



# Venus Express: The Spacecraft

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**T**he Venus Express project began with the fortunate inheritance of a set of spare spacecraft units and an industrial setup from the Mars Express mission, as it was clear that this second 'Express' mission would only be possible both financially and schedule-wise if new developments were kept to a minimum. Likewise for the payload, the strong legacy from Rosetta and Mars Express in terms of the scientific instruments was equally essential for mission success. Another critical factor was strict adherence to the spacecraft Assembly, Integration and Test campaign schedule, to ensure that the fixed launch window would be met.

### Introduction

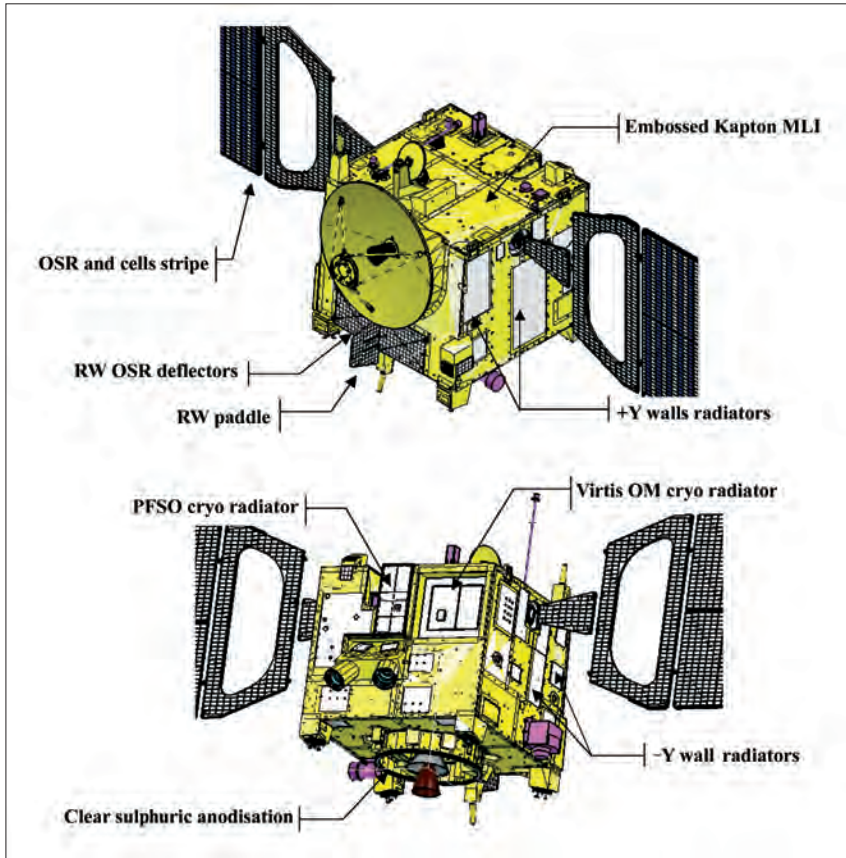
The main technical challenges faced with Venus Express have been the demanding mission requirements coupled with the need to make maximum reuse of the Mars Express spacecraft design in order to reduce the development risk. Equally challenging was the fact that everything had to be completed within a very short time frame, with the project getting the go-ahead in the autumn of 2002 for a launch in the autumn of 2005.

Consequently, the Venus Express spacecraft is very similar to Mars Express in the following areas:

- Unchanged system concept, with body mounted instruments, fixed antennas and a pair of solar arrays mounted on one-degree-of-freedom drive mechanisms.
- Similar structure with only local changes.
- Fully recurrent propulsion-subsystem and avionics units.







Views of the top (nadir-facing) and bottom (cryo-radiator) faces of the spacecraft

predicted surface temperatures (up to 250 deg), together with an intense ultraviolet environment, a rapid programme of thermal design, material selection and demonstration was instigated. Because of the severe schedule constraints, it was decided to adopt a conservative margin for the thermo-optical properties of the chosen materials.

The passive thermal control used on Mars Express has been retained, but the spacecraft's external coatings have been modified to eliminate multiple reflections and avoid solar flux entering the spacecraft directly. In particular, Kapton multi-layer insulation (MLI) covers most of the spacecraft, while optical solar reflectors (OSRs) are used on the lateral radiators and solar arrays, and sulphuric anodisation on the launch-vehicle adapter (LVA) ring's external surface. The heater power has

been increased compared to Mars Express, which at first sight would appear counter-intuitive for a mission to an inner planet, but due to the passive thermal design there is a cold bias to the satellite. The additional heating is particularly required during the mission's early cruise phase and during eclipse.

### Electrical Features

The Venus Express electrical architecture satisfies the needs of an interplanetary mission driven by high-autonomy requirements due to the lack of real-time control, and the highly variable environment in terms of distance, aspect angle, spacecraft attitude, orbit insertion and maintenance, together with the need to collect and format large volumes of science data for return to Earth.

### Power subsystem

The spacecraft's onboard power is managed and regulated by the Power Control Unit (PCU) to provide a +28V regulated main supply for use by both the platform and payload units. Power is distributed to all spacecraft units via a Power Distribution

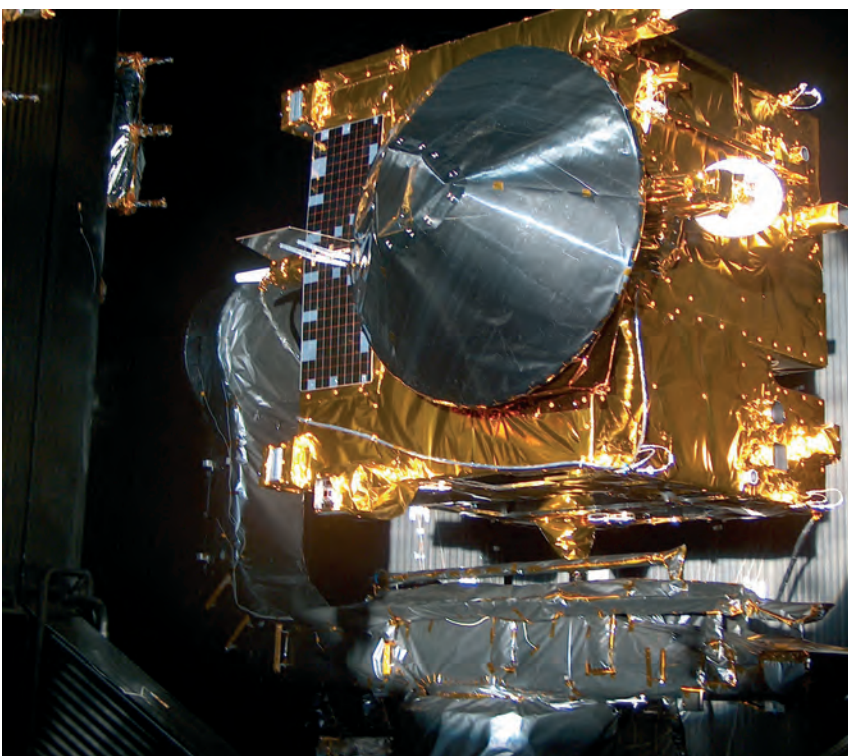


One of the solar-array wings after a successful deployment test at Intespace in Toulouse (F)





The spacecraft undergoing integration at Alenia in Turin (I)



The spacecraft in the SIMLES facility at Intespace in Toulouse (F)

### **Communications subsystem**

The mission's Telemetry, Tracking and Command (TT&C) requirements were driven by the total volume of scientific data to be returned, and the operational requirements for spacecraft command and telemetry, spacecraft navigation and radio science. Compatibility with both the ESA TT&C Standards and the NASA Deep-Space Network (DSN) was mandatory to allow cross-agency support.

The configuration of the planets during the mission and the need to maintain a cold spacecraft face pointing away from the Sun led to the inclusion of a second smaller High-Gain Antenna (HGA2) that will be used for approximately one quarter of the mission, centred around inferior conjunction when the spacecraft will be at its closest to the Earth.

The TT&C subsystem has at its core two redundant dual-band transponders and two high-power 70 W travelling-wave-tube amplifiers interconnected with a radio-frequency (RF) switching network.

The spacecraft communications system also hosts the VeRa radio-science experiment's high-performance Ultra-Stable Oscillator (USO), which is essential for the one-way downlink experiments.

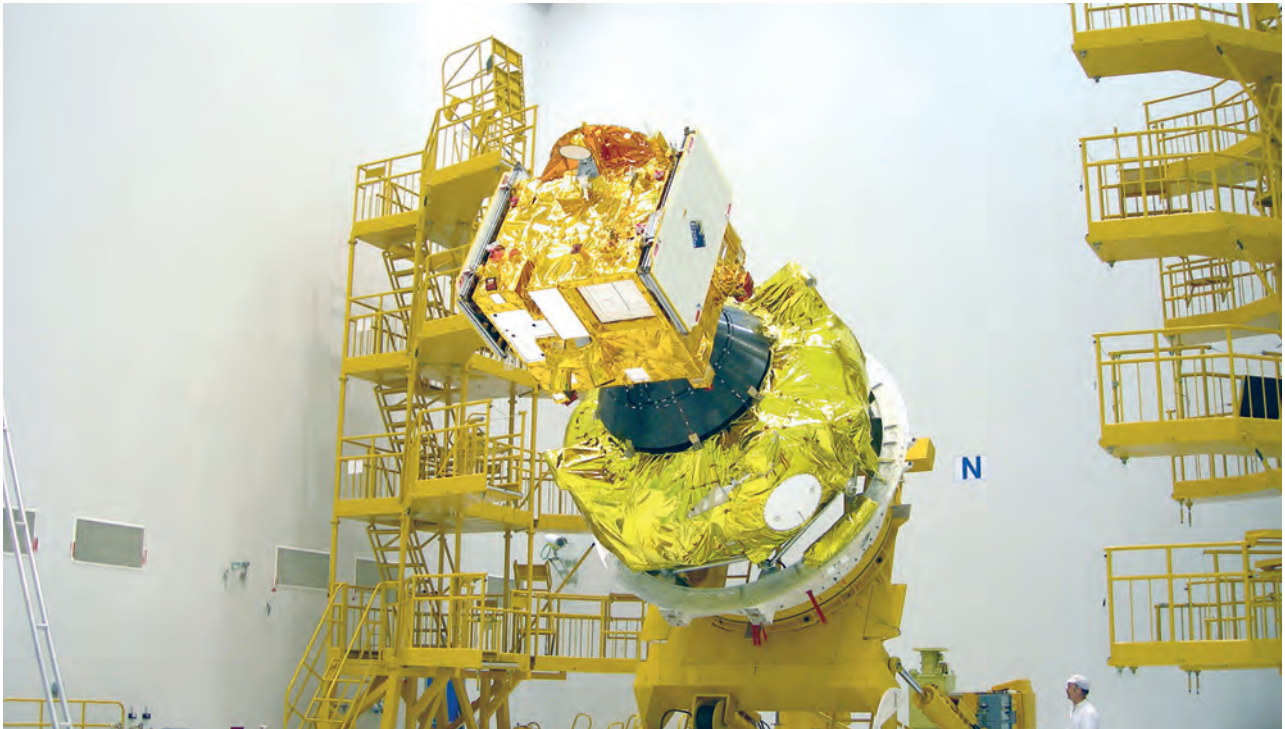
### **Data-handling subsystem**

The spacecraft's data-handling architecture is centred on two Control and Data Management Units (CDMUs), which together constitute the Data Management System (DMS), a Remote Terminal Unit (RTU), an AOCs Interface Unit (AIU) and a Solid-State Mass Memory (SSMM).

The main tasks of the CDMUs are:

- Decoding of the telecommands from the ground and ensuring their execution, onboard housekeeping and science-data telemetry formatting for transmission.
- Execution of DMS software for overall data management, including the mission timeline.
- Execution of the attitude and orbit control system software.

The RTU is the interface between the DMS system and the payload and platform units. Instructions to these units are passed over one of the two redundant OBDH busses. In



*The combined stack of the Venus Express spacecraft and Fregat upper stage being readied for launch at the Starsem facilities in Baikonur*

the return direction, telemetry from the payload or platform units is gathered by the RTU for return to the DMS.

The SSMM is a file-based 12 Gbit mass-memory store for housekeeping and science data collected by the DMS system. However, two of the payloads, VIRTIS and VMC, generate such large volumes of data at high speed that they have their own dedicated direct links to the SSMM.

### Attitude and Orbit Control Subsystem

As the spacecraft is of a fixed-antenna and body-mounted-instrument design and there is the need for a main-engine burn to achieve orbit insertion around Venus, the Attitude and Orbit Control System (AOCS) has to provide a high degree of attitude manoeuvrability. Attitude estimation is therefore based on star-tracker and gyroscope data. There is also a Sun-acquisition sensor for initial orientation of the spacecraft after its separation from the Fregat at launch and for safe modes. Reaction wheels are used for most attitude manoeuvres, thereby reducing fuel consumption.

### Testing

The true 'express' nature of the Assembly,

Integration and Test (AIT) activities can be appreciated from the fact that the spacecraft structure was delivered to Alenia's integration facility in Turin (I) on 5 April 2004 and the environmental test campaign was successfully completed just 15 months later, on 2 July 2005.

Following the initial integration of all of the platform units, payload units, thermal hardware, spacecraft harness, RF waveguides and antennas, an Integrated Subsystem Test was first completed. The spacecraft was then moved to the Intespace facility in Toulouse (F) in order to complete the system and environmental testing close to Astrium, the Venus Express prime contractor.

Owing to the unique characteristics of a Venus mission and the high solar flux experienced, it was necessary to upgrade the solar simulator facility (SIMLES) at Intespace. The solar flux was temporarily increased by introducing a removable lens into the optical path of the simulator, thereby concentrating the solar beam into a smaller area to illuminate the spacecraft with the higher flux representative of the flight environment.

The first spacecraft Integrated System Tests were run at Intespace at the end of

November 2004, and the mechanical vibration and acoustic testing was performed immediately after Christmas. These tests showed that the spacecraft should perform as expected after its ride into space aboard the Soyuz/Fregat launcher.

By the spring of 2005, Venus Express was ready for the Thermal Balance/Thermal Vacuum test campaign. The results of these tests successfully demonstrated that the spacecraft would perform as predicted in the harsh thermal environment to be expected around Venus. The spacecraft underwent radiated Electromagnetic Compatibility (EMC) testing, including an auto-compatibility test to demonstrate that when the spacecraft is transmitting to Earth none of its other functions will be affected. In late spring, the System Verification Test performed by ESOC, and a further Integrated System Test, rounded off the successful Environmental Test Campaign.

