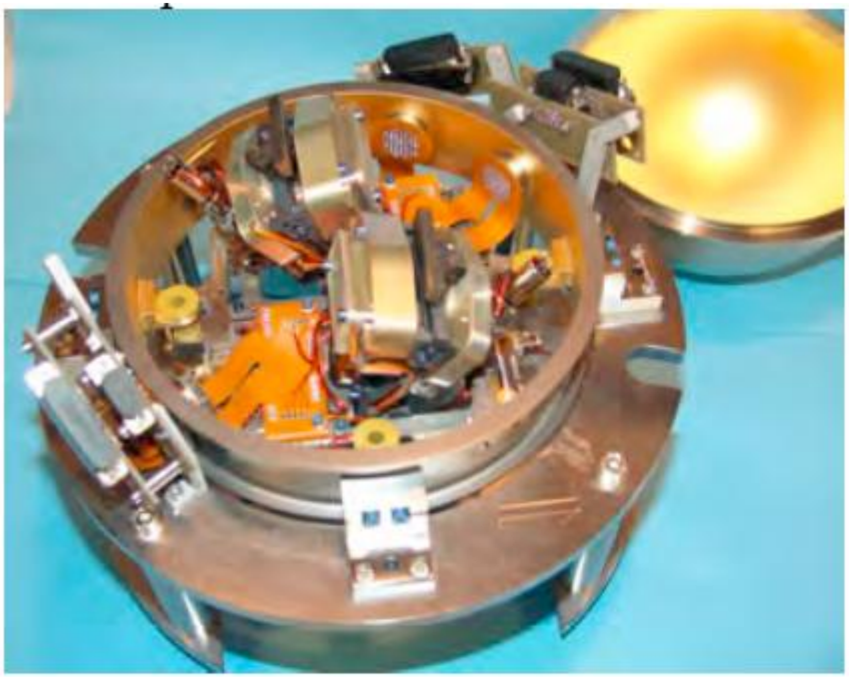


Wieczorek 2007, Gravity and Topography of the Terrestrial Planets

Lander Instruments - Seismic system

Broad Band Seismometer (2x)
Heritage from InSight

Baseline: approx. 5 - 10 km
Mass each: 3 kg
Power each: 2 W
Dimension: 30 cm x 10 cm
Frequency: 0.05 - 5 Hz



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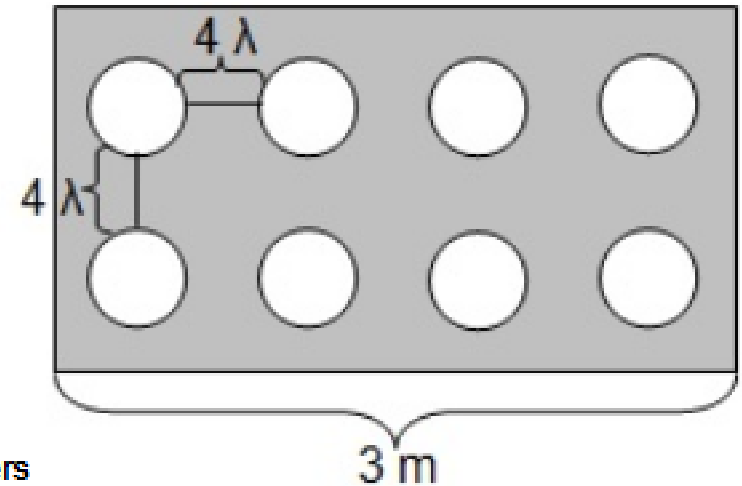
SAR Antenna



Key Parameters

λ (L band)	25 cm
Mass	225 kg
Maximum Power	800 W
Maximum Resolution	1.5 m
Nominal Resolution	15 m

→ $\left(\frac{D}{2}\right)$

→ $\left(\frac{10D}{2}\right)$

Two-way Atmospheric Attenuation

Incidence Angle	Attenuation
25°	-10 dB
30°	-12.5 dB
40°	-17.5 dB

Wieczorek 2007, Gravity and Topography of the Terrestrial Planets

Wieczorek 2007, Gravity and Topography of the Terrestrial Planets