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Venus Express

Science Activity Plan (SAP)

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CHANGE RECORD SHEET

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10 Jun 2004	D	1	All	first go	
3 Sep 2004	D	2	All	Scientific focus specified in more detail by D. Titov Removed outage period for Phase 9 as there will be no outage according to current studies (RH) Chapter 1, 1.1 Introduction and 1.2 scope modified; In chapter 3 all paragraphs on Mission Phase objectives merged with the paragraphs 3.x.3 Scientific Focus; 3.x.4 Explicitly include the instruments objectives in the Requests Description paragraph; A paragraph on the Venus orbit was added (replacing trajectory); Editorial and layout cleanup; Additions to distribution list; (HS)	
1 Jan 2005	1	1	All	Scientific focuses specified in more detail for all mission phases. Details of conceptual design of SAP1A and SAP2A plans are added. Appendix B (Nominal mission	

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				overview) is added. Appendix C (SAP1A detailed timeline for the nominal mission) is added. Appendix D (SAP2A detailed timeline for the nominal mission) is added.	
15 July 2005	1	2	All	Detailed description of mission phases	
August 15, 2005	1	3	All	• After approval at the SWTM#7 • FD orbit numbering • VeRa request (Synopsis-2) accommodated including DSN passes • Analysis of mission goals and parameter space coverage • SAP analysis wrt thermal constraints	
April 3, 2006	2	0	All	• After SOWG#7, March 7-8,2006 • Orbit FD9 • VeRa experiments distribution agreed with the PI and with the Team • Compliance with the current thermal rules and expected VUM update	
				•	

Date	Iss.	Rev.	pages	Description/Authority	CR No.
June 5, 2006	3	0	All	• The timelines are presented in MTPs not in Phases • Possible additional combinations of pericentre cases like (#1+#6) or (#5+#1) are added if they do not violate thermal constraints • Table with the schedule of VeRa experiments up to Phase IV of the mission with booking of the NNO and DSN stations.	
February 22, 2007	3	1		• The table of the VeRa experiments (Annex 3) is updated. • Mission overview poster (Annex 1) is updated	

Revisions are indicated by a vertical bar at the outside border.

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1. INTRODUCTION

1.1 Introduction

Venus Express (VEX) is ESA's first mission to Venus. VEX is scheduled to be launched in October 2005. It has a payload consisting of seven scientific instruments, ASPERA, PFS, SPICAV/SOIR, VeRa and VIRTIS, with heritage from Mars Express (MEX) and Rosetta, and MAG and VMC, which are new instruments. The VEX Science Operations Centre (VSOC) has the task to coordinate the scientific operations of the VEX mission.

1.2 Scope of the document

The Science Activity Plan (SAP) for Venus Express describes in a structured way the scientific activities to be carried out throughout the nominal part of the mission. It follows the objectives set out in the Science Requirements Document (AD6), and is enhanced with specific information applicable to each phase of the mission, as provided by VSOC and the Science Working Team during meetings and in written correspondence. It also includes the requests, per MTPs (Middle Term Planning cycle of 28 days), from each individual instrument team for the observations required to fulfil the different objectives for the respective phases. This document will for quite a period be a living document due to its iterative nature. In this respect the document can be considered as a combination of the long term plan and the medium term plan as outlined in the VSOC development plan. Once this document has been established and agreed, it will be used as an input for the detailed short-term plan.

1.3 Change forecast

The VeRa experiments for the late phases of the nominal mission included in this version of SAP result in illumination of the –X wall. The expected profiles are with the ones allowed by the spacecraft but violate the VIRTIS requirements. The decision to carry out these VeRa experiments will be taken after the VIRTIS thermal analysis but should be done before booking the ground stations. This fine tuning will be included as update of the SAP.

1.4 Applicable Documents

1.4.1 Higher-level documents

AD2: Venus Express Mission Definition Report, ESA-SCI(2001)6, SCI(2001) October 2001

AD3: VEX-RSSD-PL-005_D_2_SAP_implementation_plan

AD4: VEX-RSSD-TN-001_1_b_VEX_Science_Cases

AD5: VEX-RSSD-SP-001_2_0_VSOC_Design_Specification_and_Requirements

AD6: VEX-RSSD-SP-002_1_1_VEX_Science_Requirements_Document

AD7: VEX-RSSD-LI-004_2_0_VEX_science_themes

AD8: VEX-T.ASTR.-TCN-00665_3/0_Science_Cases_Definition_and_Study_Assumptions

AD9: VEX-T.ASTR-TCN-00932_3/0_Synthesis_of_Science_Cases_Analysis, May 29, 2006.

AD10: VEX-T.ASTR-UM-01098_1/1_ Flight User Manual

AD11: VEX-RSSD-TN-0003_1/0_Thermal constraints and science planning

AD12:VEX-RSSD-TN-0006_1/1_Proposal for the post-FAR thermal analysis of the science cases

AD13: Venus Express science cases thermal analyses report, Draft, December 2005.

1.4.2 Documents on the same level

TBD

1.4.3 Lower-level documents

TBD

1.5 Reference Documents

TBD

1.6 Abbreviations

Note: A complete list of all experiment abbreviations and mission phases is given in RD1.

S/C	Spacecraft
CVP	Commissioning and Verification Phase
FoV	Field of View

1.7 Definitions

2. SCIENCE OPERATIONS PLANNING

2.1 Overview

Ten types of orbital science operations (called “science cases”) were designed and studied early in the mission planning. They are now used as building blocks to design the Science Activity Plan. In order to check the experiment inputs and to merge them into a consolidated timeline, the VSOC uses a planning concept and three computer based planning tools, PTB, MAPPS and EPS. The concept and the tools are described below.

2.2 Science Cases

Science Cases are typical scientific orbital operations to be used as building blocks in the SAP development. The following ten science cases were designed in the early phase of mission planning (AD4, AD8).

Case #1: Pericentre observations (spacecraft sizing case)
Case #2: Off-pericentre observations
Case #3: Apocentre VIRTIS mosaic
Case #4: VeRa bistatic sounding
Case #5: SPICAV stellar occultation
Case #6: SPICAV solar occultation
Case #7: Limb observations
Case #8: VeRa radio occultation
Case #9: VeRa solar corona studies
Case #10: VeRa gravity anomaly studies

The Astrium study of the science cases (AD9) proved their feasibility with some constraints related to the thermal aspects and having seasonal implications.

2.3 SAP planning concept

In order to develop the Science Activity Plan a step-wise approach will be used. A detailed description of the steps are given in the SAP implementation plan (AD3). Previous versions of

SAP used one (SAP 1, section 2.3.1) or two (SAP 2, section 2.3.2) cases per orbit. Current SAP (section 2.3.4) does not impose any limitations on number of cases as soon as the operational constraints (thermal, power, pointing etc) are not violated.

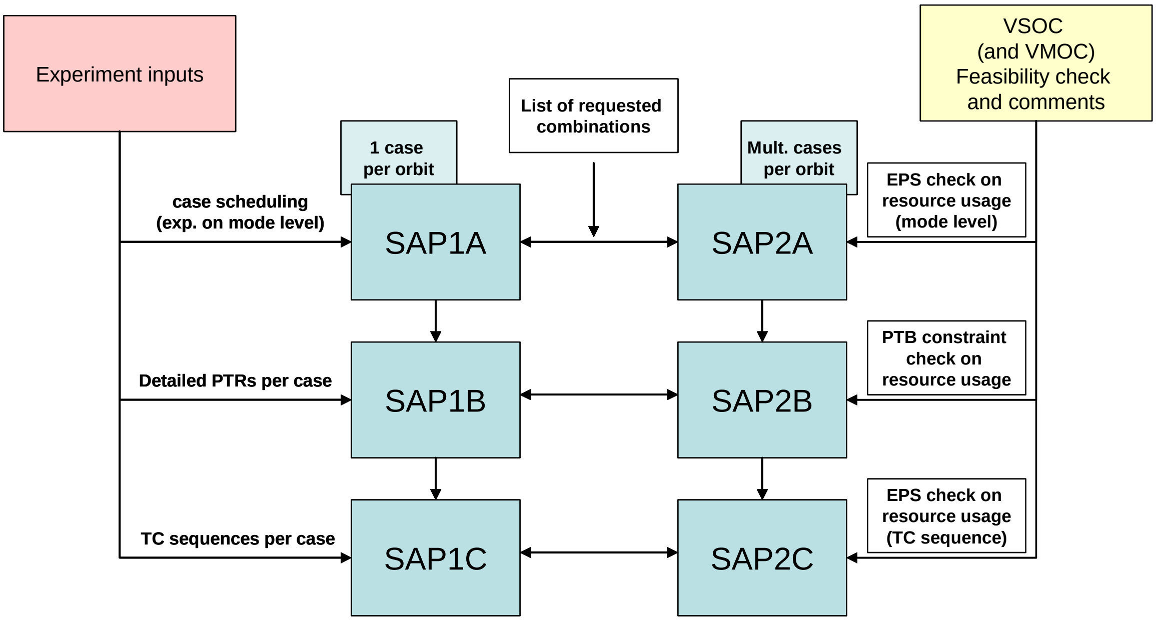


Figure 2.1 *SAP overview diagram*

2.3.1 SAP 1

SAP1A – 1 case per orbit with experiment operations on mode level and same PTR for each case

SAP1B – 1 case per orbit with experiment operations on mode level, but with specific PTRs for cases

SAP1C – 1 case per orbit with experiment operations on TC sequence level with specific PTRs for cases

Note for SAP1C it will not be necessary to create TC sequence level for complete SAP, but representative orbits need to be verified down to detailed level.

2.3.2 SAP 2

SAP2A – multiple cases per orbit with experiment operations on mode level and same PTR for each case (although for some case combinations PTR already requires modification)

SAP2B – multiple cases per orbit with experiment operations on mode level, but with specific PTRs for cases

SAP2C – multiple cases per orbit experiment operations on TC sequence level with specific PTRs for cases

Note for SAP2C it will not be necessary to create TC sequence level for complete SAP, but representative orbits need to be verified down to detailed level.

2.3.3 SAP 1+

The operation rules were formulated by Astrium in the Flight User Manual [RD 10]. Thermal behaviour of the spacecraft imposes severe limitations on the observations. An attempt to take these aspects into account led to development of so-called SAP 1+ plan. This plan is similar to the SAP2 in a sense that it combines two science cases in each orbit, however, only one of them being thermally demanding, i.e with the sun illuminating ±-X, or –Z panels of the spacecraft. Also in the SAP1+ a pericentre pass can be shared between two or more observation types if this combination is compliant with operation rules and spacecraft resources. More detailed B and C levels of the SAP1+ are currently under development for the phases 0 through 2 of the mission.
The SAP1+ has been approved by the Venus Express science team and is now considered as a baseline. However, in view of expected evolution of the thermal flight rules we foresee that the current SAP1+ plan would be modified. The impact of possible FUM evolution has been preliminary studied and possible descoping options were identified.

2.3.4 Current SAP

The current version of SAP (issue 3) is based on the SAP1+ and takes into account the thermal restrictions and flight rules as they are now for the beginning of the mission and the expected update of the VUM for the later phases.

2.4 PTB

The Project Test Bed (PTB) has been extended to cover Venus Express. The PTB is an environment simulator which will allow

- identification of science opportunities
- evaluate coverage of the Venus surface target
- evaluate coverage of the Venus atmosphere and surface mapping
- evaluate latitude coverage for Earth, Solar and Stellar occultations

In order to be able to make this analysis the PTB will require the pointing requests (PTR) files as an input. The Flight Rules from VMOC (ESOC) will also be incorporated in the PTB. This will allow the PTB to validate environmental constraint such as thermal constraints.

2.5 MAPPS

MAPPS is a software package that will be used to analyze and plan the mapping of Venus. For Venus Express the EPS (see below) will be integrated within MAPPS. As a result MAPPS will also be able to make the necessary resource validation and conflict checking.

2.6 EPS

The Experiment Planning Software (EPS) is being used in the production of the Science Activity Plan. The particular functions of EPS used for this task are:

- Model and operate experiments on mode level (Experiment Description File, EDF)
- Consistency checks between the instrument timelines (ITL) on mode level
- Consistency check between the sequences and commands contained within the VMIB.
- Consistency checks between the instrument timelines (ITL) and the VMIB.
- ITL verification on mode level, EPS execution is prevented if ITL actions/transitions not consistent with mode.
- Modelling the resource allocation over the operational timeline.
- Output POR files for ingestion into VMOC MCS.

The use of EPS in planning is discussed in more detail in throughout this document. For more information on the capabilities of EPS refer to the user manual [AD xx].

2.7 Venus Express orbit and visibility of the ground stations

The Venus Express will be inserted in a polar orbit with a period of 24 hours. The pericentre altitude will be maintained between 250km and 350 km. The apocenter altitude will be about 66,000 km. The pericentre latitude will be about 78 deg, depending on exact launch date and will slightly drift during the mission.

The Venus Express orbit is divided in three parts (figure 2.2): two of them allocated for observations and the third one for telecommunications with the ground station.

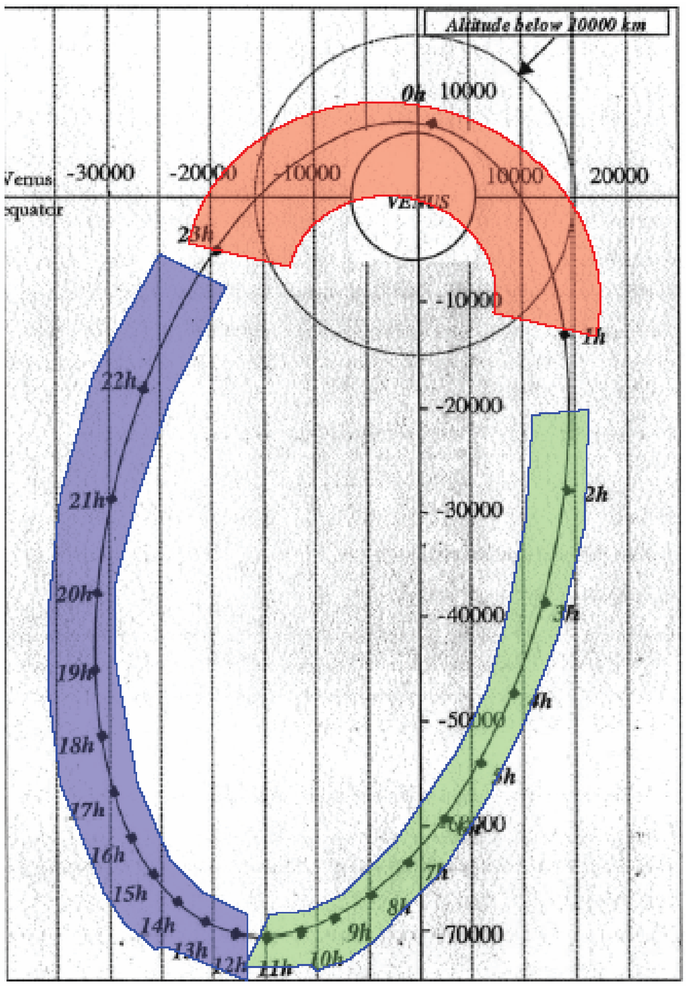


Figure 2.2 *The Venus Express orbit and orbital phases: red- pericentre observations, blue off-pericentre observations in ascending branch, green – telecommunications with Cebreros.*

Communication with Earth will take place in each orbit after the pericentre passage, i.e. in the descending part of the orbit. The orbit period will be tuned such that the communication window always will fall in daytime at the primary ground station Cebreros. Figure 2.3 shows visibility of the Cebreros station from the satellite. The lower of the upper two lines shows the end of telecommunication slot. Its duration does not exceed 10 hours even in case visibility of the planet is longer. Green bars mark the periods when the telecommunication phase ends early enough. These periods provide favorable conditions for the Case#3 apocentric mosaic since the observations can be carried out around pericentre.

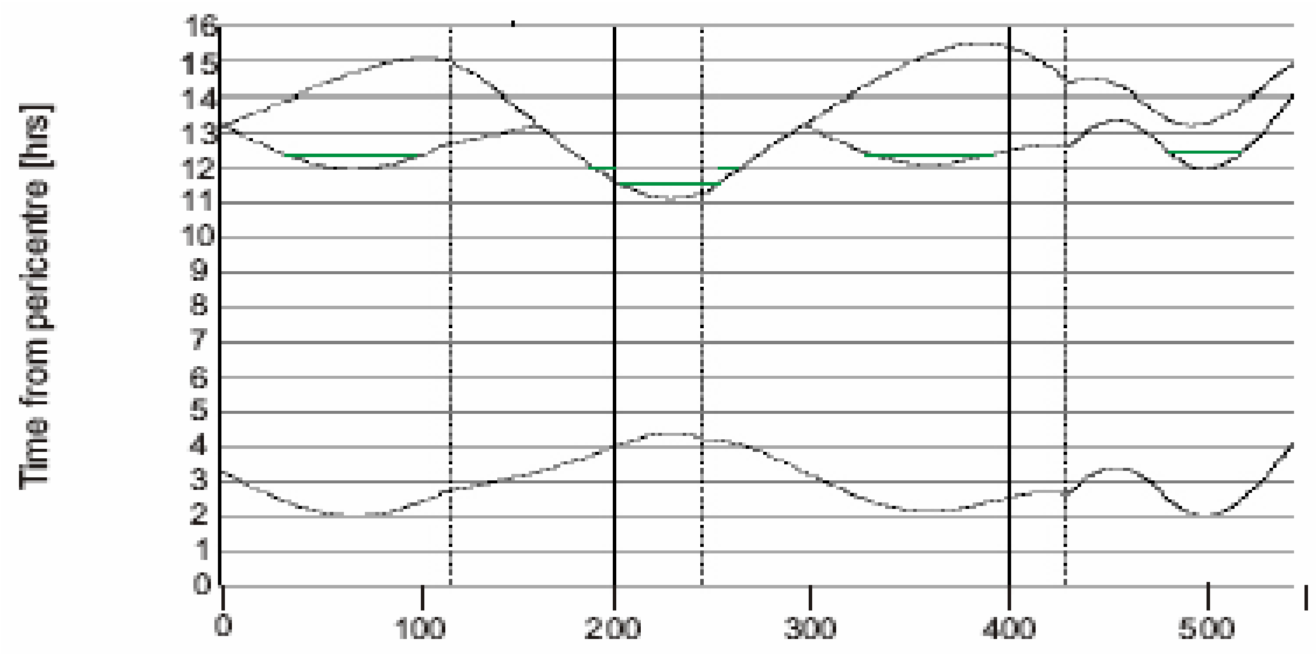


Figure 2.3 *Visibility of the Cebreros ground station from the satellite.*

The ground station at New Norcia, Australia, will be visible around pericentre and will be used for the radio science experiments. The DSN support to the VeRa bi-static radar, solar corona, and some radio occultations as well as the support for the data downlink in the periods of low data rate is agreed between ESA and NASA.

3. THE SAP PROPER

This section gives an overview of the Science Activity Plan as a whole (chapter 3.1). It is followed by descriptions of payload activity for the specific phases of the mission. Depending on the different environmental conditions (occultation, illumination conditions etc.), the science will focus on different mission objectives during the different phases.

3.1 Science Activity Plan overview

3.1.1 Coverage

The SAP will cover the complete nominal mission from June 4, 2006 till October 2, 2007 plus the commissioning phase. In case the mission will be extended, it is likely that the extended mission will be covered by a similar document for the extension. During the mission there will be different phases with different environmental conditions, which allow making specific science observations.

3.1.2 Mission Objectives

The Venus Express mission aim is a global investigation of the Venus atmosphere, plasma environment and some important aspects of the surface. The detailed Science Objectives of the Venus Express mission are described in AD6.

3.1.3 Main principles of the SAP development

The SAP development was based on the following principles:

1. Complete and uniform coverage of the science themes;
2. Balance between distant and close-up views of the planet;
3. Balance between the observations of the Northern and Southern hemisphere;
4. Synergy between experiments in covering science objectives;
5. Use of two cases in each orbit: one in pericentre and one in apocentre;

6. Even distribution of pericentic science cases with priority given to the solar and Earth radio occultation experiments in specific seasons of the mission;
7. Apocentric cases (#2 and #3) are grouped in campaigns of 10 orbits that is required by the atmospheric dynamics mission objectives.
8. Maximum compliance with the current flight rules.

3.1.4 Instruments objectives and Request Summary

3.1.4.1 Introduction

In this section the individual objectives for each instrument are summarised and their over all operational requests are listed.

3.1.4.2 ASPERA

ASPERA shall be ON during the entire mission thus permanently collecting data. Strategically the ASPERA activity will consist of two parts: survey observations in the beginning of the mission and more specific, more detailed observations performed on selected part of orbit later in the mission. Data is collected at different rates depending on the selected mode.

3.1.4.3 MAG

MAG shall be ON during the entire mission and would permanently collect data. Data is collected at different rates depending on the selected mode.

3.1.4.4 PFS

Environment independent. PFS will provide high spectral resolution observations of the Venus atmosphere with as full as possible latitude and local time coverage. Mars Express experience shows that repeated observations would be needed to get sufficient signal-to-noise ratio especially in case of observations of weak emissions from the night side.

3.1.4.5 SPICAV

Environment dependent. The main goal of the SPICAV experiment is to sound the Venus atmosphere in solar and stellar occultation geometry with sufficient latitude and local time coverage. In these cases SPICAV will define the spacecraft pointing profile. It will be hardly possible to combine solar occultation, that require SPICAV solar port pointing to the Sun, with observations of the +Z looking instruments. SPICAV stellar occultation that require +Z axis pointing to a star at the limb will be combined with the observations of other +Z looking instruments. In case of stellar occultation observations of dark limb are preferable.

Environment independent. (1). Nadir observations by SPICAV will be performed together with other +Z looking experiments. (2). SPICAV will observe the Venus hydrogen corona. For this purpose in apocentre the s/c will perform a 90 degrees slew from nadir pointing and back.

3.1.4.6 VeRA

The VeRa experiment will perform 4 kinds of *"environment dependent"* observations.

(1) Earth occultation with as good as possible latitude and local time coverage of Venus. Attitude profile in this experiment is the most demanding for the spacecraft AOCS system. It will be provided by the VeRa PI for each radio-occultation individually and will define the pointing for the other experiments. It would be highly desirable to select the orientation of the spacecraft +Z axis during radio occultation so that the +Z looking instruments could simultaneously see the planet.

(2). Bi-static sounding of surface targets. The radio-signal is sent to selected targets on the Venus surface. Reflected/scattered signal is received by the ground station. Since the reflected signal is very weak the efficiency of this experiment strongly depends on the Earth-Venus distance, geometry, and properties of the specific surface targets. For this reason (1) this experiment will be preferably (but not only) carried out when Venus is close to inferior conjunction, (2) DSN antennas should receive the signal and (3) specular reflection geometry will be maintained.

(3). Solar Corona observations. This shall be carried out in vicinity of conjunctions (both inferior and exterior). However thermal constraints related to illumination of the –X wall (payload radiators) by the Sun can impose severe limitations on the duration of this experiment in inferior conjunction.

(4). Gravity anomaly. This investigation consists of precise tracking of the spacecraft while it passes over global geological formations on Venus solid body. It will be carried out twice during the nominal mission.

Total number of New Norcia station passes allocated for this experiment (currently 60 passes plus 15 "at best effort basis" for the nominal mission) is the main limiting factor in this experiment. Moreover detection of weak signal in bi-static sounding experiment is possible only with 70-meter DSN antenna. Support from the DSN antennae for the VeRa experiments as well as for the data downlink is agreed between ESA and NASA.

3.1.4.7 VIRTIS

Environment independent. VIRTIS goal is to provide spectral mapping of Venus with moderate spectral resolution and high spectral resolution observations preferably imbedded in the spectral maps. The off-pericentre and apocentre observations will be organized in special VIRTIS campaigns. They will consist of similar sessions performed on several (about 5) consecutive orbits and would allow continuous temporal coverage of atmospheric dynamical phenomena. In these periods VIRTIS will define VEX operations (e.g. pointing). VIRTIS specific pointing request concerns the apocentric observations in which the experiment will take twelve images organised in a raster of 3x3 images of the whole Venus disc. That would require 12 spacecraft re-pointings by an angle of < 5 deg.

Environment dependent. VIRTIS will provide spectral mapping of specific surface targets in order to search for traces of volcanic activity, provide thermal mapping of geologically interesting regions. This type of activity is possible on the night side only.

3.1.4.8 VMC

Environment independent. The task of VMC is to perform wide-angle imaging of Venus in 4 narrow spectral channels. VMC has no specific pointing requirements.

Environment dependent. VMC will provide imaging of specific surface targets in order to provide thermal maps of geologically interesting regions. This type of activity is possible on the night side only.

3.2 Nominal Mission Overview

The mission overview is shown in the Annex 1. The table below briefly describes the mission phases.

Phase	Duration, Days from start of mission	LTAN *)	Data rate, Mbits/ day	Scientific focus
#0	**-30…0**	**~12**	**3000**	**Commissioning of individual experiments** **Science Cases commissioning** **Extended case commissioning** **Dayside dynamics** **Solar occultation**
#1	**0…50**	**~18**	**2500**	**Morning/evening terminator**
#2	**50…100**	**~0**	**2000**	**Night side dynamics** **Radio-occultation** **Solar occultation**
#3	**100…170** **Outage ~20 days**	**~6**	**1500 (min)**	**Solar corona studies** **Systematic study of morning/evening sectors**
#4	**170…250**	**~12**	**1500 (min)**	**Dayside dynamics** **Radio-occultation**

				Solar occultation
#5	**250…290**	**~18**	**2000**	**Morning/evening terminator**
#6	**290…340**	**~0**	**2500**	**Nightside dynamics** **Solar occultation**
#7	**340…400**	**~6**	**4000 (max)**	**Earth occultation** **South pole mosaic** **Bi-static sounding** **Morning/evening sector**
#8	**400…450**	**12**	**1000 (min)**	**Dayside dynamics** **Solar occultation** **Solar corona studies** **Bi-static sounding**
#9	**450…500**	**18**	**3000**	**Morning/evening terminator** **Bi-static sounding**
#10 (exten.)	**500…550**	**24**	**1000**	**Earth occultation** **Morning/evening sector**

*) LTAN – Local Time of Ascending Node

3.3 Phase 0

3.3.1 Scientific focus

The initial phase of the mission will mainly be devoted to the spacecraft and payload checkout and in orbit commissioning. The phase will consist of the following parts:

- Experiments commissioning (till May 14, 2006, Orb #23);
- Science Case commissioning (May 15 – 27, Orb #23-36);
- Extended Case commissioning (May 28 – June 3, Orb #37-43). The ECC will also occupy the first half of phase 1

3.3.2 Environmental conditions

Local Time at Ascending Node (LTAN): ~10-14 h

Occultations: Solar occultation season till Orbit 41 (May26, 2006)

Night side surface targets: TBD

Data rate: 3300-2500 Mbits/day

The phase 0 belongs to the “hot” type, i.e. the –Z wall is illuminated by the sun during Case#2 and #3 observations

3.3.3 Timeleine

Dates: May 14 – June 3, 2006

Orbits #23-43 (Flight Dynamics orbit numbering)

Phase duration: 20 days

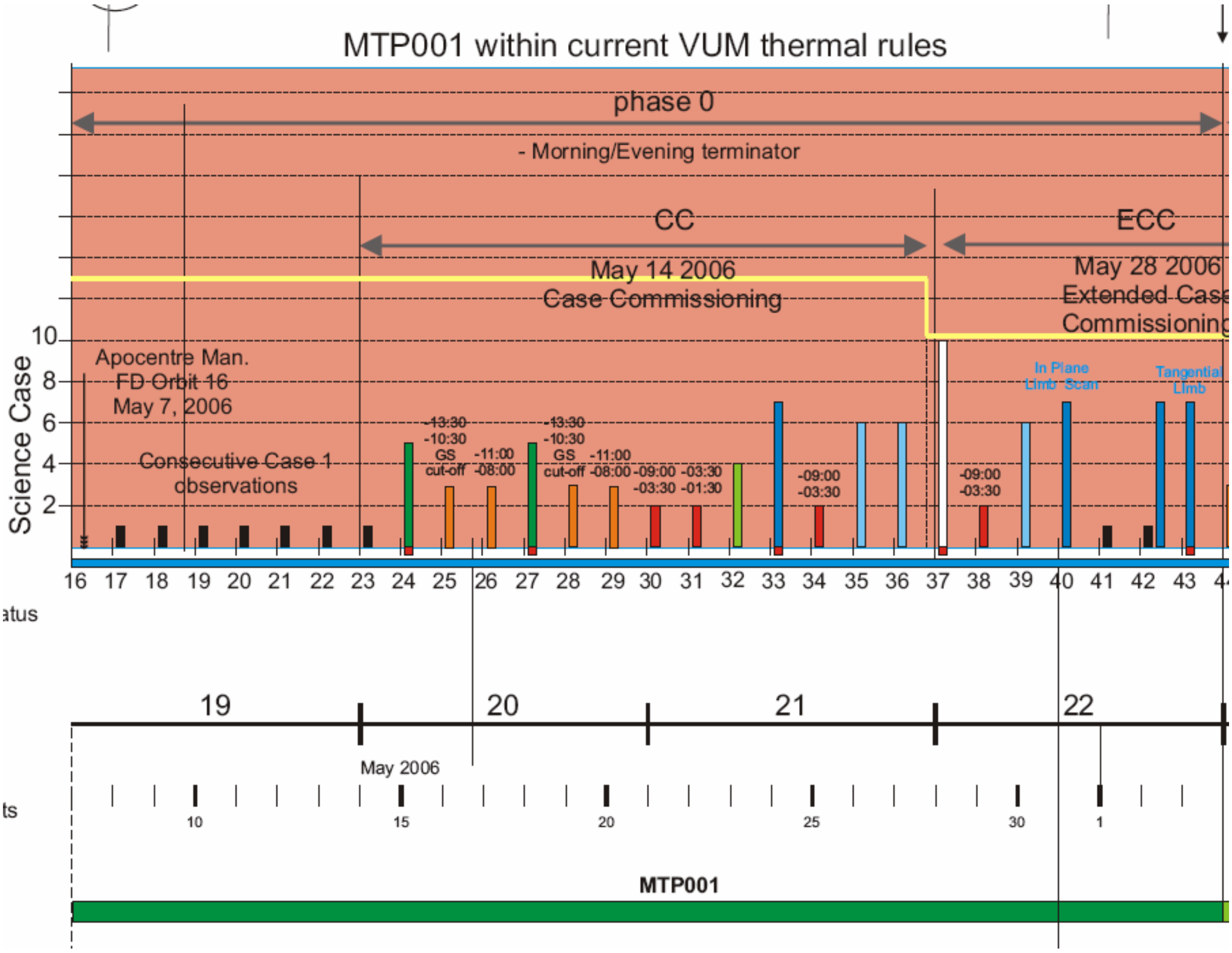


Figure 3.1 Phase 0 timeline.

3.3.4 Individual Instrument Objectives and Requests Description

Table 3.5. Observations of individual experiments.

Experiment	Observations	
	Environment independent	**Environment dependent**
ASPERA	Night side plasma observations except for the time devoted to individual commissioning of other experiments.	
MAG	Magnetic field	
PFS	Commissioning	

SPICAV	Commissioning of nadir observations and H-corona obs.	Commissioning of the solar occultation
VeRa		Bi-static radar commissioning
VIRTIS		Instrument and case commissioning
VMC		Instrument and case commissioning

3.4 Phase I

3.4.1 Scientific focus

Geometry in the Phase 1 is favourable for observations of the evening terminator vicinity. Main scientific focus of this phase is to provide observations of the morning/evening terminator. In particular the following observations will be performed:

- Cloud observations at terminator that would exploit illumination conditions favourable for the study of cloud and haze structure;
- Search for lightning on the night side;
- Double stellar occultation on the dark limb that would allow one to study north-south asymmetry of the aerosol vertical structure;
- Grazing solar occultation (early in the phase) that would allow one to probe horizontal structure of the hazes above the main cloud deck;
- Thermal mapping of the surface targets (Ishtar Terra, Maxwell Montes);
- Limb observations to study vertical structure of haze layers;
- Observations of the nightglows (O2, NO…) and their latitude and vertical variability.
- Bi-static sounding of the Maxwell Montes (BSR#1)
- June 5, 2006 will be devoted to the observations by SPICAV and VMC of the comet Mrkos….. that will be at closest approach to Venus on this day.

3.4.2 Environmental conditions

Local Time at Ascending Node (LTAN): ~14 - 22 h

Occultations: none

Night side surface targets: TBD

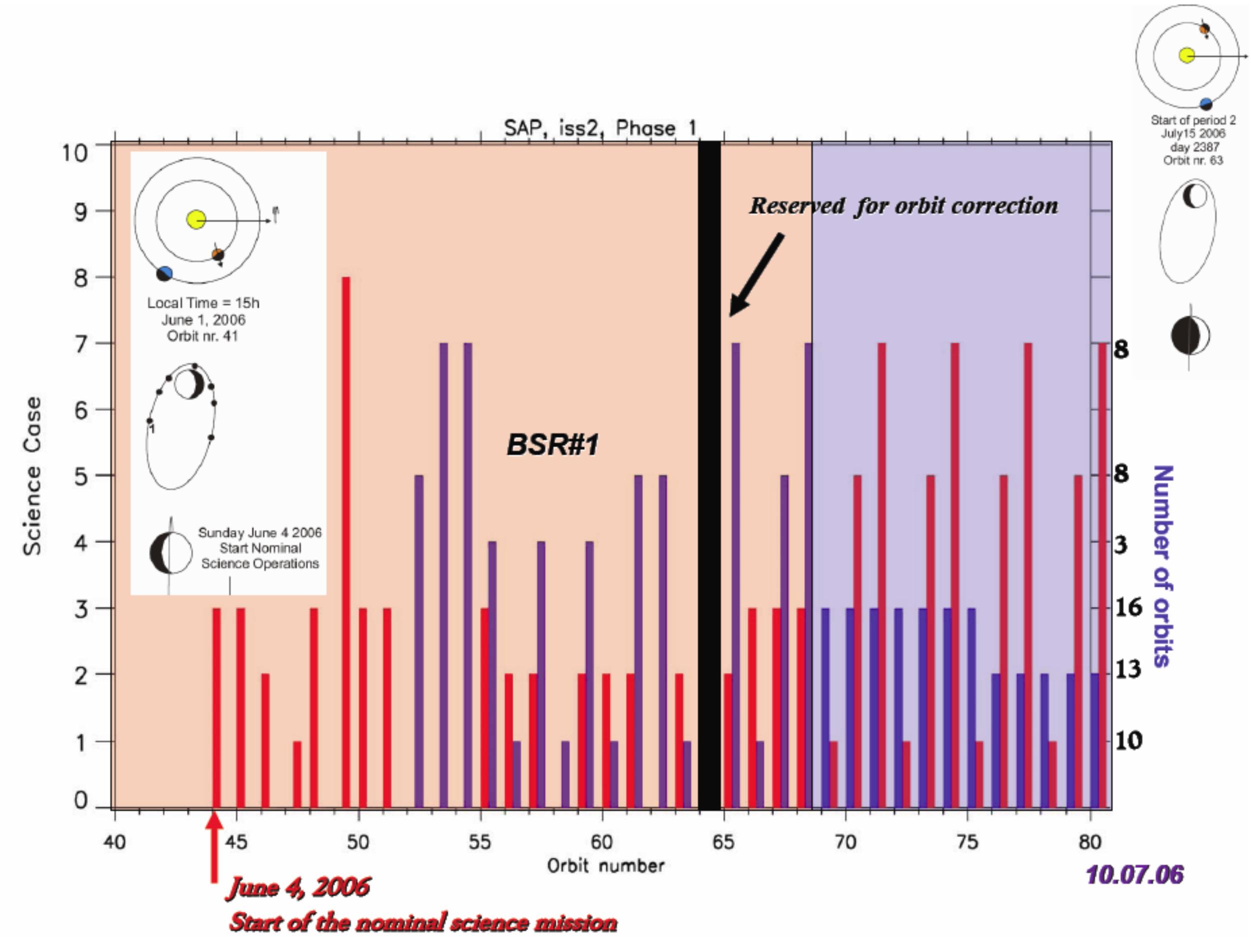


Figure 3.2 *Phase I timeline.*

Science data dump: 2500-2100 Mbits/day

The first half of the phase is of so called “hot” type. That means that the LTAN is between 6 and 18 hours and that the –Z panel of the spacecraft is exposed to the sun in off-pericentre cases (#2 and #3) with corresponding operational constraints applied.

3.4.3 Timeline

Events:<Start>=End of Commissioning; <End> = Start of Earth Occultation season #1

Dates: June 4 – July 10, 2006

Orbits # 44-81

Phase duration: 37 days

3.4.4 Individual Instrument Objectives and Requests Description

Table 3.4. Observations of individual experiments.

Experiment	Observations	
	Environment independent	Environment dependent
ASPERA	Survey observations	
MAG	Magnetic field	
PFS	Observations of the morning/ evening sector.	
SPICAV	Observations in nadir mode (15 min slots) together with other +Z looking instruments.	Stellar occultation according to the agreed list of stars.
VeRa		Bi-static sounding (BSR#1) of the Maxwell Montes on descending branch.
VIRTIS		(1). Evening sector of the planet (2). Night side mosaic observations (3).Thermal mapping of the surface (Maxwell Montes). (4). Limb observations
VMC		(1). Evening sector of the planet (2). Thermal mapping of the surface (Maxwell Montes). (3). Limb observations

3.4.5 Discussion

1. In the beginning of the phase (orbits #44-#68) the off-pericentre observations (cases #2 and #3) result in the Sun on –Z wall. Thus, the combination of pericentre and off-pericentre observations will be possible only if the pericentre observations are carried out in cold attitude of the satellite, i.e. in inertial power optimized pointing that keeps the sun in the +Z/+X quadrant.
2. In the first 20 days descending branch of the orbit passes over the Ishtar Terra and Maxwell Montes at night thus providing ideal conditions for thermal mapping of this

region. Pericentre observations (including limb and stellar occultation) should be organised so that to have +Z pointing close to local nadir when flying over Ishtar Terra.

3. BSR #1 experiment will also have Ishtar Terra and Maxwell Montes as a target.

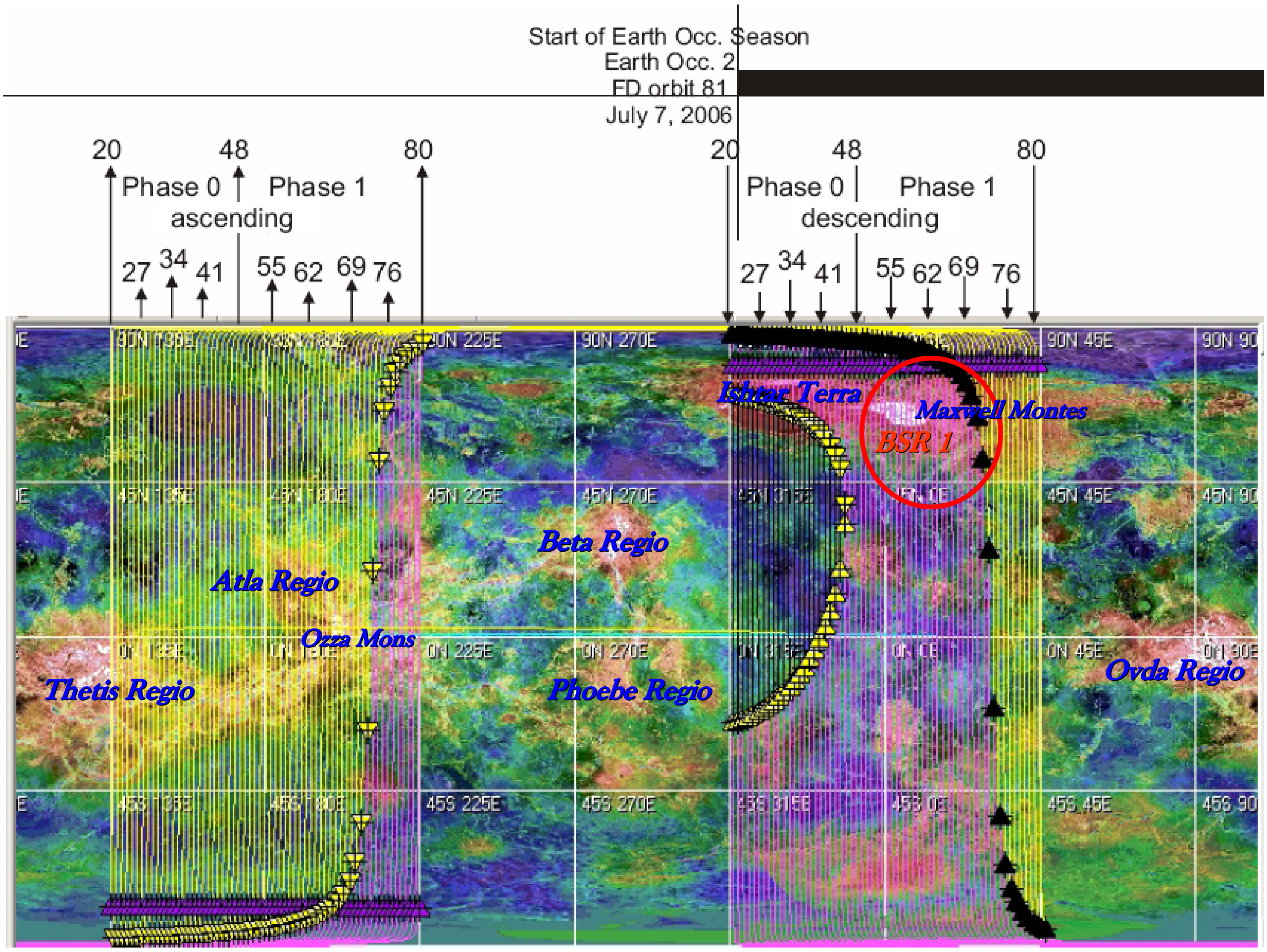


Figure 3.3 *Projection of the orbital tracks on the Venus surface in the Phases 0 and I with the region of bi-static sounding #1 shown in red circle.*

3.5 Phase II

3.5.1 Scientific focus

Phase 2 provides favourable conditions for the Earth and solar occultation, and for the nadir observations of the night side. The following observations will have highest priority in this phase:

- Solar occultation;
- Earth radio-occultation;
- Nightside dynamics with high spatial resolution;
- Twilight limb observations in forward scattering geometry
- Nightglow observations;
- Thermal mapping of the surface.

Overlap of the Earth occultation and eclipse seasons in the phase results in a dense "population" with Case#6 and Case#8 orbits. This results in that Case #1 repeats only in each 4-th orbit in the second half of the phase (orbits #60-98). Case #7 orbits are imbedded in the eclipse season to provide twilight limb observations in forward scattering geometry (Sun behind the planet) that should be effective in sounding of the structure and particle population of the haze layers above the main cloud. Also tangential limb sounding will be used.

3.5.2 Environmental conditions

Local Time at Ascending Node (LTAN): ~ 22 – 4h

Sun illumination: Cases#2 and #3 can be run without exposing –Z wall to the Sun ("cold" phase)

Occultations: Earth occultation, Solar occultation

Night side surface targets: Beta Regio, Theia Mons, Phoebe Regio, Ishtar Terra (Lakshmi PLanum) in ascending branch

Science data dump: 1500 Mbits/day

3.5.3 Timeline

Events: <Start> = Start of the Earth occultation season #1

<End> = End of Eclipse season #1

Dates: July 11 – September 13 2006

Orbits # 81 - 145

Phase duration: 64 days

The timelines for MTP#3-5 of the phase II are shown in the Figures 3.4-3.6

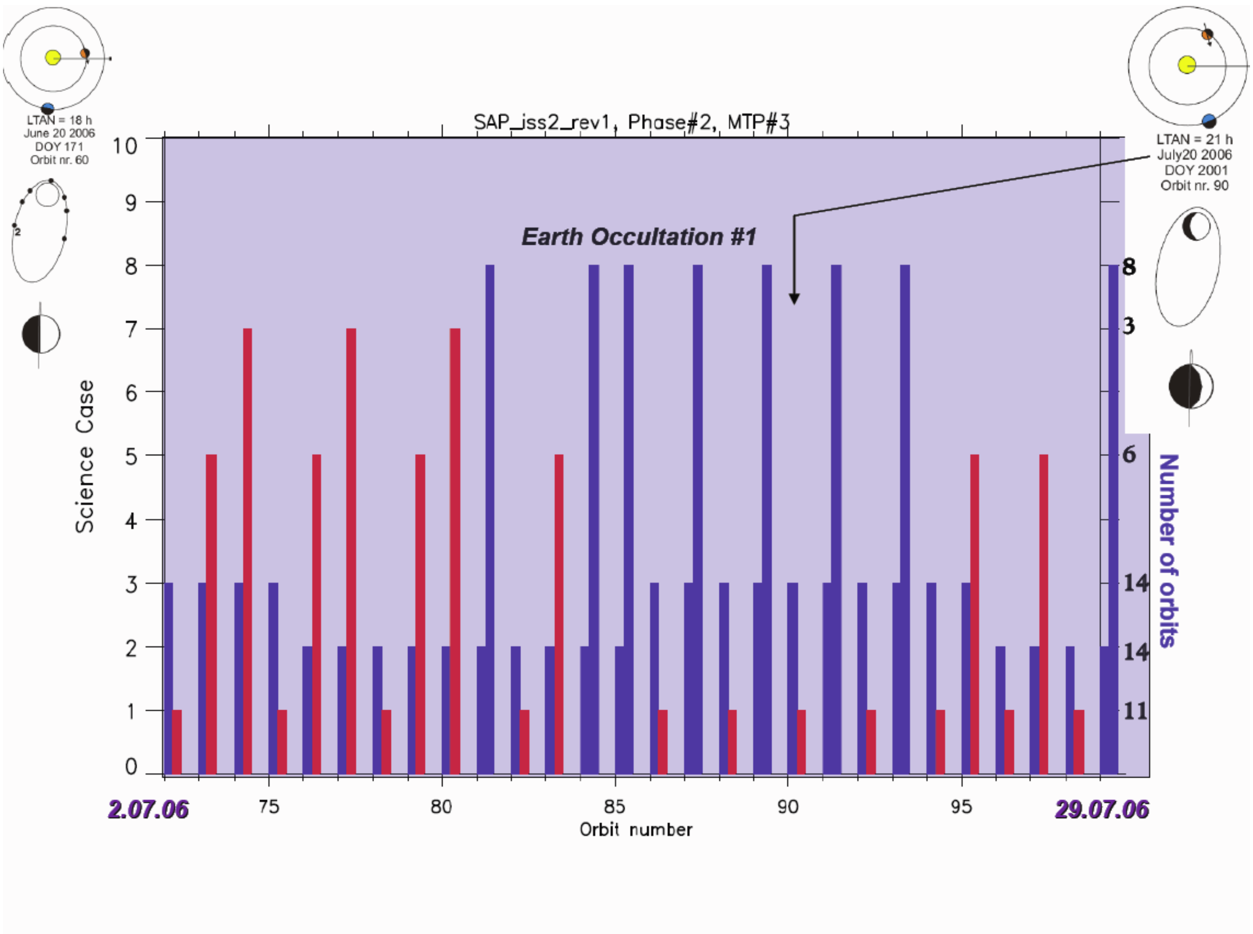


Figure 3.4 MTP#3 timeline

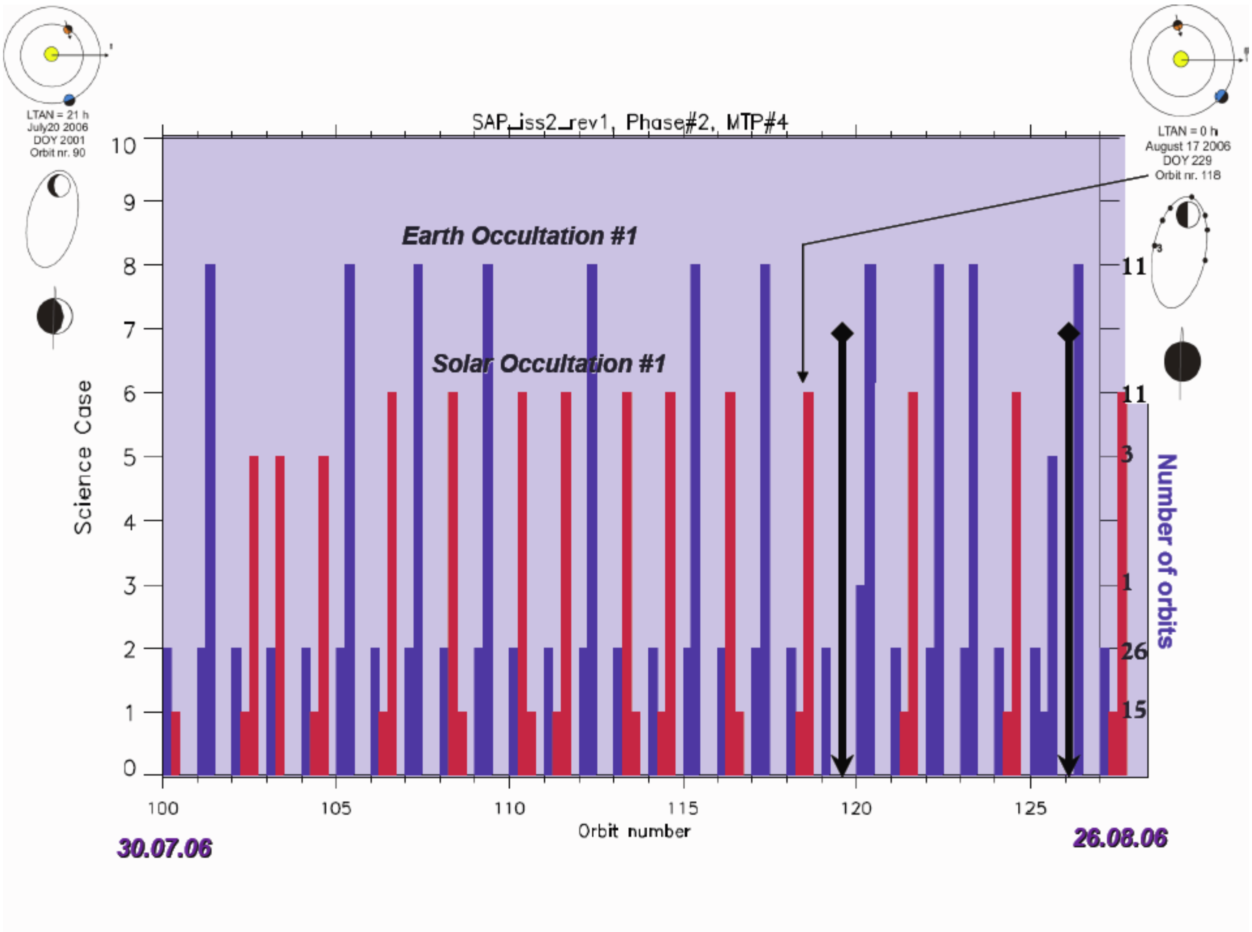


Figure 3.5 MTP#4 timeline

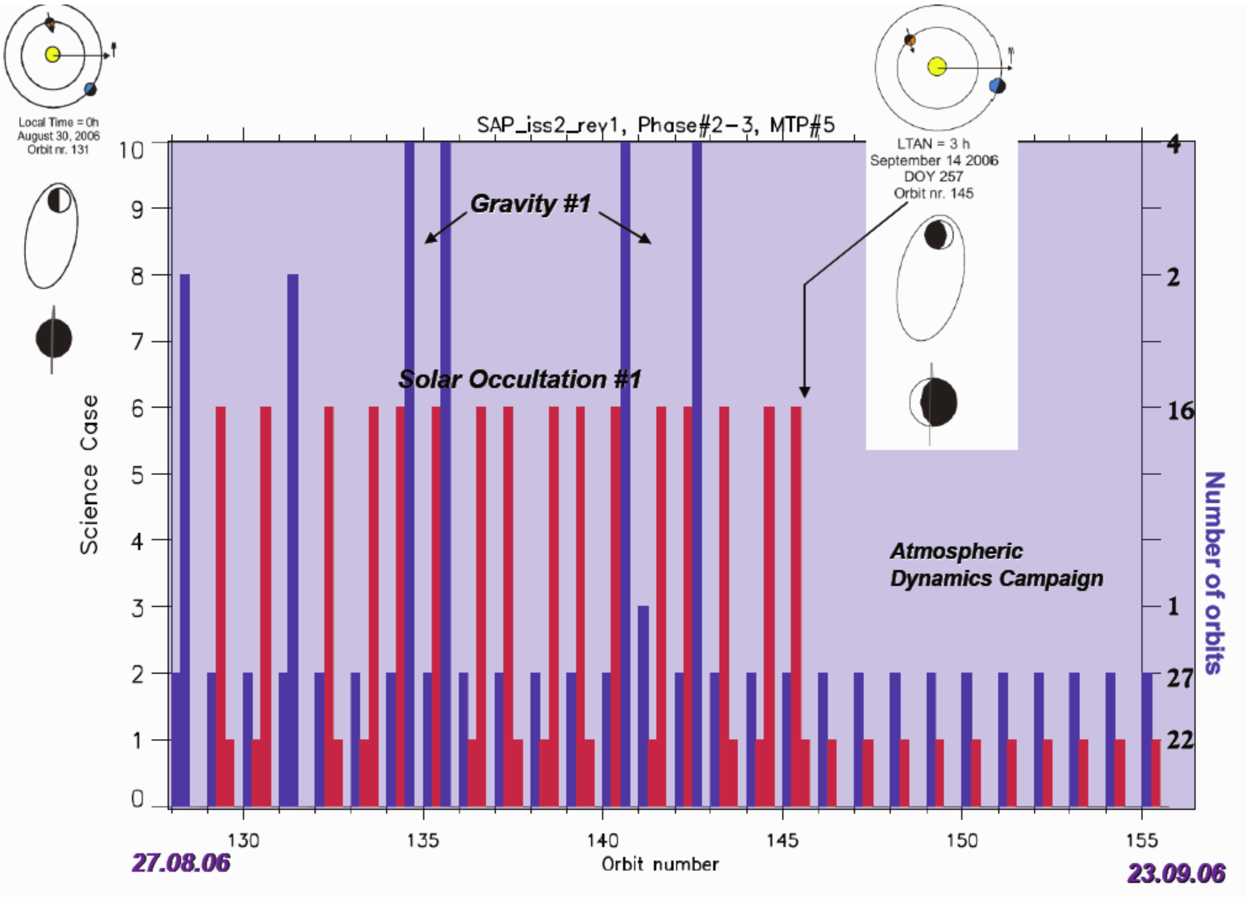


Figure 3.6 MTP#5 timeline

3.5.4 Individual Instrument Objectives and Requests Description

Table 3.5. Observations of individual experiments.

Experiment	Observations	
	Environment independent	Environment dependent
ASPERA	Night side plasma	
MAG	Magnetic field	
PFS	Night side observations	
SPICAV	Observations in nadir mode (15 min slots) together with other +Z looking instruments.	Solar occultation season #1: simultaneous occultation in the north and south hemispheres. Occultation should be uniformly distributed with latitude.

VeRa		(1). Earth occultation season #1. (2). Gravity #1 experiment
VIRTIS		(1). Night side atmospheric dynamics (2) Night side surface mapping (Beta Regio, Theia Mons, Phoebe Regio, Ishtar Terra (Lakshmi PLanum)) (ascending branch)
VMC	Night side observations with emphasis on the global observations in Cases 2 and 3.	(1). Night side atmospheric dynamics (2) Night side surface mapping (Beta Regio, Theia Mons, Phoebe Regio, Ishtar Terra (Lakshmi PLanum)) (ascending branch) (3). Nightglow and search for lightning

3.5.5 Discussion

(1). Since in this phase cases#2 and #3 can be run “cold”, i.e. without exposing –Z wall to the Sun, combining of pericentre and off-pericentre observations in one orbit would be possible if updated VUM would either give thermal recovery times <10 hours for pericentre cases or would allow the switch on of the instruments while the spacecraft is in thermal recovery break. This issue is expected to be resolved by additional thermal modelling of the science cases. It is also possible to run combinations of pericentre and apocentre cases if pericentre ones are reduced to cold configuration.

(2). Groups of different versions of Case#2 (2a, 2b, 2c..) proposed by the VIRTIS Dynamics Group [AD4] should be run in turn, i.e. ten orbits of Case#2a, ten orbits of Case#3, ten orbits of Case#2b etc. However the constraints related to late completion of the telecommunications will limit case #3 observations.

(3). Earth occultation experiment can be performed with +Z axis pointing towards the planet, thus allowing the other instruments to observe the planet simultaneously. Visibility of the planet by the +Z instruments during the Earth occultation will be assessed by the VeRa PI. In case of the Earth in the orbital plane there is a chance to observe the same region on the planet in nadir and occultation geometry that is of great scientific value.

(4). In this phase solar occultation occur on ascending branch of the orbit. In each orbit solar occultation can be combined with +Z observations of the planet after egress occultation is completed. For this the s/c should be turned in inertial orientation with +X to the Sun and +Z pointing close to local nadir in the vicinity of the North pole. A possibility to start inertial pointing after egress occultation should be also studied. In this case the descending part of pericentre pass will be performed in the Case #1 configuration. This combination (as well as that with Case #8) would allow to compensate small number of pure Case #1 in orbits 110 – 145.

(5). Gravity #1 experiment will be performed at the descending branch of the orbit and will investigate Atalanta Planitia which was poorly studied by Magellan. It will be started in the end of phase II and completed in the beginning of Phase III. This experiments should be combined with the +Z observations when possible. Illumination of the –X wall during the Gravity 1 experiments should be checked.

(6). The downlink capabilities in phase II are very limited. The instruments (especially VIRTIS, VMC and ASPERA) should provide a strategy of data volume reduction.

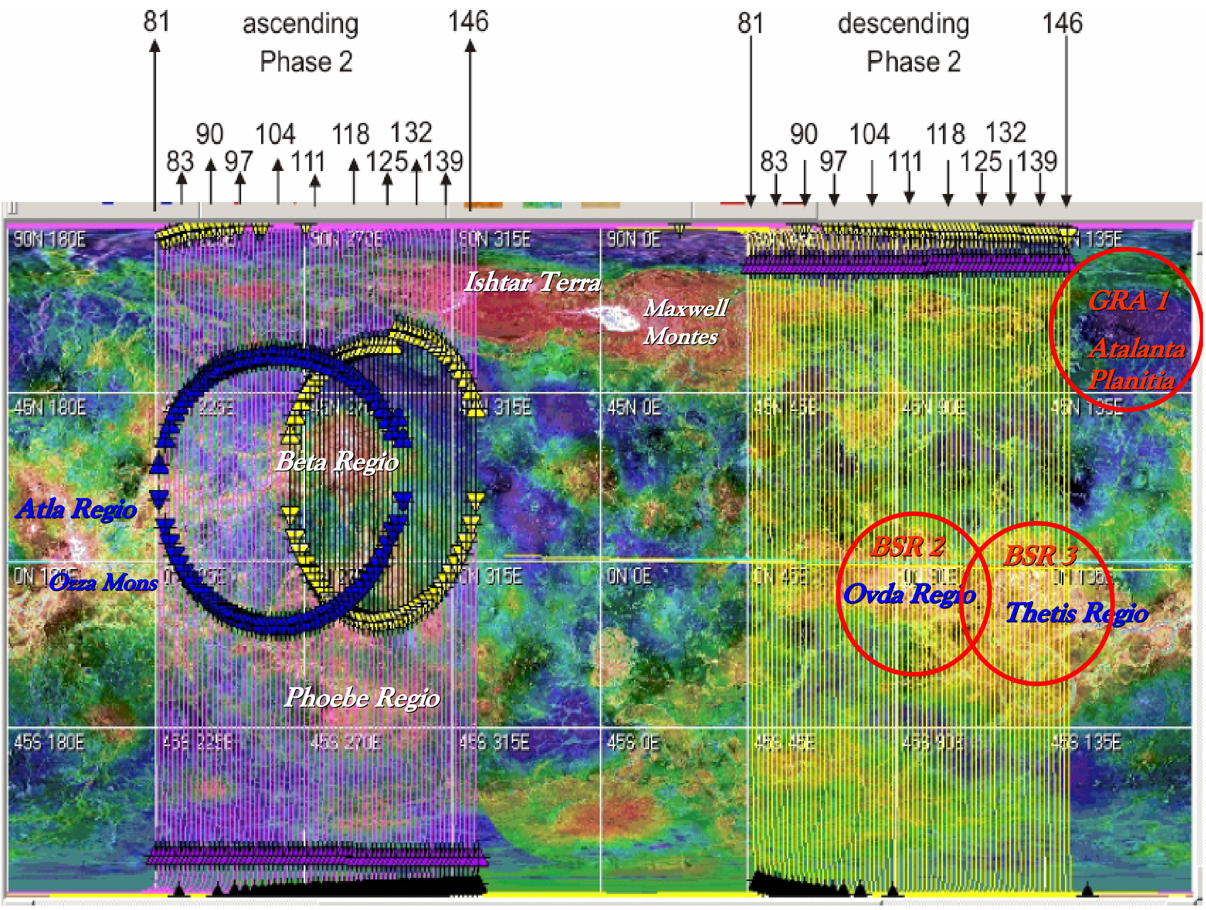


Figure 3.7. *Projection of the orbital tracks on the Venus surface in the Phase II. Triangles show the spacecraft position where occultation occurs. It should be taken into account that in case of radio occultation the beam swings around the planet below 60 km altitude thus resulting in significant longitude averaging.*

3.6 Phase III

3.6.1 Scientific focus

In the beginning of Phase 3 the Venus dark side could be observed. This opportunity will be used by the payload for thermal mapping of the surface and observations of the night side dynamics. Phase 3 will also have conditions for systematic observations of the morning/evening terminator. The phase will end with the superior conjunction outage period of ~ 20 days. Another peculiarity of this phase is minimum downlink capabilities that should be taken into account in planning the observations. Radio science will have conditions for Solar corona studies. In particular the following observations will be performed:

- Cloud observations at terminator that would exploit illumination conditions favourable for the study of cloud and haze structure;
- Coordinated campaign of atmospheric dynamics observations in Northern and Southern polar regions;
- Search for lightning on the night side;
- Double stellar occultation on the dark limb that would allow one to study north-south asymmetry of the aerosol vertical structure;
- Mapping of the surface targets (Ishtar Terra);
- Limb observations to study vertical structure of haze layers;
- Observations of the nightglows (O2, NO…) and their latitude and vertical variability;
- Solar corona studies;
- Gravity anomaly #1

3.6.2 Environmental conditions

Local Time at Ascending Node (LTAN): 4 - 10 h

Peculiarities: Superior Conjunction

Occultations: none

Night side surface targets: TBD

Low downlink rate: 1200 Mbits/day

3.6.3 Timeline

Events: <Start> = End of Eclipse season #1

<End> = Start of Eclipse season #2

Dates: September 14, 2006 – November 15, 2006

Orbits # 146 - 208

Phase duration: 62 days

The timelines for MTP#6, 7 of the phase III are shown in the Figures 3.8-3.9. Beginning of the phase is shown in Figure 3.6 (section 3.5).

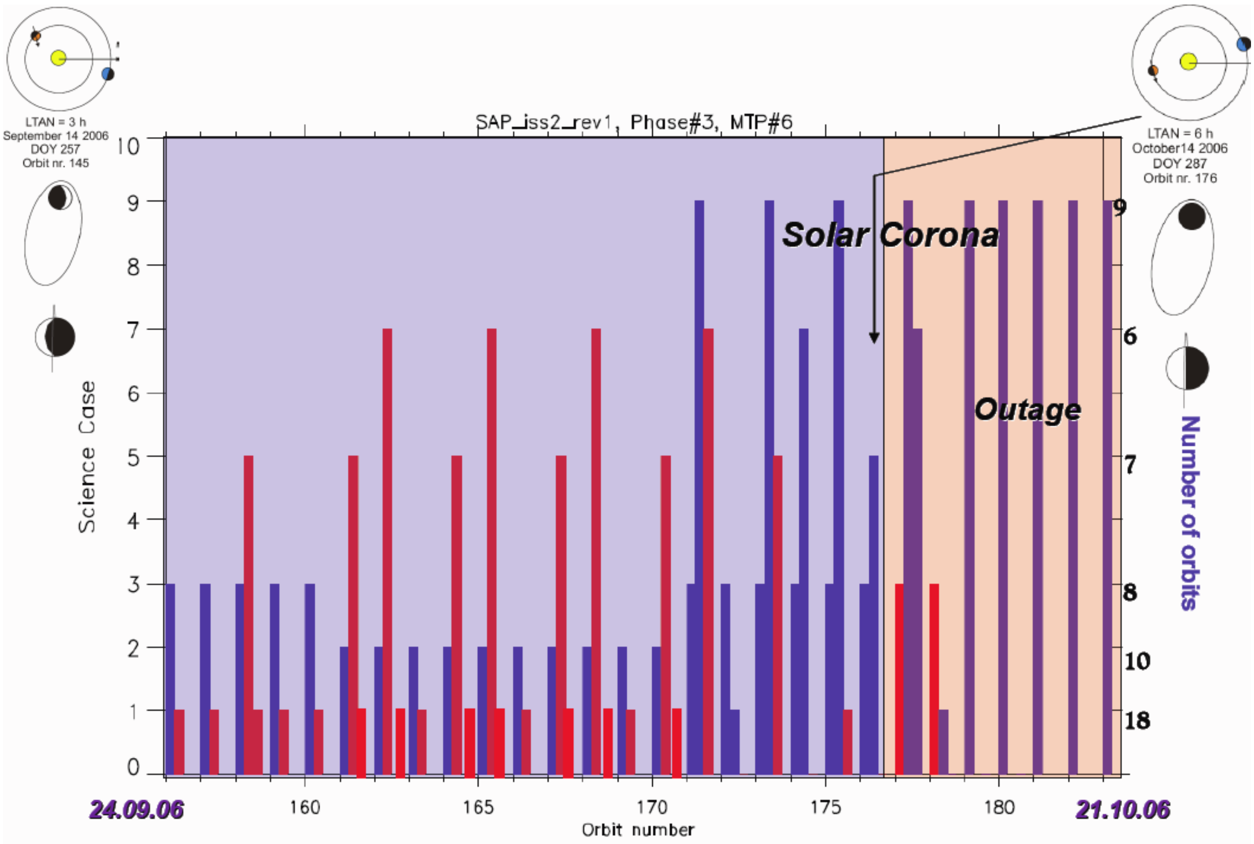


Figure 3.8. *MTP#6 timeline.*

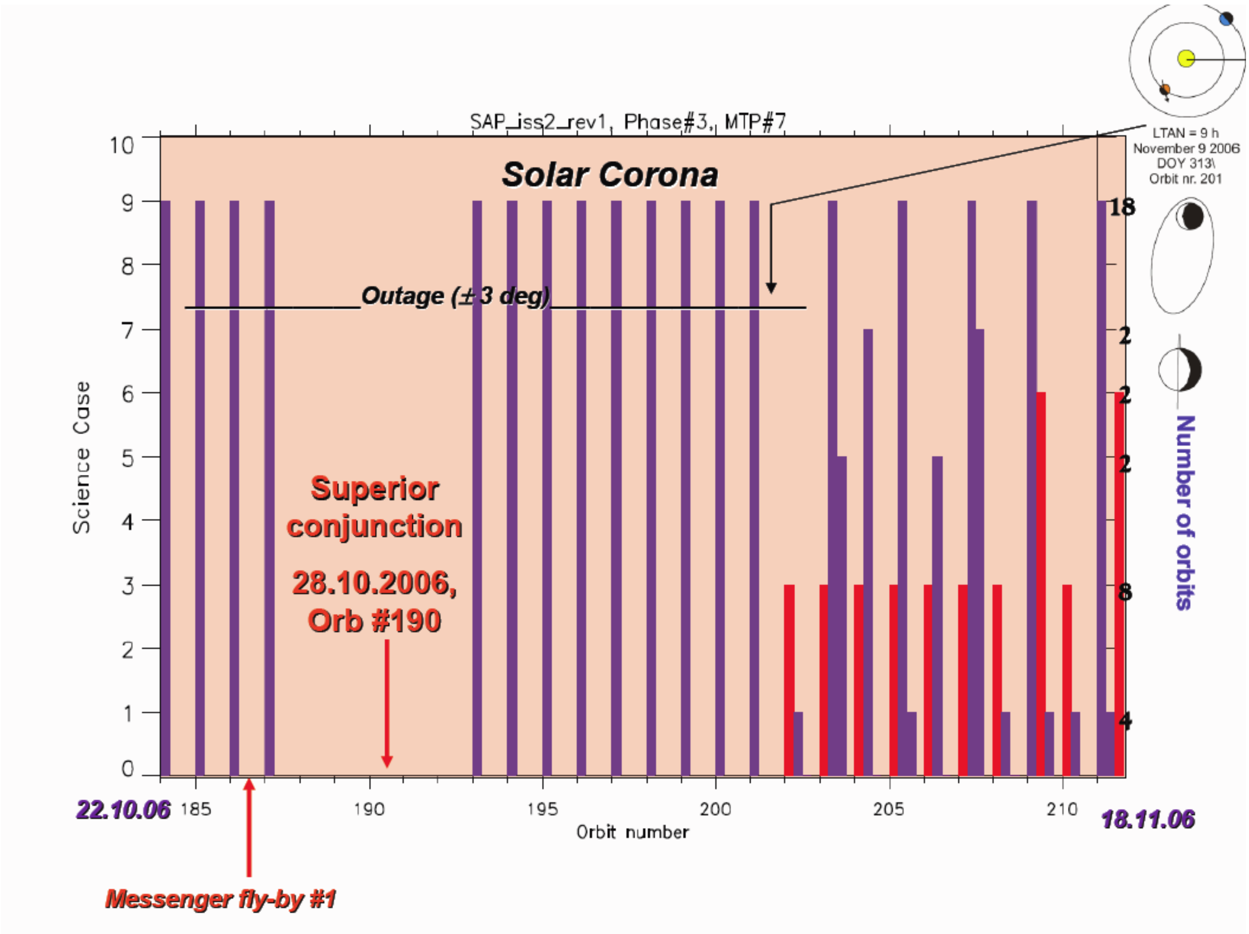


Figure 3.9 MTP#7 timeline

Phase III

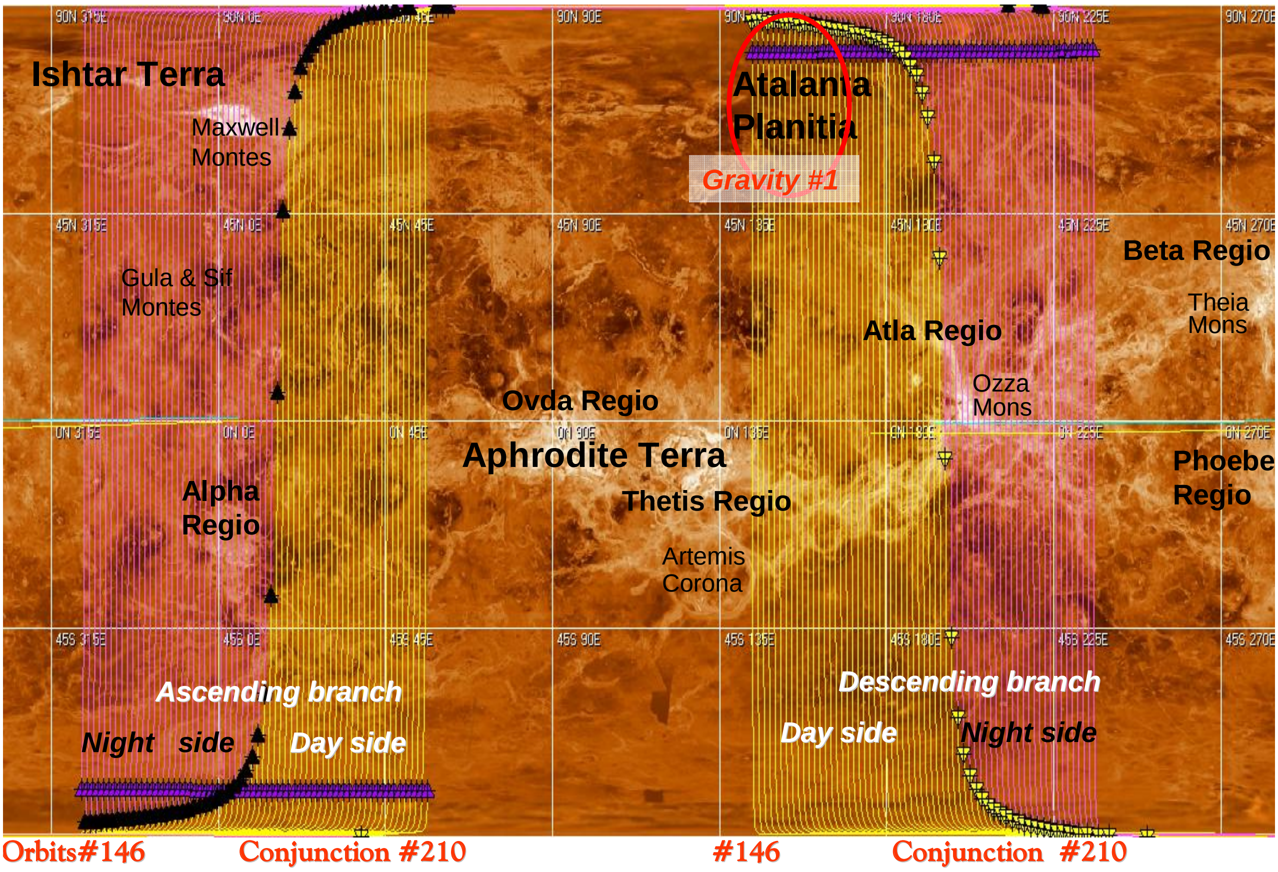


Figure 3.10. *Projection of the orbital tracks on the Venus surface in the Phase III. Triangles show the spacecraft position where occultation occurs.*

3.6.4 Individual Instrument Objectives and Requests Description

Table 3.5. Observations of individual experiments.

Experiment	Observations	
	Environment independent	Environment dependent
ASPERA	Detailed observations of the morning sector in selected portions of the orbit.	
MAG	Magnetic field in the morning sector.	
PFS	(1). Systematic study of the morning sector; (2) North/South polar dynamics campaign	
SPICAV	Observations in nadir mode (in 15 min slots) together with other +Z looking instruments.	Stellar occultation
VeRa		(1). Solar Corona (3). Gravity anomaly #1 (cntd from phase II)
VIRTIS	North/South polar dynamics campaign	(1). Night side observations (Ishtar Terra) (2). Observations of the morning sector.
VMC	North/South polar dynamics campaign	(1). Thermal mapping of the surface on the night side (Ishtar Terra); (2). High-resolution atmospheric dynamics on the dayside; (3). Nightglow and search for lightning

3.6.5 Discussion

(1). Off pericentre cases:

- In the first half of the phase III (orbits 146-180) the cases#2 and #3 can be run "cold", i.e. without exposing –Z wall to the Sun. This allows combining of pericentre and off-pericentre observations in one orbit if updated VUM would either give thermal recovery times <10 hours for pericentre cases or would allow the switch on of the instruments while the spacecraft is in thermal recovery break. This issue is expected to be resolved by additional thermal modelling of the science cases.
- Groups of different versions of Case#2 (2a, 2b, 2c..) proposed by the VIRTIS Dynamics Group [AD4] should be run in turn, i.e. ten orbits of Case#2a, ten orbits of Case#3, ten orbits of Case#2b etc.
- North-South pole dynamics campaign. It would be beneficial to merge cases #3, #2, and #1 to get complete pole-to-pole coverage. It is important to get continuous "slice" of observations covering all latitudes. However the downlink budget can impose limitations on the observation modes.

(2). North-South dynamics campaign in the beginning of the phase will also give good conditions for thermal mapping of the Ishtar Terra (Lakshmi Planum, Maxwell Montes).

(3). Solar Corona studies (case#9). 28.10 is the date of Superior Conjunction. Solar Corona study will be performed +/- 40 days around this date. This VeRa investigation has no thermal constraints in this season. Second half of the phase is almost entirely inside the outage period. Since Solar Corona experiment requires observations during -5…+5 hours it can impose limitations on the Case #2 observations in this period. Duration of the experiment should be maximised. The signal should be received by the ground station with X and S band. The Canberra station will give the experiment time between -5 and +5 hours. Using the Goldstone antenna would shift this slot towards apocentre thus giving more flexibility in combining the case#9 with cases #2 and #3. Combination of the Solar Corona experiment with the downlink seems to be hardly possible due to limitations of the ground stations.

(4). Downlink capabilities in phase III are very limited. The Science Team should agree upon a strategy of downlink share. Use of the DSN stations to increase downlink capabilities is under discussion.

(5). It is possible for VeRa to use the Solar Corona experiment for additional data downlink, i.e. to leave the TM on. It is feasible technically, but organizational and financial issues should be solved.

(6). The first Messenger Venus flyby will take place on October 24, 2006. However, this will be the time of superior conjunction when no science operations are foreseen.

3.7 Phase IV

3.7.1 Scientific focus of the Phase IV

This mission phase will have solar occultation, dayside off-pericentre observations, and Earth radio occultation as first priority. Solar occultation measurements will be given relatively high weight in order to achieve good latitude coverage. In orbits #190-200 cases#1,#4 and #8 sound approximately the same region in the Northern hemisphere. This opportunity can be used for correlated observations of the atmospheric structure. Observations of the Venus day side when the planet is in full phase are of high importance especially for atmospheric dynamics. There are two aspects that limit these observations in phase 4. First, thermal limitations (sun on the –Z wall) will reduce observation time from 8 to 5-3 hours. Second, the downlink rate is low in this period that would not allow the experiments to use high resolution modes. Radio occultation experiment will be carried out at moderate frequency since its efficiency in phase 4 is strongly reduced by large distance to Venus. Solar Corona sounding will be continued.

3.7.2 Environmental conditions

Local Time at Ascending Node (LTAN): ~10-14 h.

Occultations: Earth occultation season 2, Solar Occultation season #2.

Science data dump: 800-1400 Mbits/day.

Thermal constraints in cases #2 and #3 due to illumination of –Z panel.

3.7.3 Timeline of the Phase IV

Events: <Start> = Start of Eclipse season #2

<End> = End of Earth occultation season #2

Dates: November 16, 2006 – January 31, 2007.

Orbits # 209-285

Phase duration: 76 days

The timelines for MTP#8-10 of the phase IV are shown in the Figures 3.11-3.13.

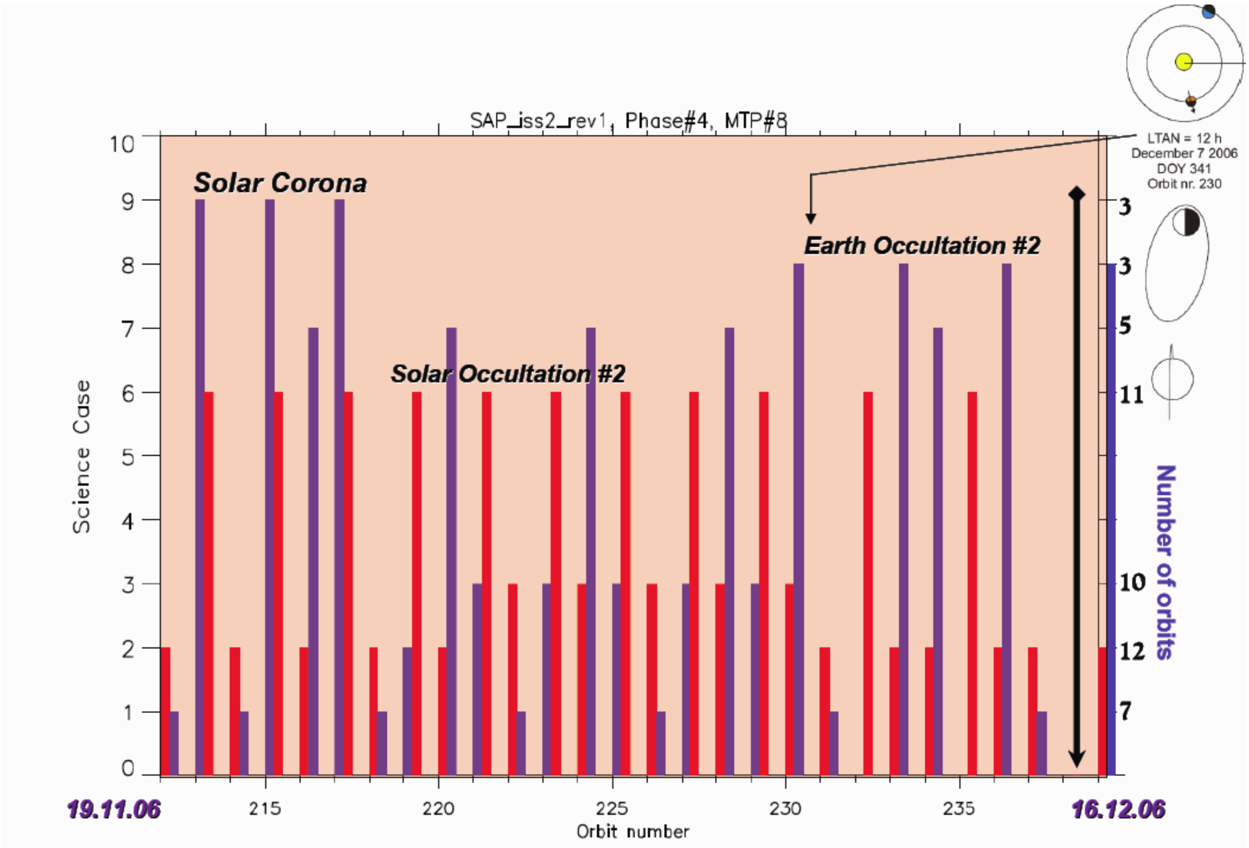


Figure 3.11 ***MTP#8 timeline*.**

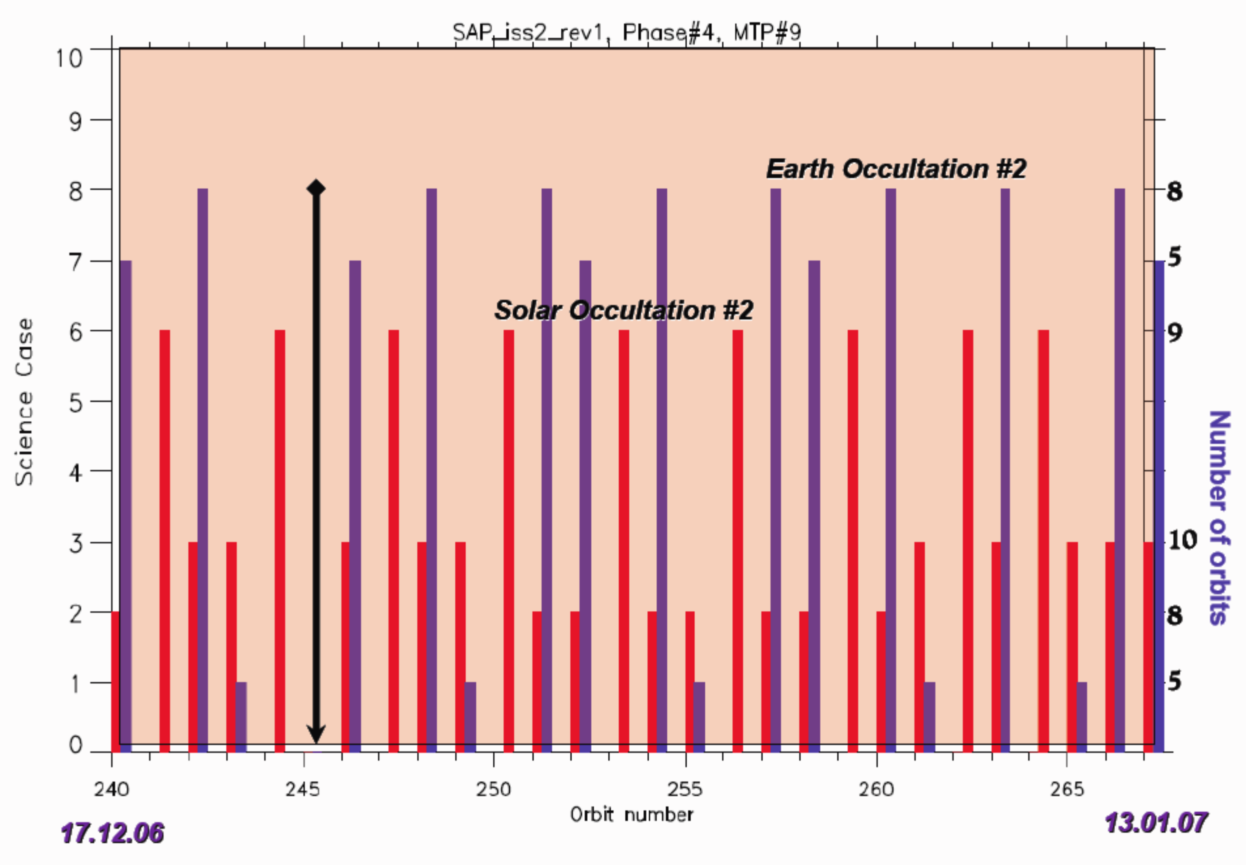


Figure 3.12 MTP#9 timeline.

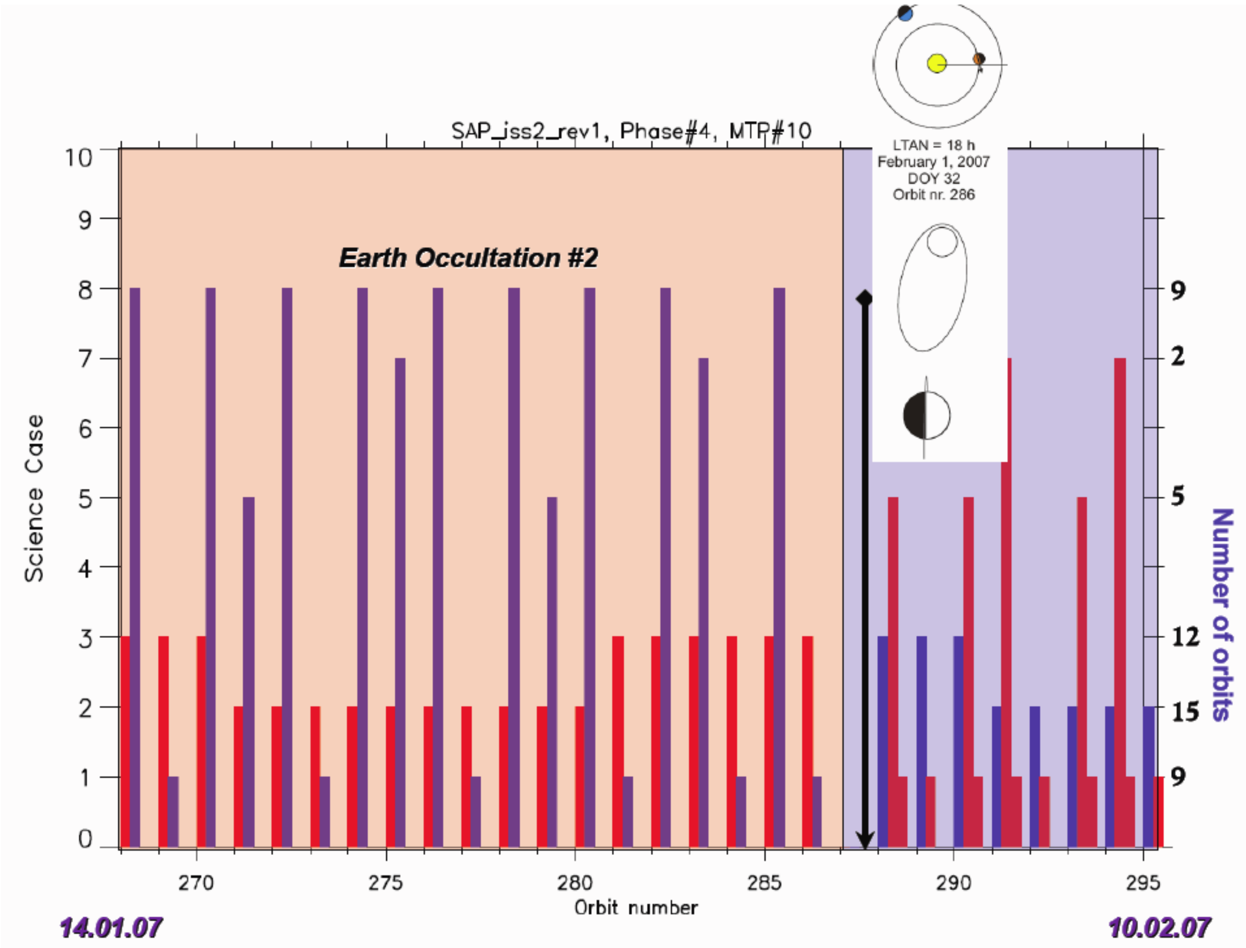


Figure 3.13 MTP#10 timeline.

Phase IV

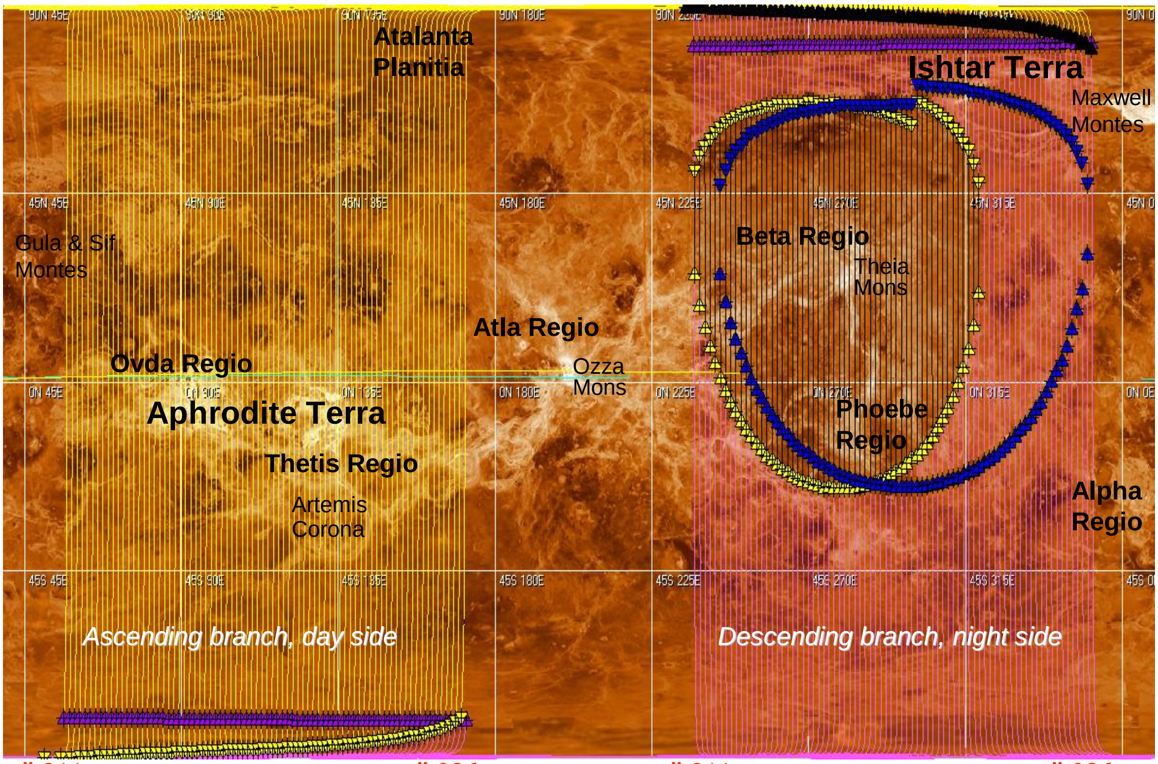


Figure 3.14 *Phase IV timeline.Projection of the orbital tracks on the Venus surface in the Phase IV. Triangles show the spacecraft position where occultation occurs.*

3.7.4 Individual Instrument Objectives and Requests Description

Table 3.5. Observations of individual experiments.

Experiment	Observations	
	Environment independent	Environment dependent
ASPERA	Detailed observations of plasma on the nightside	
MAG	Magnetic field on the nightside..	
PFS	Observations at noon and mid-night .	
SPICAV	Observations in nadir mode (15 min slots) together with other +Z looking	Solar occultation season #2

	instruments.	
VeRa		(1). Earth occultation season #2 (2). Solar Corona.
VIRTIS		(1). Dayside observations (2). Night side obs of Theia Mons and Lakshmi Planum.
VMC		(1). Dayside observations (2). Night side obs of Theia Mons and Lakshmi Planum.

3.7.5 Discussion

(1). Thermal constraints.

- The phase IV belongs to the “hot” type since the –Z wall is illuminated by the Sun in Case #2 and #3 observations. In this situation operational thermal constraints will limit possibility to combine cases. This subject is expected to become clearer by the time of phase IV due to additional thermal modelling of the science cases and in-flight thermal characterization of the spacecraft. The proposed timeline of the phase IV will be modified accordingly.

(2). Overlap of the Earth and solar occultation seasons in this phase results in that significant portion of pericentre passes is occupied by case #6 and #8 observations. It is important to merge these cases with case #1 when possible to keep dense coverage of the Northern hemisphere by +z observations in this period.

(3). Night side observations at descending branch of the orbit will cover Theia Mons and Lakshmi Planum.

(4). Case #9. End of Solar Corona observations falls in the beginning of this phase. Case #9 will be performed each 2-3 orbit. Requirements on observations time (-5…+5 hours orbital time) in SC experiment impose constraints on the Case #2 observations.

(5). The downlink capabilities in phase IV are very limited. The Science Team should agree upon a strategy of downlink share.

3.8 Phase V

3.8.1 Scientific focus

Phase 5 has neither solar nor Earth occultation opportunities. The Phase has favourable conditions for observations of the evening terminator. By the end of the phase conditions for the off-pericentre night side observations will be fulfilled. Main scientific focus of this phase is to provide observations of the evening terminator and the night side. In particular the following observations will be carried out:

- Cloud observations at terminator that would exploit illumination conditions favourable for the study of cloud and haze structure;
- North/South atmospheric dynamics campaign;
- Search for lightning on the night side;
- Double stellar occultation on the dark limb that would allow one to study north-south asymmetry of the aerosol vertical structure;
- Mapping of the surface targets;
- Limb observations to study vertical structure of haze layers;
- Observations of the nightglows (O2, NO…) and their latitude and vertical variability.

3.8.2 Environmental conditions

Local Time at Ascending Node (LTAN): 14 - 22 h

Most of the phase is “cold”: cases #2 and #3 can be run without illumination of the –Z panel.

Occultations: none

Night side surface targets: Atla Regio, Ozza Mons.

Science data dump:1400-2000 Mbits/day

3.8.3 Timeline

Events: <Start> = End of the Earth occultation season #2

<End> = Start of eclipse season #3

Dates: February 1 – March 16, 2007.

Orbits # 286-329

Phase duration: 43 days

The Phase V starts in MTP #10 which timeline is shown in the Figure 3-13. Figure 3-15 shows the end of Phase V.

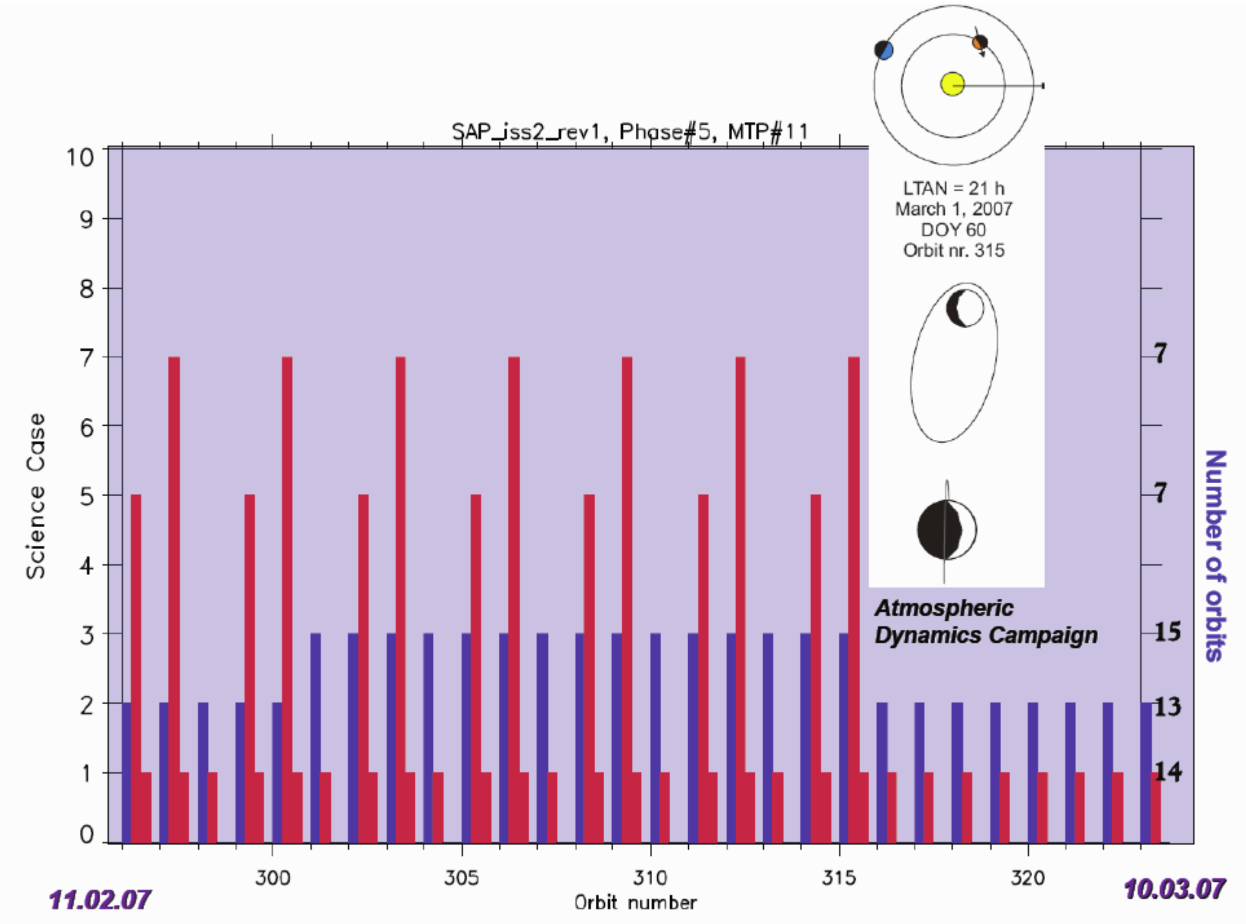


Figure 3.15. ***MTP#11*** *timeline*

Phase V

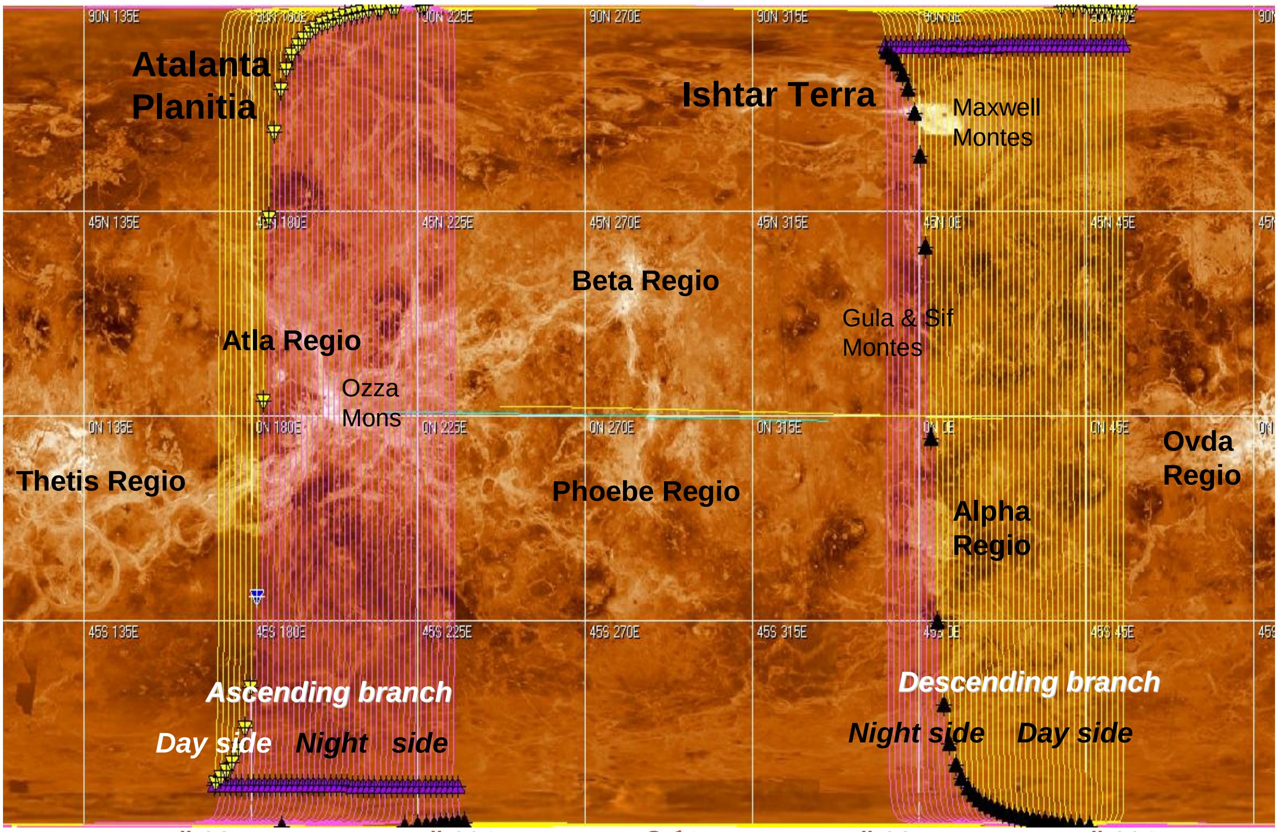


Figure 3.16. *Projection of the orbital tracks on the Venus surface in the Phase V.*

3.8.4 Individual Instrument Objectives and Requests Description

Table 3.8. Observations of individual experiments.

Experiment	Observations	
	Environment independent	Environment dependent
ASPERA	Detailed observations of the evening sector in selected portions of the orbit	
MAG	Magnetic field in the evening sector.	

PFS	Observations of the evening sector.	
SPICAV	Observations in nadir mode (15 min slots) together with other +Z looking instruments.	Regular stellar occultation
VeRa	No observations	No observations
VIRTIS	(1)Regular case 2 and 3 observations (2) North/South pole dynamics campaign	Night side observations
VMC	(1)Regular case 2 and 3 observations (2) North/South pole dynamics campaign	Night side observations

3.8.5 Discussion

(1). In this phase SAP consists of regularly repeated cases 1, 5, and 7 in the pericenter.

(2). Thermal constraints:

- In this phase the cases#2 and #3 can be run “cold”, so even with current VUM constraints the SAP can be implemented with minor limitations. The situation will become clearer after in-flight thermal characterization of the s/c is performed.

(3). Off-pericentre observations:

- Groups of different versions of Case#2 (2a, 2b, 2c..) proposed by the VIRTIS Dynamics Group [AD4] should be run in turn, i.e. ten orbits of Case#2a, ten orbits of Case#3, ten orbits of Case#2b etc.
- North / South pole dynamics campaign will be carried out in the end of the phase. North-South dynamics campaign could also include combination of cases #2 and #3 with case#1 (probably run in cold configuration, i.e. inertial pointing) thus giving complete pole-to-pole cross section of the planet. However downlink budget should be checked.
- Campaigns of Case#1 and #2 consecutive orbits might be also favourable for the thermal mapping of the surface targets (Atla Regio, Ozza Mons).

3.9 Phase VI

3.9.1 Scientific focus

This phase provides good conditions for observations of the night side and atmospheric sounding in solar occultation geometry (eclipse season 3). Solar occultation observations will be used to study composition and structure of the atmosphere above the cloud top. Campaigns of cases #2 and #3 repeated in several consecutive orbits will be used to study composition and dynamics of deep atmosphere on the night side. Conditions will be also favourable for observations of nightglows to study composition and dynamics of the thermosphere and search for lightning. Limb observations in forward scattering geometry (spacecraft in eclipse) will provide good opportunity to study vertical structure of hazes above the main cloud. Relatively high downlink rate would allow the experiments to use high resolution operation modes to study small scale features and dynamics. Thermal mapping of the surface and search for active volcanism will be performed in this phase. One bi-static sounding experiment (BSR #4, Theia Mons) is scheduled in this phase.

3.9.2 Environmental conditions

Local Time at Ascending Node (LTAN): 22 - 2 h

Cold phase: off-pericentre cases can be run without exposing –Z panel to the Sun

Occultations: Eclipse season 3

Night side surface targets: Beta Regio, Theia Mons, Phoebe Regio.

Science data dump: 2100-3200 Mbits/day

3.9.3 Timeline

Events: <Start> = Start of eclipse season #3

<End> = End of eclipse season #3

Dates: March 17 – April 25, 2007.

Orbits # 330 - 369

Phase duration: 39 days

The MTP#12 and MTP#13 timelines are shown in the Figures 3-17, 3-18.

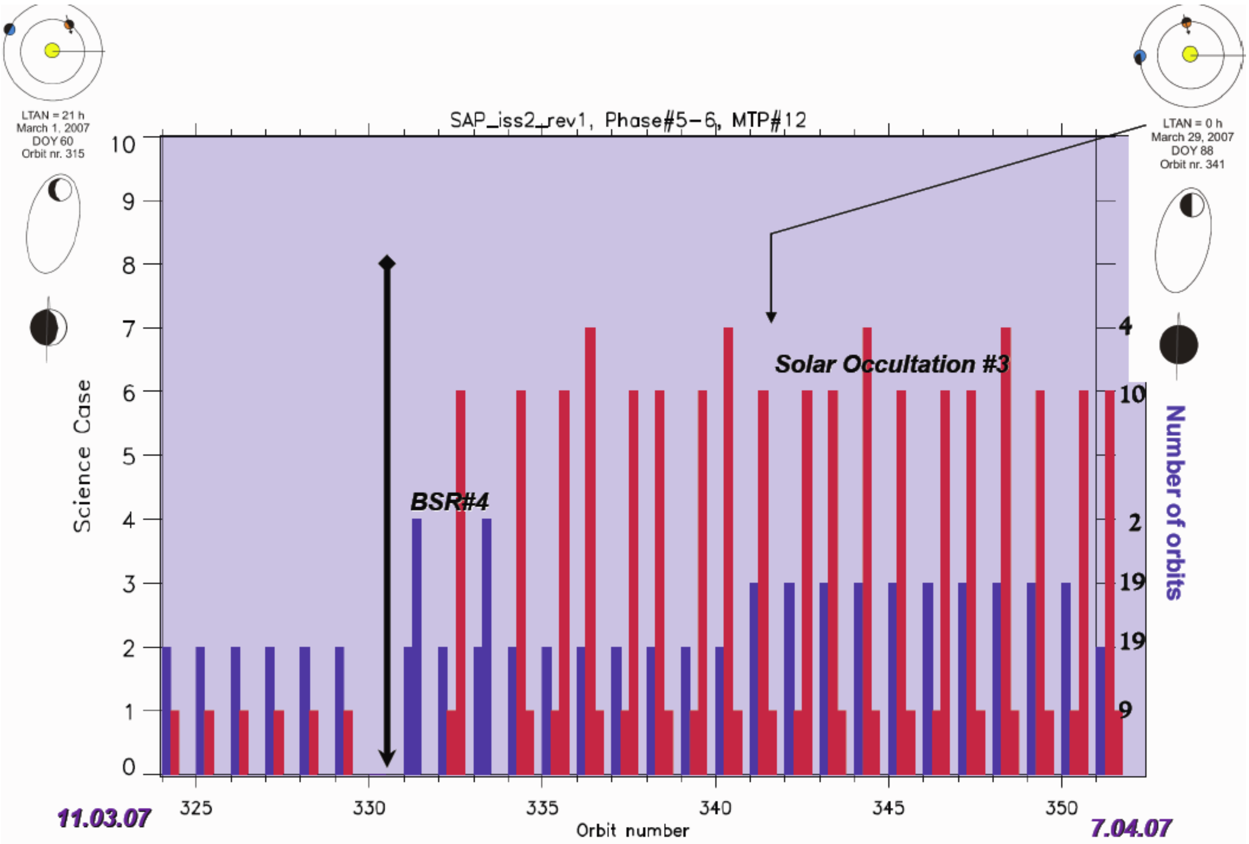


Figure 3.17 ***MTP#12*** *timeline.*

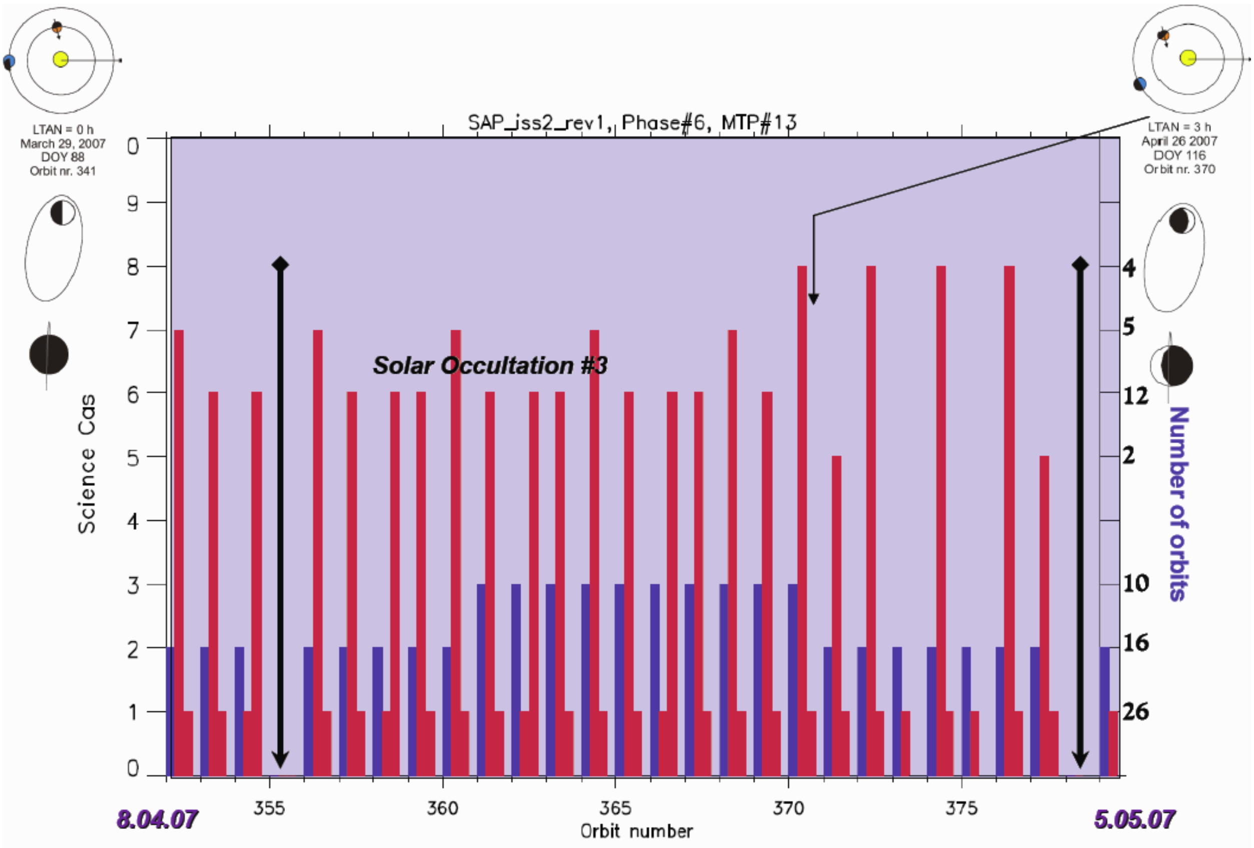


Figure 3.18 MTP #13 timeline

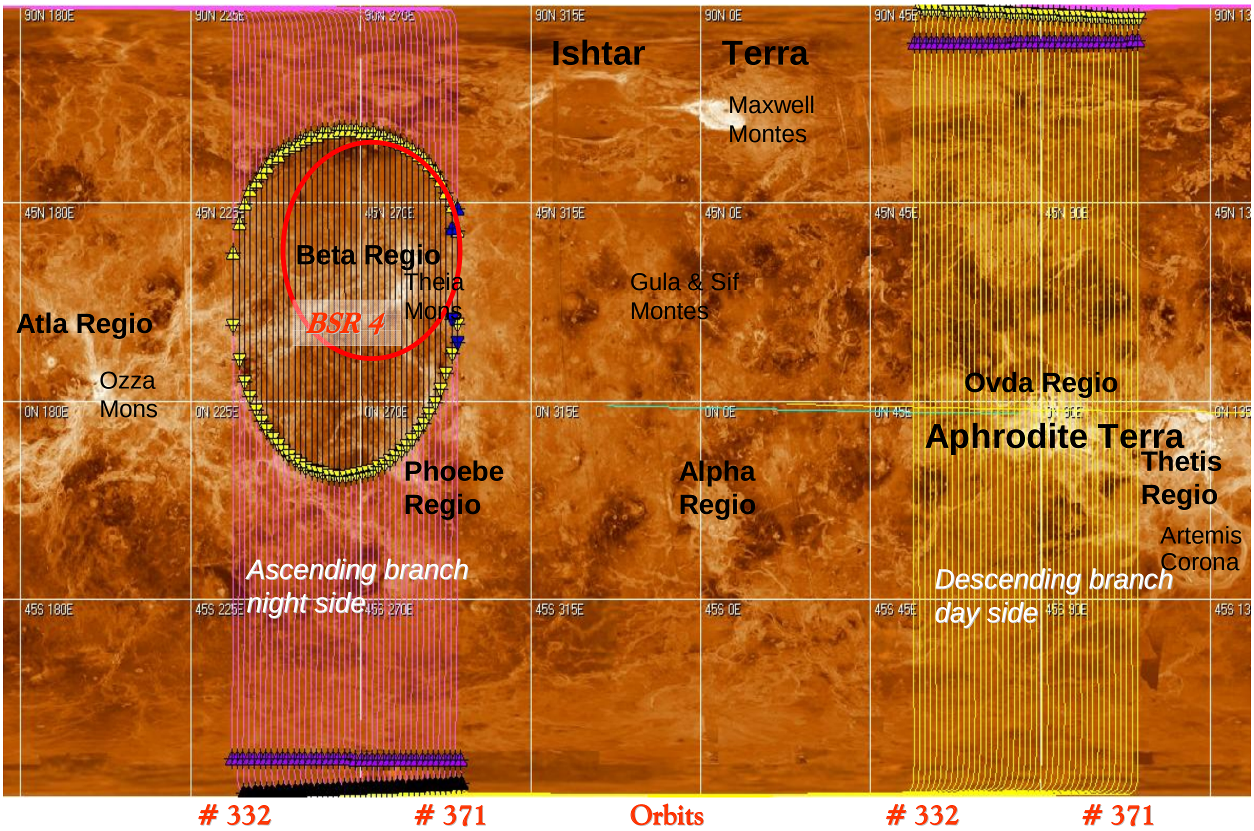


Figure 3.19 *Projection of the orbital tracks on the Venus surface in the Phase VI. Triangles show the spacecraft position where solar occultation occurs.*

3.9.4 Individual Instrument Objectives and Requests Description

Table 3.9. Observations of individual experiments.

Experiment	Observations	
	Environment independent	Environment dependent
ASPERA	Observations of the noon/ midnight plasma	
MAG	Magnetic field	

PFS	Sounding of the noon/ midnight sector	
SPICAV	Observations in nadir mode (15 min slots) together with other +Z looking instruments.	Solar occultation season 3
VeRa		BSR #4 (Theia Mons)
VIRTIS	Regular case 2 and 3 observations and obs in push-broom mode (case #2e).	Night side observations (Themis and Phoebe Regio)
VMC	Regular case 2 and 3 observations	Night side observations (Themis and Phoebe Regio)

3.9.5 Discussion

(1). Thermal constraints. Phase VI is a “cold” one. Hence combination of the off-pericentric and pericentric cases can be done with minor limitations.

(2). Solar occultation season #3.

(3). Limb observations (case#7) are imbedded in the eclipse season providing an opportunity of twilight limb observations in forward scattering geometry .

(4) Bi-static radar experiment (BSR#4, Beta Regio, Theia Mons).

(5) Off-pericentre observations.

- Groups of different versions of Case#2 (2a, 2b, 2c..) proposed by the VIRTIS Dynamics Group [AD4] should be run in turn, i.e. ten orbits of Case#2a, ten orbits of Case#3, ten orbits of Case#2b etc. Also cases 2 and 3 can be combined that would allow complete pole-to-pole coverage.
- Illumination conditions (nightside at ascending branch) and relatively high downlink allow high-spectral resolution observations of the night side.
- Night side surface observations can cover the Beta and Phoebe Regio and provide simultaneous observations with the bi-static radar experiment.

3.10 Phase VII

3.10.1 Scientific focus

Phase 7 includes Earth occultation season. Proximity to the Earth creates excellent conditions for bi-static sounding and radio-occultation experiment that can reach maximum sounding depth. Surface targets and corresponding orbits will be defined later. Avantage of this phase is that it has maximum downlink data rate. So it will be used to study the atmosphere with high spatial resolution. As earlier in phases 1, 3, 5 the terminator sector of the planet will be available for observations in this phase. Thus cloud structure and atmospheric dynamics will be important goals.

3.10.2 Environmental conditions

Local Time at Ascending Node (LTAN): ~6 h

Occultations: Earth occultations

Night side surface targets: Gula and Sif Mons, Guinevere Planitia, Ishtar Terra on ascending branch and Atalanta Planitia, Atla Regio and Ozza Mons at the descending branch of the orbit.

Science data dump: 3300-6500-500 Mbits/day

3.10.3 Timeline

Events: <Start> = End of eclipse season #3

<End> = Start of eclipse season #4

Dates: April 26 – June 30, 2007.

Orbits # 370 - 435

Phase duration: 65 days

The timelines of MTP #14 and #15 that fall into this phase are shown in Figures 3-20, 3-21.

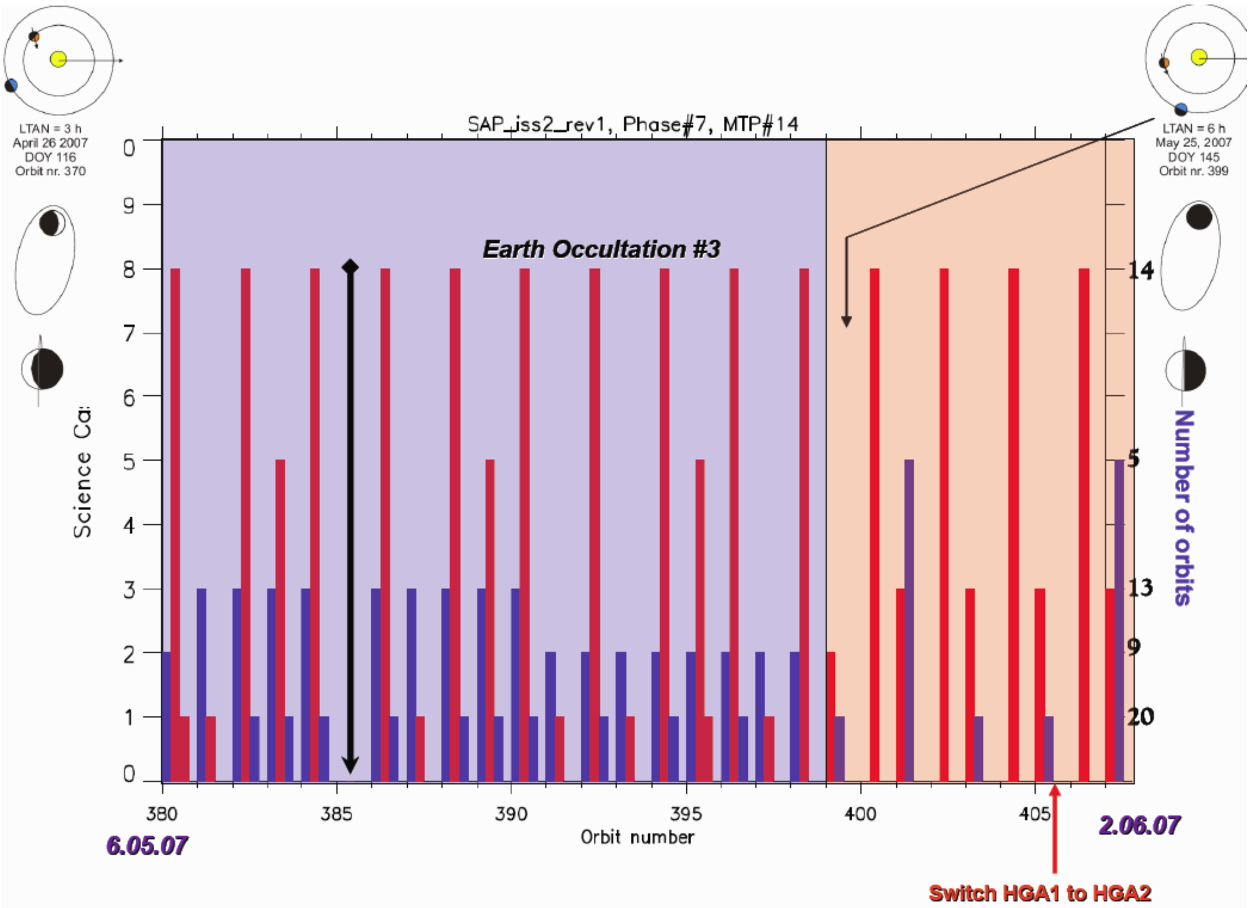


Figure 3.20 ***MTP#14** timeline***.**

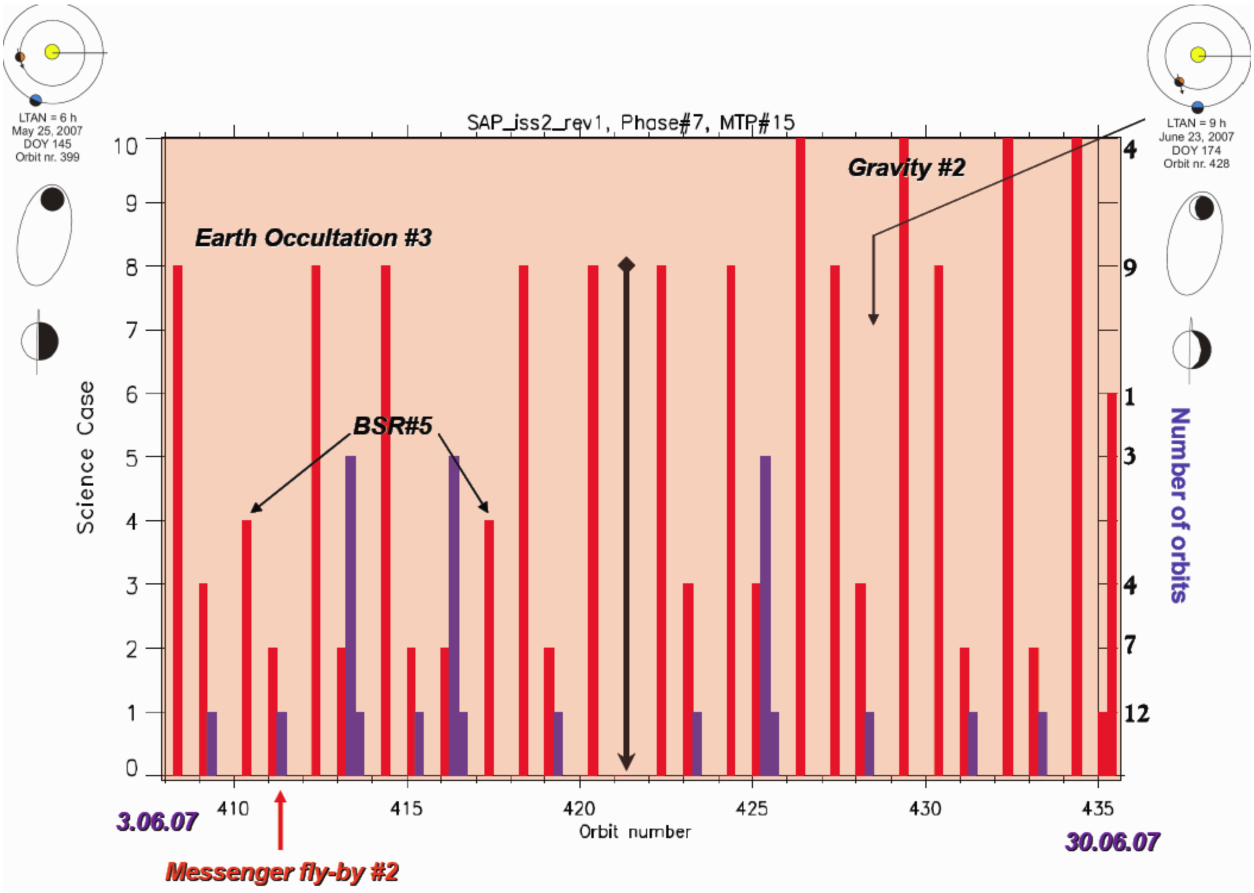


Figure 3.21 MTP #15 timeline

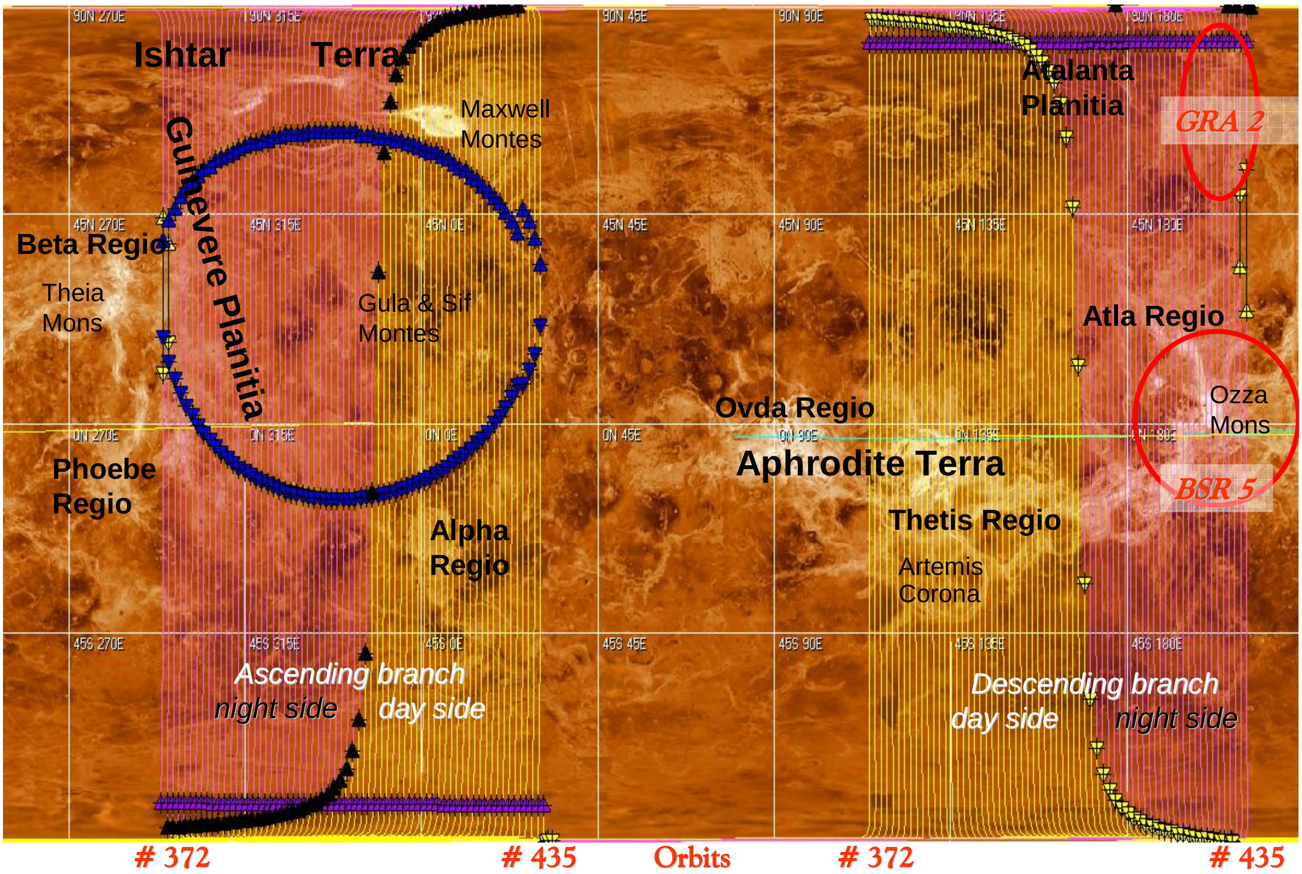


Figure 3.22. *Projection of the orbital tracks on the Venus surface in the Phase VII. Triangles show the spacecraft position where solar occultation occurs.*

3.10.4 Individual Instrument Objectives and Requests Description

Table 3.10. Observations of individual experiments.

Experiment	Observations	
	Environment independent	Environment dependent
ASPERA		
MAG		
PFS	Observations of the morning/	

	evening sector.	
SPICAV	Observations in nadir mode (15 min slots) together with other +Z looking instruments.	Regular stellar occultation
VeRa		(1). Radio-occultation season #3 (2) Bi-static radar #5 (Ozza Mons)
VIRTIS	Regular case 2 and 3 observations in the morning/evening sectors	Night side observations at ascending branch of the orbit (Ishtar Terra, Maxwell Montes)
VMC	Regular case 2 and 3 observations in the morning/ evening sectors	Night side observations at ascending branch of the orbit (Ishtar Terra, Maxwell Montes)

3.10.5 Discussion.

(1).Thermal aspects: first half of the phase is cold, the second is hot.

(2). Night side thermal mapping of the Ishtar Terra and Maxwell Montes at ascending branch of the orbit and Atla Regio (Ozza Mons) at the descending branch..

(3). Earth occultation season #3:

- This phase is the most favorable for the Earth occultation experiment due to proximity of the Earth.
- Illumination of the –X wall during the radio occultation experiments is possible and should be checked.

(4). The downlink rate has its extremes in this phase:

- Orbits 372-410 have the highest rate (up to 6 Gbits/ orbit).
- Orbits 410-435 have very low downlink rate (< 1 Gbits / orbit)

(5). Combination of the high downlink rate with cold conditions for Cases #2 and #3 makes the first part of the phase favourable for a campaign of extensive spectro imaging.

(6). Bi-static radar experiment #5 will have Ozza Mons as a target thus providing simultaneous observations with thermal mapping.

(7). Gravity #2 experiment can also result in the sun illuminating –X wall. The fact that the experiment is performed on the descending branch of the orbit and the satellite goes into eclipse can help to cope with the problem of thermal illumination of the –X wall.

(8). The second Messenger Venus flyby will take place on June 6, 2007. Joint observations are foreseen.

3.11 Phase VIII

3.11.1 Scientific focus

Phase 8 contains eclipse season #4. Thus significant portion of orbits will be devoted to solar occultation observations. This phase is favourable for investigation of dayside dynamics especially in the end of the phase when the downlink data rate reaches its maximum. Proximity to the Earth provides good conditions for solar corona studies and bi-static sounding. Gravity #2 target is Atalanta Planitia which was poorly covered by the Magellan observations.

3.11.2 Environmental conditions

Local Time at Ascending Node (LTAN): ~12 h

Occultations: Solar occultations, Solar Conjunctions, Bi-static sounding.

Night side targets: Beta region, Theia Mons, coronae.

Science data dump: 1000-3200 Mbits/day

3.11.3 Timeline

Events: <Start> = Start of eclipse season #4
<End> = End of eclipse season #4

Dates: July 1 – August 21, 2007.

Orbits # 436 – 487.

Phase duration: 51 days.

The timelines of MTP #16 and #17 that fall into this phase are shown in Figures 3-23, 3-24.

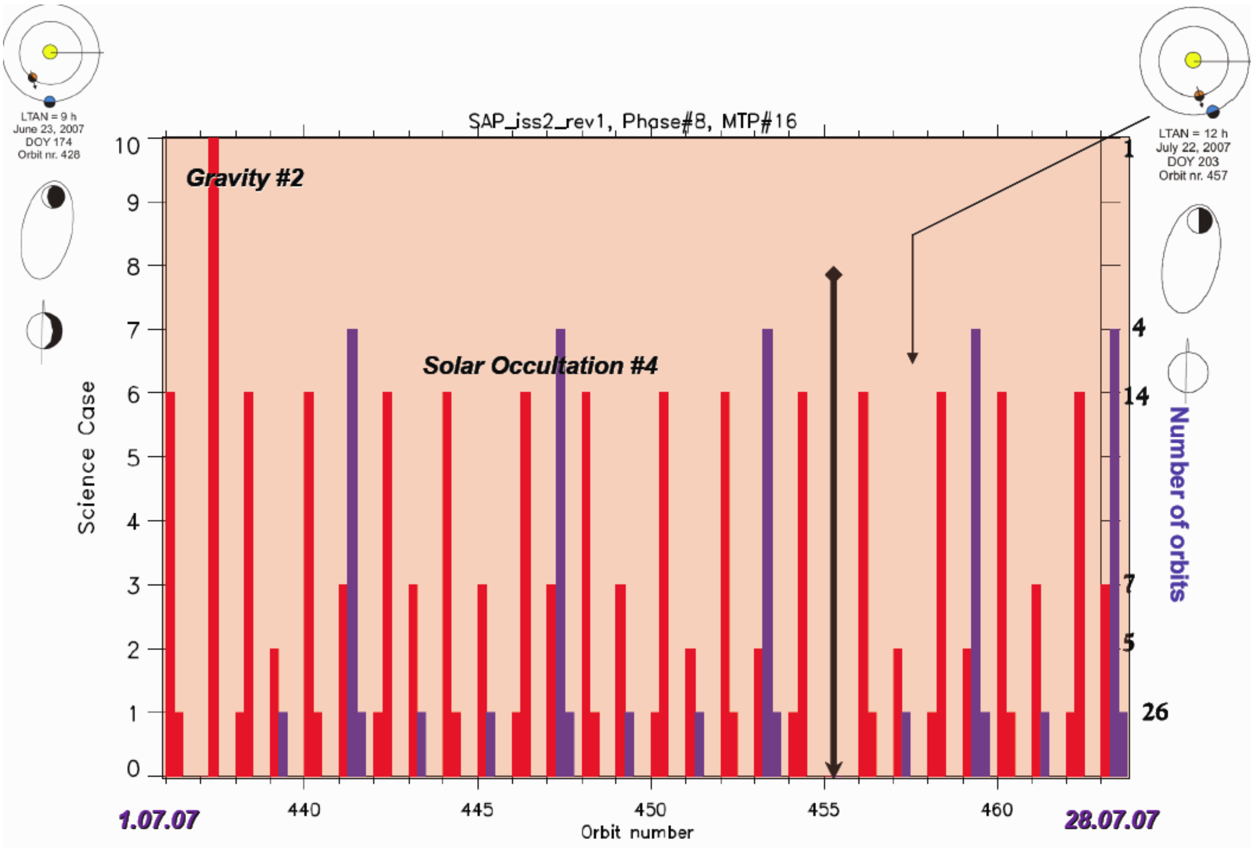


Figure 3.23. ***MTP#16*** *timeline.*

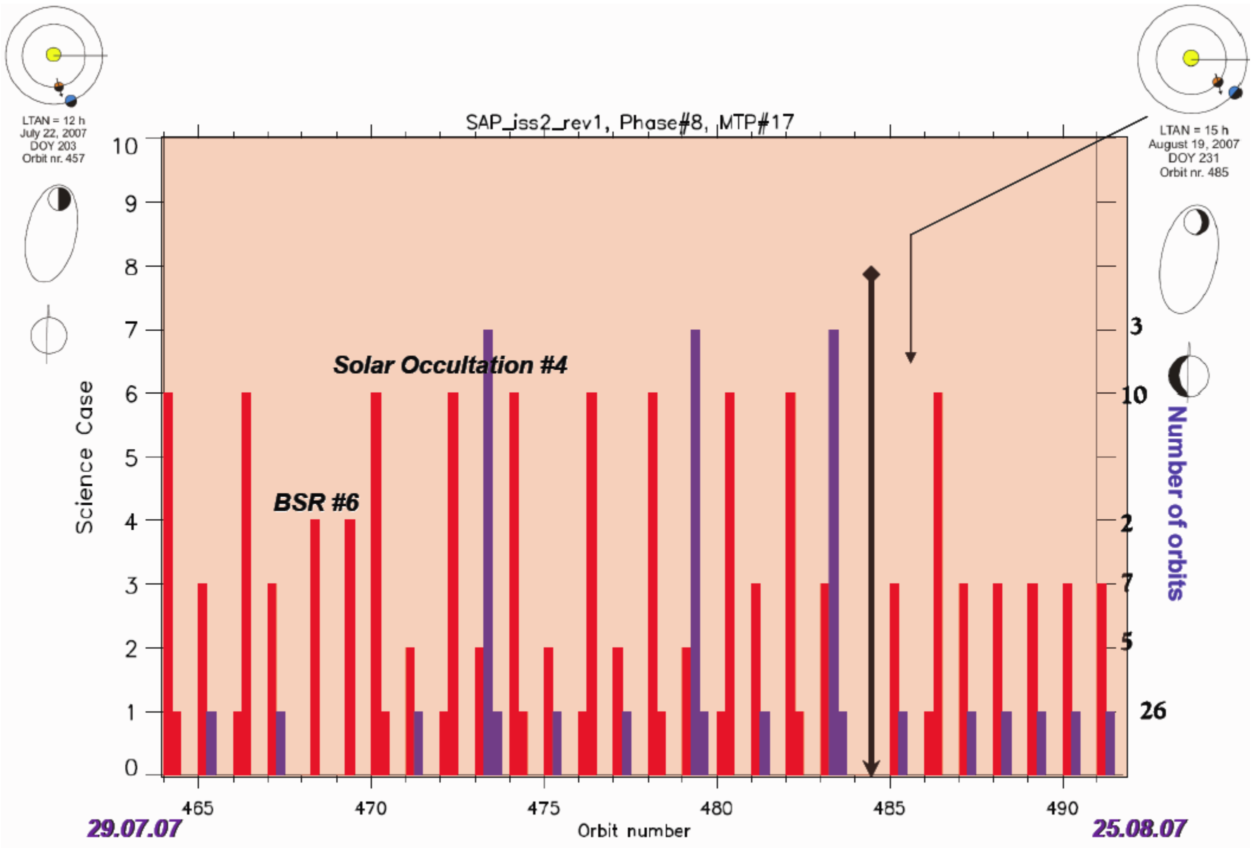


Figure 3.24 MTP #17 timeline.

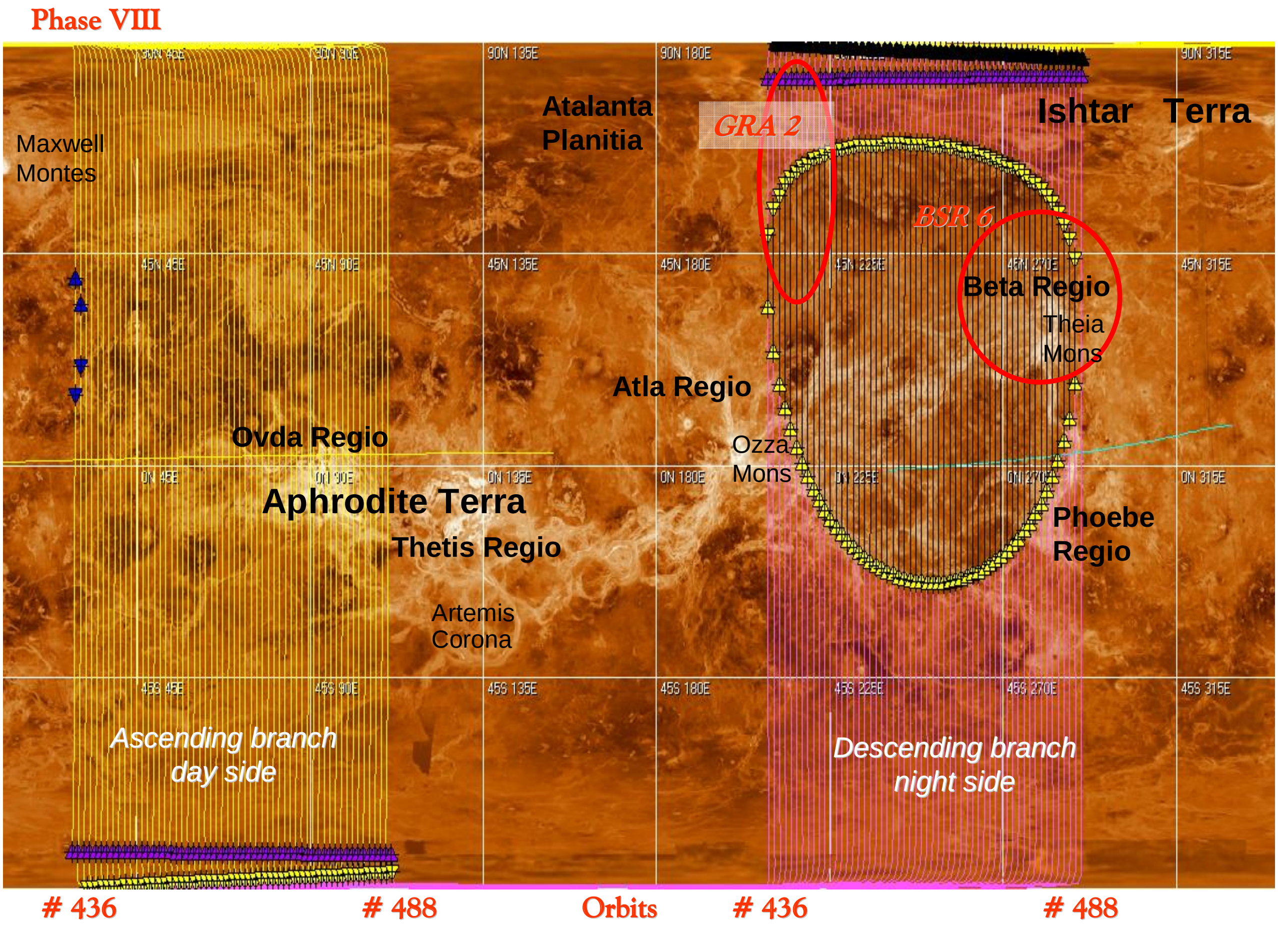


Figure 3.25. *Projection of the orbital tracks on the Venus surface in the Phase VIII. Triangles show the spacecraft position where solar occultation occurs.*

3.11.4 Individual Instrument Objectives and Requests Description

Table 3.11. Observations of individual experiments.

Experiment	Observations	
	Environment independent	Environment dependent
ASPERA	Selected studies	
MAG	Selected studies	
PFS	Systematic study of the day and	

	night sides	
SPICAV	Observations in nadir mode (15 min slots) together with other +Z looking instruments.	Solar occultation season #4
VeRa		(1). Gravity #2 experiment (2) Bi-static radar #6
VIRTIS	Regular case 2 and 3 observations of the dayside	
VMC	Regular case 2 and 3 observations of the dayside	

3.11.5 Discussion.

(1). Thermal aspects:

- All orbits are hot in this phase;
- Since some of pericentre cases (solar occultation and bi-static radar) are hot the off-pericentre observations of this orbit should be skipped.

(2). Several case #7 orbits are imbedded in the eclipse season to provide limb observations in the forward scattering geometry.

(3). Night side thermal mapping will cover Beta Regio, Phoebe region and lowlands to the west that has several coronae and chasma.

(4). BSR #6 investigation will cover Beta region (Theia Mons) thus providing simultaneous observations with thermal mapping. The Earth-Venus distance is minimal, so conditions are favourable for the bi-static sounding experiment. Possibility to add more bi-static sounding passes should be investigated.

(5). Number of passes allocated for the Gravity experiment is reduced from 10 requested to 5. The reason is the need to share the time with solar occultation observations.

3.12 Phase IX

3.12.1 Scientific focus

Similarly to phases 1 and 3 the geometry in Phase 5 is favourable for observations of the vicinity of evening terminator. By the end of this season conditions for the off-pericentre night side observations will be fulfilled. Main scientific focus of this phase is to provide observations of the evening terminator. In particular the following observations will be carried out:

- Cloud observations at terminator that would exploit illumination conditions favourable for the study of cloud and haze structure;
- Search for lightning on the night side;
- Double stellar occultation on the dark limb that would allow one to study north-south asymmetry of the aerosol vertical structure;
- Grazing solar occultation (early in the phase) that would allow one to probe horizontal structure of the hazes above the main cloud deck;
- Mapping of the surface targets (to be selected from the list);
- Limb observations to study vertical structure of haze layers;
- Observations of the nightglows (O2, NO…) and their latitude and vertical variability.

3.12.2 Environmental conditions

Local Time at Ascending Node (LTAN): ~18 h
Occultations: Solar Conjunctions
Night side surface targets: Atalanta Planitia and coronae at ascending branch; Guinevere Planitia and Ishtar Terra on descending branch.
Science data dump: 3200-1000 Mbits/day

3.12.3 Timeline

Events: <Start> = End of eclipse season #4
<End> = End of nominal mission

Dates: August 22 – October 2, 2007.

Orbits # 488- 531.

Phase duration: 43 days.

The timelines of MTP #14 and #15 that fall into this phase are shown in Figures 3-20, 3-21.

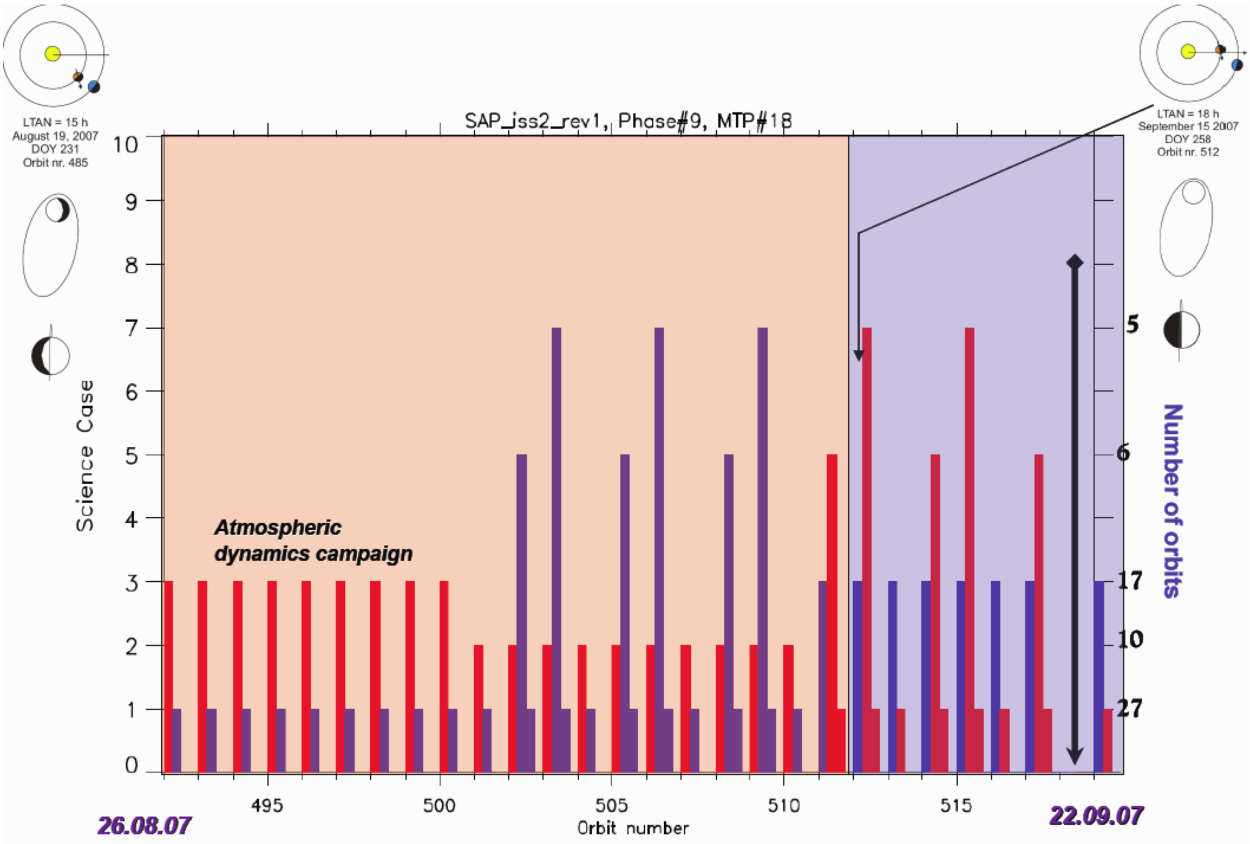


Figure 3.26. ***MTP #18*** *timeline.*

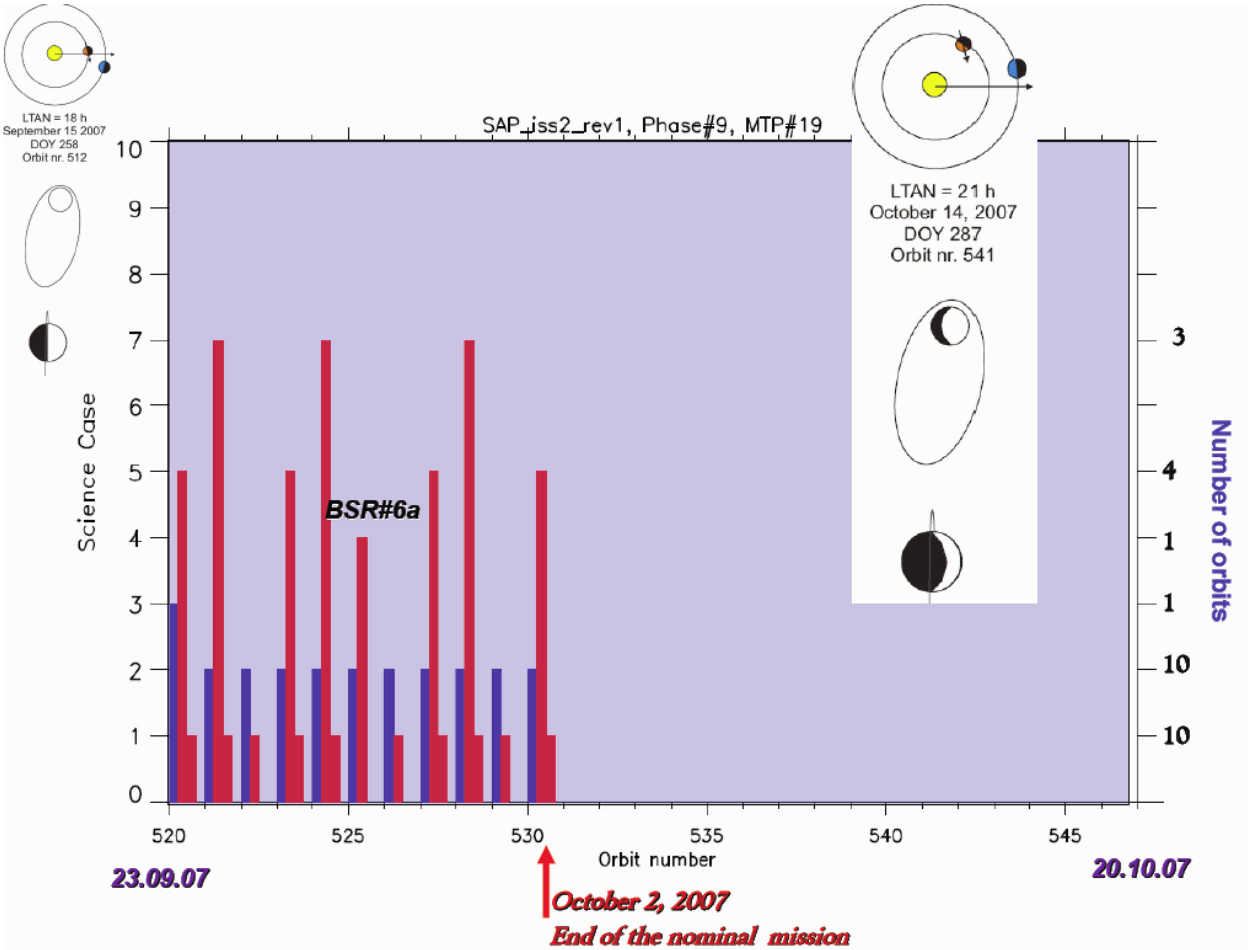


Figure 3.27 MTP#19 timeline

Phase IX

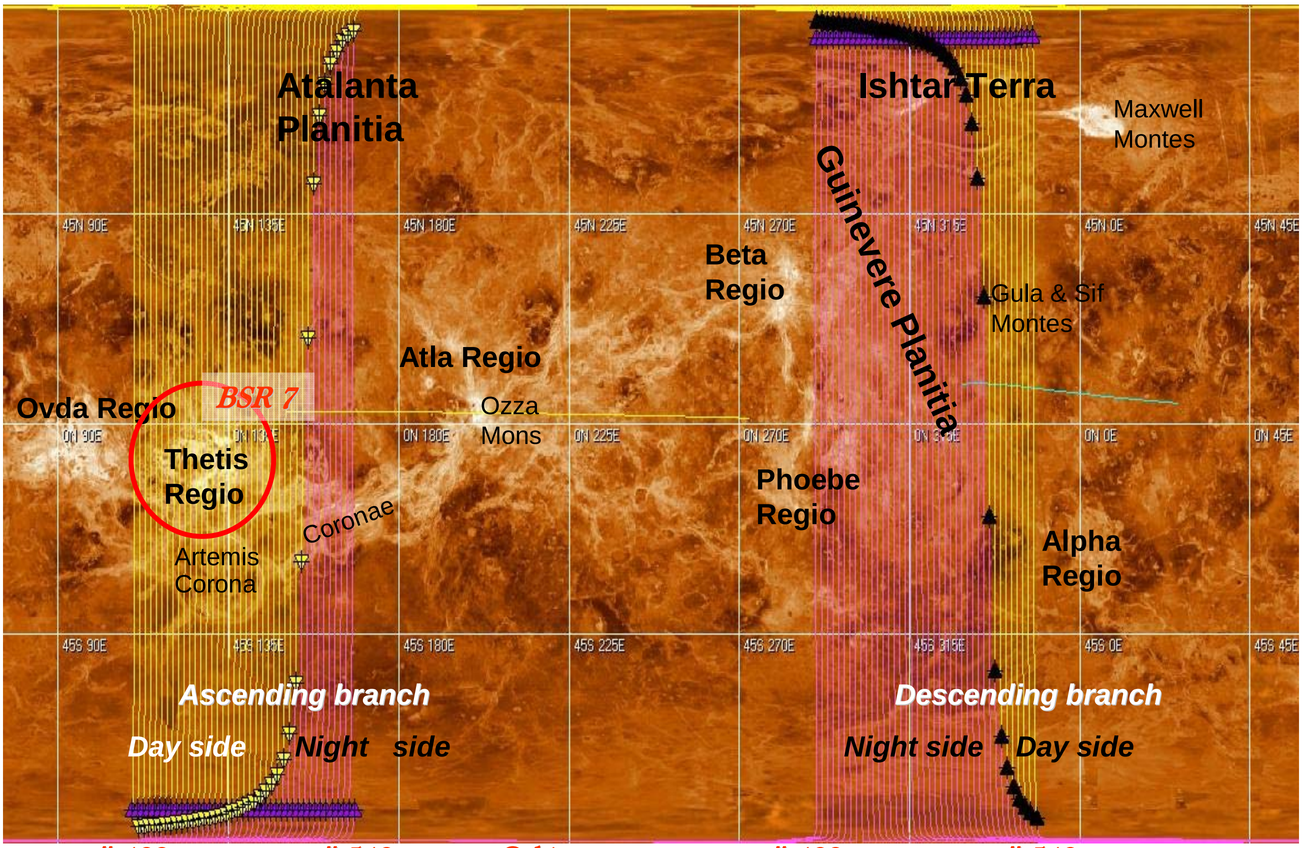


Figure 3.28. *Projection of the orbital tracks on the Venus surface in the Phase IX. Triangles show the spacecraft position where solar occultation occurs.*

3.12.4 Individual Instrument Objectives and Requests Description

Table 3.12. Observations of individual experiments.

Experiment	Observations	
	Environment independent	Environment dependent
ASPERA	Selected studies	
MAG	Selected studies	
PFS	Systematic study of the evening	

	sector.	
SPICAV	Observations in nadir mode (15 min slots) together with other +Z looking instruments.	Stellar occultation
VeRa		(1). Bi-static radar #6a
VIRTIS	Systematic study of the morning/ evening sector.	
VMC	Systematic study of the morning/ evening sector.	

3.12.5 Discussion

(1). Thermal aspects: first half of the phase is the hot one.

(2). The downlink rate is high (~3Gbits / orbit) in the beginning of the phase.

(3). North-South polar dynamics campaign is scheduled in the period of high downlink rate. At the same moment this period is the hot one. Combination of cases #1 and #3 will be possible if the thermal recovery time of case #3 is reduced to ~8 hours.

3.13 Preliminary plans for extended Mission Overview

- Goals and strategy
- Accelerometre investigation
- Aerobraking : Circularization of the orbit to decrease the sun gravity effect on the pericentre altitude and prolong the mission duration
- Cancellation of the pericentre altitude maintenance activity to let the altitude increase in order to get a global view of the Venus North pole.

4. ANALYSIS OF THE SAP

This section contains the analysis of the proposed Science Activity Plan from the point of view of fulfilling the mission goals, latitude and local solar time coverage, as well as surface targets observations by various experiments. It also presents analysis of science cases distribution, downlink budget, and downlink sharing between experiments.

4.1 Science cases distribution

The basic principle of the SAP development was to reach balance between distant and close-up observations of Venus. This was achieved by combining pericentre and apocentre cases in each orbit. It is possible without any constraints in the cold periods of the mission, i.e. when the cases #2 and #3 could be run in cold configuration without exposing –Z wall to the Sun. In hot periods of the mission current FUM impose some limitations. Namely, after the off-pericentre observations when the spacecraft receives thermal load the pericentre cases should be run in cold orientation (i.e. in inertial power optimized orientation with the sun kept in +Z/+X quadrant). This limits the freedom in selection of the limb or stars and also does not permit local nadir pointing. When the pericentre cases are inevitable hot (like cases 6 and sometimes 4) the preceding off-pericentre observation should be skipped.

Figure 4-1 shows relative distribution of the science cases in the nominal mission. Note that total number of cases (955) used in this plot is twice as many as the number of orbits since two cases per orbit are implemented in this version of SAP. The off-pericentre cases (#2 and #3) together occupy approximately the same number of orbits as the pericentre cases (#1 and #4 – 10). Cases 2 and 3 have the same share (~25%). Both solar and Earth occultation observations have equivalent share of 7-9% (~75 orbits). Pure Case #1 (with the spacecraft nadir pointing for 96 minutes around pericentre) has relative weight of 18% (~170 orbits in total). However, the share of observations of the Northern hemisphere by the +Z looking instruments can be increased if occultation observations could be combined with the planet observations by proper orientation of the spacecraft. Also case #7 orbits (limb) can be used for planet observations between the limbs.

In total this would increase the number of planet observations in nadir or inertial orientation to about 400 in the nominal mission.

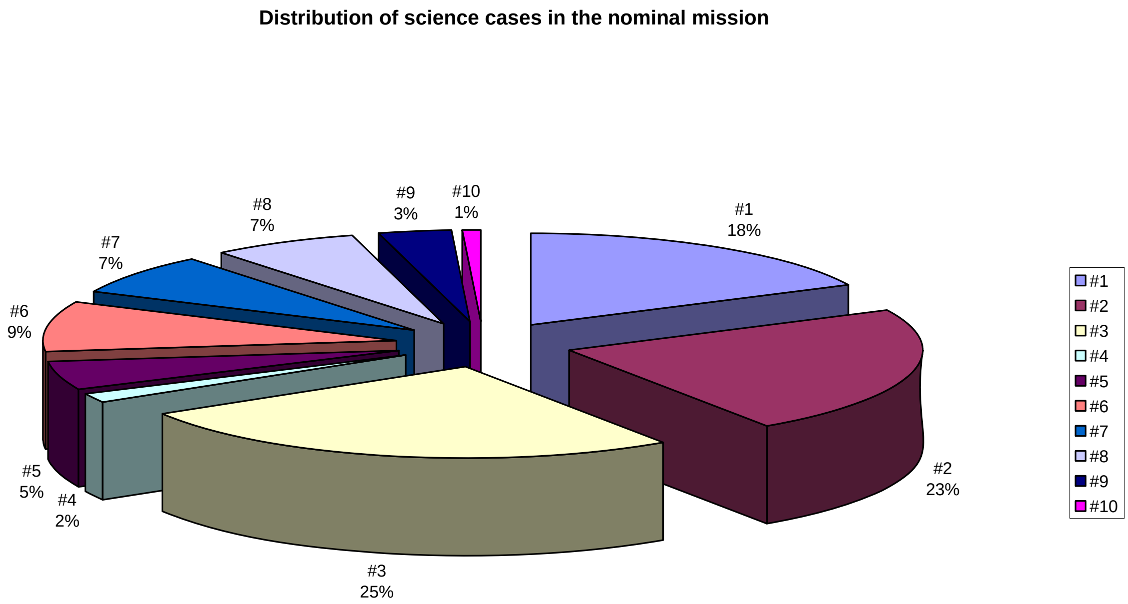


Figure 4.1. *Distribution of the science cases in the nominal mission.*

4.2 Coverage of the observation parameters space

One of the main goals of the Venus Express mission is to provide complete observation coverage of latitudes and local solar time. The Venus local solar time has repetition cycle of 225 days (one Venus year). Thus the local solar time at ascending node changes by 1.6 degrees each orbit that corresponds to 6.4 minutes per orbit.

Pure *Case #1 (pericentre nadir observations)* will be implemented in each third orbit on average thus providing one Case #1 observation in ~20 min local time. Additional observations associated with other pericentre cases will increase density of the local solar time coverage. Latitudes covered by the Case #1 observations (± 47 minutes around pericentre) will range from equator in ascending branch of the orbit to ~30S in descending branch.

Cases #2(off-pericentre) observations in ascending branch are grouped in campaigns of 10 consecutive orbits. 10-days gaps between case #2 campaigns correspond to the change in LTAN (local time at ascending node) of ~ 1 hour (16 degrees longitude or ~1600 km on equator). However, since these observations will be carried out from a distance of more than 10,000 km from the Venus surface and keeping in mind possibility of off-track pointing these gaps will be easily covered. Case #2 implemented in nadir pointing will cover latitudes from ~70S to equator. This latitude range can be slightly increased by off-nadir pointing in orbital plane.

Case #3 (apocentre mosaic) observations will be performed close to the apocentre. Each mosaic will provide complete coverage of all local times in the Southern hemisphere since the planet will be observed from a distance of ~60,000km with satellite over the pole.

Case #4 (bi-static radar) will investigate specific surface targets described in the section 4.3. The table in Annex 3 provides details about the Case#4 scheduling.

Case #5 (stellar occultation) will use the stars from the list in Annex 2. (Coverage TBD)

Case #6 (solar occultation) will be distributed in four eclipse seasons. These observations will cover only terminator region (LTAN=6 and 18 hours). Latitude and local solar time coverage planned in this experiment is shown in figure 4.2.

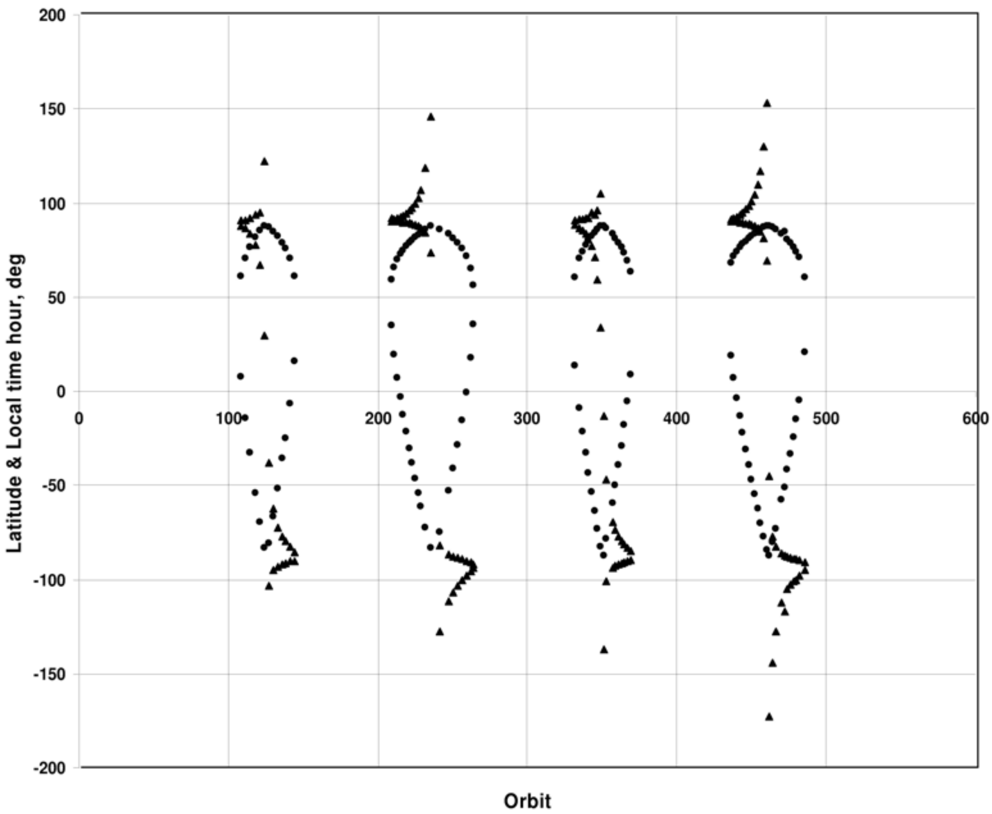


Figure 4.2 Latitude (solid circles) and local time hour (triangles) coverage in the SPICAV/SOIR solar occultation experiment during the nominal mission. The local hour angle of 0° corresponds to the noon, positive (negative) local hour angles correspond to the afternoon (morning) hours.

Case #7 (limb observations) is scheduled in about 70 orbits that are roughly evenly distributed over the nominal mission thus giving one limb observation in ~7 orbits. The spacing between the limb orbits will be ~10-15 degrees longitude that corresponds to ~45min – 1 hour LTAN. It is planned that the spacecraft will have several limb pointings during the pericentre pass thus providing complete coverage of the Northern hemisphere.

Case #8 (Earth radio occultation) will be distributed in three seasons in the nominal mission (Figure 4.2). The sounding provides complete latitude coverage from pole to pole (Figure 4-3.). However it should be mentioned that the latitudes shown in the figure are the latitudes at the ray ingress/egress into the atmosphere. For the deep atmospheric sounding below ~60 km the ray bending can strongly affect the pass in the atmosphere.

The details of all VeRa experiments are compiled in the Annex 3. Total number of passes allocated in the current SAP is: 76 New Norcia (radio-occultation and gravity experiments) and 45 DSN (solar corona and bi-static radar).

Case #10 (VeRa gravity experiment) will target specific locations on the surface (see section 4.3 and Annex 3).

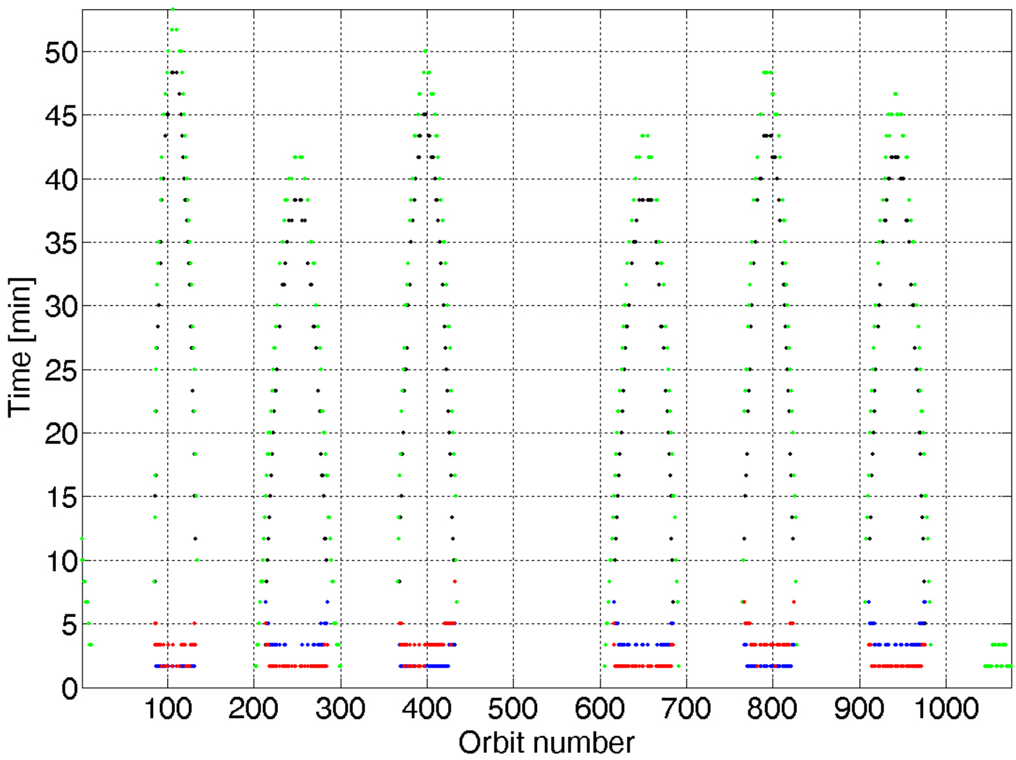


Figure 4.3. *Occultation seasons for VeRa for the nominal (orbit number < 500) and extended mission (orbit number > 500). Black dots indicate the duration of a pure planetary occultation,*

green dots indicate the duration of the occultation assuming an atmosphere/ionosphere with an altitude of 240 km).

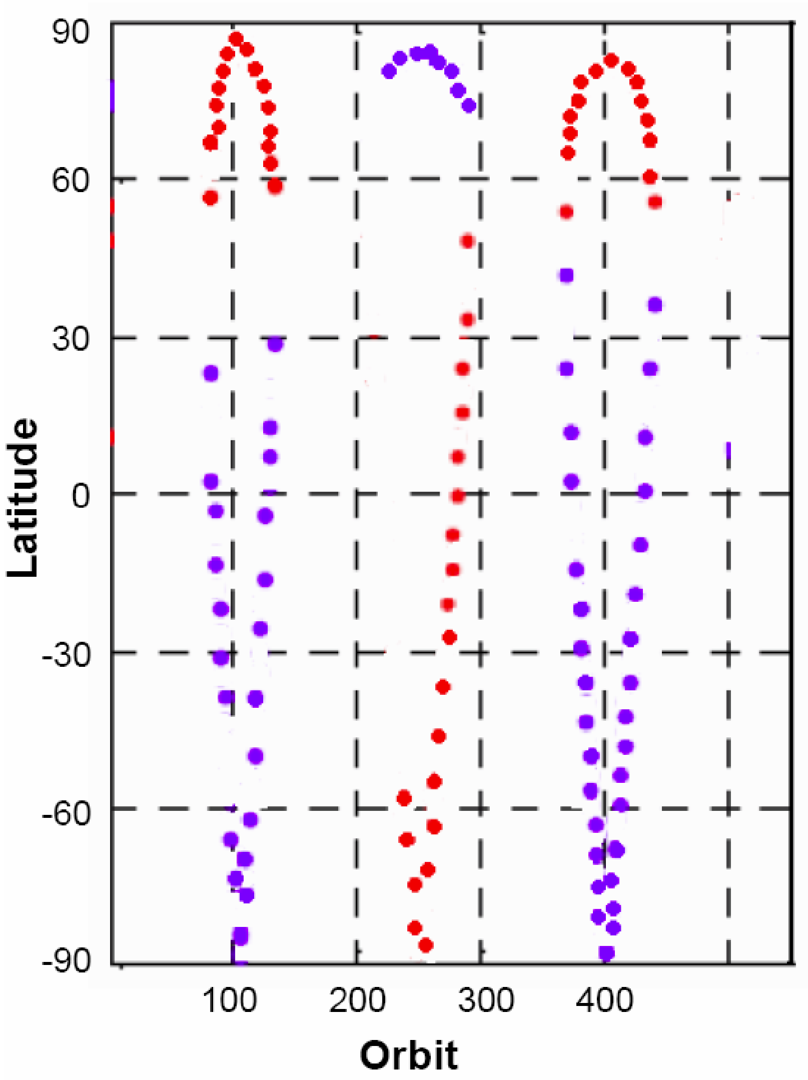


Figure 4.4. *Distribution of planetocentric latitudes for occultation ingress (red dots) and egress (blue dots) assumed to be at the planetary surface.*

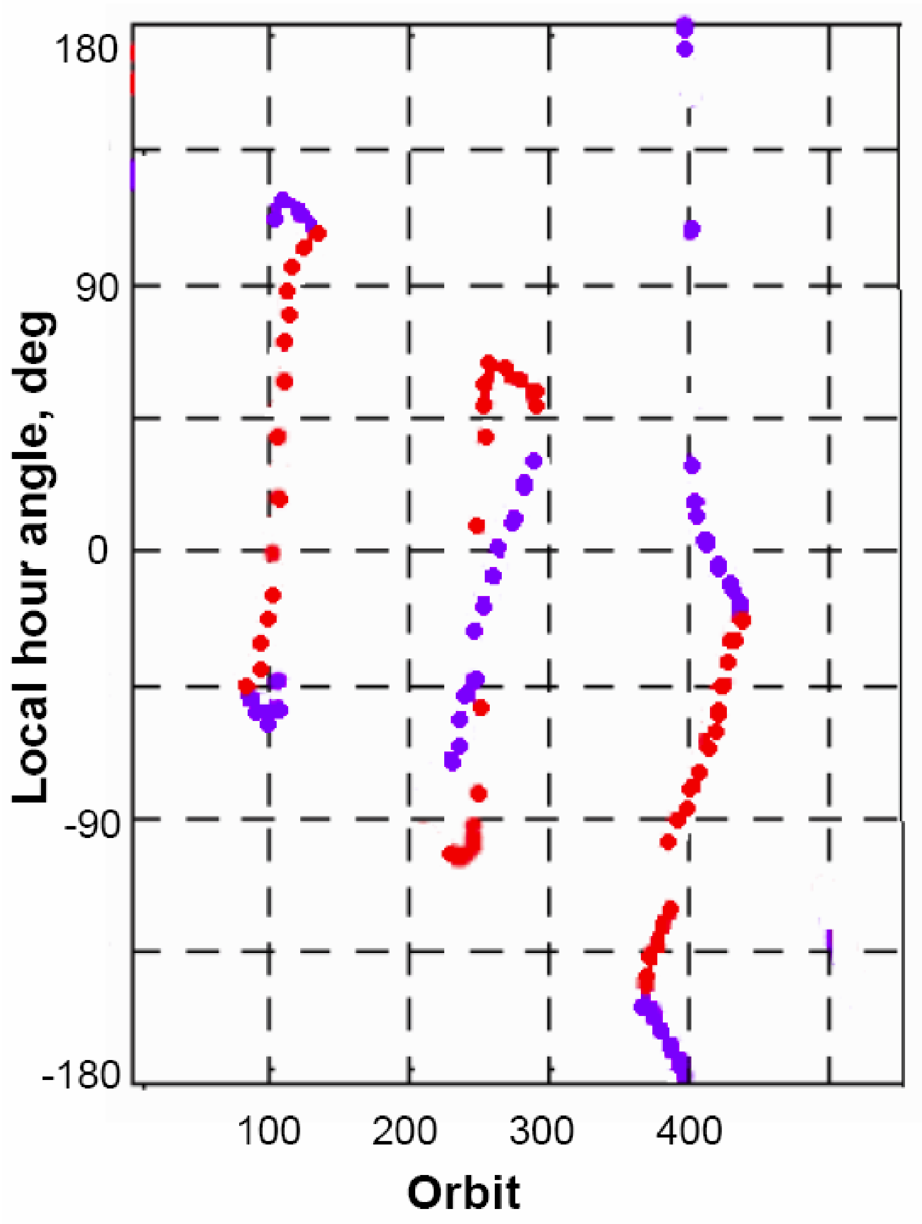


Figure 4.5. *Local solar time coverage by the VeRa radio occultation experiment during the nominal mission. The local hour angle 0° corresponds to the local noon, positive (negative) local hour angles correspond to the afternoon (morning) hours.*

4.3 Surface observations

Venus Express will contribute to the Venus surface studies in several ways: bi-static radar and gravity experiments by VeRa and thermal sounding in the near-infrared spectral windows by spectrometers and imagers. The thermal sounding requires night conditions. Figure 4.4 shows the areas on the Venus surface covered by these investigations. The Western hemisphere (west from the 0 meridian) will be well covered by thermal mapping while the main part of the Eastern hemisphere will remain unobserved.

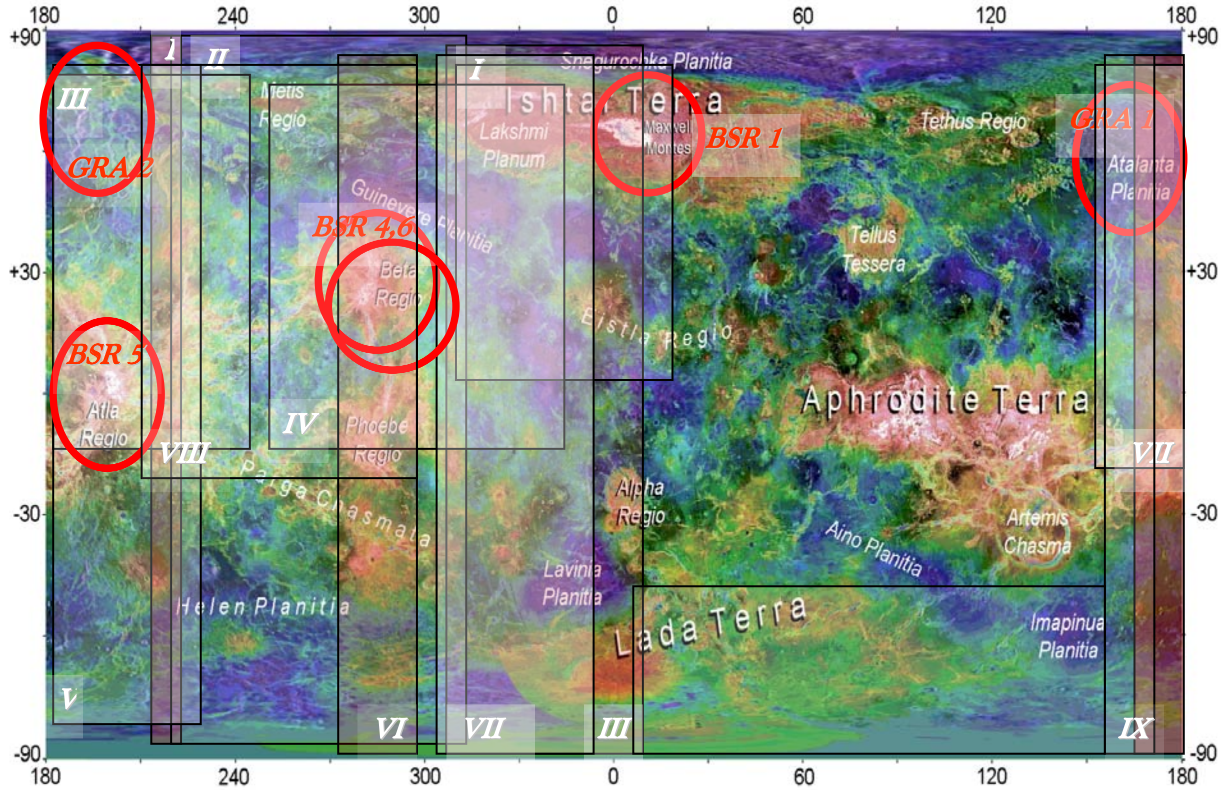


Figure 4.6. *Venus surface coverage by investigations onboard Venus Express: red circles – bi-static radar (BSR) and gravity (GRA), semi-transparent rectangles – locations covered by the night side thermal mapping. Mission phases are marked by white roman numbers.*

4.4 Downlink analysis

4.4.1 Downlink budget

The volume of scientific data daily dumped to the Earth strongly varies from less that 5 Mbits/orbit to more than 6 Gbits/orbit over the mission. In the main portion of the mission the downlink deficit can be compensated by using higher data compression factors by the instruments. In the periods of very low downlink and fixed data share should be agreed between the experiments. In the periods of very high downlink burst modes of the experiments will be used, in particular, extensive spectro-imaging campaigns can be performed. The tests of the downlink rate performed after the orbit insertion showed that the actual downlink data rate is by about 60% higher than that shown in the figure 4.7.

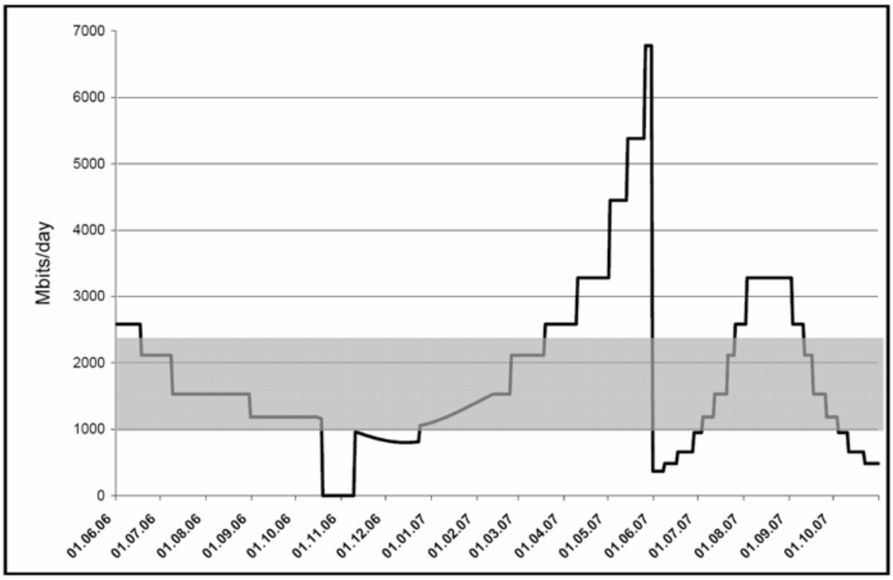


Figure 4.7. *Daily downlink of the scientific data to Cebreros antenna. Grey belt shows nominal level of daily data production by the payload.*

4.4.2 Data share between the experiments

One of the main principles of the SAP development was that no downlink share between experiments was imposed up-front. Distribution of the science cases and payload activity was defined by the mission science goals. This section presents the resulting downlink share between the experiments. Figure 4.6 shows the share with VIRTIS in nominal mode (see table in Annex 4). This situation approximately corresponds to the lower boundary of the payload data production belt in the Figure 4.5.

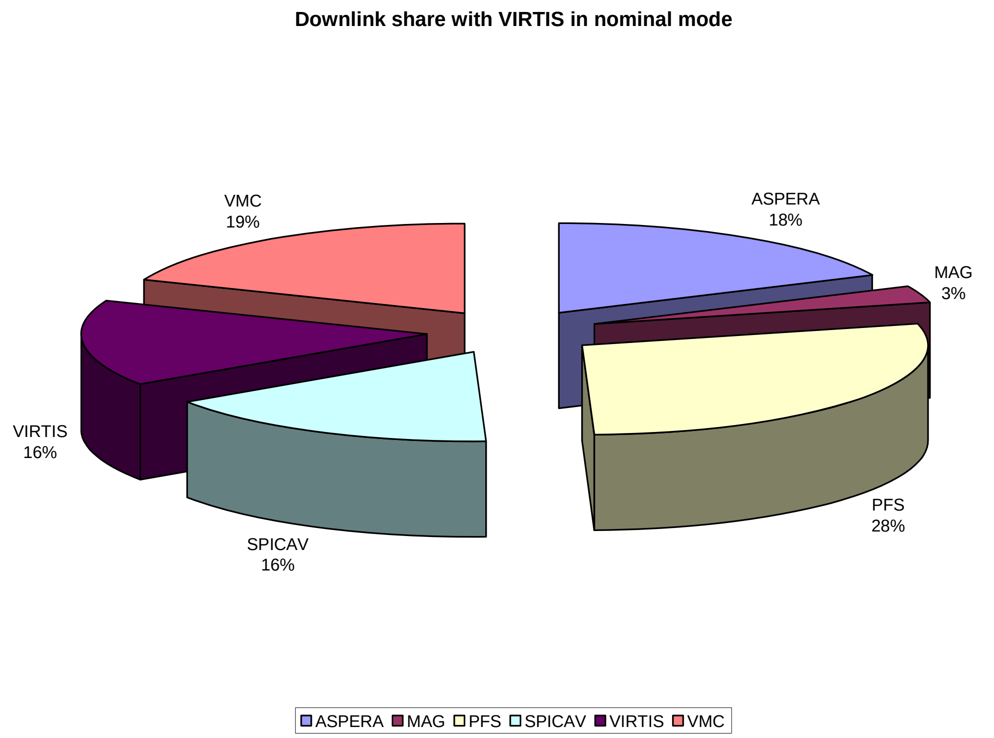


Figure 4.8. *Downlink share with VIRTIS in nominal mode.*

By using other modes with high-spatial and high-spectral resolution VIRTIS can significantly increase data production. Figure 4.7 illustrates the downlink share between the experiments when VIRTIS is in high-spectral resolution mode that corresponds to the upper boundary of the data production in the figure 4.5. VIRTIS can produce even more data in high-spatial resolution mode. Actually VIRTIS is the only experiment that can significantly increase collected data volume and fill the downlink in the periods of very high data rate. In this case using high-spatial-high-spectral resolution modes would increase the VIRTIS instant downlink share. Note that in both above mentioned cases moderate data compression factors had been taken into account for VIRTIS and VMC.

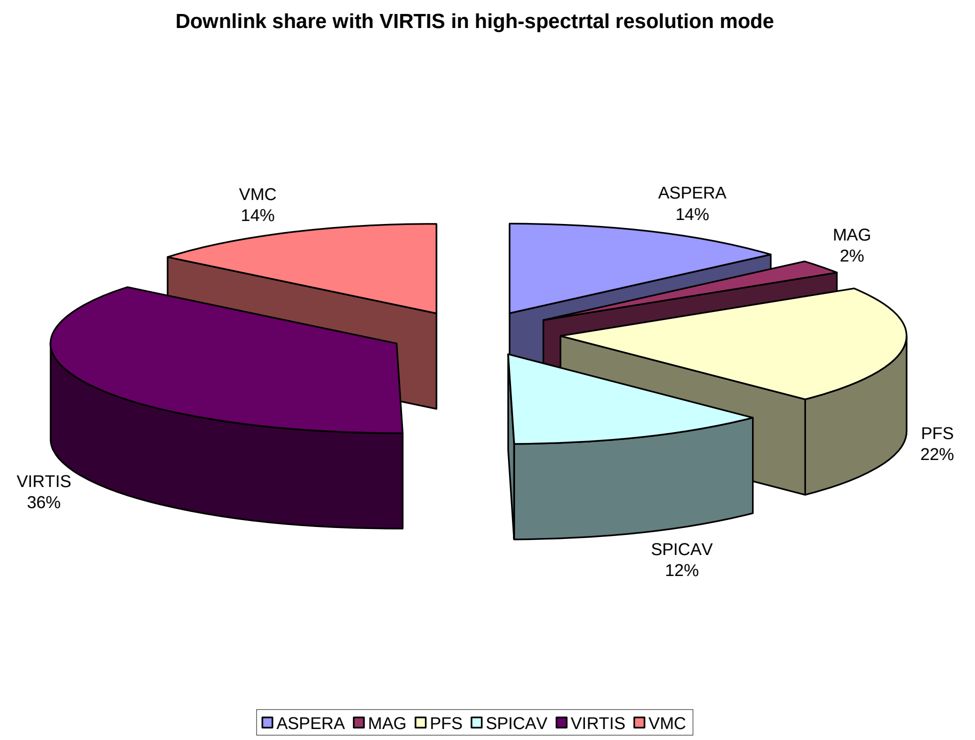


Figure 4.9. *Downlink share with VIRTIS in the high-spectral resolution mode.*

4.5 Science activity plan and operational constraints

Study of the science cases in terms of available mission resources and operational constrains carried out by Astrium [RD 9] gives a good basis for understanding the limitations of the current science activity plan.

4.5.1 Pointing and AOCS capabilities.

Pointing is considered as one of the main spacecraft resources that is shared by the payload. Current SAP A1+ is agreed between the experiments and, hence, is in general free of pointing conflicts "by design". Minor adjustments of the operations will be done later in the mid-term and short-term planning cycles.

The SAP A1+ uses the pointing modes that are within the spacecraft capabilities and are already implemented in the ESOC software (pericentre nadir, inertial, mosaic etc). Rough analysis of the SAP in terms of AOCS capabilities also did not show any major problems. Details of the operations will be checked in the MTP and STP.

4.5.2 Energy and power resources.

CDR study of the science cases concluded that in the nominal situation simultaneous operations of the payload even inside eclipse shadow are feasible during 96 minutes of the pericentre pass. The off-pericenter observations will be performed in the power optimized orientation (solar panels perpendicular to the sun direction). The only limitation results from the PDU overload when all instruments are switched ON simultaneously with the HGA transmission during radio science experiments. This situation will be additionally analyzed.

4.5.3 Onboard data handling

The problem of OBDH overload and SPICAV pooling identified during the CDR was solved by modification of the DMS software. Current capabilities of the OBDH bus to receive the data from OBDH-based experiments will not be exceeded even during simultaneous operations of the whole payload. The volume of the solid state mass memory (SSMM) (~ 8 Gbits at EOL) is quite enough to store the data collected by the whole payload in one orbit.

4.5.4 Downlink

The downlink budget was discussed in detail in the Section 4.4 above. The main conclusion is that expected downlink deficit can be compensated by using the payloads modes with reduced data production and high data compression factors.

4.5.5 Thermal constraints

Thermal aspects impose the most severe constrains on the Venus Express operations. Thermal flight rules are summarized in the spacecraft Flight User Manual [RD10]. The spacecraft can withstand long-standing illumination of two wall only: +X and +Z. Illumination of the other four walls (+/-Y, -Z, and –X) is allowed only within very limited profiles with a requirement of relatively long thermal recovery brake after that.

Since the time of SAP, issue 1 appeared significant progress has been made in this field. The implications of the thermal constraints on the science activity planning was analysed in [AD11]. This resulted in the proposal to the Project and Astrium to carry out additional numerical study of certain configurations and questions that are of crucial importance for the science planning. The results of this study are drafted in the [AD13] and are currently being translated into the VUM statements. The main results of the post-FAR study can be summarized as follows:

- The new study provides individual thermal recovery times for all science cases. Duration of thermal recovery break ranges from 12 hours to 20 hours.
- It was allowed to switch on the payload during the thermal recovery periods.

These modifications provide much more flexibility to the science planning. They will be used starting with early phases of the mission.

4.6 EPS analysis

4.6.1 EDF

The EDFs contain all the experiment models on mode level in order to make SAP A1+ and B1+ analysis. For SAP C1+ it will analyse experiments on TC sequence level.

4.6.2 ITL

An ITL is created for the complete mission. This ITL includes the lower-level ITLs for each Science Case. This allows to run through the complete SAP and make conflict and resource analysis

4.6.3 EPS commands

Give example commands use for running EPS.

4.6.4 Planning files consolidation

SAP 1+ can contain more then one case per orbit. The EPS allows to "include" multiple Science cases per orbit. However, as ASPERA and MAG are on all the time, they have to be separate from the Science Case ITL files and specific ASPERA and MAG ITLs need to be generated. These will also be included for every orbit. This means the following:

- ASPERA and MAG are on for every orbit
- Multiple Science Cases can be executed per orbit

Note that the simple inclusion of multiple science cases might not be correct, as certain operations might not be required by making the combination (for example if one experiment is already switched on for the first case, it might not want to be power-cycled, before it gets switched on for the second case scheduled)

4.6.5 EPS results

Here the results of the power and data-rate are provided and also the conflicts and recommendations are briefly mentioned. More details on the conflicts and recommendations should be in chapter 6.

For the first iteration of SAP2A this data will not be present. After the first SAP2A has been agreed by the experiment teams, the VSOC will make the analysis and report them in this document (or if requested in a separate one, TBD)

5. PLANNING FILE STATUS

5.1 Overview

5.2 Naming Convention

5.3 Observation Planning Files (merge with next chapter and remove)

5.4 Scenario Observation Planning Files

6. SAP CONFLICT EVALUATION

To be included in the SAP:

- Mechanism of solving conflicts
- Instrument priority scheme (for quick resolution of the conflicts at ESOC level).

6.1 Overview

6.1.1 SAP1

Here a list of all the conflict concerning case requests will be documented. It will also contain the list of possible combinations of cases in order to solve some of the conflicts.

6.2 PTB conflicts

6.3 EPS conflicts

6.4 Additional proposed modifications

7. SUMMARY AND CONCLUSIONS

Analysis of the proposed SAP plan leads to the following conclusions:

1. SAP provides an excellent baseline to achieve the mission science goals. In particular it provides perfect balance between close-up observations of the planet from pericentre and global view from apocentre. SAP allows us to perform atmospheric dynamics campaigns (repetition of cases #2 and #3 in several orbits) without interrupting regular pericentric (case #1) observations or occultation measurements.
2. SAP in general satisfies the plans of individual experiments and minimizes conflicts between them. The plan was approved by the Science Team.
3. SAP timeline is free from pointing conflicts.
4. Analysis of the downlink budget based on proposed instruments timelines showed that for about half of the nominal mission SAP is well within the downlink capabilities. In the periods of low downlink rate the timelines of experiments as well as data compression factors can be adjusted in order to keep the downlink budget positive.
5. The SAP described above is compliant with the thermal rules. In the “cold” periods of the mission such as in phases 2, 5, 6 when the cases #2 and #3 do not result in illumination of the sensitive walls, the off-pericentre observations can be immediately followed by any of the pericentre cases. In the “hot” periods, such as in phases 4 or 8, the spacecraft receives significant thermal load during the off-pericentre observations and, hence, the pericentre cases should be either skipped or modified in order to prevent the sun illuminating the sensitive walls. This can be achieved almost in all pericentre cases by using appropriate inertial orientation of the satellite to keep the sun in the +X/+Z quadrant. The drawback of such attitude is the loss of flexibility in selection of stars and limbs. Also the case#1 observations

will not anymore have nadir geometry during the pericentre pass. Case #6 (solar occultation) always results in illumination of the +Y wall of the spacecraft and, thus, cannot be preceded by the off-pericentre observations in the "hot" periods. This results in skipping of some case #2 and #3 observations when a mission "hot" phase overlaps with an eclipse season like in the second half of phase 7

6. SAP provides high scientific return and fully exploits spacecraft capabilities and mission resources.

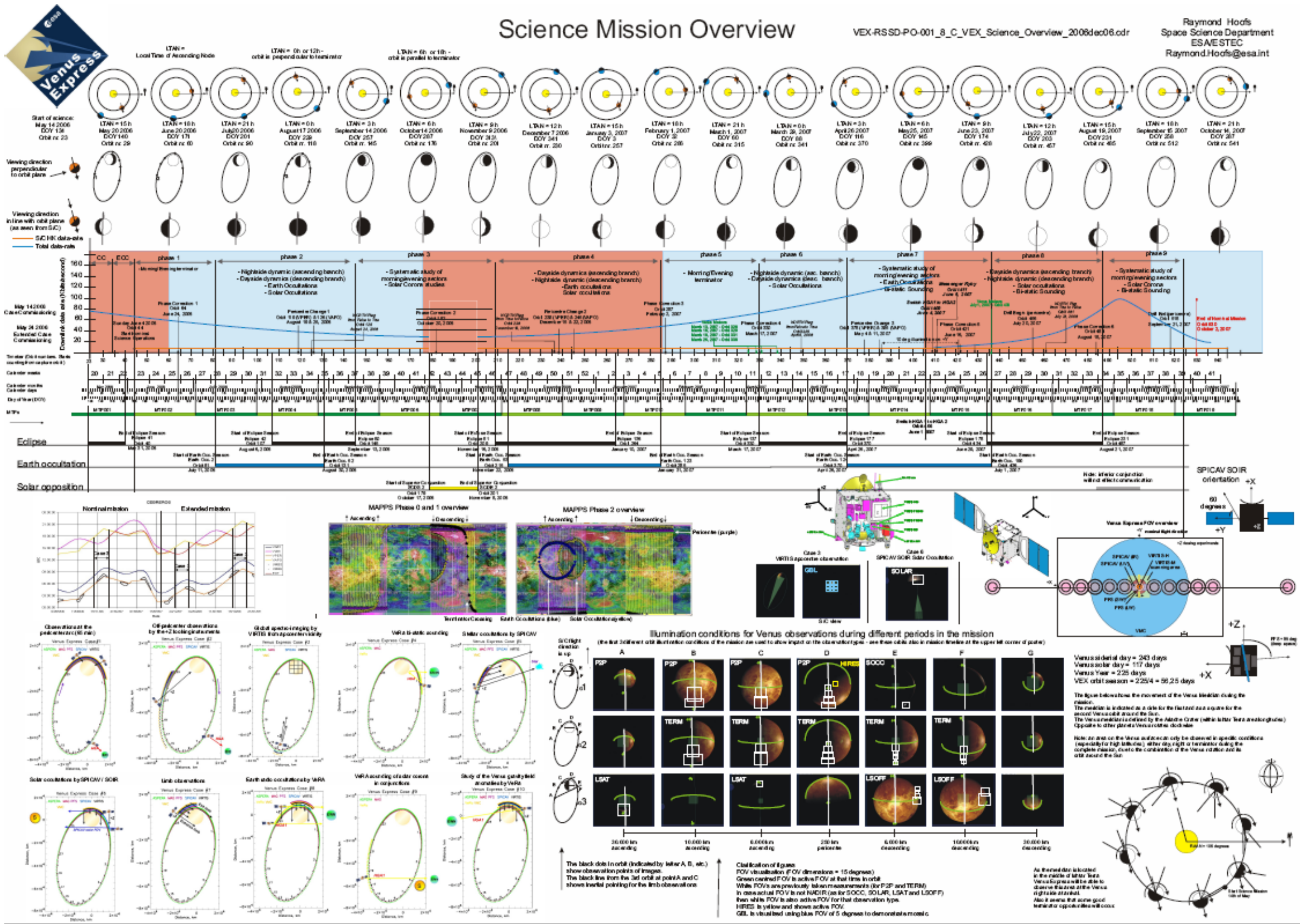
8. FUTURE WORK AND RECOMMENDATIONS

8.1 Overview

8.2 Missing inputs and future work

8.3 Action Items

8.4 Recommendations


Science Mission Overview
VEX-RSSD-PO-001_8_C_VEX_Science_Overview_2006dec06.cdr
Raymond Hoofs
Space Science Department
ESA/ESTEC
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Eclipse
Earth occultation
Solar opposition
MAPPS Phase 0 and 1 overview
MAPPS Phase 2 overview
Illumination conditions for Venus observations during different periods in the mission

Figure9.1

9. ANNEX 1 – NOMINAL MISSION OVERVIEW

PTB	Star	RA	DEC	RelTimeSt	RelTimeE	Lat.in	Long.in	LSunIn	day/night	Lat.out	Long.out	LSunOut	day/night	OccDurIn	Dist.In	OTAngle	OccDurOu	Dist.Out	OTAngle	TotOccDur
0	Star02	14,18	60,72																	
1	Star05	24,43	-57,24	-00:15:24	0:06:39	-1,52615	76,51323	2,626595	day	22,72781	-62,6585	134,4168	night	20	6031,593	137,4298	20	2926,255	25,39706	1330
2	Star08	58,53	31,88																	
3	Star09	59,46	40,01																	
4	Star12	78,63	-8,2	-00:04:14	0:19:49	59,20332	84,87461	58,52108	day	-32,9264	-38,4585	112,0243	night	20	2281,488	14,9577	20	7500,586	50,42033	1450
5	Star14	81,28	6,35	-00:02:14	0:24:39	73,92013	79,05021	72,94643	day	-38,9943	-25,3373	100,4806	night	30	1671,059	4,914946	20	9115,084	55,89387	1620
6	Star16	83	-0,3	-00:03:14	0:22:59	67,03779	85,61797	66,31215	day	-41,4765	-32,4052	105,3624	night	30	1905,423	9,954681	10	8578,777	54,2923	1580
7	Star17	83,78	9,93	-00:01:44	0:26:49	77,29326	77,23876	76,31203	day	-44,0114	-21,5792	97,12293	night	40	1559,126	12,96677	20	9793,102	57,68868	1720
8	Star18	83,86	-5,91	-00:04:04	0:21:29	61,22688	88,54272	60,85109	day	-41,3905	-38,6019	109,8713	night	30	2113,063	14,1317	10	8095,281	52,76362	1540
9	Star19	84,05	-1,2	-00:03:24	0:22:59	66,05069	87,02989	65,4361	day	-43,0943	-33,8472	106,0254	night	30	1924,192	10,79526	10	8573,839	54,2463	1590
10	Star20	85,19	-1,94	-00:03:24	0:22:59	65,26197	87,71637	64,71658	day	-44,7144	-35,236	106,5763	night	20	2005,366	10,79526	10	8583,436	54,33569	1590
11	Star21	86,94	-9,67	-00:04:34	0:21:09	57,29751	91,5157	57,44477	day	-44,3804	-45,1392	113,335	night	20	2277,305	16,59827	20	7937,852	51,94641	1550
12	Star25	95,68	-17,96	-00:05:34	0:19:49	49,09939	98,23362	51,35743	day	-46,941	-63,5439	122,8486	night	20	2651,067	21,41675	10	7512,451	50,53084	1530
13	Star28	101,29	-16,72	-00:05:24	0:20:29	50,69713	101,6513	53,8204	day	-50,5652	-72,5089	124,2366	night	20	2547,36	20,62522	10	7748,924	51,4704	1560
14	Star29	104,66	-28,97	-00:07:04	0:17:19	38,80049	104,4555	45,23914	day	-38,7178	-79,7036	136,8199	night	20	3095,736	143,3061	10	6649,52	47,01372	1470
15	Star36	120,9	-40	-00:08:24	0:14:19	29,63647	113,6572	44,89034	day	-22,8603	-92,125	155,8545	night	10	3655,507	143,7496	10	5613,058	42,21509	1370
16	Star41	140,53	-55,01	-00:11:04	0:10:29	15,64025	121,4636	45,94201	day	-0,98847	-93,032	170,3865	night	10	4572,081	142,5674	20	4226,653	34,27959	1300
17	Star44	160,74	-64,39	-00:13:34	0:08:09	4,658614	125,9419	48,70821	day	13,13918	-91,2806	161,9285	night	10	5424,197	139,87	20	3401,374	28,78338	1310
18	Star46	182,09	-50,72	-00:11:54	0:06:29	20,99942	138,0424	62,45686	day	27,94993	-98,2228	150,7571	night	20	4807,523	141,7882	20	2865,369	24,92755	1110
19	Star48	186,65	-63,1	-00:14:54	0:06:19	2,881351	133,6256	56,32148	day	25,90673	-92,5787	151,4038	night	10	5897,068	138,1165	20	2814,149	24,54457	1280
20	Star49	186,65	-63,1	-00:14:54	0:06:19	2,881351	133,6256	56,32148	day	25,90673	-92,5787	151,4038	night	10	5897,068	138,1165	20	2814,149	24,54457	1280
21	Star53	191,93	-59,69	-00:14:44	0:05:49	6,217824	136,7763	59,55759	day	29,98369	-93,8861	147,9248	night	20	5827,177	138,3426	20	2654,043	23,31475	1240
22	Star55	201,3	-11,16																	
23	Star56	204,97	-53,47	-00:14:54	0:04:29	11,59861	143,4431	66,4495	day	40,67981	-94,6861	137,7106	night	20	5903,796	138,1165	30	2147,901	19,15139	1170
24	Star57	206,88	49,31																	
25	Star59	208,88	-47,29	-00:13:54	0:03:29	20,78805	147,4832	71,15649	day	48,10999	-96,6269	130,6286	night	20	5544,446	139,4451	30	1891,641	17,05003	1050
26	Star60	210,96	-60,37	-00:17:14	0:04:29	-1,55653	140,1299	62,88125	day	38,58507	-92,0297	139,2418	night	20	6686,812	134,8496	20	2237,505	19,98597	1310
27	Star62	218,88	-42,16	-00:14:14	0:01:49	25,96898	153,5111	74,414	day	58,79292	-96,78	120,1165	night	30	5651,26	138,9936	40	1543,116	14,07431	970
28	Star65	220,48	-47,39	-00:16:24	0:02:29	13,74902	151,1879	71,13378	day	54,01476	-93,7994	124,7265	night	20	6406,017	136,0191	40	1652,793	15,01162	1140
29	Star70	239,71	-26,11																	
30	Star71	240,08	-22,62																	
31	Star73	241,36	-19,81																	
32	Star74	245,3	-25,59																	
33	Star76	248,97	-28,22	-00:23:54	-00:06:44	17,83872	162,7077	82,40637	day	73,85444	-174,197	93,22955	term	60	8889,839	125,8604	110	2971,777	25,76973	1030
34	Star77	249,29	-10,57																	
35	Star84	263,4	-37,1	-00:36:04	-00:02:04	-33,6313	163,8089	85,16366	day	75,47152	-97,1408	103,4659	night	20	12628,92	113,5194	60	1601,644	14,59286	2040
36	Star86	265,62	-39,03	-00:36:24	-00:01:24	-39,3528	161,7472	84,04897	day	73,61713	-90,8344	105,1381	night	20	12718,15	113,2478	60	1434,464	13,10046	2100
37	Star89	283,82	-26,3	-00:53:44	-00:06:14	-79,3618	170,6336	91,09294	term	85,94663	-96,5174	92,99871	term	20	17419,86	102,3025	50	2807,568	24,52729	2850
38	Star91	306,41	-56,74	-00:29:14	0:02:09	-50,076	83,67022	51,35008	day	53,44445	-73,3506	120,3645	night	20	10586,77	119,8081	30	1562,408	14,22119	1890
	LSun	=	Local	(Zenith)																
		angle	>	90	->	dark	conditions													
		angle	=	90	->	terminator	conditions													
		angle	<	90	->	light	conditions													
		RA	of	Express	orbit	is	102	degrees												
		Stars	in	102	and	282	(102	+		180)	will	get		occulted	easily					
		Stars	in	192	(102	+	90)	and		12	(102	-		90)	will	not	get	occulted	easily	

10. ANNEX 2. LIST OF STARS FOR STELLAR OCCULTATION OBSERVATIONS

11. ANNEX 3. TABLE OF THE VERA EXPERIMENTS

Scheduling of the VeRa observations is agreed up to Phase IV of the mission. The New Norcia and DSN ground stations are booked for this period.

Time Period /Date refers to the date of the pericentre for the current orbit/	**Orbit Number**	**VeRa Experiment**	**Distance Earth-Venus [AU]**	**Surface Target**	**Station**	**Number of Passes**	**Start Time** /wrt pericentre/	**End Time** /wrt pericentre/
Phase 0 (Commisioning phase)								
23.05.2006	32	Bistatic Radar Commissioning	1.1	Akna Montes Lakshmi Planum	DSN/NNO	1	-00:10:29	00:49:31
09.06.2006	49	USO tuning	1.1		NNO	1	-00:20:00	00:20:00
Phase I								

15.06.2006- 20.06.2006 (preferred days are below)		Bistatic Radar 1 /descending branch/	1.3	Maxwell Montes Slant Range:850km	DSN	3 request 3 alloc		
15.06	55	#1				1	-00:02:00 tbd	02:30:00 tbd
17.07	57	#2				1	-00:02:00 tbd	02:30:00 tbd
19.07	59	#3				1	-00:02:00 tbd	02:30:00 tbd
Phase II								
07.07.2006- 26.08.2006 (preferred dates below)		Earth Occultation 1 /ascending branch of the orbit/	1.5		NNO	25- request 21- alloc		
11.07	81	#1					-1:10:00	00:05:00
14.07	84	#2					-1:10:00	00:05:00
15.07	85	#3					-1:10:00	00:05:00
17.07	87	#4					-1:10:00	00:05:00
19.07	89	#5					-1:10:00	00:05:00
21.07	91	#6					-1:10:00	00:05:00
23.07	93	#7					-1:10:00	00:05:00

29.07	99	#8					-1:10:00	00:05:00
31.07	101	#9					-1:10:00	00:05:00
04.08	105	#10					-1:10:00	00:05:00
06.08	107	#11					-1:10:00	00:05:00
08.08	109	#12					-1:10:00	00:05:00
11.08	112	#13					-1:10:00	00:05:00
14.08	115	#14						
16.08	117	#15						
19.08	120	#16					-1:10:00	00:05:00
21.08	122	#17						
22.08	123	#18						
25.08	126	#19						
27.08	128	#20						
30.08	131	#21						
01.09.-10.09.2006		Gravity 1 /descending branch/	1.7	Atalanta Planitia, Coronae	NNO	4		
02.09	134	#1			NNO	1	00:00:00 tbd	00:30:00 tbd
03.09	135	#2			NNO	1	00:00:00 tbd	00:30:00 tbd
08.09	140	#3						

10.09	142	#4						
Phase III								
09.10.2006- 24.11.2006		Solar Corona	1.7		DSN	30 request	4 hours between -05:00:00	And 05:00:00
20.09-13.11 1 pass in 1-2 orbits except for the peak of outage period around 28.10					**DSN**	30 allocated in Phases III and IV	4 hours between -05:00:00	And 05:00:00
			1.7					
9.10	171							
11.10	173							
13.10	175							
15.10	177							
17.10	179							
18.10	180							
19.10	181							
20.10	182							

21.10	183							
22.10	184							
23.10	185							
24.10	186							
25.10	187							
28.10.2006	**190**	**Superior Conjunction**	1.7					
31.10	193							
1.11	194							
2.11	195							
3.11	196							
4.11	197							
5.11	198							
6.11	199							
7.11	200							
8.11	201							
10.11	203							
12.11	205							
14.11	207	Excluded from DSN plans						
16.11	209	Excluded from DSN plans						
18.11	211	Excluded from DSN plans						

20.11	213	Excluded from DSN plans						
22.11	215							
24.11	217	In the DSN plans						
Phase IV								
6.10.2006- 28.01.2007		Earth Occultation 2 /descending branch of the orbit/	1.6		NNO **& DSN**	15 request 15 alloc		
7.12	230	#1	1.6		NNO			
10.12	233	#2	1.6		NNO			
13.12	236	#3	1.6		NNO			
17.12	240	#4			NNO			
18.12	241	#5			NNO			
25.12	248	#6	1.6		NNO			
27.12	250	#7	1.6		NNO			
31.12	254	#8	1.6		NNO			
3.01.2007	257	#9	1.6		NNO			
6.01	260	#10	1.6		NNO			
9.01	263	#11	1.6		NNO			
12.01	266	#12	1.6		NNO			

14.01	268	#13	1.6		NNO			
16.01	270	#14	1.6		NNO			
18.01	272	#15	1.6		NNO			
20.01	274	#16						
22.01	276	#17						
24.01	278	#18						
26.01	280	#19						
28.01	282	#20						
31.01	285	#21						
Phase VI								
17.03.2007- 20.03.2007		Bistatic Radar 4 /ascending branch/	1.3	Theia Mons	DSN	2 total		
18.03	331	#1			DSN			
20.03	333	#2			DSN			
Phase VII								
22.04.2007- 26.06.2007		Earth Occultation 3 /ascending branch of the orbit/	0.8		NNO	36 request 29 alloc		

26.04	370	#1			NNO			
28.04	372	#2			NNO			
30.04	374	#3			NNO			
2.05	376	#4			NNO			
4.05	378	#5			NNO			
6.05	380	#6			NNO			
7.05	381				DSN 70m request			
8.05	382	#7			NNO			
10.05	384	#8			NNO			
12.05	386	#9			NNO			
14.05	388	#10			NNO			
16.05	390	#11			NNO			
18.05	392	#12			NNO			
20.05	394	#13			NNO			
22.05	396	#14			NNO			
24.05	398	#15			NNO			
25.05	399				DSN 70m request			
26.05	400	#16			NNO			

27.05	401				DSN 70 m request			
30.05	404	#17			NNO			
31.05	405				DSN 70m request			
1.06	406	#18			NNO	HGA2		
3.06	408	#19			NNO	HGA2		
6.06	411	Messenger flyby						
7.06	412	#20			NNO	HGA2		
9.06	414	#21			DSN 70 m	HGA2		
13.06	418	#22			NNO	HGA2		
15.06	420	#23			NNO	HGA2		
17.06	422	#24			NNO	HGA2		
19.06	424	#25			NNO	HGA2		
22.06	427	#26			NNO	HGA2		
25.06	430	#27			NNO	HGA2		
		Bistatic Radar 5 /descending branch/	0.7	Ozza Mons	DSN	2		
~~5.06~~	~~410~~	~~#1~~			~~DSN~~			Cancelled

								because of the Messenger flyby
12.06	417	#2			DSN			
~~23.06.2007-~~ ~~02.07.2008~~		~~Gravity 2~~ ~~/descending branch of the orbit/~~ **Gravity#2 cancelled**	~~0.75~~	~~Atalanta Planitia, Coronae~~	~~NNO~~	~~10-request~~ ~~5 alloc~~		
~~21.06~~	~~426~~	~~#1~~						
~~24.06~~	~~429~~	~~#2~~						
~~27.06~~	~~432~~	~~#3~~						
~~29.06~~	~~434~~	~~#4~~						
Phase VIII								
~~2.07~~	~~437~~	~~#5~~				~~1~~		
02.08.2007-03.08.2007		Bistatic Radar 6 /descending branch of the orbit/	0.3	Theia Mons		2		
02.08	468	#1			DSN			

03.08	469	#2			DSN			
17.08.2007		Inferior Solar Conjunction	0.3					
Phase IX								
		Bistatic Radar 6a /ascending branch/	0.5	Maxwell Montes	DSN	3		
27.09	525	#1						
?????								
??????								

Extended Mission

Time Period /Date refers to the date of the pericentre for the current orbit/	**Orbit Number**	**VeRa Experiment**	**Distance Earth-Venus [AU]**	**Surface Target**	**Station**	**Number of Passes**	**Start Time** /wrt pericentre/	**End Time** /wrt pericentre/
06.10-11.10.2007		Bistatic Radar 7		Thesis Regio	DSN	2		
?????		#1						
?????		#2						
09.11-15.11.2007		Bistatic Radar 8		Maat Mons/ Ozza Mons	DSN	2		
?????		#1						
?????		#2						
21.12-25.12.2007		Bistatic Radar 9	1.1	Theia Mons/ Dali Chasma	DSN	2		
?????		#1						
?????		#2						

23.12-01.03.2008		Gravity 3	1.3	Atalanta Planitia, Coronae	NNO	No NNO passes in 2007		

2008

31.12.2007-10.03.2008	Earth Occultation 4	1.3		NNO	
23.12.2007-01.03.2008	Gravity 3	1.3	Atalanta Planitia, Coronae	NNO	At least 15 passes separated by 1-3 orbits
09.06.2008	Superior Solar Conjunction	1.7			
02.05.2008-15.07.2008	Solar Corona	1.7		DSN	30
02.06.2008-28.07.2008	Earth Occultation 5	1.7			
06.09.2008-27.10.2008	Gravity 4	1.4	Atalanta Planitia, Coronae		
25.10.2008-27.12.2008	Earth Occultation 6	1.0			

Source: ESA **Orbit File :**	**ORVF_FDLVMA_DA_______________00001.VE** **X**		**15.04.2005** **B.H./J.S.**		