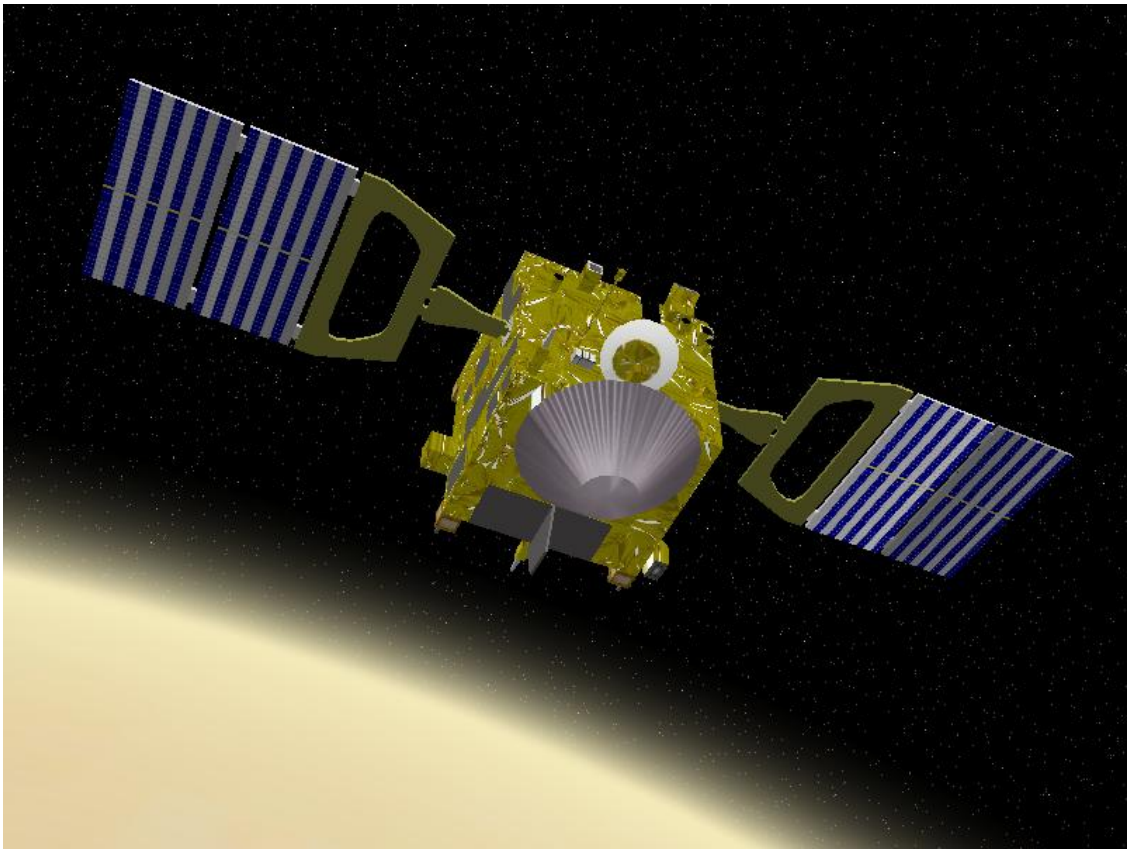
Venus Express Manual

-By MartySpaceLines & Jekka-



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Introduction

On November 9, 2005, 03:33 (UT) a Soyuz booster with its 4th stage Fregat, rises slowly in the sky above the Baikonur Cosmodrome in Kazakhstan. At its top, the European Space Agency (ESA) probe Venus Express, which begins, supported by its control centre in Darmstadt (Germany), a five-months-long journey towards the Morning Star.

The main objectives of the mission are the study of the Venusian atmosphere and its interaction with the surface and the interplanetary environment (in particular solar wind).

Launch preparation.

Installation

To install this add-on, just unzip "MSLJ_VenusExpress.zip" in your Orbiter directory.

!!!Warning: some other add-ons are essential to run Venus Express correctly!!!

You will have to install the following add-ons before Venus Express:

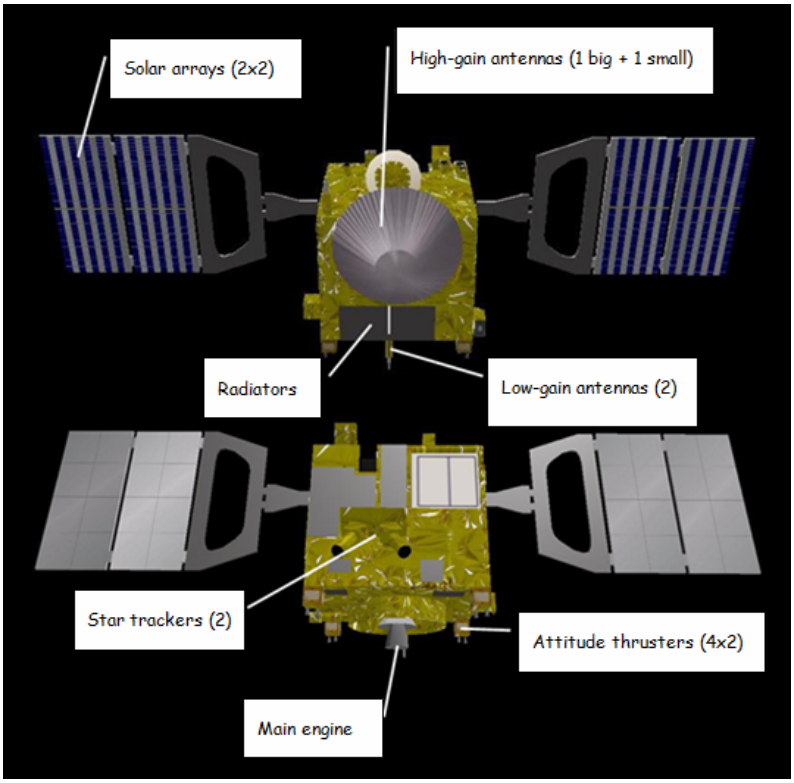
- Baikonur, LC1-pad5 for Soyuz by Mustard & BrianJ: http://orbiter.mustard-fr.com
- Soyuz Series by Mustard & No Matter: http://orbiter.mustard-fr.com
- Multistage2.dll and Spacecraft3.dll by Vinka: http://users.swing.be/vinka/
- IMFD 5.1 or higher version, by Jarmo Nikkanen: http://koti.mbnet.fi/jarmonik/Orbiter.html

Many thanks to the developers mentioned above for their creations.

The spacecraft

Venus Express' structure is almost the same as Mars Express', of which it has the name. This approach allowed a fast (three years, which explains the name "Express") and relatively cheap development: 220 million Euros, including 23 million for the scientific equipments and 35 million for the launch. The probe re-uses a few equipments from Rosetta, and its realization was entrusted to the European company EADS Astrium.

The spacecraft's main body, called the "bus", is a honeycomb aluminium box about one and a half meter wide. With its solar arrays extended, the probe measures more than 8m across. The scientific instruments are mounted on the bus, which also contains the fuel tanks.



Venus Express' main parts.

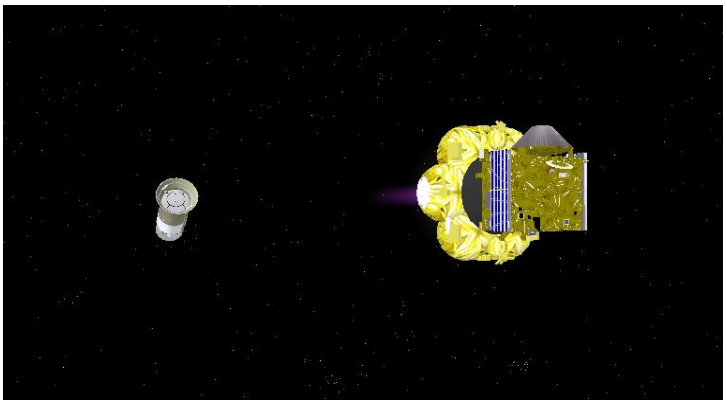
The main technical difference between Venus Express and its older brother Mars Express resides in the thermal control: since Venus is twice closer to the sun than Mars, Venus Express must tolerate external temperatures four times higher than Mars Express in order to maintain its internal temperature between 20 and 25°C (68-77°F).

Consequently, the radiators located on the sides of Venus Express are larger and more efficient than those of Mars Express. Moreover, the probe's external insulation (MLI for Multi-Layer Insulation) is gold (contrary to that of Mars Express, which is black) to better reflect the sun's radiation.

The electric power is provided by two solar arrays, forming a total surface of approximately $6m^2$. These arrays can generate a little more than 800W close to the Earth and up to 1100W around Venus. When the probe is in the shadow, the power is provided by three lithium-ion batteries, recharged by the arrays.

For obvious reasons, the size of the panels of Venus Express is twice smaller than that of those of Mars Express.

Venus Express' main engine, which delivers 400N of thrust, uses the 570kg of onboard propellants (nitrogen trioxide and mono-methyl hydrazine). The mass of these propellants corresponds to almost half of the total mass of the spacecraft. In order to do minor trajectory corrections (approximately every 50 days), Venus Express uses four pairs of small attitude engines mounted on the bottom of the probe, each one delivering 10N of thrust.



Separation of the 3rd stage and the Fregat.

The task of correctly orientating Venus Express (and the solar panels) is accomplished by three laser gyroscopes. This system receives the information transmitted by two star trackers, two solar sensors and three accelerometers. The spacecraft usually takes half an hour to change its attitude by 180°, because of its gyroscopes. For the needs of IMFD if you use it, we have largely reduced this time.

The onboard computer has a storage capacity of 12Gb, to store the results of the experiments while waiting for the moment they are transmitted to the earth station, when the orientation of the probe in relation to the Earth allows it.

The communications with the ground are mainly assured by two high-gain antennas (respectively 1.3m and 30cm of diameter), according to the orientation of the probe and the needs of the experiments in progress.

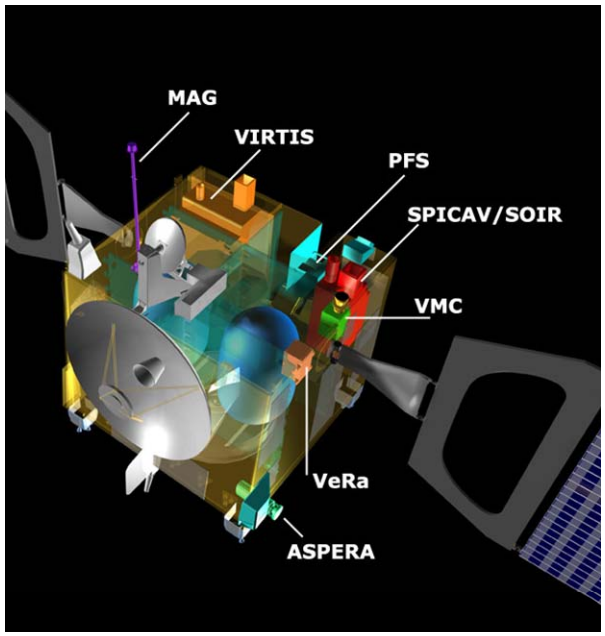
Venus Express has also two low-gain antennas, used for transmission during launch, the first days of travel and in case of a breakdown of the high-gain antennas. These antennas are not able to transmit important data like images over long distances.

Orbiter instruments

Venus Express' payload is composed by the following instruments:

- **Analyser of Space Plasma and Energetic Atoms (ASPERA)**
  Inherited from Mars Express, the ASPERA has the mission of studying the interactions between Venus' atmosphere and the solar wind.
  Manufacturer: Institute of Space Physics, Kiruna, Sweden.

- **Venus Express Magnetometer (MAG)**
  The MAG, which reuses sensors initially designed for the Rosetta Lander, is used to analyse the Venusian magnetic field, caused by solar wind (Venus does not have its own magnetic field).
  Manufacturer: IWF, Graz, Austria.



Location of the main orbiter instruments.

- **Ultraviolet and Infrared Atmospheric Spectrometer (SPICAV/SOIR)**
  These two elements, also derived from those of Mars Express, have for purpose the analysis of the temperature and density of the atmosphere (80-180km of altitude). They look for oxygen and water, too.
  Manufacturer: Service d'Aéronomie du CNRS, Verriesres, France; Institute for Space Aeronomy, Belgium; IKI, Russia

- **Planetary Fourier Spectrometer (PFS)**
  This instrument was build to measure and precisely analyze Venus' atmospheric temperature (55-100km of altitude). The FPS is also present on Mars Express.
  Manufacturer: IFSI-INAF, Rome, Italy.

- **Ultraviolet/Visible/Near-Infrared mapping spectrometer (VIRTIS)**
  Already used on Rosetta, the VIRTIS is used to analyze the composition of the clouds and the atmosphere below 40km of altitude.
  Manufacturer: CNR-IASF, Rome, Italy ; Observatoire de Paris, France.

- **Venus Radio Science Experiment (VeRa)**
  The VeRa, inherited from Rosetta as well, is used for the analysis of the Venusian ionosphere and the solar wind in the internal solar system.
  Manufacturer: Universität der Bundeswehr, Munich, Germany.

- **Venus Monitoring Camera (VMC)**
  The VMC, improved from Mars Express, is a wide-angle camera that takes pictures of Venus in the infrared, ultraviolet and visible wavelengths. It was built to study the clouds and identify the phenomenon studied by the other instruments.
  Manufacturer: MPS, Katlenburg-Lindau, Germany.

Piloting & known problems

Venus Express uses three animations and one autopilot:

Deployment of the solar arrays:	key [k]
Rotation of the arrays (does not function if they are not deployed):	key [g]
Deployment of the MAG:	key [m]
Autopilot "barbecue-mode":	key [b]

You can consider the mission as a success when you are in orbit around Venus (see flight plan).

The launch autopilot starts when you hit key [p]. If you want to do a manual launch, please refer to the documentation of Mustard & No Matter's Soyuz Series.

!!!Warning: depending on the power of your PC, the autopilot will function more or less well. The one included in this pack was tested with a Intel® Centrino® Duo CPU under Windows® Vista ™!!!

After the separation of the last stage of the Soyuz, there is a time of approximately one minute before the Fregat stage burns for about 20s. You should not stop the autopilot during this time.

When you have separated from Fregat after the trans-Venusian injection, you have to reconfigure IMFD with the proper parameters. This problem is due to the fact that at this time, Orbiter changes the vessel handling, passing from Soyuz to Venus Express.

It is useless to specify that it is wise to save fuel, under penalty of not having enough to perform the orbit insertion, which lasts about 50min.

IMFD parameters should be the following:

TIn = 13.24Ms

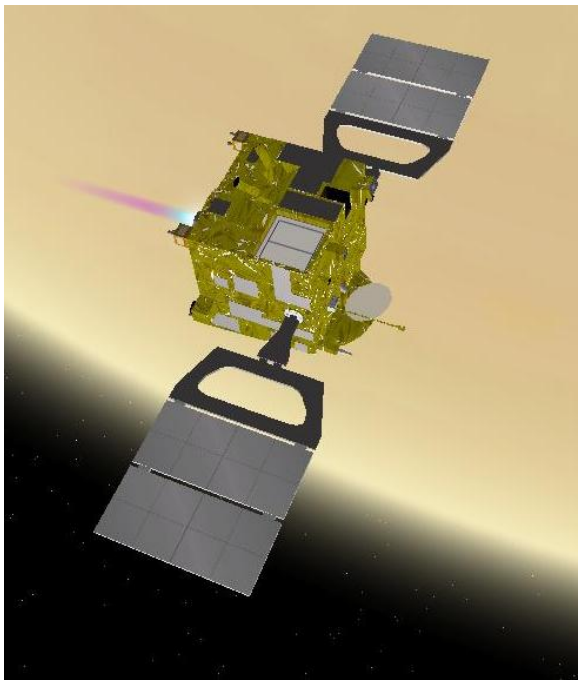
EIn = ~ 0.12°

TEj = ~ 09:00 TU

EjA = < 0.76°

BT = ~ 830s

Trajectory corrections occur about every 50 days, so every 4.32Ms.



Breaking and orbit insertion !

The autopilot "barbecue-mode" makes Venus Express to rotate around its z-axis, in order to distribute the thermal stresses on the whole spacecraft. We advise you not to run this autopilot while the main engine is burning.

We conceived and studied this add-on for use with IMFD. Despite all our efforts in the domain of realism, the purists will want more. Indeed, we had to adapt some details, in particular the attitude control system of the probe, much more powerful here than in reality. If you want to respect the original flight plan perfectly (corrections of trajectory etc...), you can consult the page devoted to Venus Express on the European Space Agency (ESA) website:

http://www.esa.int/SPECIALS/Venus_Express/index.html

After its separation from the Fregat, Venus Express is found without fuel. The cause of this bug is for the moment unknown, but it is perhaps due to

Multistage2.dll. It is thus necessary to fill the tanks of the probe "manually", with the scenario editor.

Flight plan

Here is a summary of the main events of the mission:

Mission Elapsed Time (MET) [dd:hh:mm:ss]	**Date [TU] [dd.mm.yy] [hh:mm:ss] [MJD]**	**Event**	**Corresponding scenario**
00:00:00:00	09.11.05 03:33:34 676803.851690	Launch (key [p]). The autopilot stops at MET + ~ 650s, after the first Fregat burn.	01 – Launch.scn
00:01:20:00	09.11.05 04:53:34 53683.203866	14min Fregat burn for the Trans-Venusian Injection. Have a nice trip!	02 – Fregat burn.scn
00:01:36:30	09.11.05 05:10:04 53683.215324	Separation of Venus Express and Fregat. You can now put the probe in "barbecue-mode" (key [b]).	
00:02:08:00	09.11.05 05:41:34 53683.237199	Solar array deployment (keys [k] and [g]).	
09:00:00:00	18.11.05 53692.0	MAG deployment (key [m]).	
153:07:10:27	11.04.06 07:10:27	Orbital insertion. The main engine breaks for 50min 13s. Arrival	03– Venus orbit insertion.scn

	53836.298924	orbit: 350'000 km to 400km of altitude.	
157:00:00:00	15.04.06 53840.0	1st Pericentre Control Manœuvre (PCM). Speed change: -5.8m/s.	
162:00:00:00	20.04.06 53845.0	1st Apocentre Lowering Manœuvre (ALM): -199.9m/s.	
165:00:00:00	23.04.06 53848.0	ALM-2: -105. m/s.	
168:00:00:00	26.04.06 53851.0	ALM-3: -9.2m/s.	
171:00:00:00	29.04.06 53854.0	ALM-4: -8m/s.	
174:00:00:00	02.05.06 53857.0	Apocentre trim (ALM-4 was too long): +2m/s.	
180:00:00:00	06.05.06 53861.0	PCM-2 :-3.1 m/s.	
180:00:00:00	From 06.05.06 53861.0	Congratulations! Venus Express has reached its final operational orbit.	04 – Venus orbit.scn

Pericentre altitude:	250km
Apocentre altitude:	66'000km
Period:	24h
Orbit inclination:	~89°
Pericentre latitude:	80°

Thanks & limitations

We want to thank in particular:

- The whole French speaking Orbiter community, with DanSteph, No Matter, BrianJ and Pagir
  http://orbiter.dansteph.com
- Kodiak, who gave us his Fregat mesh
  http://kodiakspace.blogspot.com/
- And Thorsten Siwitza, who gave us some of the textures
  http://www.esa.int/SPECIALS/Venus_Express/index.html

In the hope that this add one will fully satisfy you, we wish you a good flight!

MartySpaceLines & Jekka – April 2008