European Venus Explorer

An in-situ Venus explorer proposed in Dec 2010 as a Cosmic Vision M3 mission, for launch in 2020 – 2025

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CNES & Astrium teams

International Planetary Probe Workshop , Toulouse - June 2012

Why Venus?

- **Venus should be the most Earthlike planet we know.**
  - ***Created at roughly the same time***
  - ***Apparently similar bulk composition***
  - ***Almost the same size & density***
  - ***Similar solar energy input***
    - ***(due to high reflectivity of Venus clouds).***

- **Early Venus was probably much like early Earth**

  Hot dense atmosphere rich in CO_2 and water

- **Venus also illustrates the probable fate of the Earth.**

  In ~ 1 billion years, with a brighter sun, the insolation at Earth will be similar to that at Venus today.

  Will we be able to avoid the runaway greenhouse warming that is found at Venus?

Need to understand the 'life story' of terrestrial planets

Why Venus?

- **Venus provides the key to understanding terrestrial planets and exo-planets.**

Venus allows study of the factors determining planetary habitaility:

Radiative balance *(greenhouse warming, role of clouds)*

Dynamics *(role of super-rotation and equator-pole circulations in re-distributing heat)*

Evolution of atmospheric composition *(surface-atmosphere and atmosphere-space exchanges)*

Role of magnetic field and solar wind interaction *in governing escape rates.*

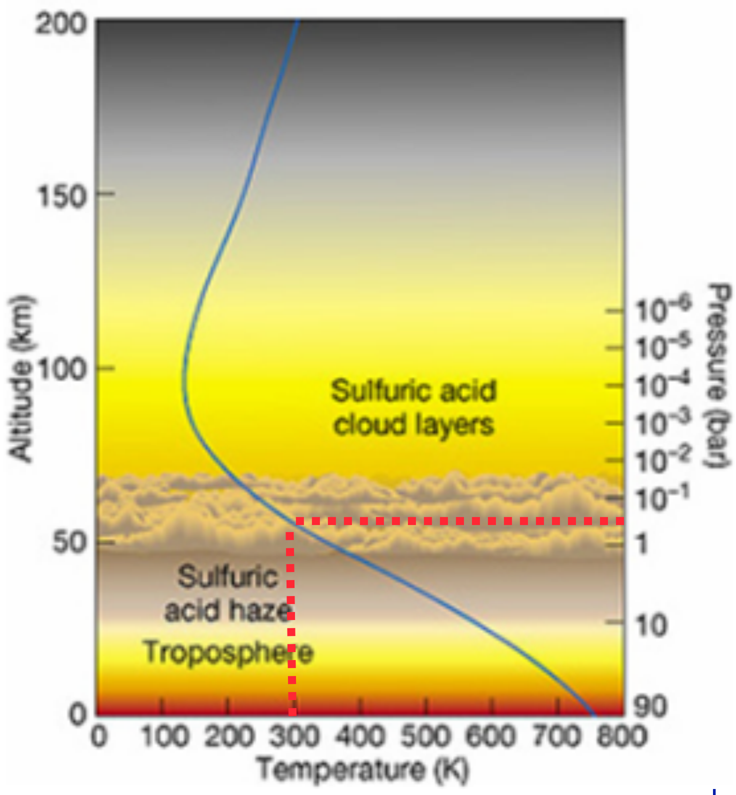
Which is the most common outcome for terrestrial planets: Venus-like, Earth-like, or Mars-like?

Need to understand the 'life story' of terrestrial planets

Why Venus?

Venus is accessible!

- **Short cruise time (5-6 months)**
- **Abundant solar power**
- **Not too far from Earth (<~1 A.U. distance), good data rate.**
- **Low-cost single-element missions (<€500m).**
- **Well-suited for multi-agency co-operative campaign**
  - **Balloon mission**
  - **Next-generation radar / data relay orbiter**
- **Extensive heritage**
- **Benign cloud-level environment (~20 deg C)**
- **Great test-bed for in situ payloads**
  - **Re-fly at Titan, Saturn, Uranus, Mars ...**



A balloon mission in the heart of the habitable layer

- **Helium superpressure balloon, 53-57 km float altitude.**
- **Benefit from benign climate: 10 – 50 °C, atmospheric densities like those found at 0 to 5 km altitude on Earth.**
- **Explore clouds of liquid water (albeit mixed with sulphuric acid).**
- **Use high winds of 200-250 km/h to circumnavigate the planet in 5-8 days.**

T. Balint

EVE 2010 vs. EVE 2007

- **2007 EVE was for a large multinational mission.**
  - Orbiter + Balloon + Lander
  - Russia was to provide launcher, lander, and EDLS components
  - optimistic mass & budget estimates

- **2010 EVE proposal was for an ESA-only balloon mission**
  - A more tightly focussed mission, achievable without non-ESA partners
  - A balloon element only
    - Cruise vehicle provides data relay during flyby
    - Thereafter, balloon communicates Direct-to-Earth
  - More robust treatment of mass, power, and cost.

CNES funded a detailed phase 0 mission study in 2009-2010.

- Astrium (Toulouse) was subcontracted for aspects of mission design, including entry system and carrier spacecraft.

EVE – Measurement goals

- **Exploring the cloud-level environment**
  - **Chemistry**
  - **Microphysical properties**
  - **Dynamics**
  - **Radiative Balance**
  - **Electric properties**

- **Evolution of Venus & its climate**
  - **abundances of noble gases (Ar, Kr, Xe, …) and isotopic ratios of light elements (O,C, N …)**

EVE – 15 kg science payload

- **Exploring the cloud-level environment**
  - –**Chemistry** — **GC/MS with Aerosol inlet; Tunable laser Spec., XRF**
  - –**Microphysical properties** — **Nephelometer**
  - –**Dynamics** — **p, T, tracking of balloon (winds)**
  - –**Radiative Balance** — **6-ch radiometer (↑ and ↓, λ = 0.25 – 25 µm)**
  - –**Electric properties** — **Permittivity, conductivity, electric charge of aerosol, lightning**

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Dedicated mass spectrometer with getters, cryotraps

Tunable diode laser to resolve ambiguities (e.g. CO vs N_2)

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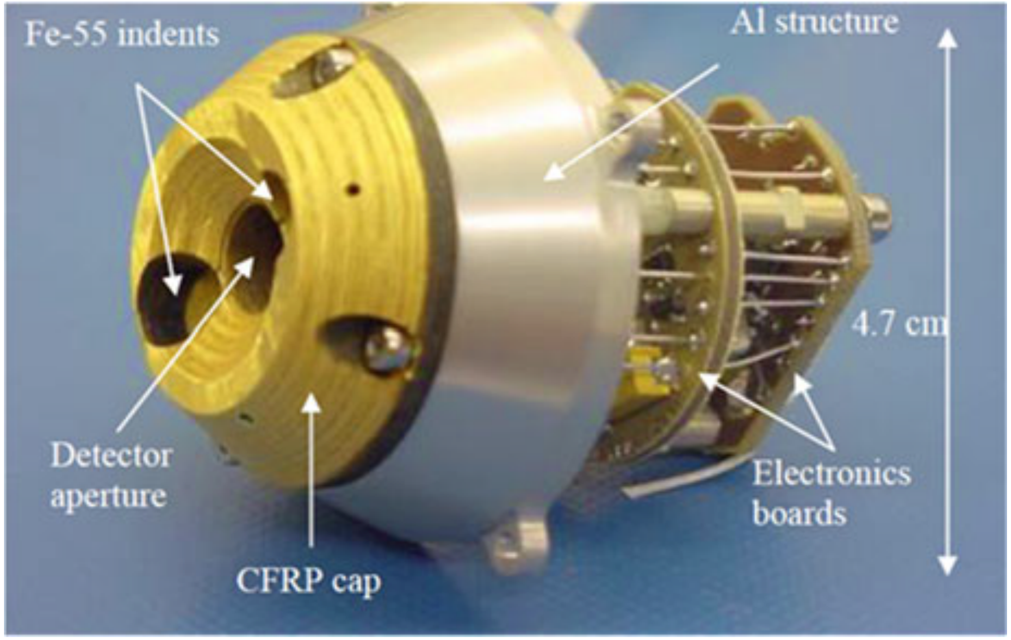
EVE – 15 kg science payload

- **X-ray Fluorescence Spectrometer**
  - **Current cloud models have only H2SO4 : H2O.**
  - **Venera descent probes had XRF which detected S, P, Fe, and Cl in cloud particles.**
  - **These measurements need to be repeated!**



Open University – Beagle 2 XRF

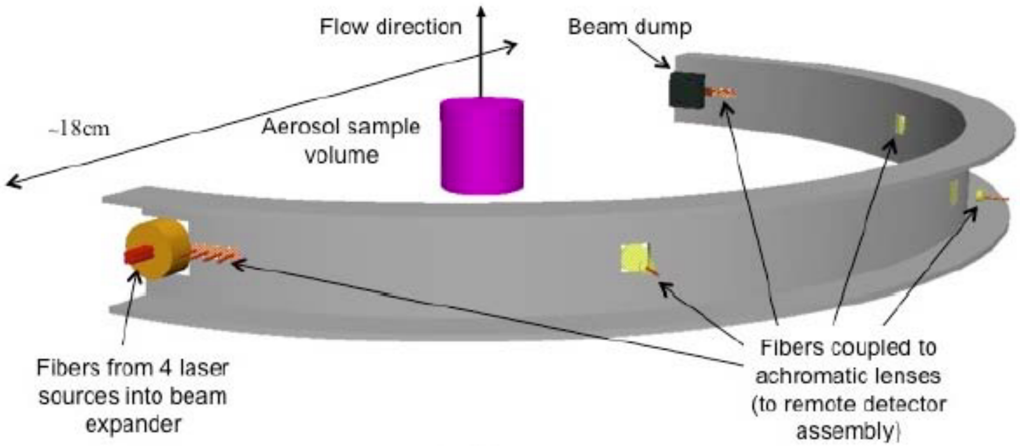
EVE – 15 kg science payload

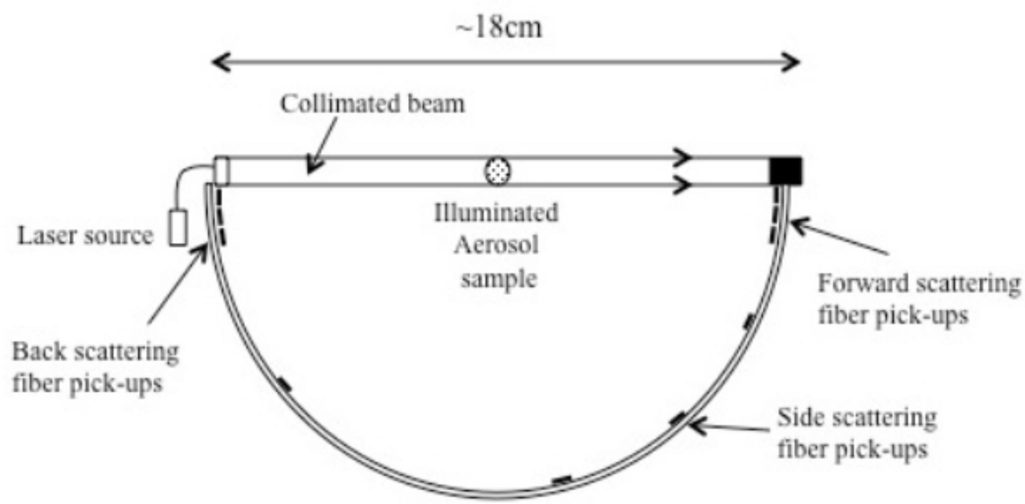
- **Polarising nephelometer**
  - **Measures scattered light intensity and polarisation as function of scattering angle.**
  - **Determine refractive index (constraint on composition)**
  - **Liquid / crystalline / amorphous particles**
  - **Determine size distribution**

Characterize cloud microphysics;

Search for ‘mode 3’ large particles;

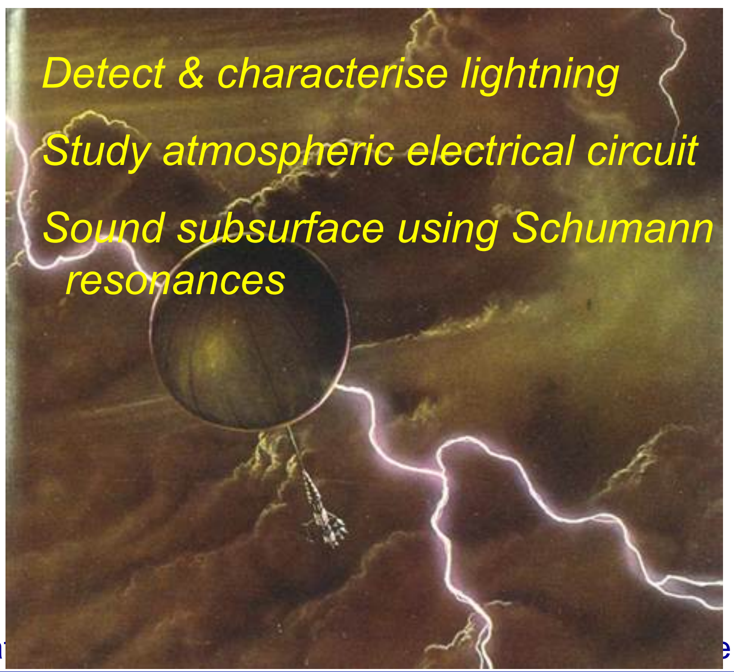
Clues to unknown UV absorber





EVE – 15kg science payload

- **Electromagnetic wave analyser and permittivity sensor.**
  - **Measure horizontal and vertical electric field (AC and DC)**
  - **Measure perpendicular horizontal magnetic field**
  - **also, optical and acoustic lightning sensors**



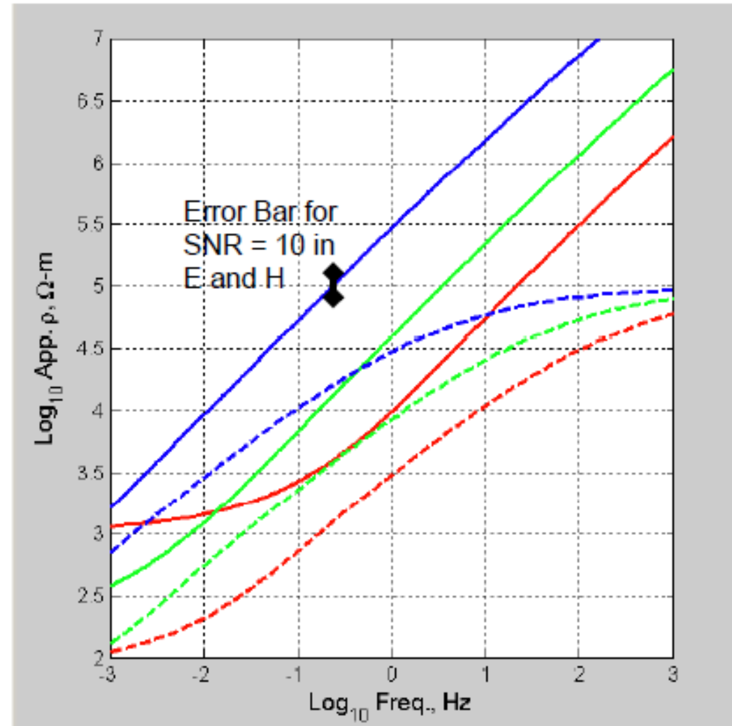
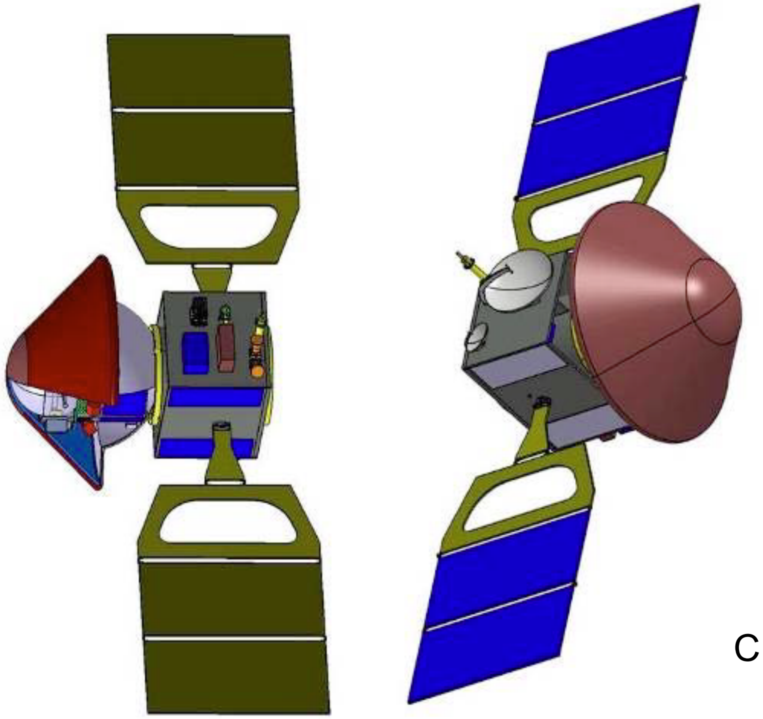


Figure 1. Forward modeling of MT signatures of different thermal structures and mantle compositions of Venus. Red: Incipient melting, L = 30 km, ΔT = 750 K. Blue: Mobile lid, L = 100 km, ΔT = 1000 K. Green: Stagnant lid, L = 500 km, ΔT = 1300 K. Solid: Dry olivine. Dash: Olivine with 1 ppm H_2O. Note separation of L curves >> error bar and different frequency slope of water-bearing mantle. *Grimm et al., LPI 2009*

Mission profile

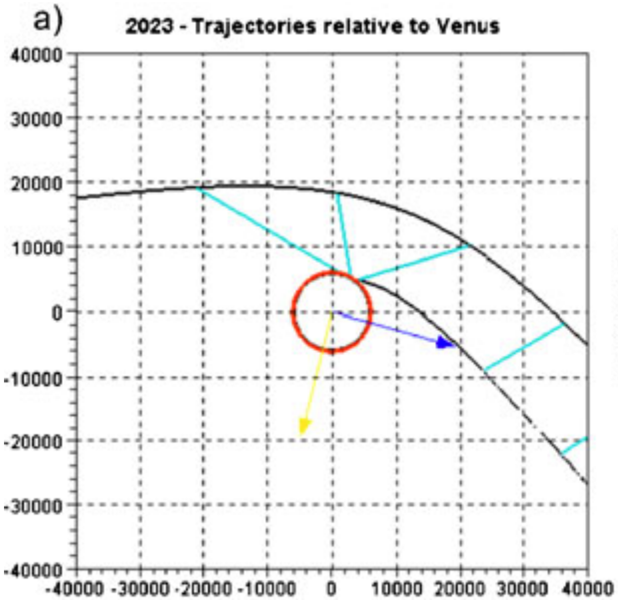
- **Soyuz-Fregat 21-1b aunch from Kourou, in 2021 or 2023.**
- **Six months for Earth-Venus transfer.**
- **Entry Probe (EP) released from carrier a few days before arrival.**
- **Flyby craft used as data relay during first 2 hours of mission**

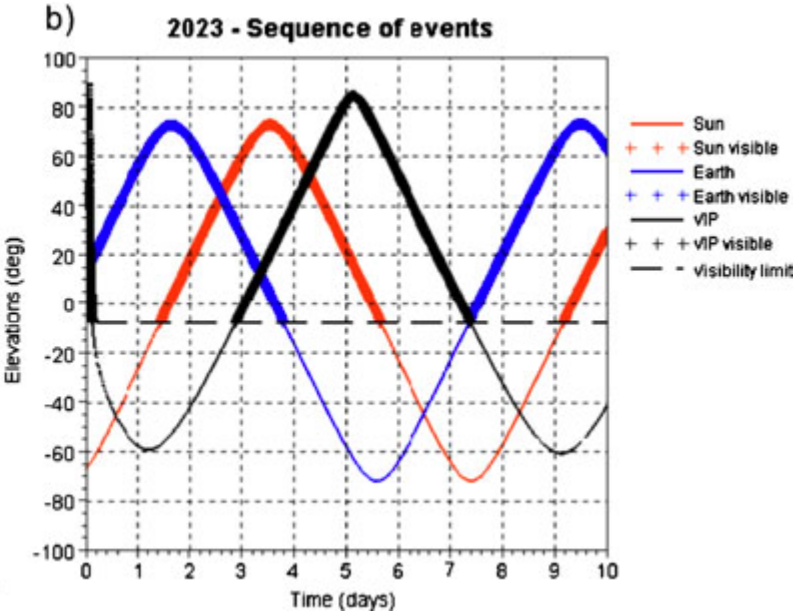


CNES / Astrium

Mission profile

- **Entry point is visible from Earth and is on nightside.**
- **First 3-4 days of mission are on visible face of Venus**
  - **First 2 hours: downlink via flyby craft**
  - **Then, direct-to-Earth communications**
- **Next 3-4 days are on far side, not visible from Earth**
  - **no data downlink via carrier, but carrier-probe link used for Doppler tracking.**

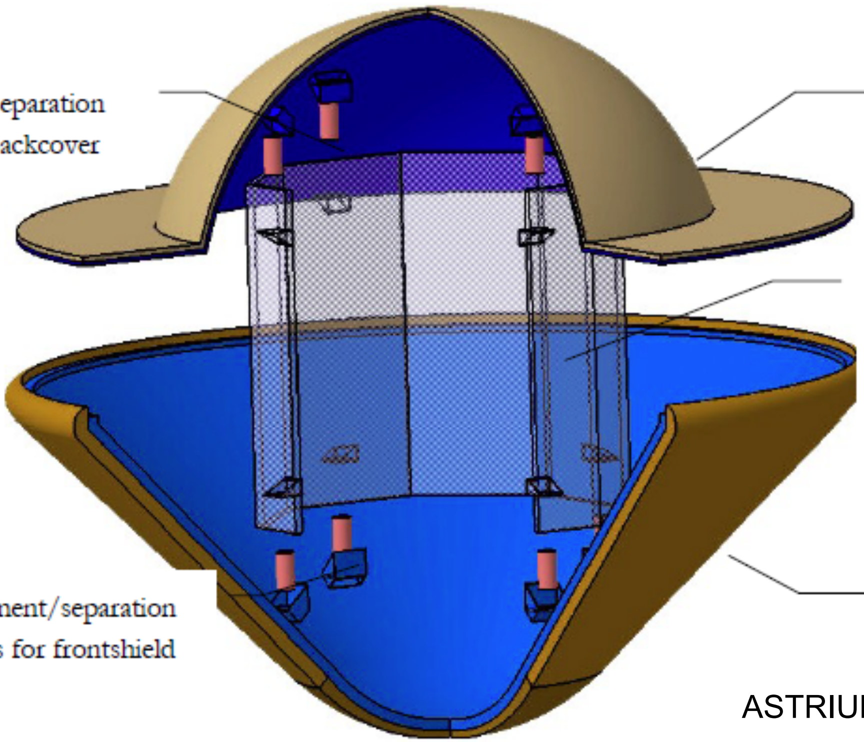




(Left) Trajectories of entry probe and flyby vehicle; pale blue lines show probe-carrier line ofsight; and (right) visibility of Sun, Earth, and flyby vehicle from balloon.

Entry System

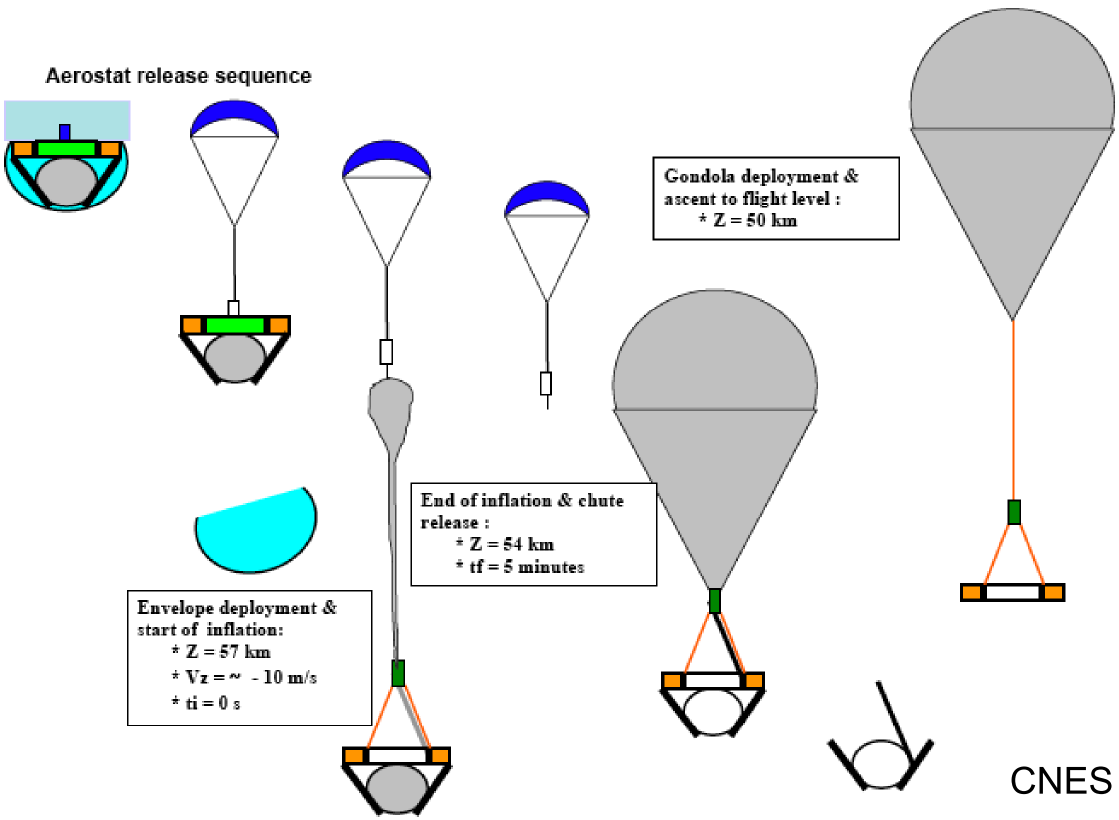
- **Total entry mass is 665 kg.**
- **Pioneer-Venus like external shape, with a main diameter of 2.3 m, nose radius of 0.575 m.**
- **Frontshield TPS: Carbon Phenolic (as Pioneer Venus).**
- **Entry System mass : 300 kg including 81 kg for frontshield TPS.**



ASTRIUM / CNES

Balloon & deployment system

- **Balloon is helium superpressure balloon, 6.6 m diameter.**
- **Float altitude 55 km (20°C, 0.5 bar).**
- **Builds strongly on French/Russian Vega balloon heritage.**
- **Note that inflation system (gas tank + harness) is 141 kg!**



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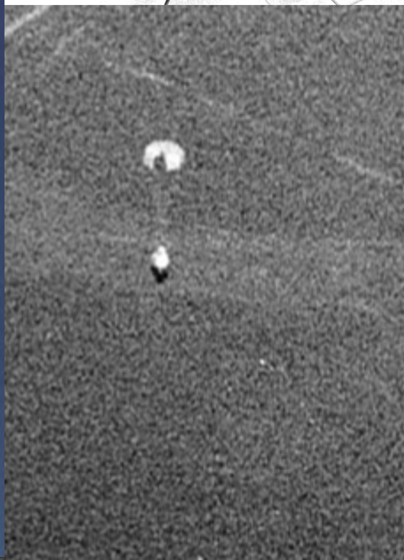
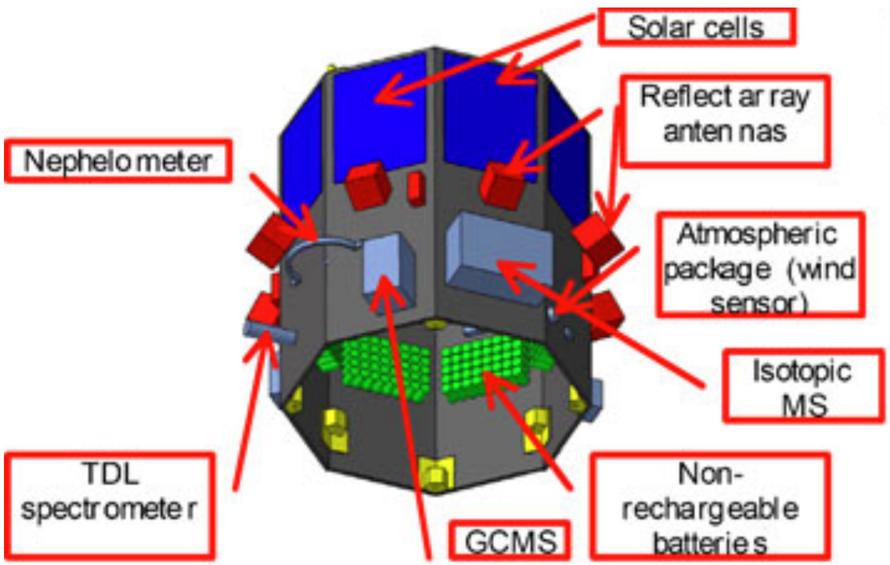
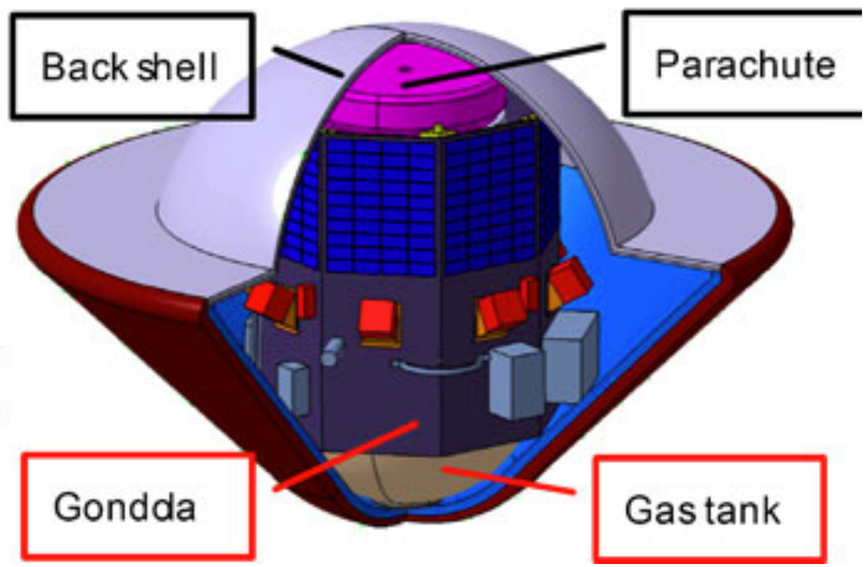


Gondola

- **Octagonal tube structure is space-efficient, and effectively transfer mechanical loads during entry.**
- **Floating Mass is 159 kg, including**
  - **16 kg helium**
  - **116 kg gondola, incl. 15 kg science payload.**





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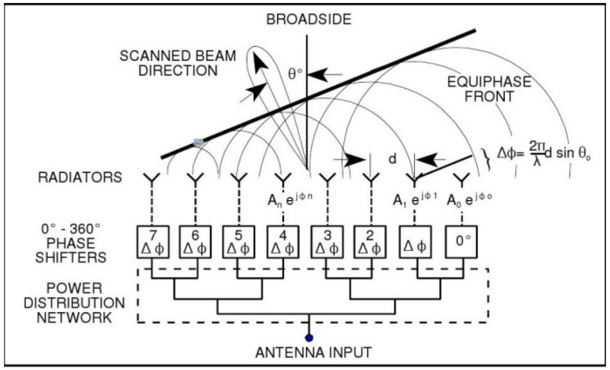
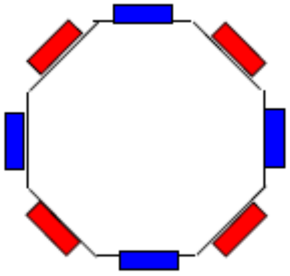
Communications system

- **Low Gain (~omnidirectional) antenna provides only 5-10 bits per second direct-to-Earth downlink.** This is insufficient for many science goals**.**



- **Options considered included:**
  - Steerable parabolic dish (2 DOF) – mechanically complex, difficult to accommodate
  - Multi-horn antennae – bulky, difficult to accommodate
  - **Phased antenna arrays in X-band – retained solution**



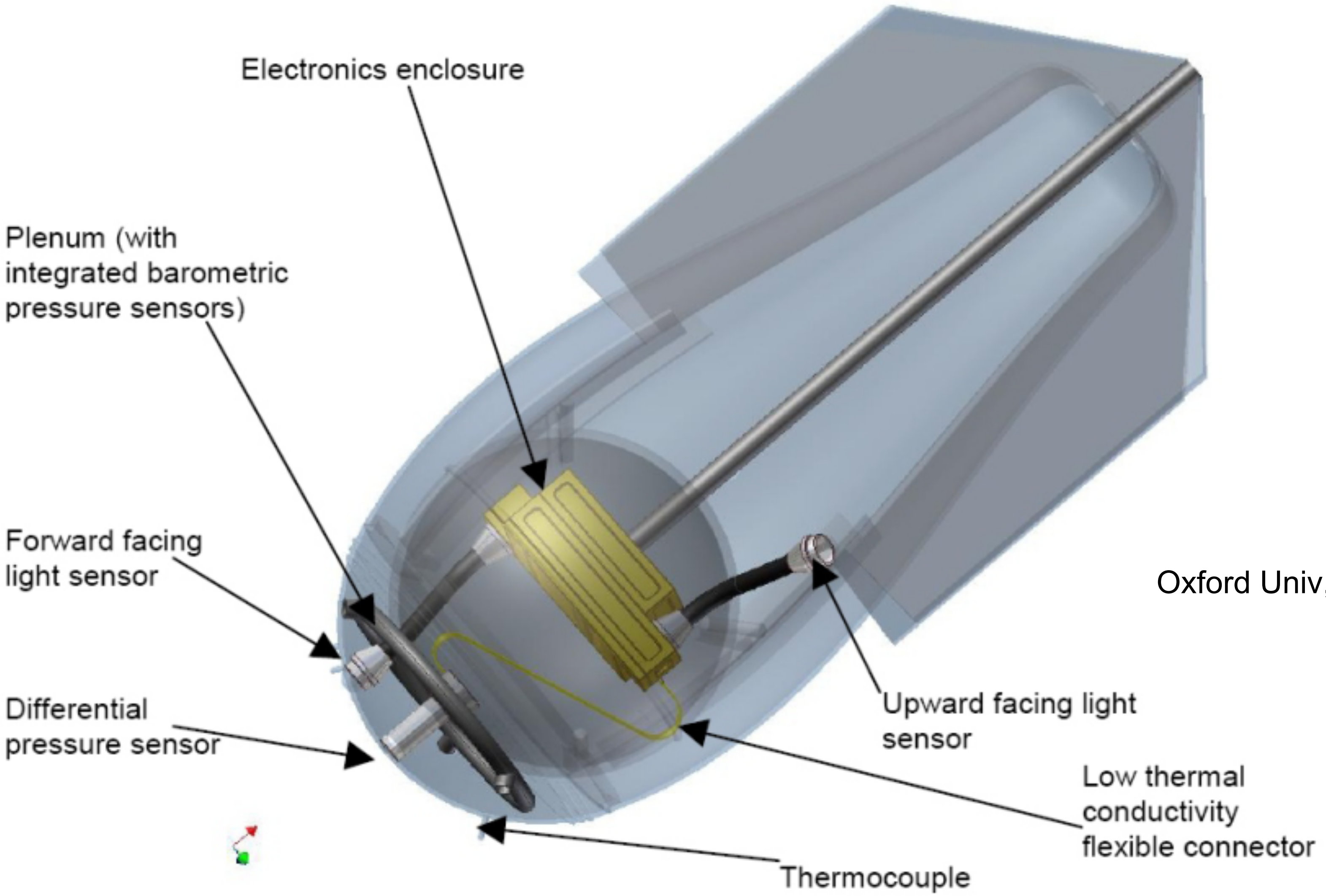
- **Solution allows > 100bps to 35m Ground Station dishes**
  - 8 phased antenna arrays, 12-15 dBi , Medium-Gain antennae, each array has dimension 100 x 100 mm.
  - Total mass on gondola is 5 kg, 25 W power consumption

4x Transmit arrays

4x Receive (and DOA determination) arrays

- **Further optimisation is certainly possible!**
  - e.g. more directional antenna

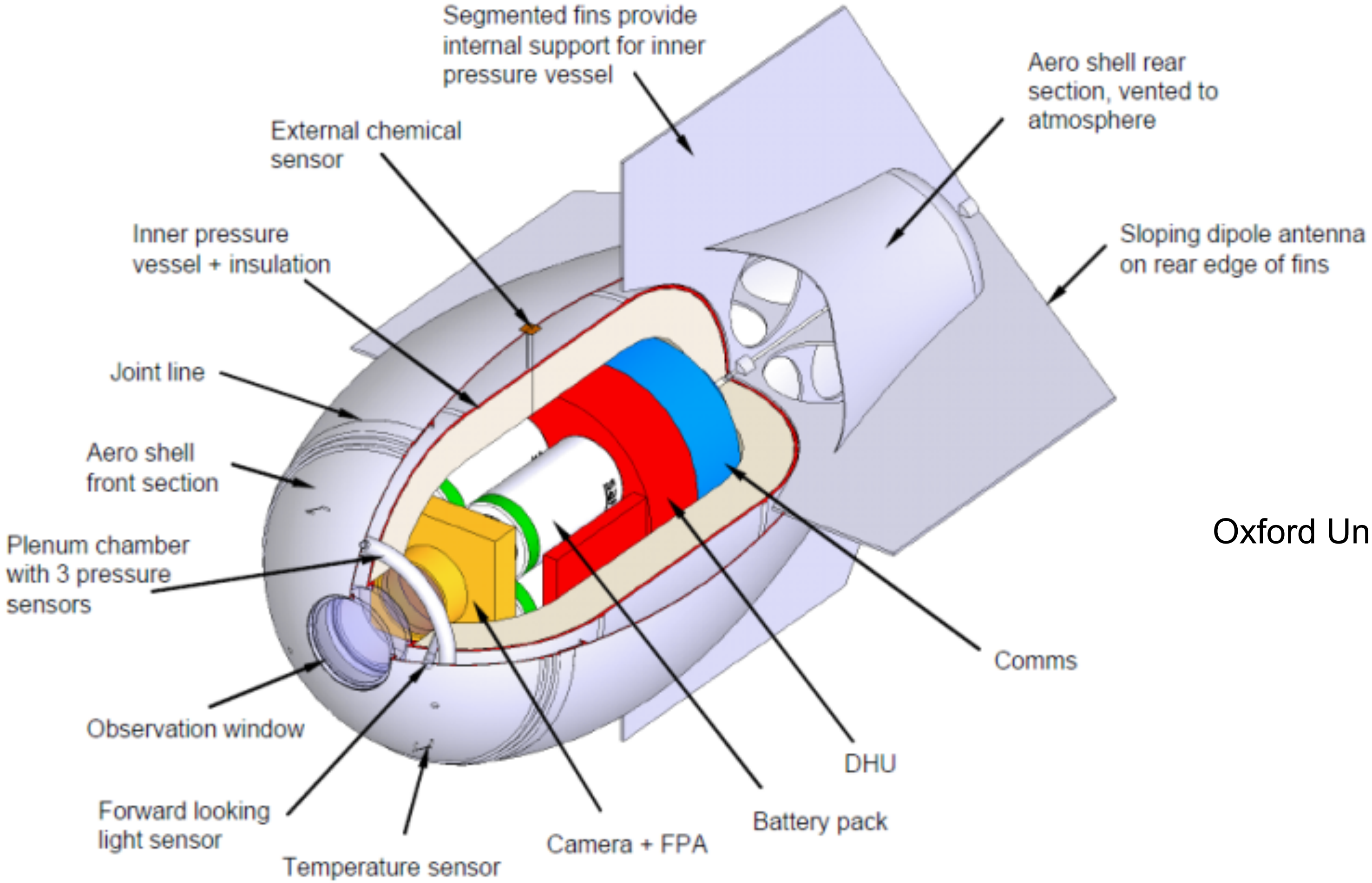
100 g balloon-deployed microprobes?



Oxford Univ, Qinetiq, ESA

1-2 kg balloon-deployed 'Miniprobes'?

- **Payload as for microprobes, but permitting imaging of surface.**



Oxford Univ, Qinetiq

Thanks for your attention

For further details:

C. Wilson et al., The 2010 European Venus Explorer (EVE) mission proposal, Experimental Astronomy, April 2012.

DOI:10.1007/s10686-011-9259-9

Lessons learned
(about getting entry missions selected)

- **Like Mars or Earth, Venus has a large and diverse set of environments**
  - Surface, low atmosphere
  - 50-60 km: sub cloud atmosphere
  - 60-75 km: Convective cloud layer
  - Mesosphere , thermosphere, ionosphere...

Difficult to satisfy all communities with a single modest mission

- **Images help to sell a mission**

- **A stand-alone *in situ* atmospheric mission has short lifetime and small data return**
  - High cost in € per Mbyte
  - partnering with orbital missions helps to mitigate this.

- **Much of the understanding of Venus comes indirectly from modelling**
  - Evolution models constrained by noble gas abundances and isotopic ratios
  - Atmospheric circulation and chemistry models
  - Radiative transfer / greenhouse models
  - Interior models

European Venus Explorer –
A logical step in Venus exploration

- **Step 1 (2005-2015) : European Venus-Express mission and Japanese Venus Climate mission Orbiter**
  - **Atmospheric and cloud dynamics**
  - **(Incomplete) global scale chemistry of the low atmosphere**

- **Step 2a (2015-2025) : in-situ mission, with the use of atmospheric probes (balloons, descent probes)**
  - **Venus climate evolution**
  - **New data relative to atmospheric isotopic ratios, chemistry of the coupled surface/ atmosphere system, dynamics of the whole atmospheric system.**

- **Step 2b (2015-2025) : Next-generation radar mission**
  - **Surface evolution**
  - **Landing site characterisaton**

- **Step 3 (2025-2035) : Long-lived landers for the characterisation of the interior structure and dynamics of Venus**

Lessons learned?
(about getting entry missions selected)

***So: why wasn't EVE selected?* Reasons include:**

And, of course, strong competition (47 proposals submitted)! M3 finalists were:

- ECHO (Exoplanet Characterisation mission)
- *Marco Polo – R (Asteroid Sample Return mission)*
- *Plato (Planetary Transit and Oscilliations of starts)*
- LOFT (Large Observatory For X-ray Timing)
- STE-QUEST (Space-Time Explorer and Quantum Equivalence Principle Space Tes)

} *Finalists in 2007 call*