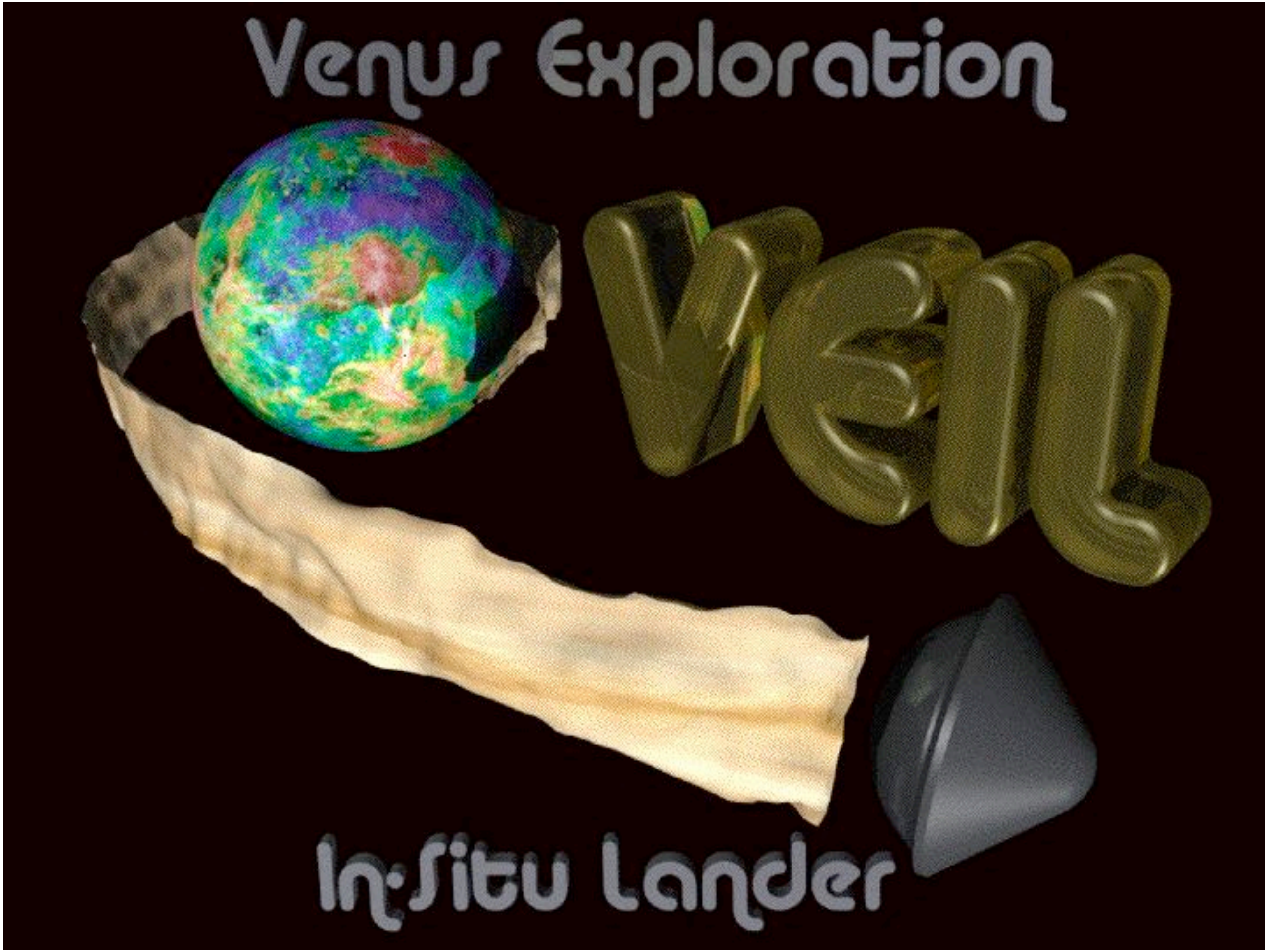
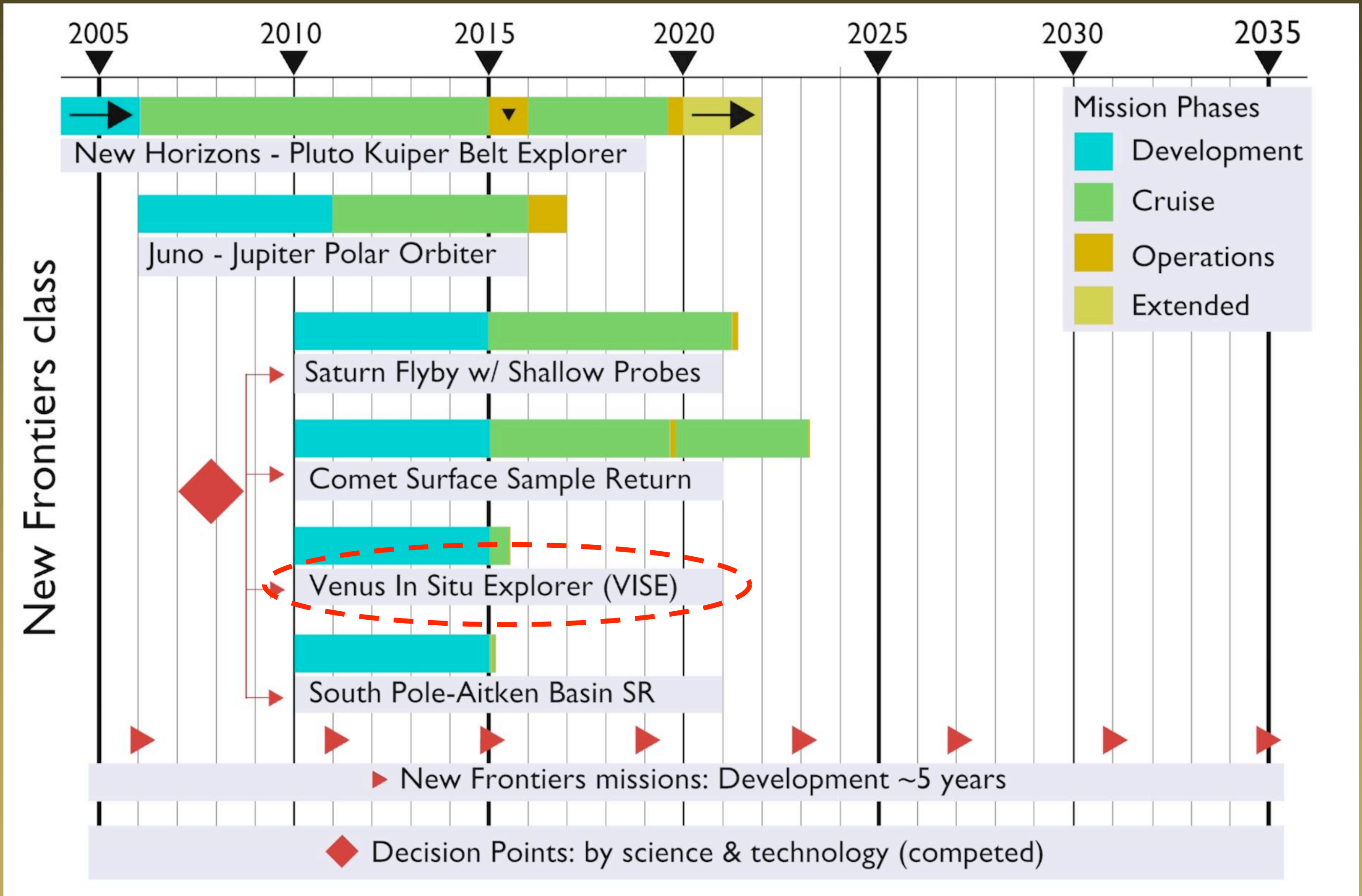

Venus Exploration
VEIL
In-Situ Lander

Team PSSS-2 2007

New Frontiers



Unanswered Questions

- **Key issues that remain unresolved:**
  - Chemical composition of the lower atmosphere
    - Only have 12 measurements of 5 species below 22 km
    - Some of these measurements conflict
      - At an altitude of 22km, Pioneer Venus reported [SO_2] = 185 +/- 43 ppm, while Vega 1 reported [SO_2] = 38 ppm
  - Mineral composition of the surface
    - Only elemental composition has been studied thus far
    - Not sensitive to elements less massive than Z < 12 (Mg)

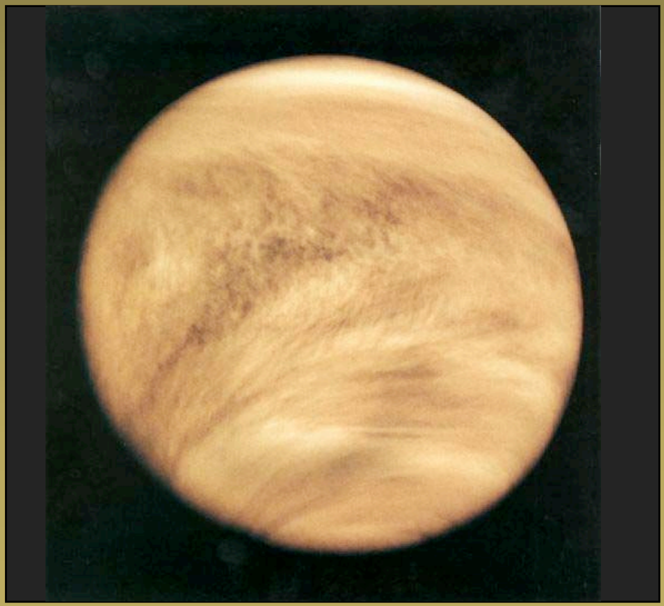
Venera 14 (NASA)

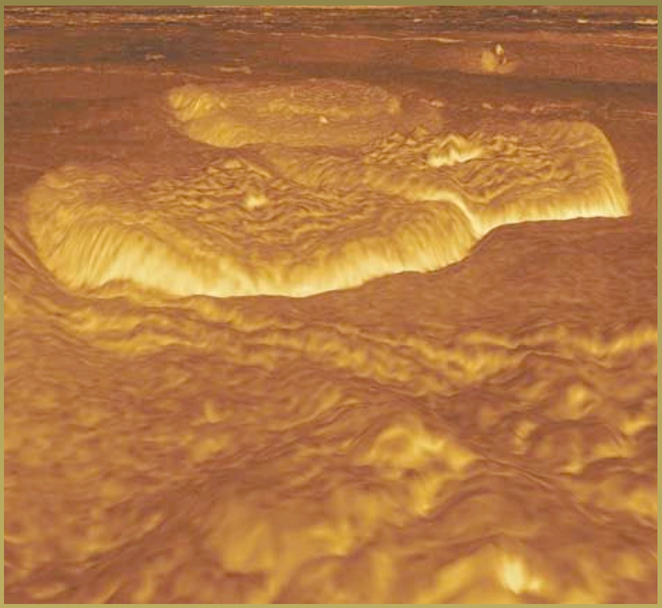
Unanswered Questions

- **Why are these measurements important?**
  - To determine if the surface interacts with the atmosphere, and how
    - (ex.) If CO is at equilibrium with CO_2 near the surface, specific iron oxide species are expected. Measuring surface minerals places a constraint on the CO-CO_2 system.
  - To understand the history of the venusian crust
    - (ex.) Measurements of felsic minerals would place constraints on the formation of the venusian crust.
  - To understand the current rate of volcanism
    - (ex.) Measurements of atmospheric sulfur gases and surface minerals will tell us if active volcanism is required to maintain the sulfur cycle on Venus.

Science Motivation

- **Main Science Goal:**
  - Investigate Venus to understand its current state and the conditions that gave rise to its extreme environment

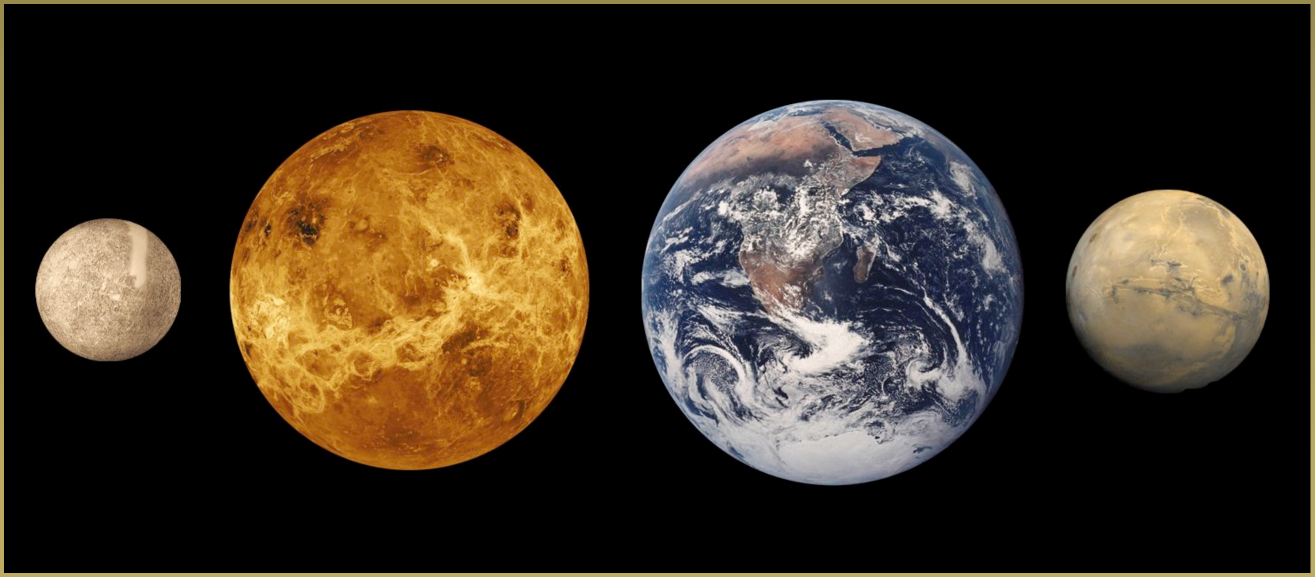




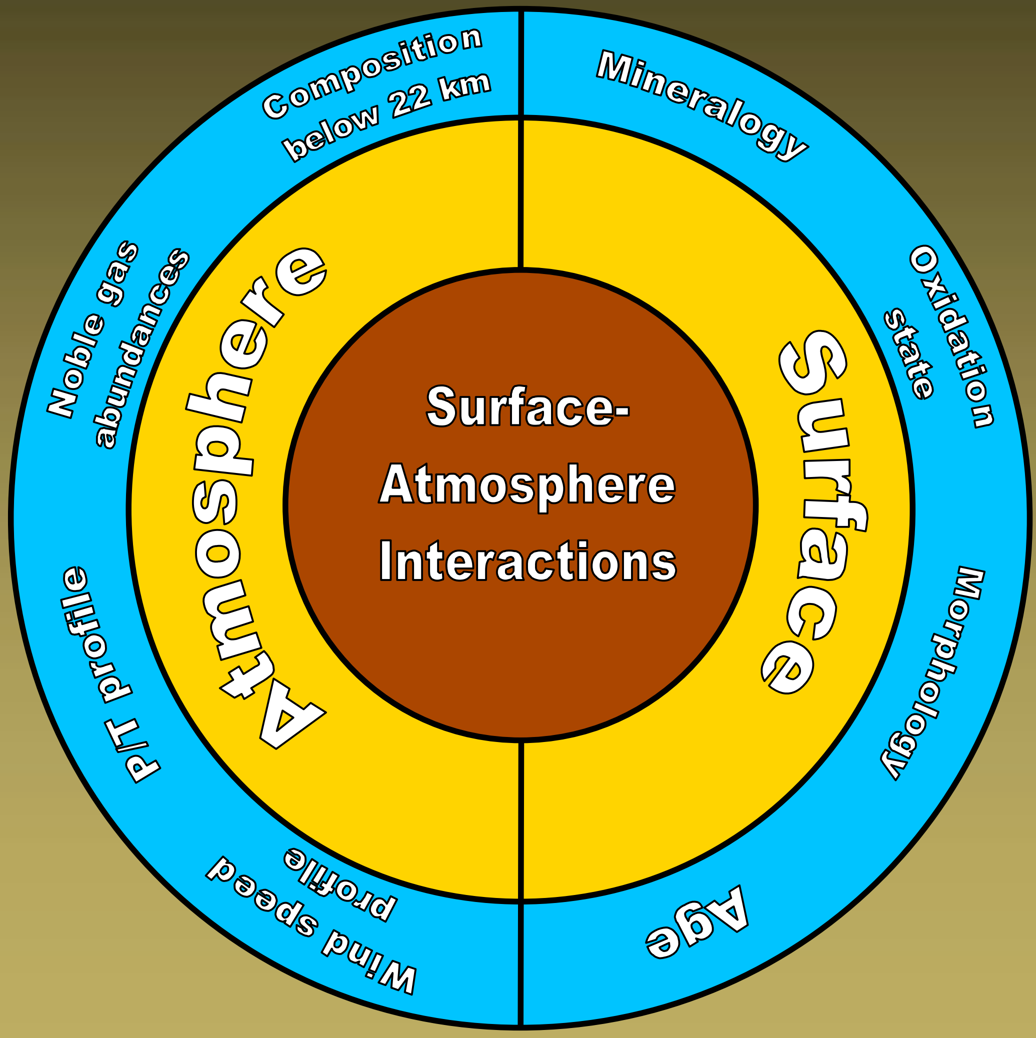
NASA/JPL/Caltech

Solar System Roadmap

- **SSE Roadmap themes addressed:**
  - Understanding solar system diversity
  - Understanding habitable regions around other stars
  - Understanding the future of Earth



Science Objectives



Science Objectives

Science Floor

A. Characterize the nature of weathering and surface-atmosphere exchange on Venus

B. Characterize the lower Venusian atmosphere

C. Determine the present surface conditions on Venus

Baseline Mission

D. Look for evidence of volcanism on Venus

E. Investigate the dynamics of the upper atmosphere

Enhanced Science

F. Search for lightning signatures

G. Investigate the space environment around Venus

Science Themes

- VEIL’s science links to three main themes:

Theme	NRC Decadal Survey	2006 Solar System Exploration Roadmap
Origins	• Learn how the Sun's family of planets originated and	• How did the Sun’s family of planets and minor bodies originate?
Evolution	evolved. • Discover how the basic laws of physics and chemistry,	• How did the solar system evolve to its current
Processes	acting over eons, can lead to the diverse phenomena observed in complex systems, such as planets.	diverse state? • Understand the processes that determine the fate of the solar system and life within it.

Science Traceability: Science Floor

Science Objective	Science Investigation	Measurement Objectives	Instruments
A Characterize the nature of weathering and surface-atmosphere exchange on Venus	A1. Determine the composition of the lower 22 km of the atmosphere.	A1a. Direct measurement of reduced (COS, H2S, S1-8) and oxidized (SO2) sulfur gases below 22 km.	GCMS
		A1b. Direct measurement of CO concentration below 13 km.	GCMS
		A1c. Direct measurement of H2O concentration below 22 km	GCMS
		A1d. Direct measurement of Hydrogen isotopes in the lower atmosphere.	GCMS
	A2. Determine the oxidation state of the Venusian crust	A2a. Determine oxidized species on surface .	Raman/IR spectrometer
		A2b. Direct measurement of CO concentration below 13 km	GCMS
	A3. Determine wind speeds, thermal and pressure profiles throughout the atmosphere.	A3a. Measure wind speeds upon descent from entrance to the surface.	Doppler tracking
		A3b. Measure temperatures through descent.	Thermometer
		A3c. Measure pressures through descent.	Barometer
	A4. Determine heat flux from the surface.	A4a. Measure the temperature gradient from the base of the cloud deck to the surface.	Thermometer
		A4b. Measure the temperature at the landing site.	Thermometer
	A5. Investigate surface for aeolian features and evidence of wind erosion.	A5a. High-resolution imaging of surface features.	Visible Imager
		A5b. Assess the size, shape and weathering of rocks near the landing site.	Visible Imager

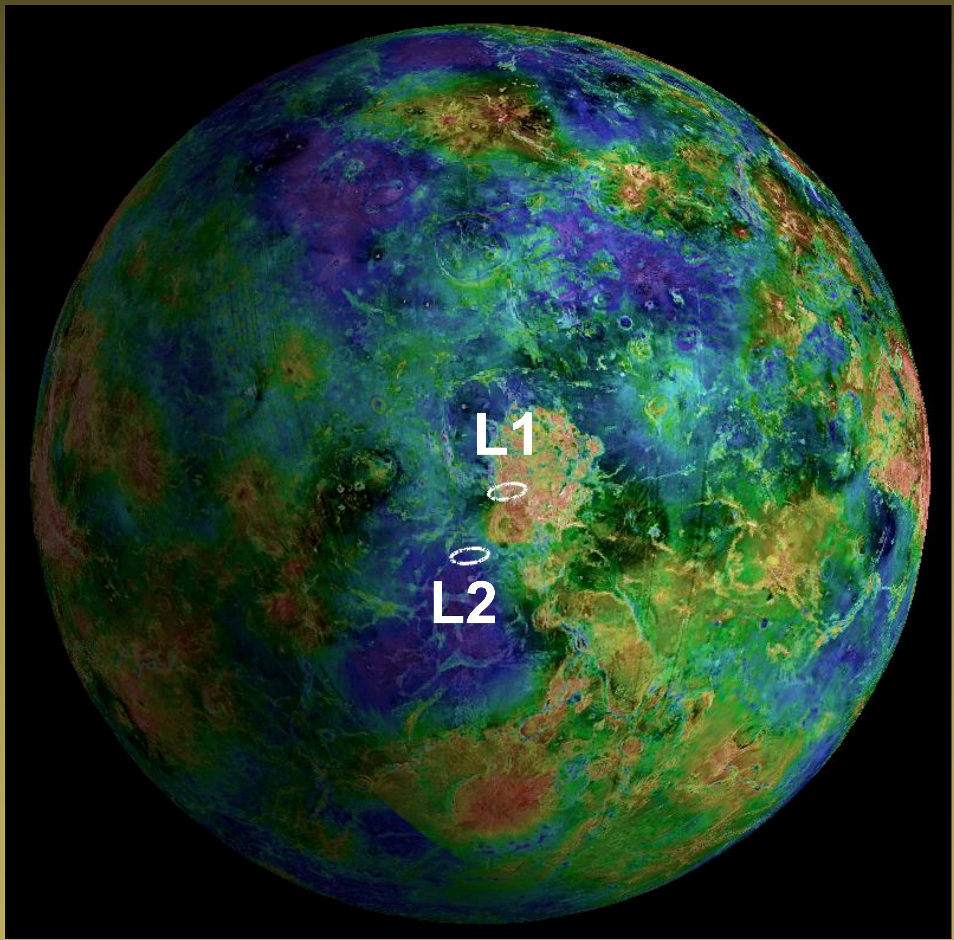
Science Traceability: Science Floor

B Determine the present surface conditions on Venus	B1. Determine the mineralogy of the surface of Venus.	B1a. Measure mineral composition on the surface, especially carbonates and basaltic minerals.	Raman/IR spectrometer
		B1b. Measure mineral composition below the weathered layer	Raman/IR spectrometer/Su
		B1c. Measure iron oxide (hematite, magnetite) abundances on surface.	Raman/IR spectrometer
	B2. Determine the oxidation state of the Venusian crust.	B2a. Determine oxidized species on surface .	Raman/IR spectrometer
		B2b. Direct measurement of CO concentration below 13 km	GCMS
	B3. Investigate surface for aeolian features and evidence of wind erosion.	B3a. High-resolution imaging of surface features.	Visible Imager
		B3b. Assess the size, shape and weathering of rocks near the landing site.	Visible Imager
		B3c. Identify regions of varying regolith properties.	Visible Imager
	B4. Assess relative surface ages.	B4a. Look for evidence of cratering.	Visible Imager
	B5. Characterize surface morphology	B5a. Image the surface of Venus on descent	Visible Imager
	B6. Assess surface strength	B6a. Measure hardness of rocks on the surface.	Surface Preparation Tool
C Characterize the lower Venusian atmosphere	C1. Determine the composition of the lower 22 km of the atmosphere.	C1a. Direct measurement of reduced (COS, H2S, S1-8) and oxidized (SO2) sulfur gases below 22 km.	GCMS
		C1b. Direct measurement of CO concentration below 13 km.	GCMS
		C1c. Direct measurement of H2O concentration below 22 km	GCMS
		C1d. Direct measurement of Hydrogen isotopes in the lower atmosphere.	GCMS
		C1e. Direct measurement of trace species (e.g. Chloride, Floru	GCMS
	C2. Determine noble gas abundances.	C2a. Measure noble gas abundances as a function of distance from the surface.	GCMS
	C3 Determine wind speeds, thermal and pressure profiles throughout the atmosphere.	C3a. Measure wind speeds upon descent from entrance to the surface.	Doppler tracking
		C3b. Measure temperatures through descent.	Thermometer
		C3c. Measure pressures through descent.	Barometer
		C3d. Measure density through descent.	Accelerometer

Instrumentation

Instruments	Mass	Power	Descoped
Visible Imager	1kg	4W	
Meteorological Package	2.4kg	5W	
Gas Chromatograph Mass Spectrometer (GCMS)	17.2kg	10W	
Thermal Infrared Imaging Spectrometer (TIRIS)	4.8kg	5W	
Raman/Laser-Induced Breakdown Spectrometer (LIBS)	12kg	15W	
Surface Preparation Tool	0.2Kg	4W	X
Lightning Detector (VLF and Photodiode) Probe & Carrier S/C	2kg	1W	X
Magnetometer on Carrier S/C	8.1kg	14W	X
Visible Imager on Carrier S/C	1kg	4W	X
Space Env. Monitor on Carrier S/C	19.5kg	10W	X

Landing Sites



L1: Alpha Regio

Lat/Lon: 0.5W, 28S

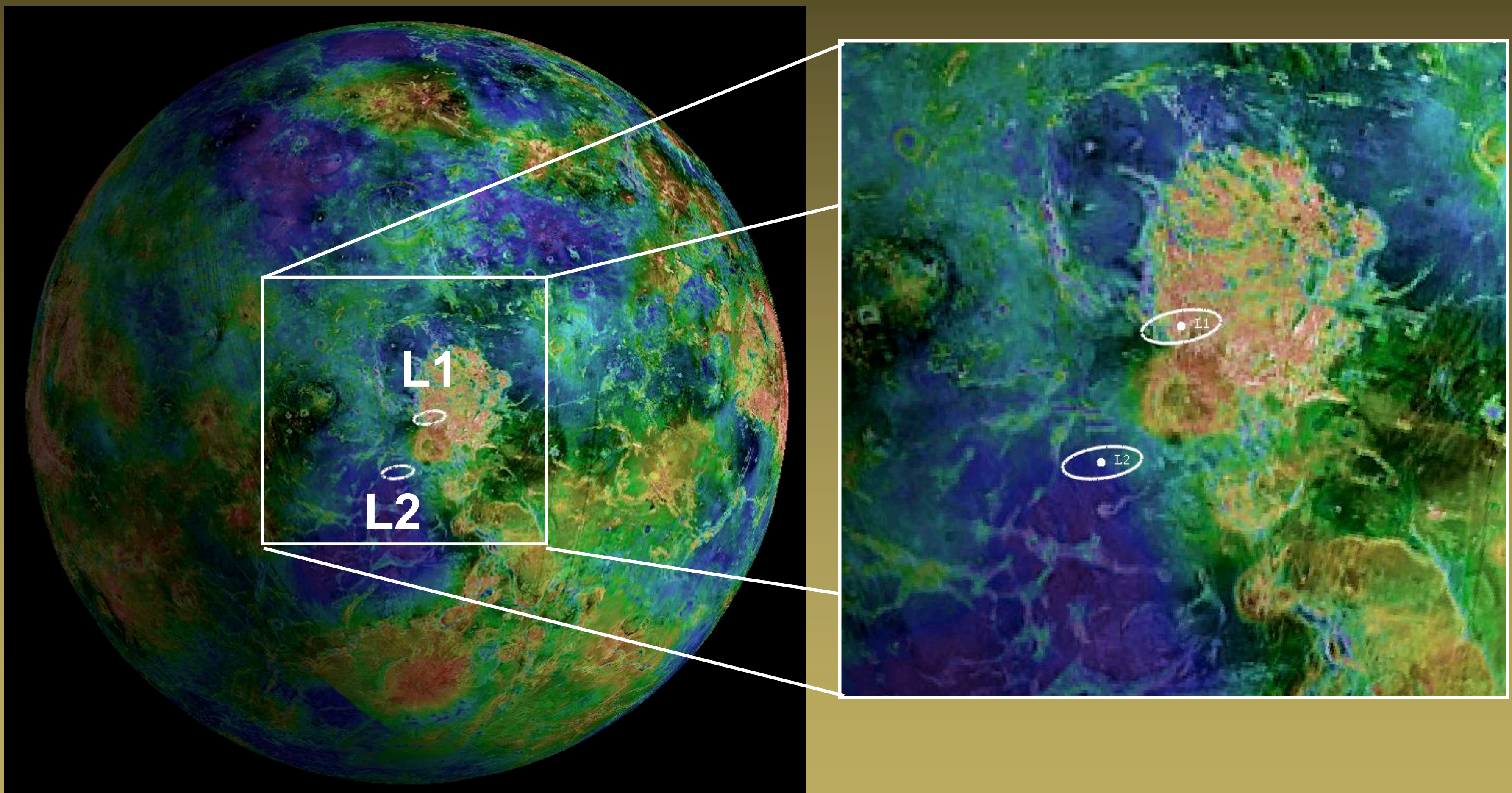
Elevation: ~ 2 km

L2: Lavinia Planitia

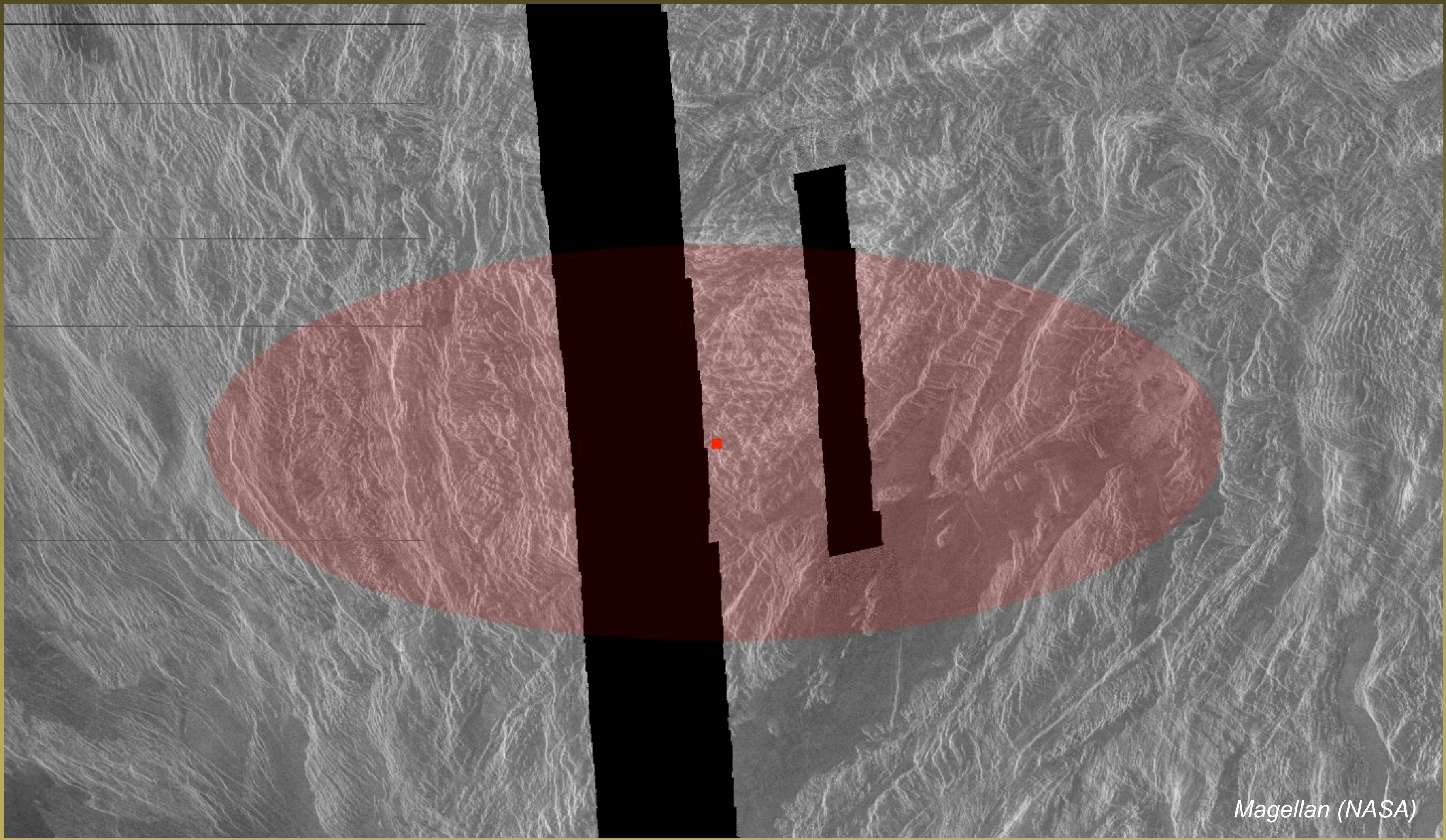
Lat/Lon: 5.5W, 35.5S

Elevation: ~ -0.5 km

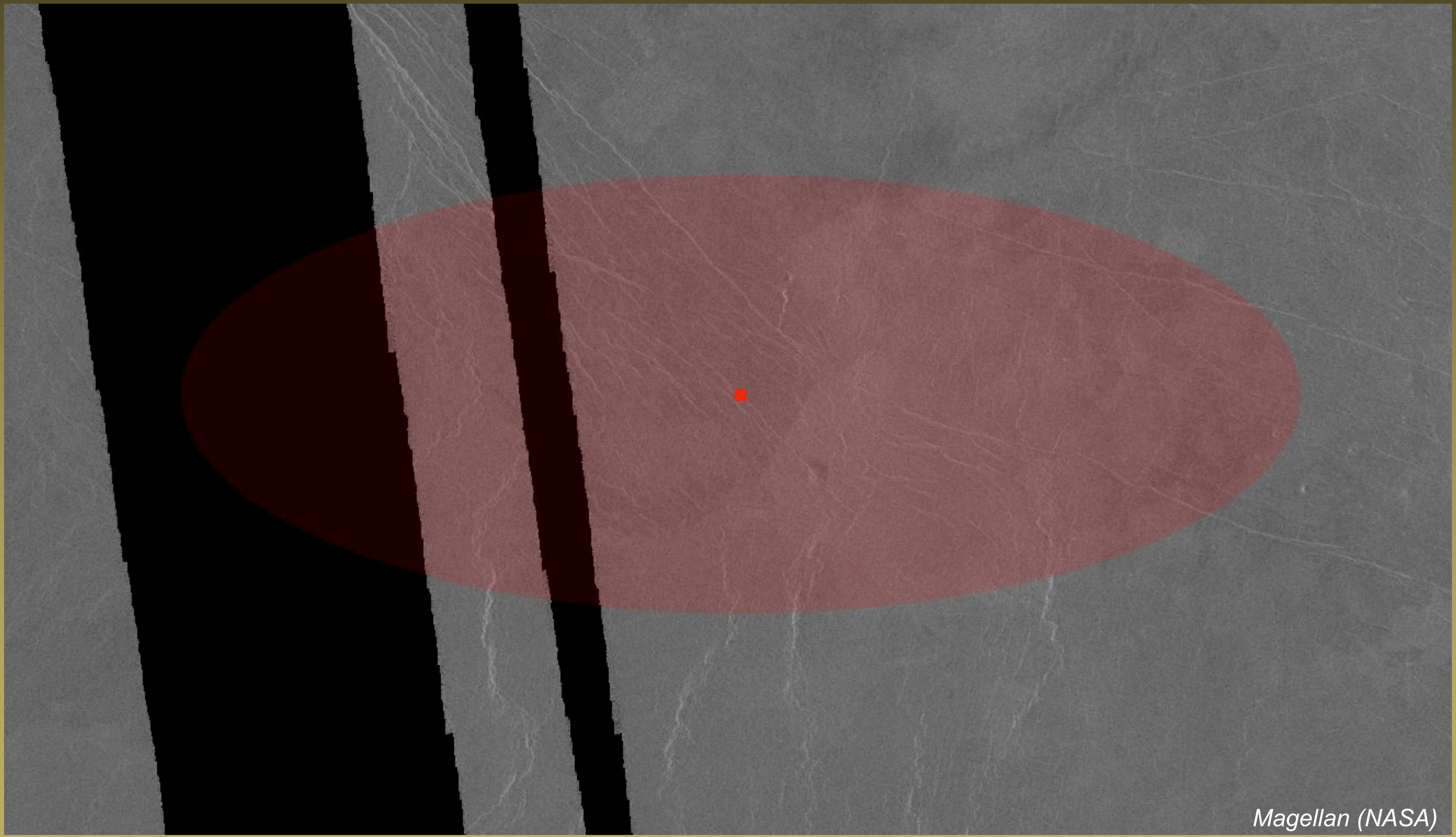
Landing Sites



Alpha Regio



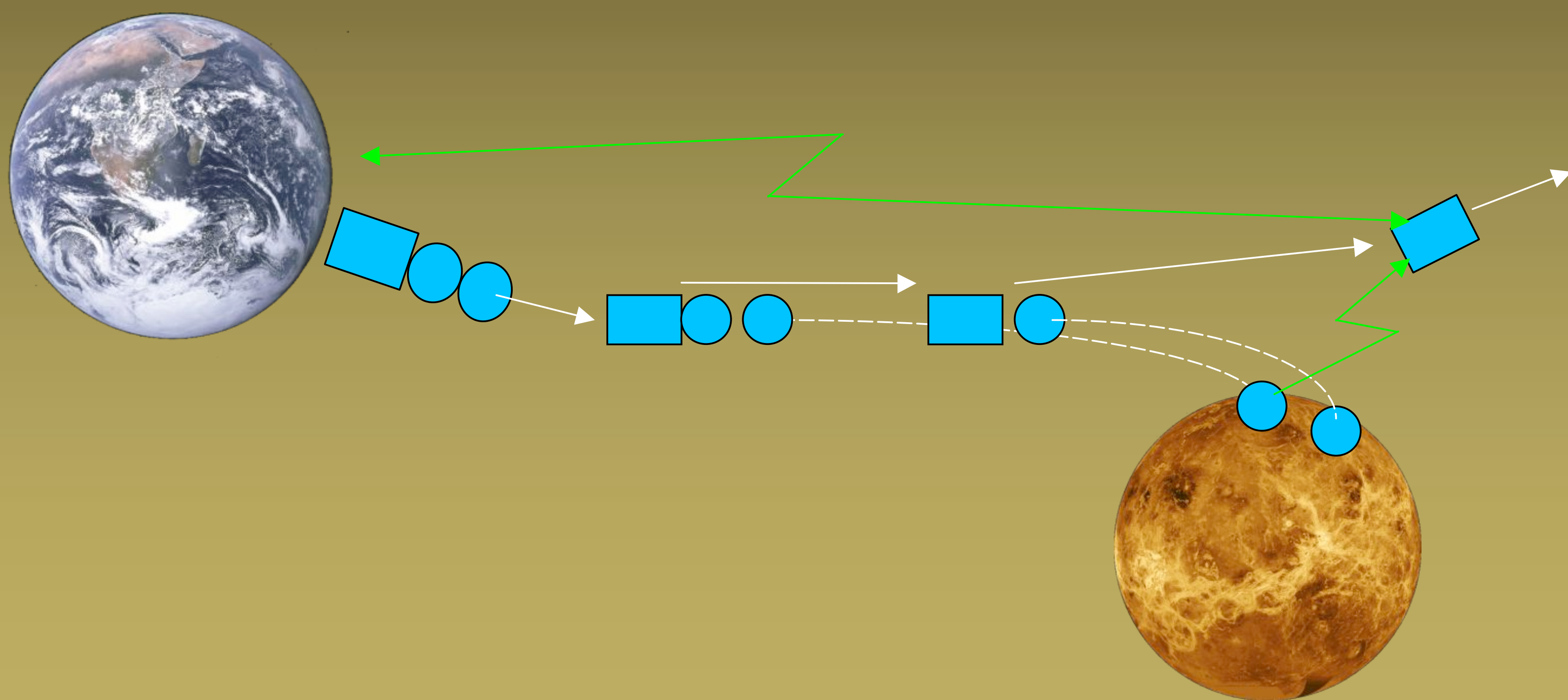
Lavinia Planitia



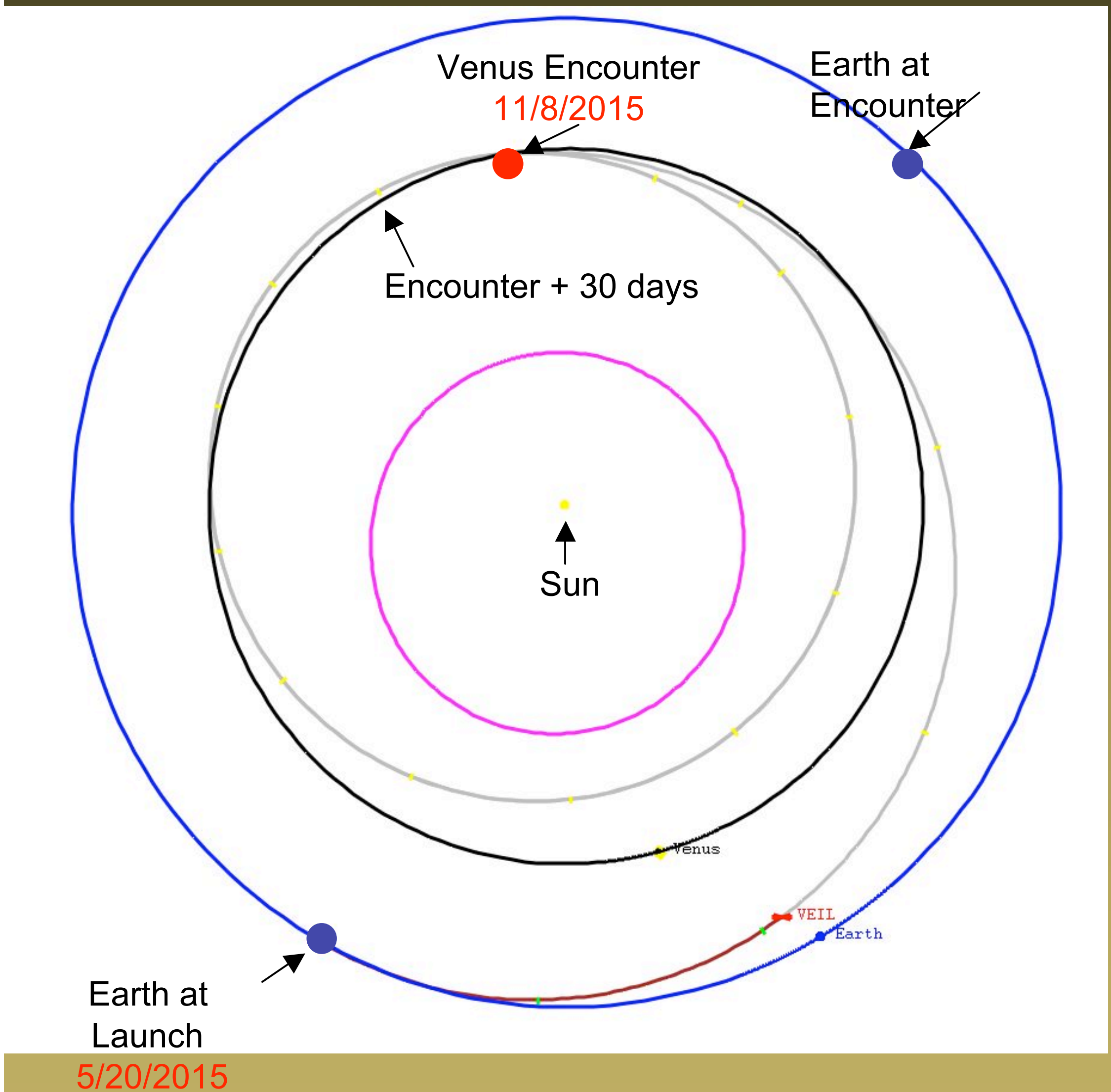
Data Acquisition Profile

Altitude	Instruments	Data
80 km	• MET package, Imager, and Doppler radio tracking	• 16 Mb
22 km	• GCMS,TIRIS, MET package, Imager, and Doppler radio tracking • Imaging rate at 5 images/sec between 80-1 km; 2 images/sec between 1 km and ground	• 183 Mb
Ground	• MET package (15 min.), Imager, TIRIS, and Raman/LIBS	• 100 Mb

MISSION DESIGN



Trajectory



30 day ticks

Launch Period					
H	Launch	Arrive	C3	DLA	EntVel
Open	5/10/2015	11/8/2015	8.89	-7.2	11.2
Mid	5/20/2015	11/8/2015	7.93	-9.2	11.1
Close	5/30/2015	11/8/2015	8.08	-11.6	11.0

7 month mission
172 day cruise

Launch Vehicle:
Atlas V (401)
2900 kg max payload

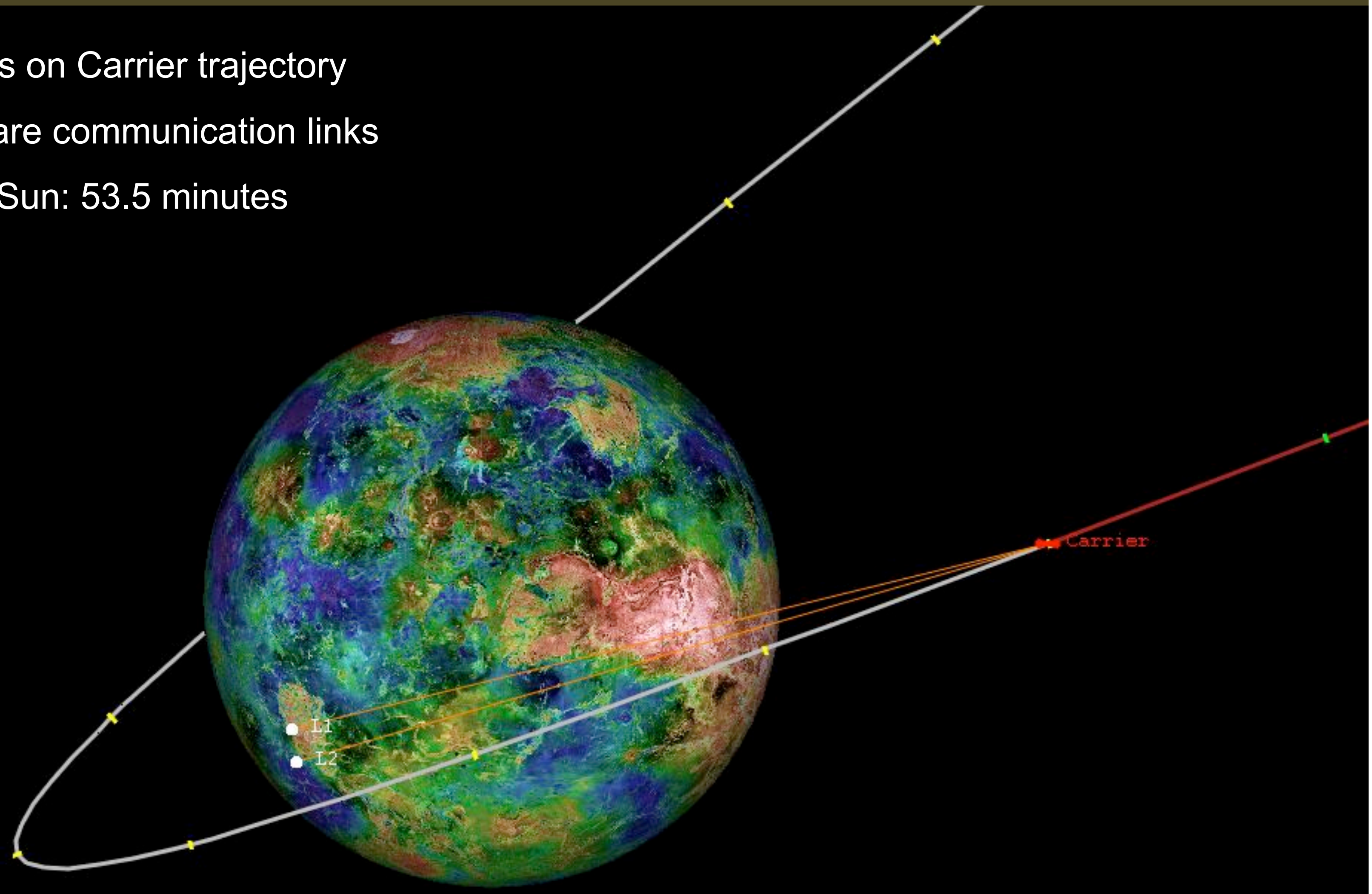
Delta-V Budget: 135 m/s
TCMs: 60 m/s
Lander 2 Retargeting: 5 m/s
Carrier Divert: 70 m/s

Sun to Venus View

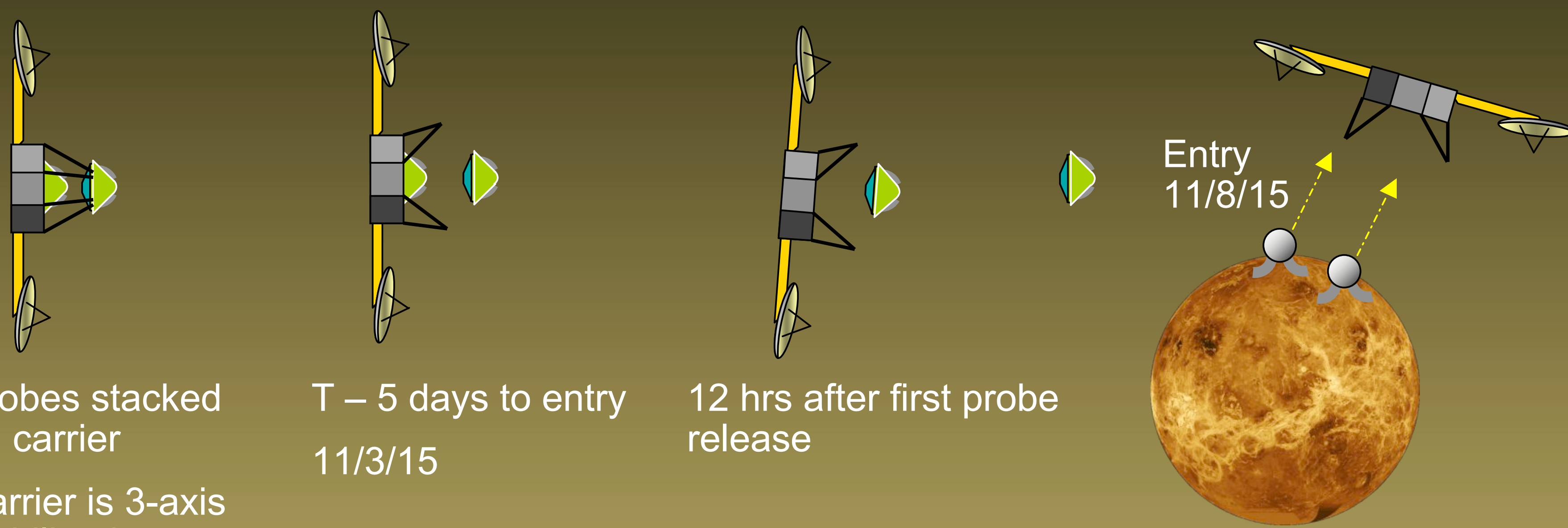
30 minute ticks on Carrier trajectory

Orange lines are communication links

Blocked from Sun: 53.5 minutes



Approaching Venus



Probes stacked on carrier

Carrier is 3-axis stabilized

T – 5 days to entry

11/3/15

-Spin S/C

-Release Probe

-Stabilize S/C

12 hrs after first probe release

-Pointing maneuver

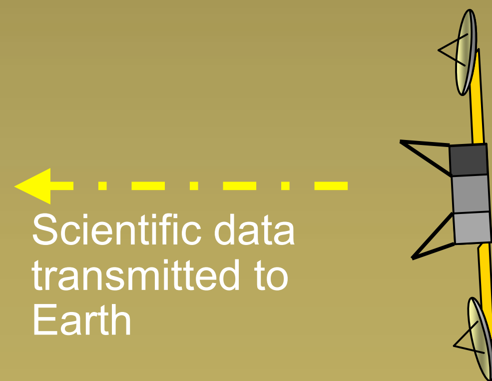
-Spin S/C

-Release Probe

-Stabilize

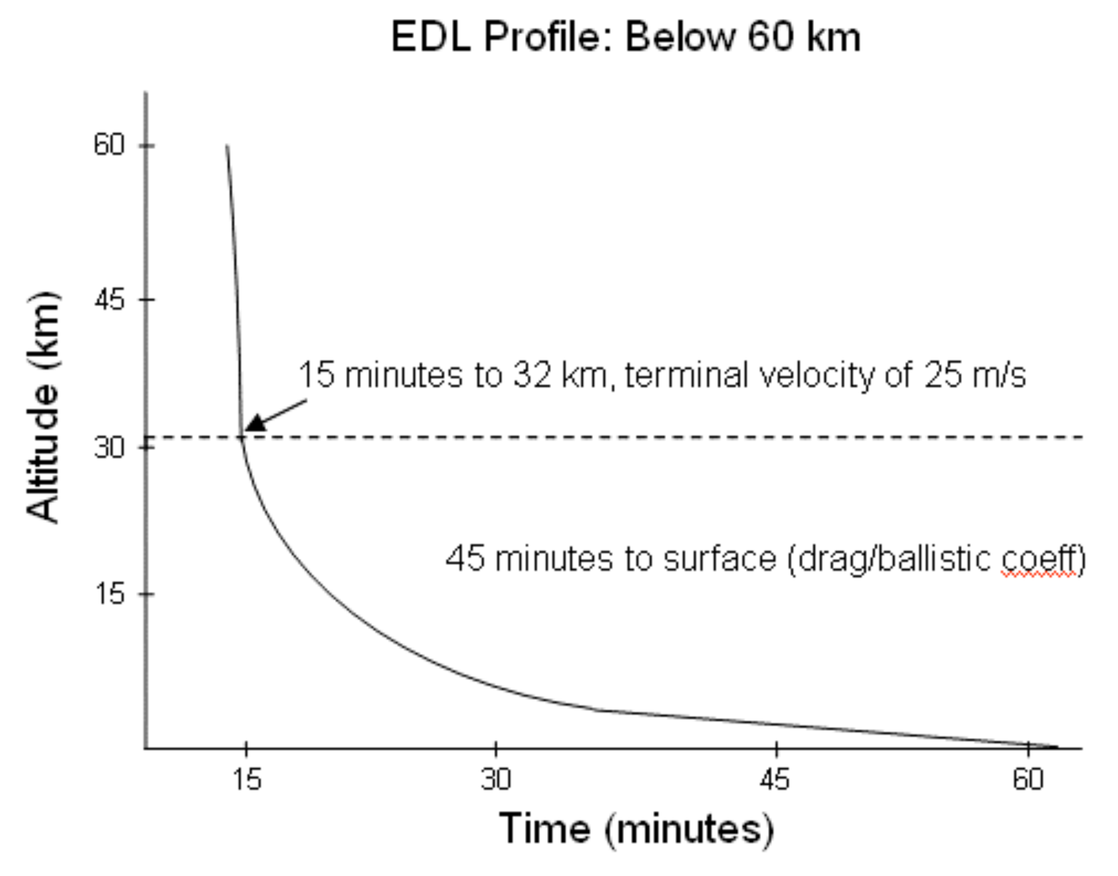
-Maneuver/ Point Antennas

-Listen for probe



Scientific data transmitted to Earth

Entry, Descent, and Landing



Assumes uniform atmospheric profile

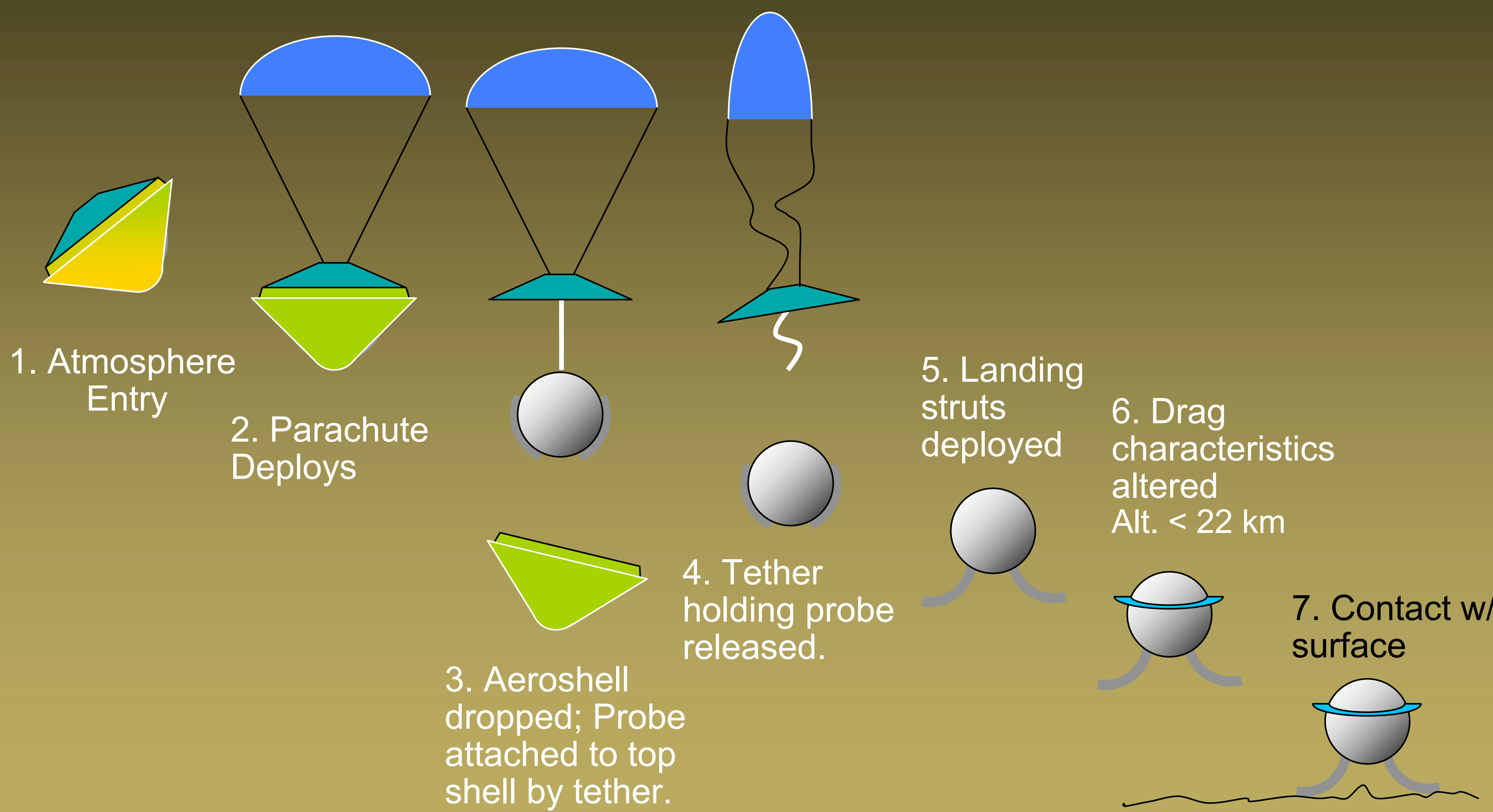
Descent to 32 km:
15 minutes
25 m/s terminal velocity

Descent to surface:
45 minutes

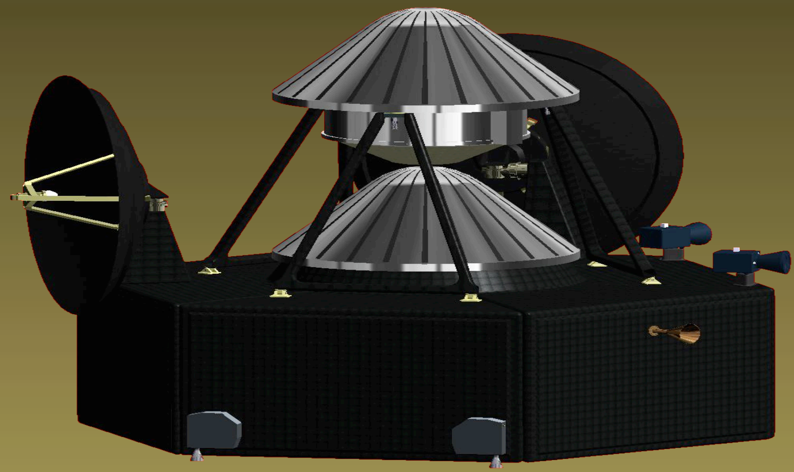
Velocity will need to be reduced to 11.85 m/s

Increase drag or reduce ballistic coefficient by a factor of 4.45

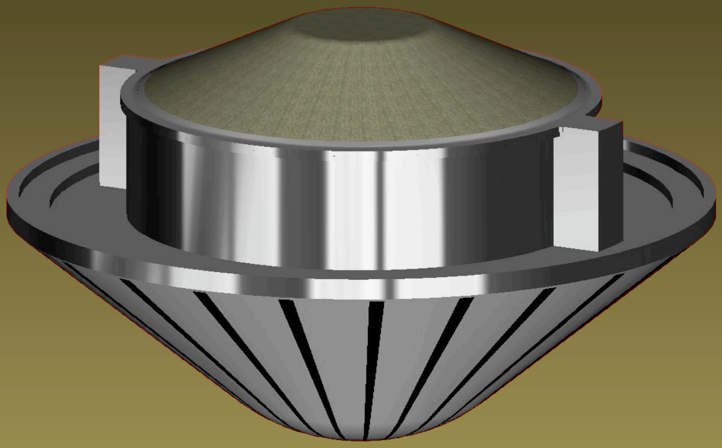
Probe Descent Profile



Major Architectural Components



Carrier Spacecraft w/ 2 probes mounted

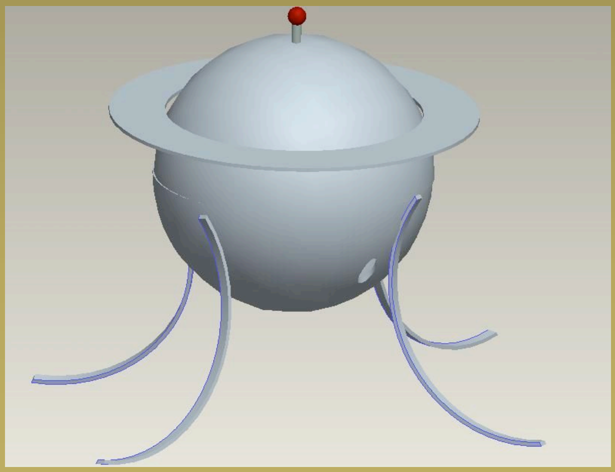


Thermal Protection System

-Two probes selected for cost effectiveness and redundancy

-Carrier S/C acts as communications relay

-TPS selection from heritage



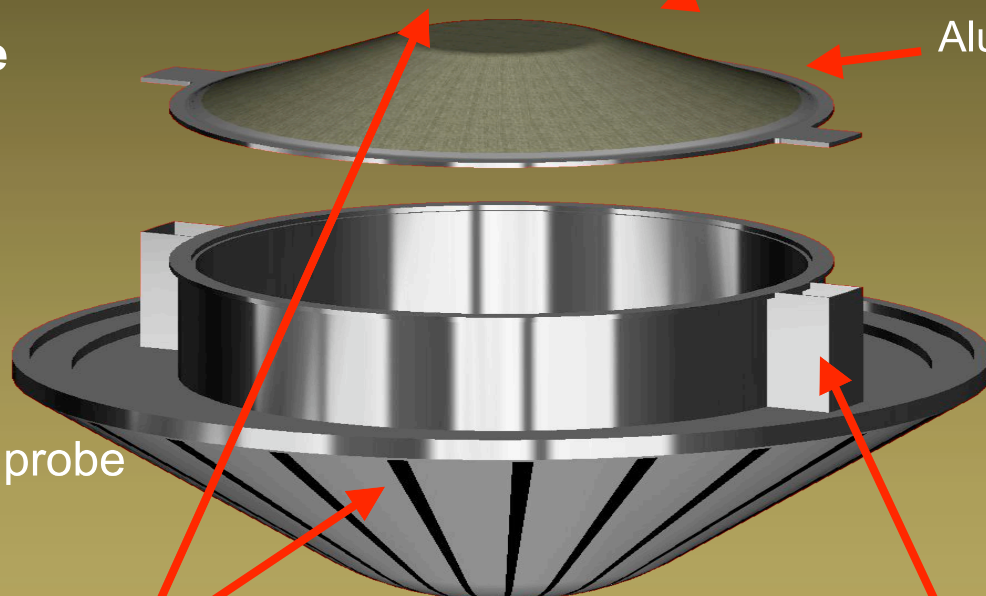
Probe Lander

VEIL Entry Vehicle

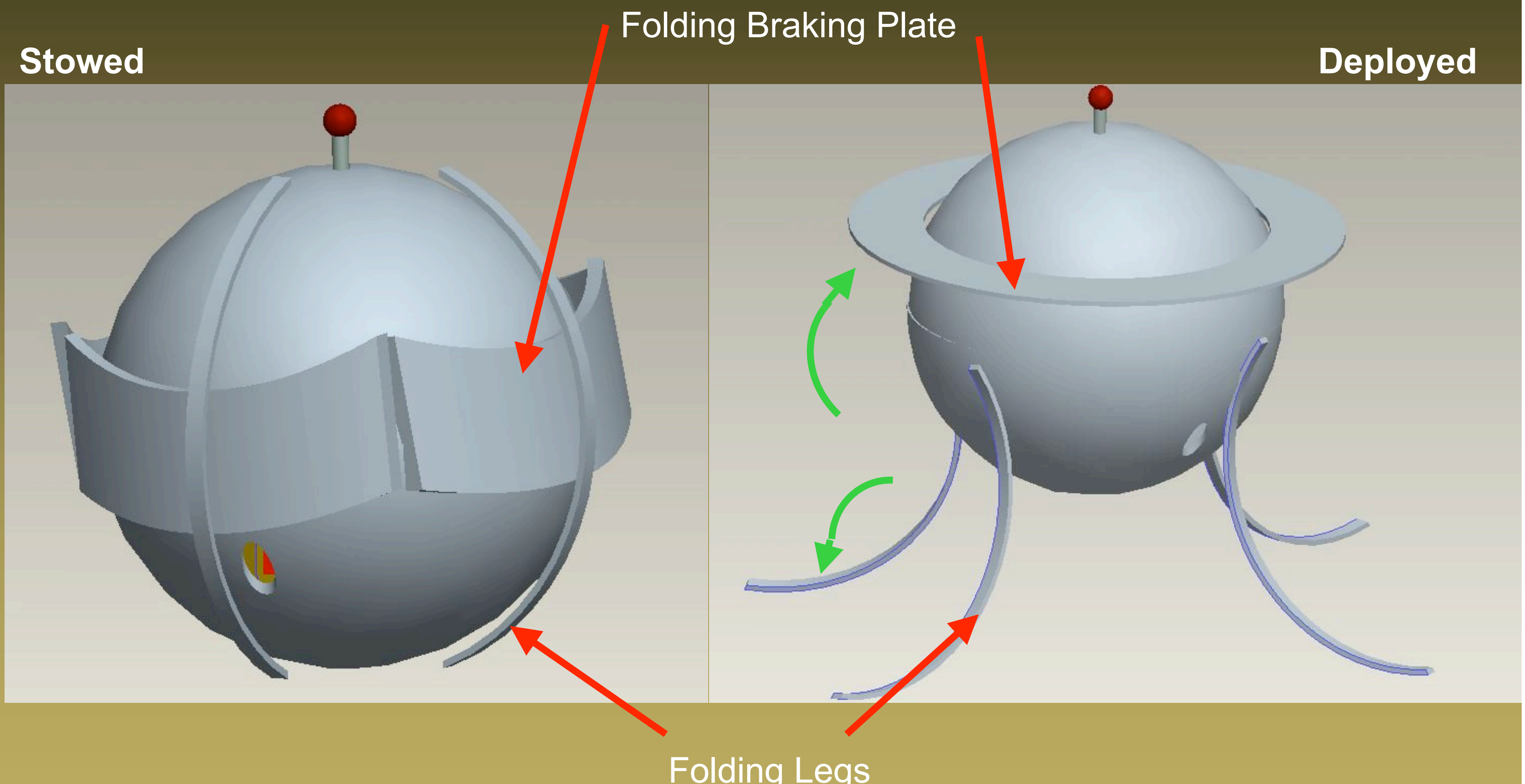
Pioneer/ Venus Heritage

Cost Constraints
No new developments
Flight qualified
Only minor modifications

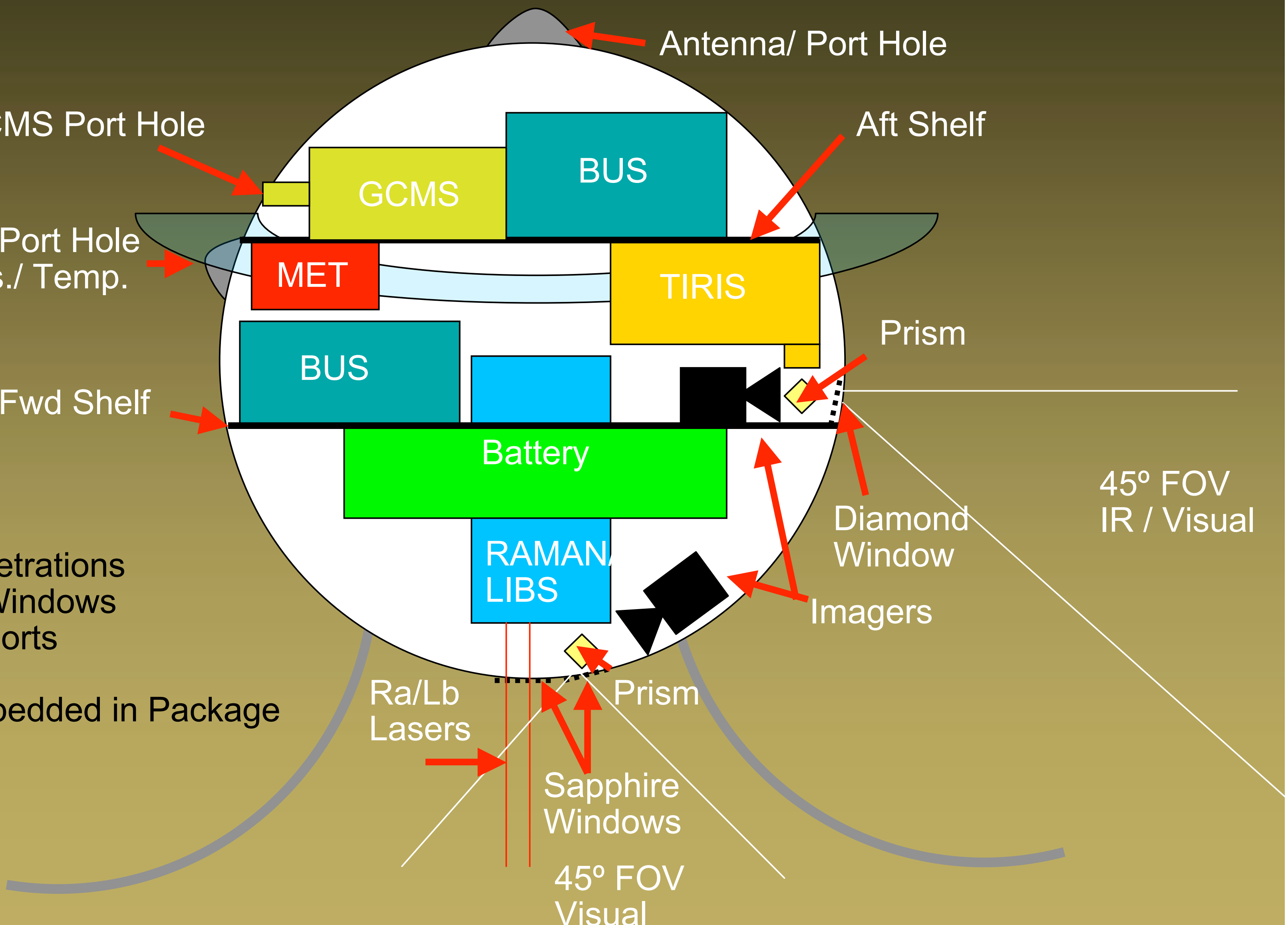
1.5m diameter entry shell
Houses 73.5cm diameter probe



Proposed Probe Design



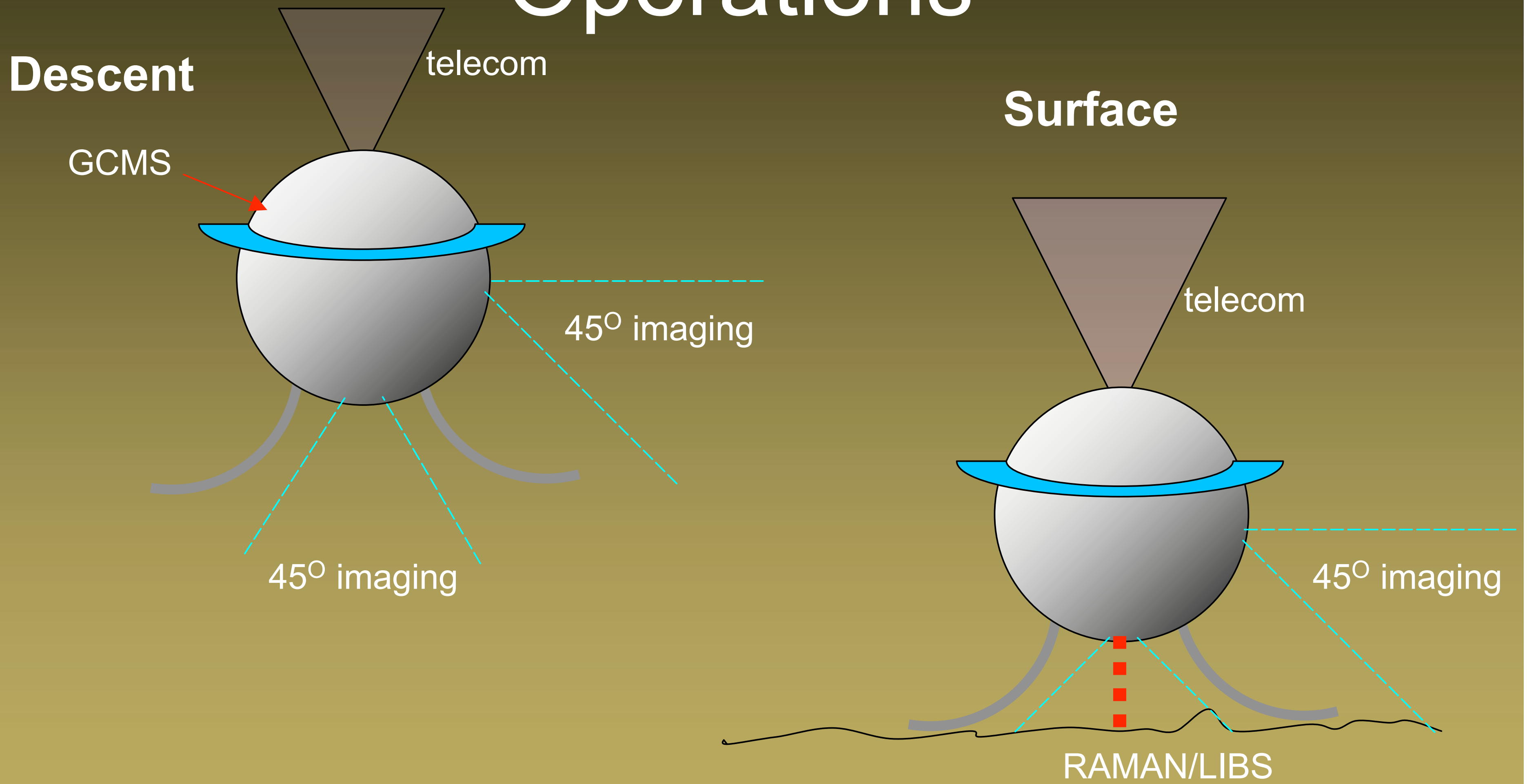
Descent Lander



- 6 Total Penetrations
  - 3 Windows
  - 3 Ports

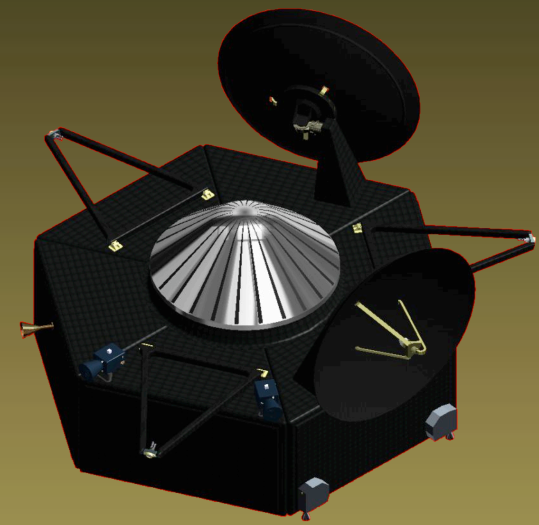
- Paraffin Embedded in Package

Atmosphere/Surface Operations

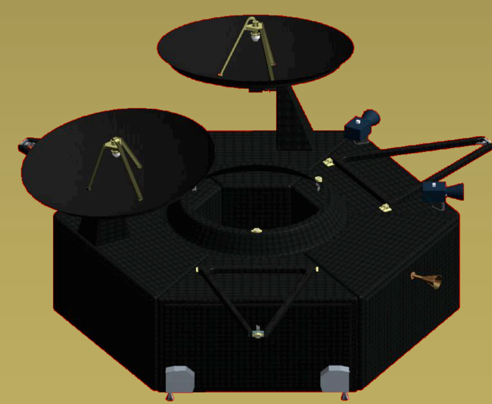


Carrier Spacecraft

Stowed



1st Probe Stowed



2nd Probe Deployed

Mass and Power

	Mass (kg)	Contingency %	Total Mass (kg)	Power (W)
1 Probe	187.7	27	240.7	209
Carrier	324.8	27	413.0	387

Total Cost

Item	Cost (M$, FY07)
Carrier & Misc. Total	578.07
Probe Total	197.76
TOTAL	775.83

Enhanced Configuration – SPT

- Mineralogical analysis of rock under the weathered exterior
  - Drill / Rock abrasion tool
  - Chisel
  - Ballistics
  - Diamond saw
  - Explosives
  - Articulated arm raises sample to camera
- Rocker chassis mechanism deploys tool to instrument workspace with little mechanical complexity

Mars Exploration Rover RAT surface preparation (NASA/JPL/Cornell)

Enhanced Configuration

- An alternative design for a higher cost cap
- Probes: $240.98M, 413.8kg
  - Surface Preparation Tool(SPT)
  - Lander lightning experiment
- Carrier: $538.08M, 369.6 kg
  - Magnetometer experiment
  - Space environment monitor
  - Imager
- Total: $906.06M
  - No change in launch vehicle or flight trajectory

Conclusions

- Venus presents challenging new scientific opportunities
- Surface and atmospheric science are feasible with New Frontiers budget
  - Architecture includes options that would increase science returns
  - Options for international collaboration
- VEIL type mission could pave the way for future exploration of Venus
  - Establishes “heritage” for landed Venus missions
  - Precursor mission to Flagship rover

Acknowledgements

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