VEP mission - Descent probes

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This document provides a first set of information concerning the payload definition of the descent probe(s) of the VEP mission. Section 1 lists all the possible experiments, section 2 provides the link between the payload and the main scientific objectives, while section 3 gives the various budgets.

Reminder: science objectives for the descent probes:

- Origin and evolution of the atmosphere
  - Noble gases isotopes
  - Non-noble gases isotopes

- Composition and chemistry
  - Abundance of trace gases not measured by VEX and VCO
  - Vertical profiles of trace gases
  - Trace gases below 20 km
- Clouds
  - Composition of cloud particles
  - Optical properties of the clouds

- Dynamics and radiative balance
  - Winds below and within the clouds
  - Eddy activity
  - Static stability
  - Radiative balance

- Plasma and wave processes
  - E/M activity and lightning

- Surface and interior
  - Composition and mineralogy
  - Surface morphology
  - Surface-atmosphere interaction

1) Possible payload

Table 1 lists all the possible experiments that could be mounted in a descent probe. Each row gives the name, the measurement requirements and the scientific justification. It is assumed that the probe(s) will have a very limited lifetime on the surface. Therefore, the payloads that require long and/or complex operations on the surface are excluded from this list (such as the heat flux sensor).

Instrument [Name]	**Measurement requirements**	**Science justification**
Attenuated Total Reflection Infrared Spectroscopy [ATR]	IR spectrum in the 2.5-25um range, spectral resolution about $5cm^{-1}$	Aerosol composition
Nephelemeter [NEP]	Intensity and polarization ratio phase functions at two wavelengths.	Characterization of cloud particles: size, shape, number density.
Ultraviolet spectroscopy experiment [ISAV]	UV light source absorbed by atmospheric constituents. Generation of spectra in the range 220-400 nm. Vertical resolution ~50 m.	Vertical profiles of SO2 and aerosols on the nightside.
Aerosol collector and pyroliser [ACP]	Collection of aerosols. Multi-step heating pyrolysis up to 600°C. Analysis of the products by the GC-MS.	Measurement of the chemical composition of the aerosols.
Gas chromatograph and mass spectrometer [GCMS]	Mass range: 10 to 250 amu ; Sensitivity: ppm-ppb. Measurements of isotope ratios. 2 GC columns: - Separation of nobles gases, N2, O2,CO, H2O, CO2 - Separation of the sulphurs and hydrocarbons.	Study of the composition of the atmosphere for the determination its the origin and evolution, the understanding of the chemical cycles, characterisation of the surface/atmosphere interaction.
Oxygen fugacity sensor [O2S]	Oxygen partial pressure	Study of the reduction and oxidation processes at work in the lower atmosphere.
Wave package [WAVE] : - PWA-type boom and sensors - Acoustic sensor - Radar altimeter	- Conductivity: 10^-14 to 10^-5 S/m - Electric field: From 50 µV/m to some V/m - Acoustic: Threshold: 10 mPa. Frequency Range: 0-6kHz. Resolution 50 Hz. - AC field: Threshold: 2 µV/m/Hz . Frequency range: 0-10 kHz. (VLF) 0-100 KHz (ELF) - Radar altimeter signal processing; measurement of surface permittivity and reflectivity.	- To study the electrical properties of the atmosphere. - Search for lightning. - To study the surface properties (surface topography, permittivity, roughness) - Reflectivity from haze, clouds, surface
Radio science [RS]: Ultra stable oscillator	Zonal wind profile: 0.1 to 500 m/s; accuracy < 1 m/s; altitude resolution < 100 m. Doppler fluctuations and signal level modulation. Surface roughness (bistatic experiment)	Study of: - Atmospheric circulation and turbulence. - Probe dynamics. - Surface properties.

Radioactivity sensor [RAD]	Alpha particle detection as a function of energy.	Detection of alpha emitting radionuclides, helping to understand the surface-atmosphere interaction.
X-ray spectrometer [X-Spec]	Spectral range: from ~1 keV to ~60 keV to detect fluorescent X-rays from 1.04 keV (Na Kα) to 59.5 keV emitted by 241Am. Detection limit: 10 ppm	geochemical analysis of rocks and soils on the surface of Venus.
Gamma-ray spectrometer [Gamma-Spec]	Detection of radioactive elements such as U, Th and K with a detection limit of ~1 ppm; Gamma rays up to 2 MeV with a detection efficiency at 2 MeV of 5%-10% and resolution levels of 1% at 600 keV	geochemical analysis of rocks and soils on the surface of Venus.
Atmospheric structure experiment [ASI]	- Temperature: 150-800K; accuracy: 0.1 K - Pressure: 0.0001-100 bars; resolution 10 μbar; accuracy: 0.1 % - Speed of sound. - Acceleration: 0-220 g (sampling rate 100 Hz) - Relative humidity: resolution 0.1%	To study the atmospheric properties during entry, descent and surface phases.

Imager/spectrometer [IM-SPEC]	- Imagers
	  - Day-time: 0.85/1.02 micron
	  - Night-time: 1.02 micron
	- Upward and downward visible and IR spectrometers
	- Photodiode with high-pass filtering
	- Solar aureole (operations above the cloud top, on the dayside)
		- Surface imaging, composition and mineralogy
		- Surface-atmosphere interaction
		- Study of the radiative balance.
		- Search for lightning.
		- Properties of clouds, haze and aerosols.

Instrumented heat shield [SHIELD]: - Recession gauges - Shock layer radiometer - Temperature sensors - Pressure sensors	- Mass ablation measurements - optical flux (range TBD) measurements - Temperatures - Pressure	- Engineering assessment of the entry phase. - Support to the reconstruction of the trajectory. - Information on the atmosphere
MEMS based chemical sensor array [CHEM]	Composition (ppm level) of carbon monoxide, sulfur dioxide, hydrocarbons, nitrogen oxides, and oxygen	Study of the composition of the atmosphere

Table 1: List of the possible payload

2) Link with the science requirements

The science requirements have been identified in a previous meeting, and the one relevant to the descent probes are listed in the first column. The first row lists the experiments from Table 1 (except the heat shield). The cross indicates that an experiment will address the scientific objective.

	ATR	NEP	ISAV	ACP	GCMS	02S	WAVE	RS	RAD	X-spec	G-spec	ASI	IM-SPEC	CHEM
Noble gases isotopes					x									
Non-noble gases isotopes					x									
Abundance of trace gases not measured by VEX and VCO					x	x								
Vertical profiles of traces gases			x		x	x								x
Trace gases below 20 km			x		x	x								x
Composition of cloud particles	x	x	x	x	x								x	
Optical properties of clouds	x	x	x										x	
Winds below and within the clouds								x					x	
Eddy activity												x		
Static stability												x		
Radiative balance												x	x	
E/M activity and lightning							x						x	
Surface composition and mineralogy							x		x	x	x		x	
Surface morphology													x	
Surface-atmosphere interaction					x				x			x	x	

Table 2: links to the science requirements for a descent probe. The instrument heat shield is not included here, because: (1) it will specifically address the science objectives as defined in the table; (2) it will give additional information on the upper atmosphere and on the entry phase, which are not the core scientific objectives.

The main conclusion of this table is that all scientific objectives of the descent probe(s) are addressed. Several experiments address the same objectives, sometimes in a redundant way (like the ATR and the NEP for the optical properties of the cloud), sometimes in a complementary way (like the IM-SPEC and WAVE for the detection of lightning).

3) Budgets

Table 3 summarizes the mass, power and data rate budgets for each experiment. Many numbers needs to be checked and updated. Table 4 gives an estimation for these three parameters.

Instrument	**Mass [g]**	**Power [W]**	**Data rate [kbits/s]**	**Comments**
ATR	2000	10	?	Descent phase
NEP	600	2	0.2	Descent phase
ISAV	?	?	?	Descent phase
ACP	750	20	0.1	Descent phase
GC-MS	2300	30	1000	Descent and surface phases
O2S	2	0.2 (+2)	0.001	Descent and surface phases
WAVE, without the radar	500	0.1	0.2	Descent and surface phases
RS	1900	10	0.01	Descent and surface phases
RAD	300	1-2	?	Descent and surface phases
X-SPEC	200	3	?	Surface phase
Gamma-SPEC	200	3	?	Surface phase
ASI	500	<3 ?	1	Entry, descent and surface phases
IM-SPEC	<6000	~10	5	Descent and surface phases
SHIELD	1000?	?	?	Entry phase. Mainly engineering.
CHEM	?	?	?	Descent and surface phases

Table 3: Budgets

Instruments	Total mass [kg]	Total power [W]	Total data rate [kbits/s]
15	>16	> 85	> 7.5

Table 4: budget summary (if we consider all experiments).

Table 5 gives what could be a possible typical payload, which address all the science objectives.

#	**Payload**
1	Cloud experiment (NEP, ATR etc…)
2	GCMS and other chemical sensors
3	Imager and spectrometer
4	Atmospheric structure instrument
5	Wave package
6	Radio science

Table 5

4) Next steps

The possible experiments listed in this document address all the scientific requirements that have been identified in the previous meeting.

The definition of the descent probe payload is not completed. The next steps identified so far are:

(1) To form a working group to update this study. We anticipate the following persons: O. Witasse, E. Chassefière, J. Leitner, P. Rosenblatt, B. Bezard, F. Ferri, Pepe, …
(2) To review the performances of the redundant payload, especially for the study of the clouds.
(3) To review the performance of the payload at the surface, taking into account the limited lifetime (X-Spec, RAD, gamma-spec, IM-spec)
(4) To investigate the link: orbiter and/or Earth,
(5) To propose a payload that may be different on the nightside and dayside probes.
(6) To update the mass, power budget and data rate for each of the payload. The masses are expected to be underestimated.
(7) To study various probe configurations (see the following table)
(8) To estimate the costs?

Entry Probe (kg)	115	150	180	210
Descent Probe (kg)	70	90	110	130
Payload (kg)	5	10	20	30

Table 5: Probe configurations. These numbers are given for a probe with <u>no</u> lifetime at the surface.