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Planetary Missions Division

Venus Express

Science Activity Plan for
Extended Mission
SAP-E

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

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TABLE OF CONTENT

1. INTRODUCTION

1.1 Introduction

Venus Express (VEX) is ESA's first mission to Venus. 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 spacecraft was inserted in orbit on April 11, 2006 and since June 2006 performs routine science observations. The Nominal Mission ends on October 2, 2007. However the mission extension till May 2009 was approved. 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 for Venus Express Extended Mission (SAP-E) describes in a structured way the scientific activities to be carried out throughout the extended mission (October 2007 till May 2009). 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. SAP-E contains preliminary MTP timelines (sequences of science cases) agreed by the VEX Science Team. The timelines will be later used as starting point for detailed discussion of each MTP planning. 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 General observation strategy for Extended Mission

The Venus Express Extended Mission has the following strategic objectives:

- Improve and complete spatial and temporal observational coverage;
- Study in detail the phenomena discovered in the Nominal Mission;
- Take advantage of the new operation modes (case#2 "pendulum", spot pointing etc)
- Perform pericentre lowering down to the altitude that still allows usual operations without entering aerobraking mode (~170-270 km);
- Perform necessary studies and tests preparing the spacecraft for future aerobraking campaign.

These goals determine the following planning outline for Extended Mission:

- October 2, 2007 – May 31, 2008 (MTPs #19-27): operations like in the Nominal Mission
- June 2008 – TBD: operations with low pericentre
- TBD – Aerobraking campaign

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). 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.

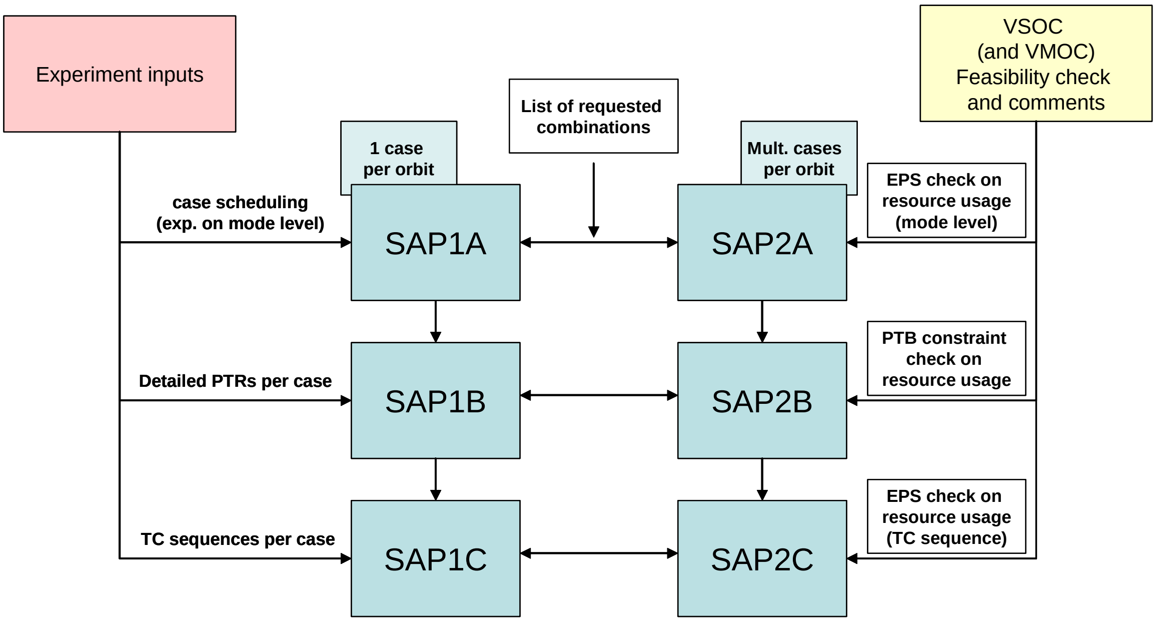

Figure 2.1 *SAP overview diagram*

2.4 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 250 km and 350 km during the first 8 months of the Extended Mission. After May 31, 2008 the pericenter will be lowered to the corridor 170-270 km to allow plasma observations in this altitude range. This pericentre lowering will not require any changes in observations strategy or special spacecraft operations (aerobraking mode). 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.

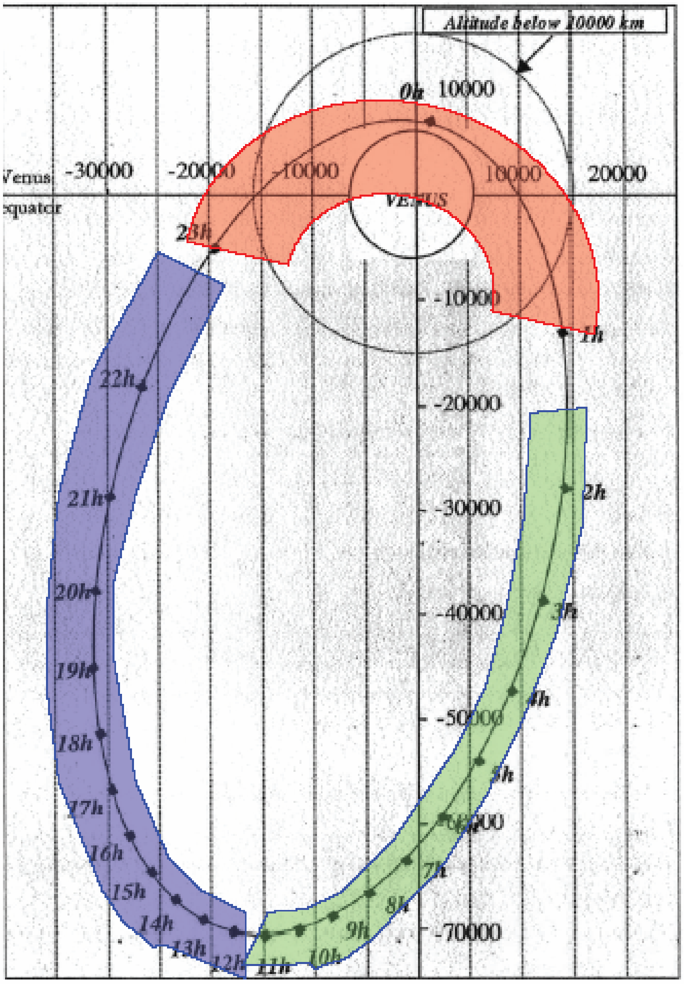

Figure 2.2 *The Venus Express orbit and orbital phases: red- pericentre observations, blue off-pericentre observations in ascending branch, green – telecommunications with Cebreros.*

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. The periods when the telecommunication phase ends early enough provide favorable conditions for the Case#3 apocentric mosaic since the observations can be carried out around pericentre. These periods are marked in figure 2.4.

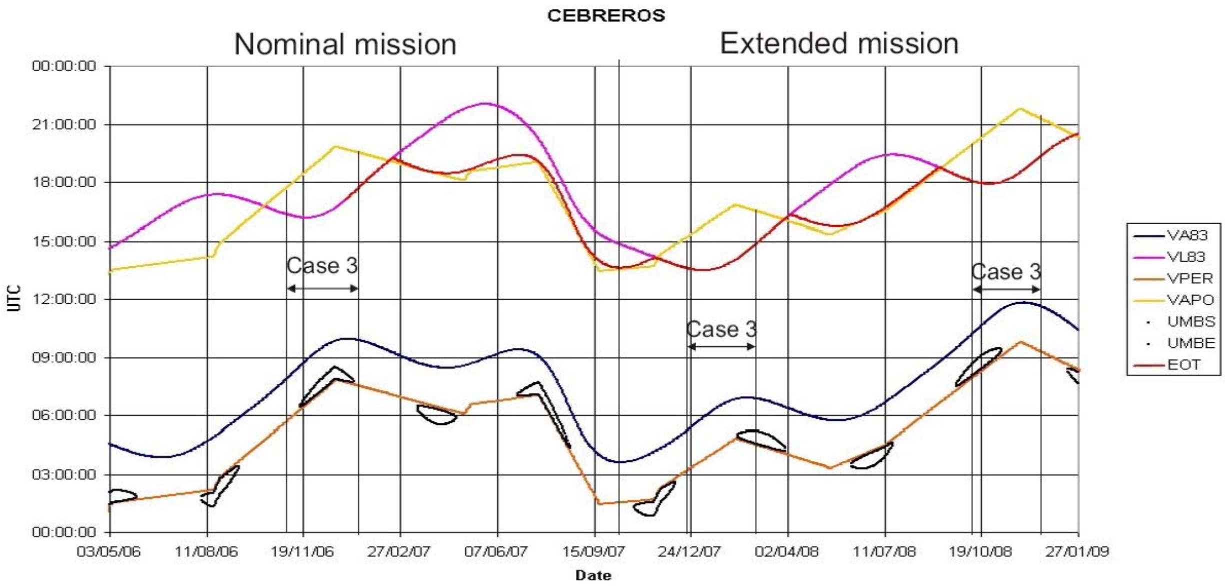

Figure 2.3 *Visibility of the Cebreros ground station from the satellite.*

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-E PROPER

This section gives an overview of the Science Activity Plan for Extended Mission as a whole (chapter 3.1). It is followed by descriptions of payload activity during first 8 months of the mission (MTP#19-27). Depending on the different environmental conditions (occultation, illumination conditions etc.), the science will focus on different mission objectives during the different MTPs.

3.1 Science Activity Plan overview

3.1.1 Coverage

The SAPE will first cover in detail 8 months of Extended mission from October 3, 2007 till May 31, 2008 and then provide general description of the rest of the mission. During the mission there will be different phases (MTPs) 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 multiple science cases in each orbit taking into account mission constraints (thermal, pointing, data volume etc);

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. Maximum compliance with the current flight rules.

3.1.4 Extended Mission overview

Extended mission overview is given in the Annexe 1.

3.1.5 Instruments objectives and Request Summary

3.1.5.1 Introduction

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

3.1.5.2 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.

3.1.5.3 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.

3.1.5.4 PFS

PFS experiment was not operational during the nominal mission despite of several attempts to unblock the scanning mechanism.

3.1.5.5 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. 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.

3.1.5.6 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. These observations are abandoned since autumn 2007 due to power loss in the S-band.

(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. Support from the DSN antennae for the VeRa experiments as well as for the data downlink is agreed between ESA and NASA.

3.1.5.7 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. These mosaics campaign will be performed in specific seasons of the mission when the telecoms with Cebreros station end relatively early (figure 2.4)

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.

3.1.5.8 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 when the spacecraft is in eclipse.

3.2 MTP #19

3.2.1 Scientific focus

This MTP has no eclipse or occultation seasons. Case #3 (mosaics) also cannot be performed due to late end of the telecoms. A routine sequence of off-pericentre observations followed by nadir or limb, or stellar occultation will be carried out.

3.2.2 Environmental conditions

- Local Time at Ascending Node (LTAN): ~19-21 h
- Cold season
- Night side surface targets: Atla Regio (Sapas, Maat, Ozza Mons), Zemina corona.
- Data rate: ~500 Mbits/day

3.2.3 Timeleine

Dates: 23.09 – 20.10.2007

Orbits #520-547

Figures 3.1 and 3.2 show observations timeline and planet coverage by orbital tracks in MTP #19.

The meaning of the symbols in the planet coverage plots is as follows: yellow triangle – s/c enters and exits solar eclipse, blue triangle – s/c enters and exits Earth occultation. Note that the night and day on the planet in the planet coverage plots is valid for the LAST orbit of the considered MTP.

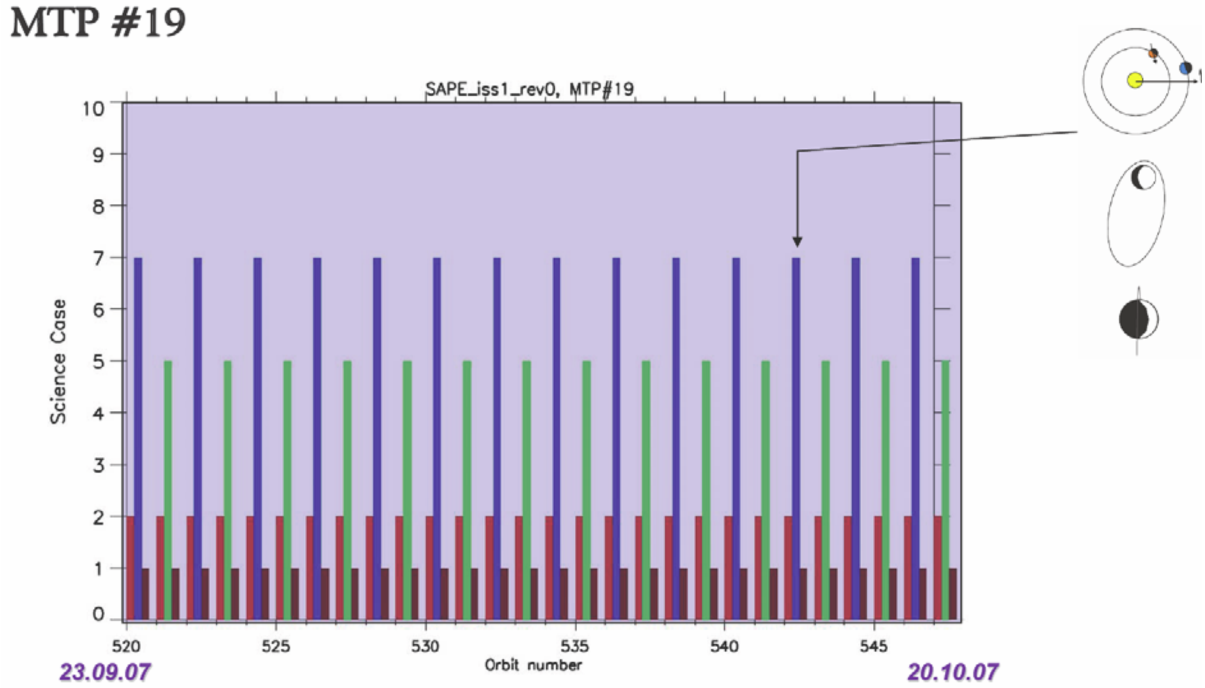

Figure 3.1 *MTP#19 timeline.*

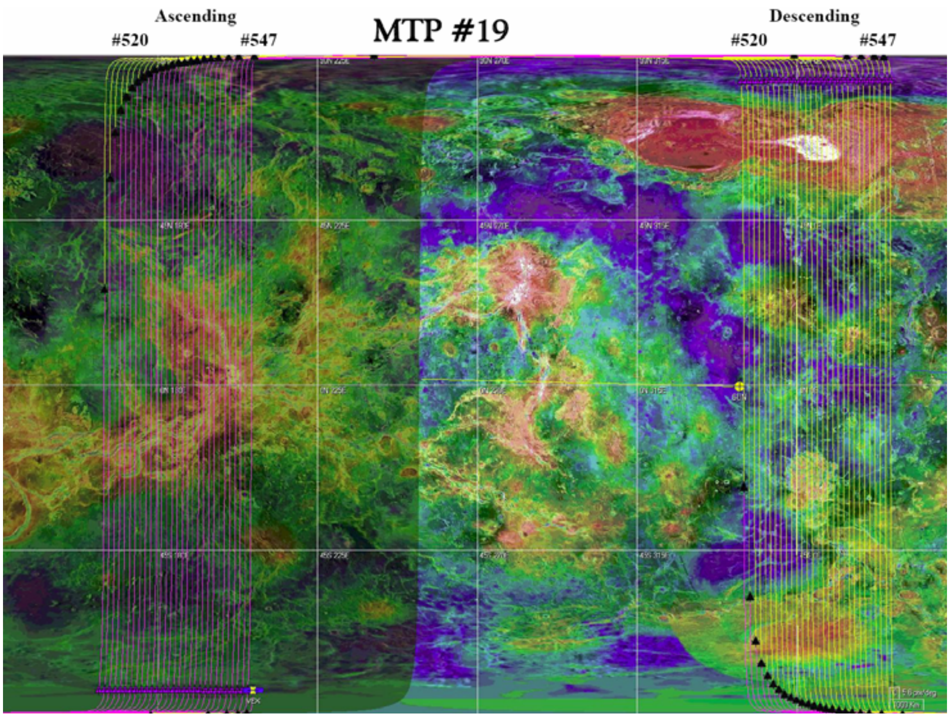

Figure 3.2. Planet coverage by orbital tracks in MTP#19 (see the note in 3.2.3)

3.3 MTP #20

3.3.1 Scientific focus

In this MTP the mission enters the “quadrature season”. This implies that during the telecommunication phase the s/c +Y wall will be illuminated by the Sun (VMC 10 deg sun avoidance). For this reason no “hot” observations are allowed during MTP #20. VIRTIS will perform “airglow campaign” – extensive observations of the airglow on the night side from ascending branch of the orbit in nadir and limb geometry. Every second CEB pass will be skipped after flip of the spacecraft in orbit #555 to allow VIRTIS to cool down. In orbit #554 the mission enters eclipse season, however no solar occultation will be performed (since case#6 is hot). VMC with get a chance of night side surface observations. Test observations in “spot pointing” mode will be carried out in orbits #561 and #571 with a goal to study cloud scattering phase function.

3.3.2 Environmental conditions

- Local Time at Ascending Node (LTAN): ~21-24 h
- Quadrature period (#546-581)
- Eclipse season (#554-597)
- Meteors in orbit #555
- Night side surface targets: Asteria Regio, Hinemoa, Gunda and Kawelu Planitia, Beta Regio (Rheja and Theja Mons), Phoebe Regio
- Switch to HGA1 in orbit #555
- Science data rate
    - Orbits #548-554: ~500 Mbits/day
    - Orbits #555-575: 5000-6000 Mbits/day

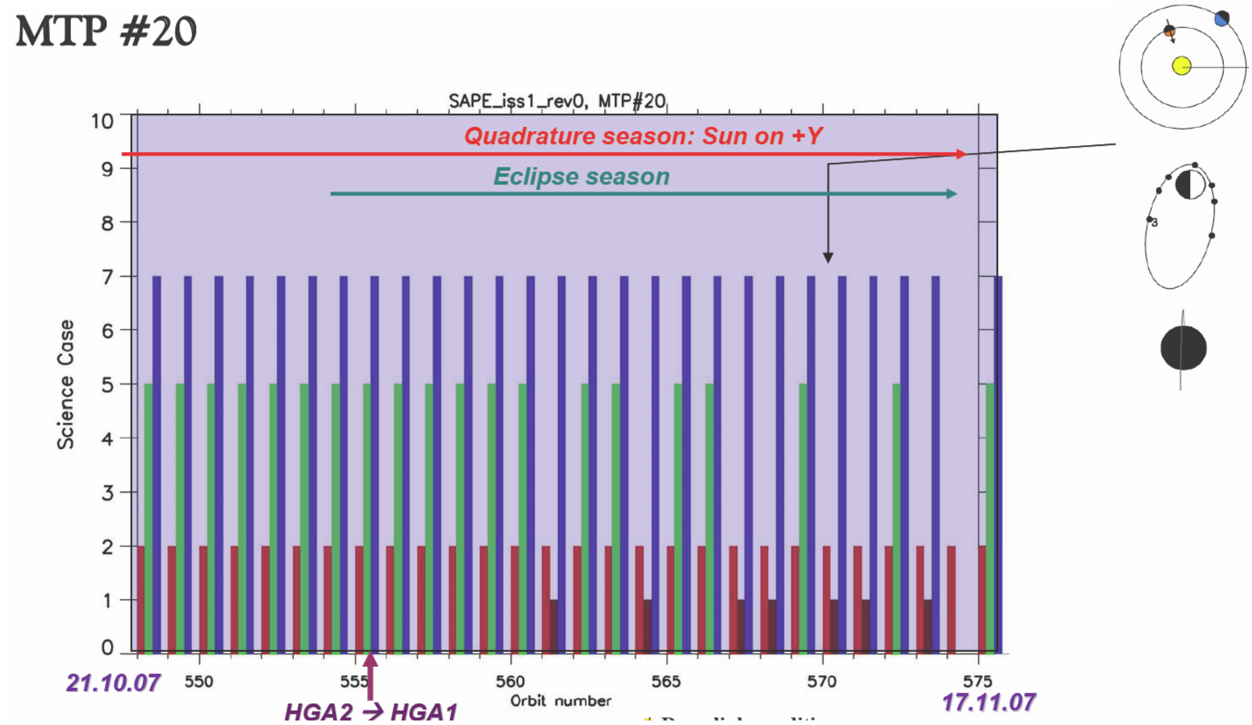

Figure 3.3 MTP#20 timeline.

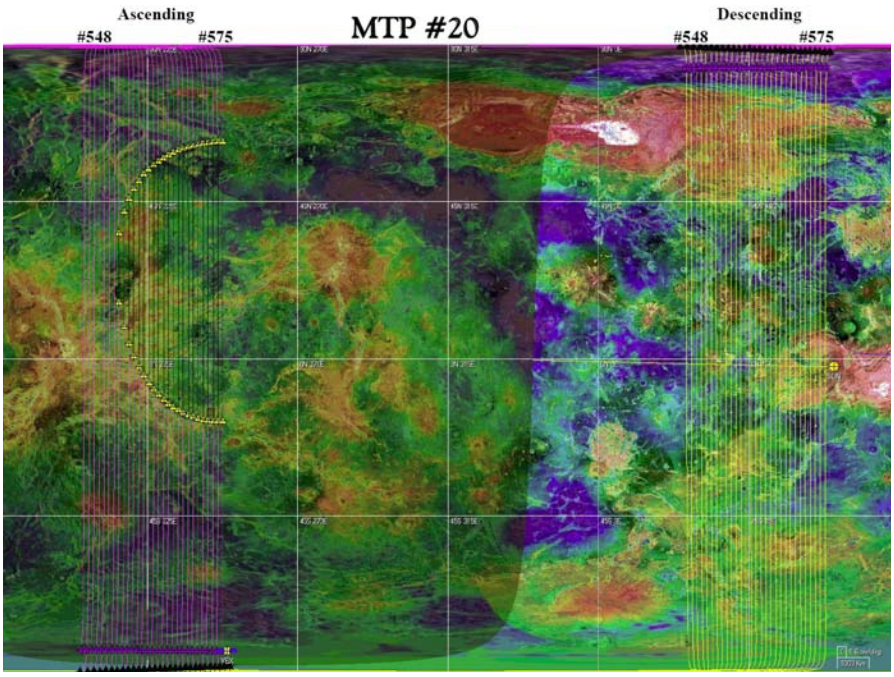

Figure 3.4. Planet coverage by orbital tracks in MTP#20 (see the note in 3.2.3).

3.3.3 Timeline

Dates: 21.10 – 17.11.2007

Orbits # 548-575

Figures 3.3 and 3.4 show observations timeline and planet coverage by orbital tracks in MTP #20.

3.3.4 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	
VIRTIS		Airglow campaign
VMC		Surface observations in eclipse

3.4 MTP #21

3.4.1 Scientific focus

The quadrature period ends in orbit #581 that opens way to "hot" observations. Priority is given to the solar occultation observations that are performed in each second orbit in the rest of eclipse season (till orbit #597). VMC will continue mapping the surface in 1 um window when the s/c is in eclipse. Ascending branch of the orbit will be busy with nadir observations by VIRTIS and VMC. In some orbits SPICAV will carry out stellar occultations at large distances (~-3h pericentre time).

3.4.2 Environmental conditions

- Local Time at Ascending Node (LTAN): ~ 0 –3h
- Sun illumination: "cold" period (cases #2 and #3 without exposing –Z to the sun)
- Occultations: Solar occultation (orbits #576-596)
- Night side surface targets: Night side surface targets: Asteria Regio, Hinemoa, Gunda and Kawelu Planitia, Beta Regio (Rheja and Theja Mons), Phoebe Regio
- Science data dump: 4000-5000 Mbits/day

3.4.3 Timeline

Dates: 18.11-15.12.2007

Orbits # 576-603

Figures 3.5-3.6 show observations timeline and planet coverage by orbital tracks in MTP #21.

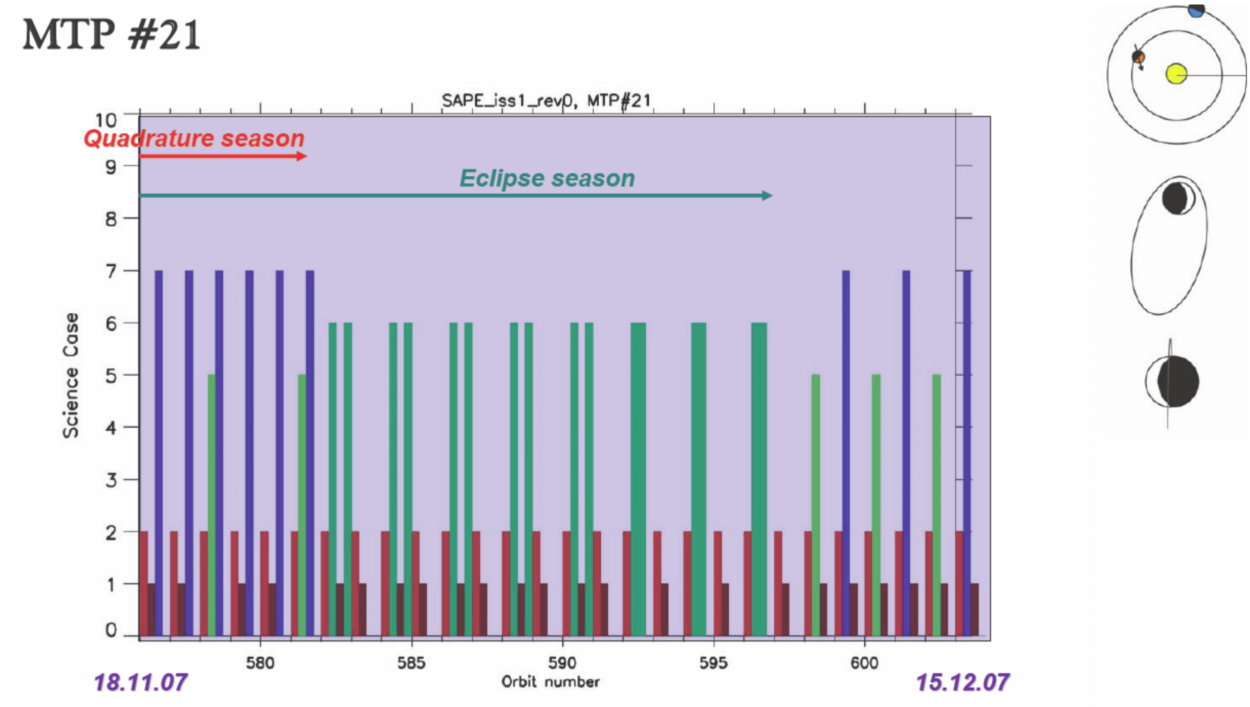

Figure 3.5 MTP#21 timeline

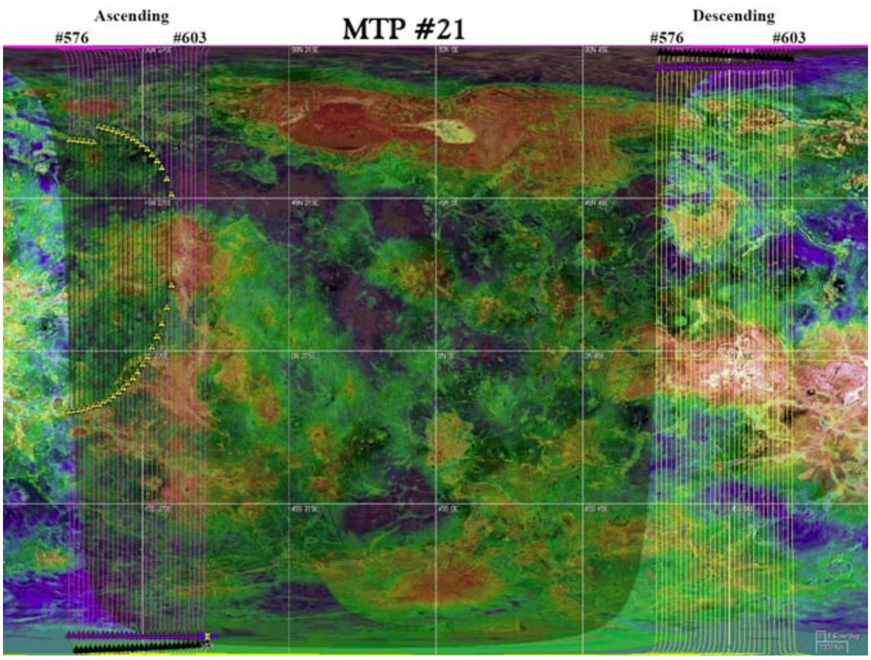

Figure 3.6. Planet coverage by orbital tracks in MTP#21 (see the note in 3.2.3).

3.5 MTP #22

3.5.1 Scientific focus

In orbit #612 the mission enters the period when the CEB telecoms pass ends rather early and there is enough time in the apocentre to perform mosaics with ~12 s/c re-pointings. In pericentre the spacecraft passes over Atalanta Planitia and gravity experiment will be carried out in orbits 615, 617, 619, 621. In orbit #624 the Earth Occultation season #4 begins, so priority in the pericentre observations will be given to the VeRa experiment. Earth occultations in the Southern hemisphere sound the same region as the VIRTIS near-IR temperature sounding. Observations of the same region will make possible to cross-correlate the temperature soundings by both techniques and to better constrain cloud structure.

3.5.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 3 - 6 h (morning terminator)
- VIRTIS apocentre mosaic season (orbits #612-631)
- Earth occultations (orbits #624-631)
- Night side surface targets: TBD
- Low downlink rate: 3000-4000 Mbits/day

3.5.3 Timeline

Dates: 16.12.2007 – 12.01.2008

Orbits # 604 – 631

Figures 3.7-3.8 show observations timeline and planet coverage by orbital tracks in MTP #22.

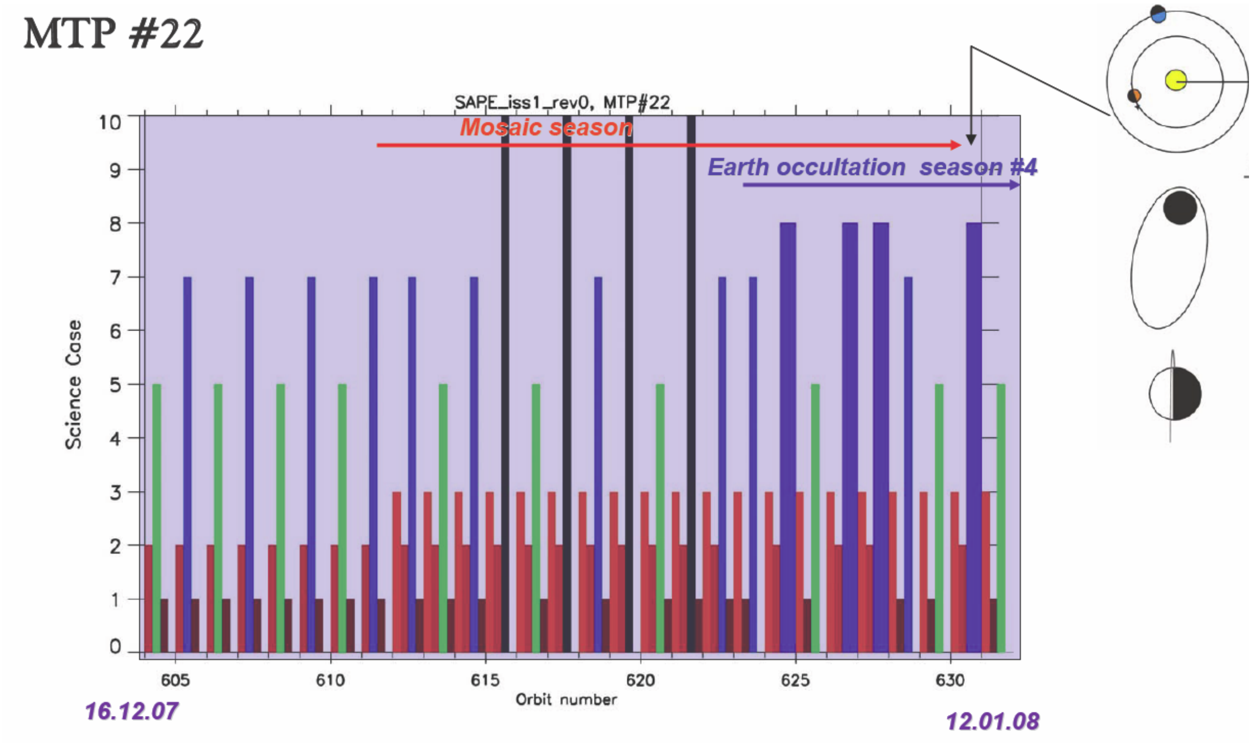

Figure 3.7 MTP#22 timeline

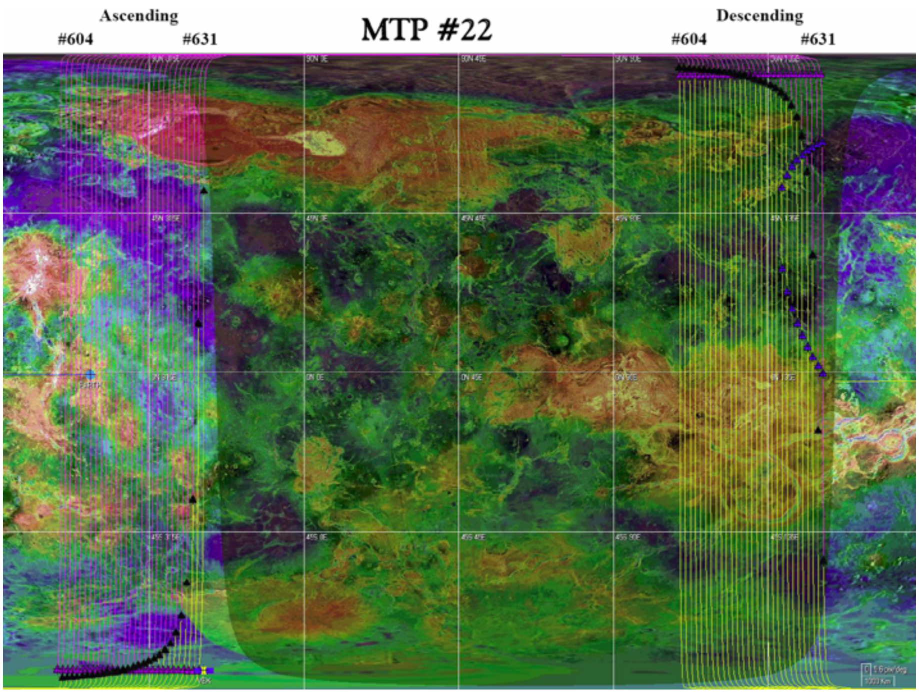

Figure 3.8. Planet coverage by orbital tracks in MTP#22 (see the note in 3.2.3).

3.6 MTP #23

3.6.1 Scientific focus

In this MTP the mission is still in the Earth occultation season #4 and the period favourable for the VIRTIS apocentre mosaics. These two kinds of observations will be given priority in this MTP. Due to maintenance of the New Norcia ground station the radio-science experiment will not be possible from orbit #645 till orbit #658. This will create a gap of ~45 deg latitude in the Southern hemisphere. This gap will be compensated by more frequent (every day) radio occiltations before and after this period. The gap will be filled with routine pericenter observations including cases 1, 5, and 7. During MTP #23 local time in ascending node will drift from morning to noon. In the last third of the MTP the case #2 “pendulum” observations of the day side will be started.

3.6.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 9-11 h.
- Earth occultation season #4 (contd)
- Apocentre mosaic season
- Hot season. Case#2 “pendulum” by the end of MTP
- Science data dump: 2000-1500 Mbits/day.

3.6.3 Timeline of the Phase IV

Dates: 13.01. – 9.02.2008

Orbits # 632-659

Figures 3.9-3.10 show observations timeline and planet coverage by orbital tracks in MTP #23.

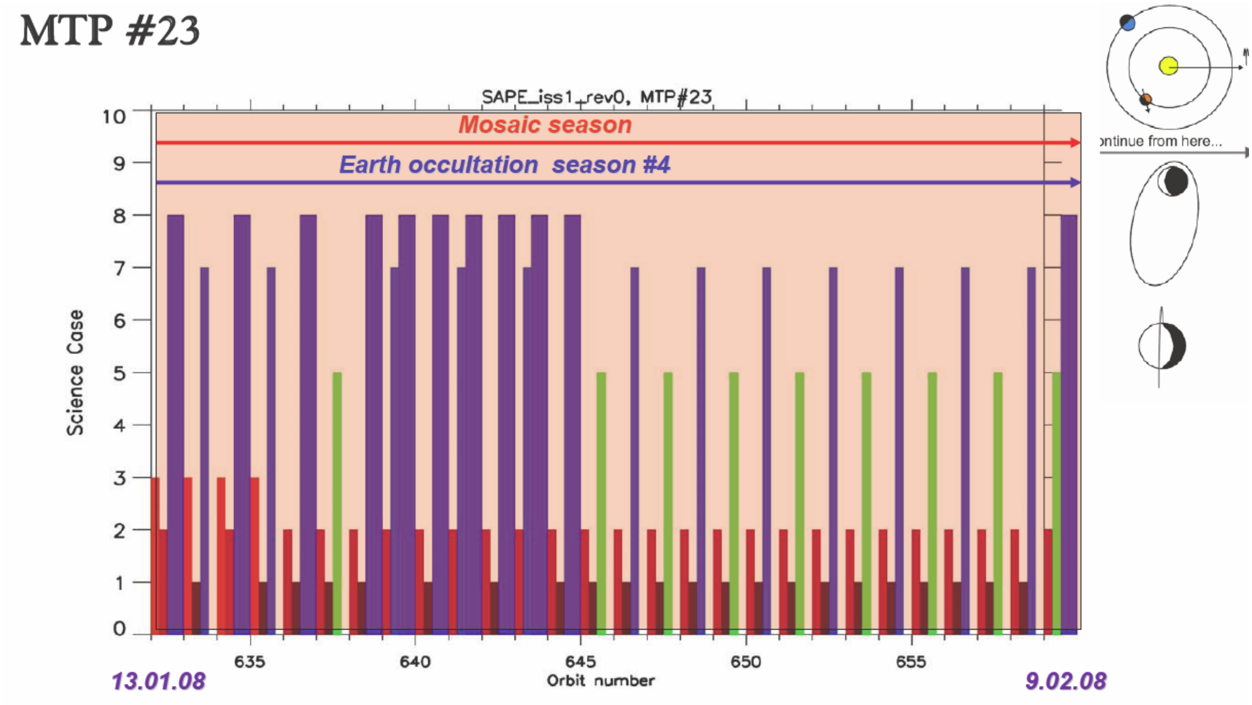

Figure 3.9 MTP#23 timeline.

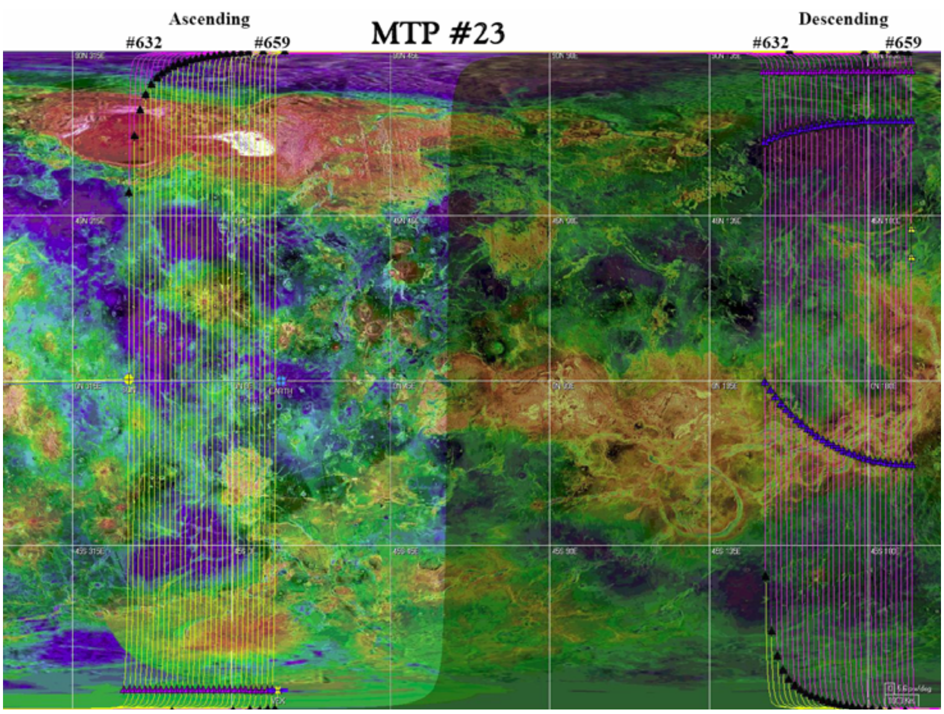

Figure 3.10. Planet coverage by orbital tracks in MTP#23 (see the note in 3.2.3).

3.7 MTP #24

3.7.1 Scientific focus

MTP #24 is characterized by overlap of three specific periods: VIRTIS apocentre mosaics, Earth occultation and eclipse seasons. Coordination of these observations, especially in what concerns temperature and composition sounding , would be highly desirable. During this MTP the ascending node of the orbit is close to noon, so the observations of the day side on ascending branch using case #2 “pendulum” and close-up mosaics would be very valuable. However MTP #24 belongs to the hot season and thermal issues will impose certain restrictions. For instance, case #2 cannot be done on ascending branch before solar occultation (case #6), but can be implemented before Earth occultation (case #8) since this observation is “cold”. Both Earth and solar occultations occur AFTER pericenter on the night side. It would be highly desirable to leave room for nadir observations of the surface on the night side by VMC, especially when eclipses are maximal. As in the earlier MTPs Case #1 can be combined with Case#6. Another limiting factor is rather low data rate in MTP #24.

3.7.2 Environmental conditions

- Local Time at Ascending Node (LTAN): ~12 h
- Hot season
- Specific periods: apocentre mosaic season, Earth occultation season #4, eclipse season.
- Night side surface targets: Atahensik and Zimina Coronae, Atla Regio (Ozza Mons) and East from it, Atalanta Planitia.
- Science data dump:1400-2000 Mbits/day

3.7.3 Timeline

Dates: 10.02 – 8.03.2008

Orbits # 659 – 687

Figures 3.11-3.12 show observations timeline and planet coverage by orbital tracks in MTP #24.

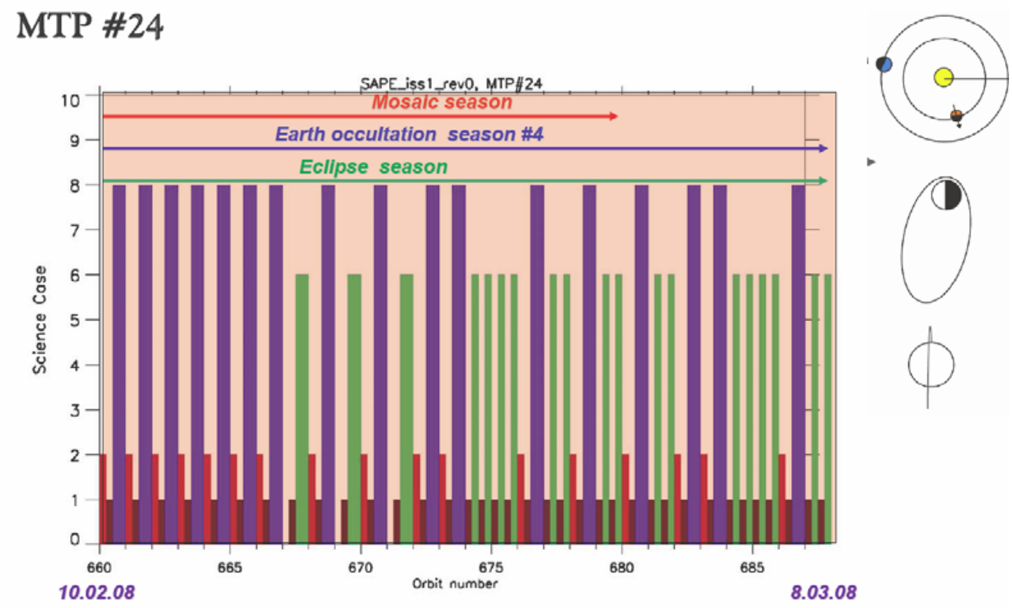

Figure 3.11. ***MTP#24*** *timeline*

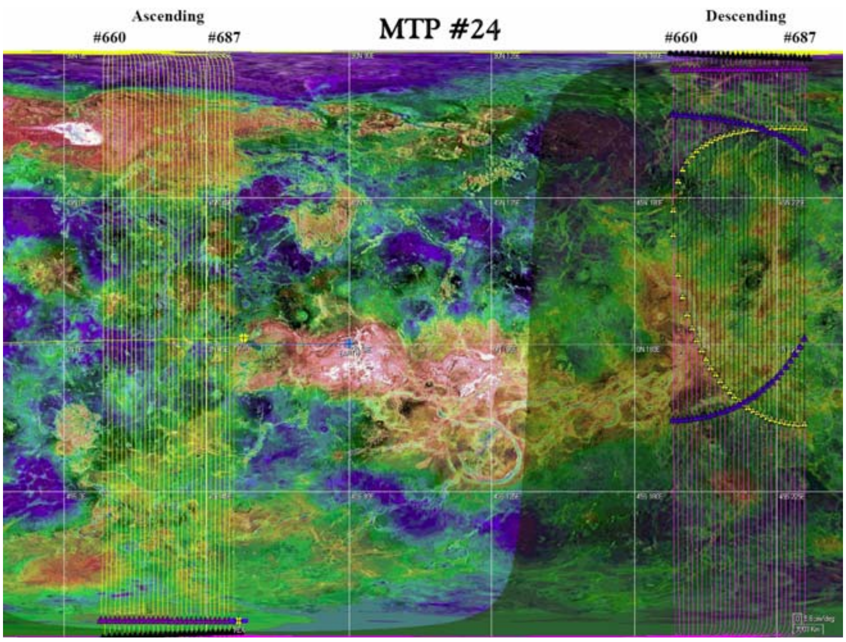

Figure 3.12. Planet coverage by orbital tracks in MTP#24 (see the note in 3.2.3).

3.8 MTP #25

3.8.1 Scientific focus

The Earth occultation season ends in orbit 693. After that the only peculiarity is the eclipse season. Case #6 (solar occs) will be performed in each second orbit. It will be alternated with the case #2 "pendulum" observations in ascending branch.

3.8.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 12 - 15 h
- Hot phase: Case #2 pendulum will be alternated with Case #6 (solar occs).
- Eclipse season till orbit #711
- Science data dump: ~1500 Mbits/day

3.8.3 Timeline

Dates: 9.03-5.04.2008

Orbits # 688 – 715

Figures 3.13-3.14 show observations timeline and planet coverage by orbital tracks in MTP #25.

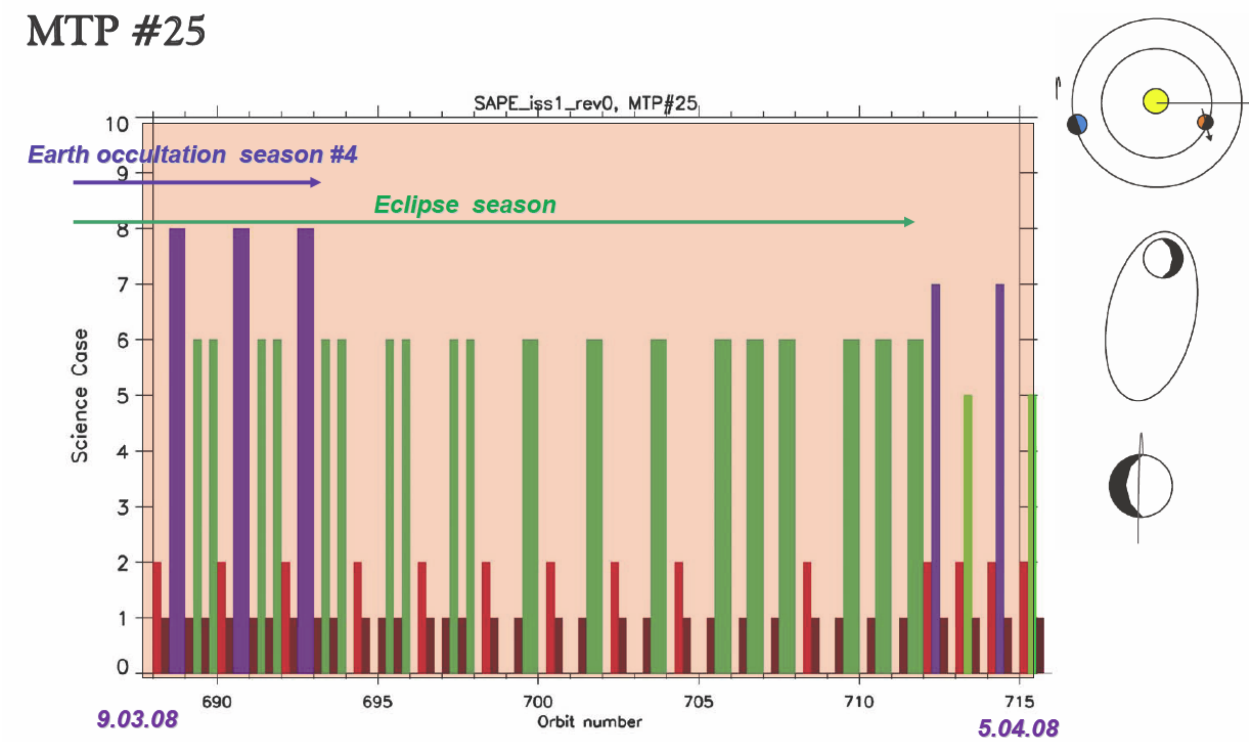

Figure 3.13. ***MTP#25*** *timeline.*

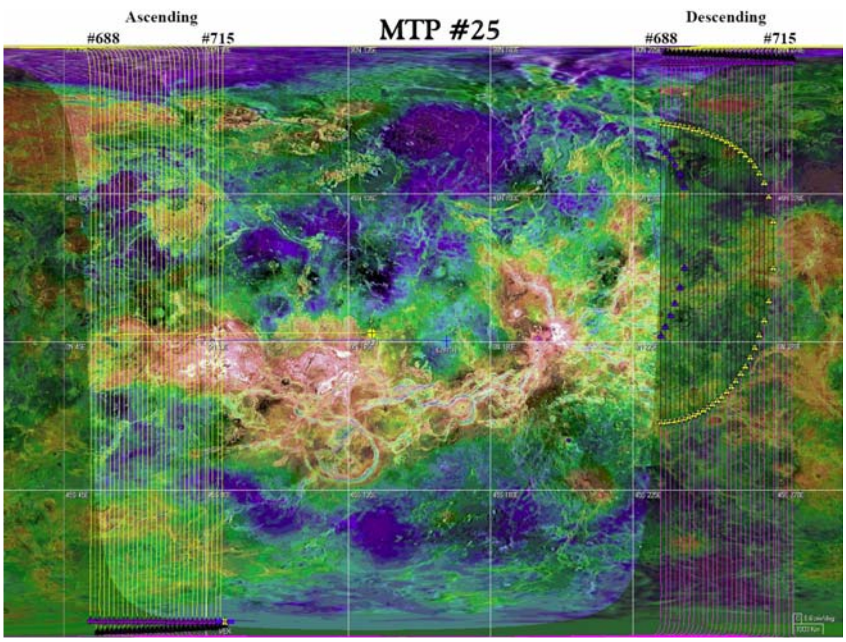

Figure 3.14. Planet coverage by orbital tracks in MTP#25 (see the note in 3.2.3).

3.9 MTP #26

3.9.1 Scientific focus

MTP#26 does not include any specific season. The observation timeline will be a routine combination of case #2 at ascending branch (with few degrees off track pointing at approach to keep Venus day side in field of view) and alternation of cases 1, 5 and 7 in pericentre. At the end of MTP (Orbit #741) the orbital track will go along the evening terminator. This particular period can be used for simultaneous sounding of the night side in IR and day side in UV to study correlations of cloud morphology.

3.9.2 Environmental conditions

- Local Time at Ascending Node (LTAN): ~15-18 h
- Hot period
- Science data dump: ~1000 Mbits/day

3.9.3 Timeline

Dates: 6.04-3.05.2008.

Orbits # 716-743

Figures 3.15-3.16 show observations timeline and planet coverage by orbital tracks in MTP #26.

Figure 3.15 ***MTP#26*** *timeline***.**

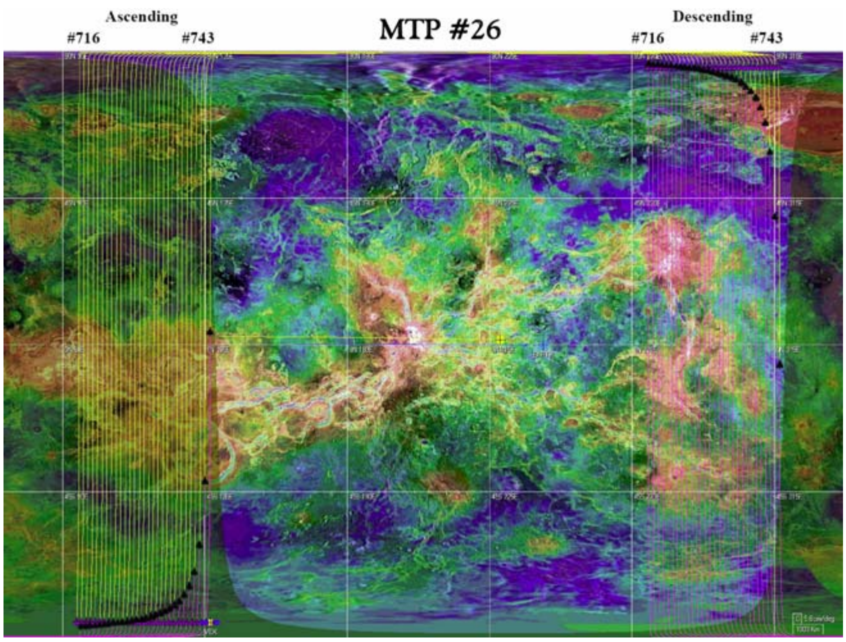

Figure 3.16. Planet coverage by orbital tracks in MTP#26 (see the note in 3.2.3).

3.10 MTP #27

3.10.1 Scientific focus

MTP #27 is similar to MTP #26 by absence of any peculiarities (occultations, eclipses).

The observation timeline will be also similar, however with more focus on the night side at ascending branch. At the end of MTP #27 (orbit #769) the mission enters superior conjunction phase and telecommunication outage period (orbits #769-790, May 29-June 19, 2008) during which all science operations will be suspended. Solar Corona experiment will not be planned because of the signal loss in the S-band.

3.10.2 Environmental conditions

- Local Time at Ascending Node (LTAN): ~18-21 h
- Cold period
- Night side targets:
- Science data dump: ~700 Mbits/day

3.10.3 Timeline

Dates: 4.05-31.05.2008.

Orbits # 744-771.

Figures 3.17-3.18 show observations timeline and planet coverage by orbital **t**racks in MTP #27.

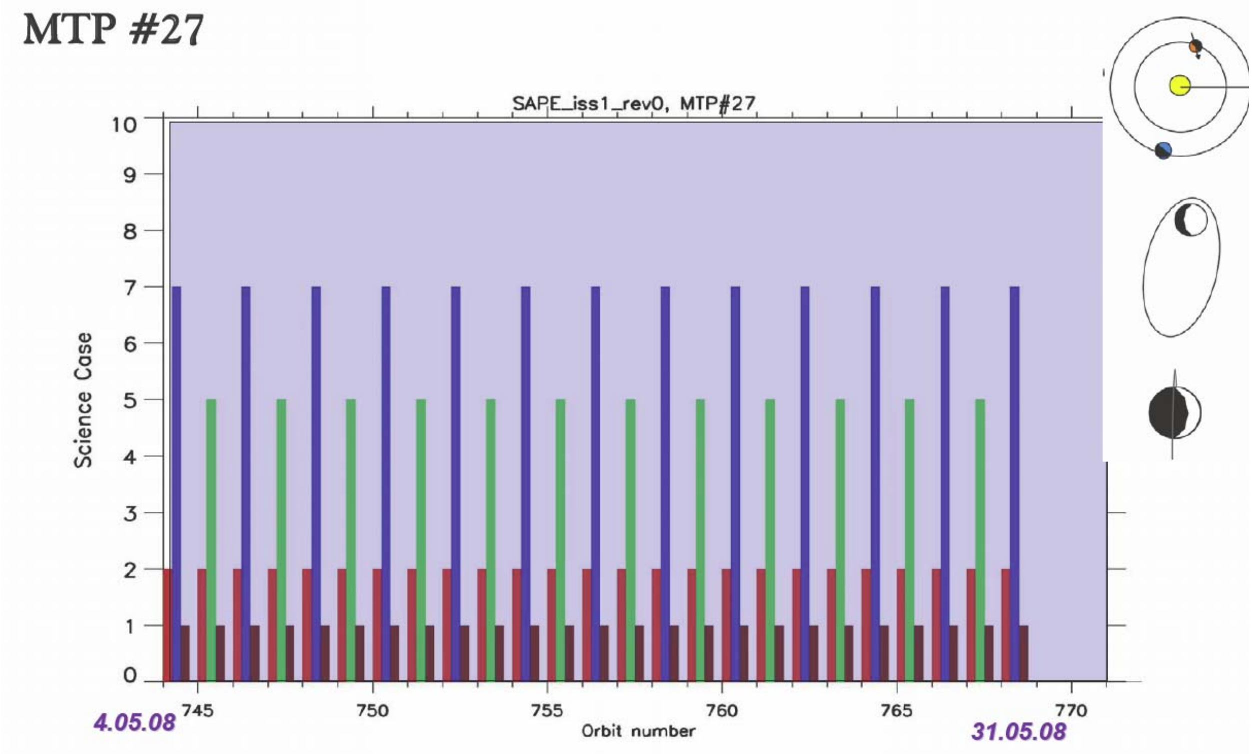

Figure 3.17 ***MTP#27*** *timeline***.**

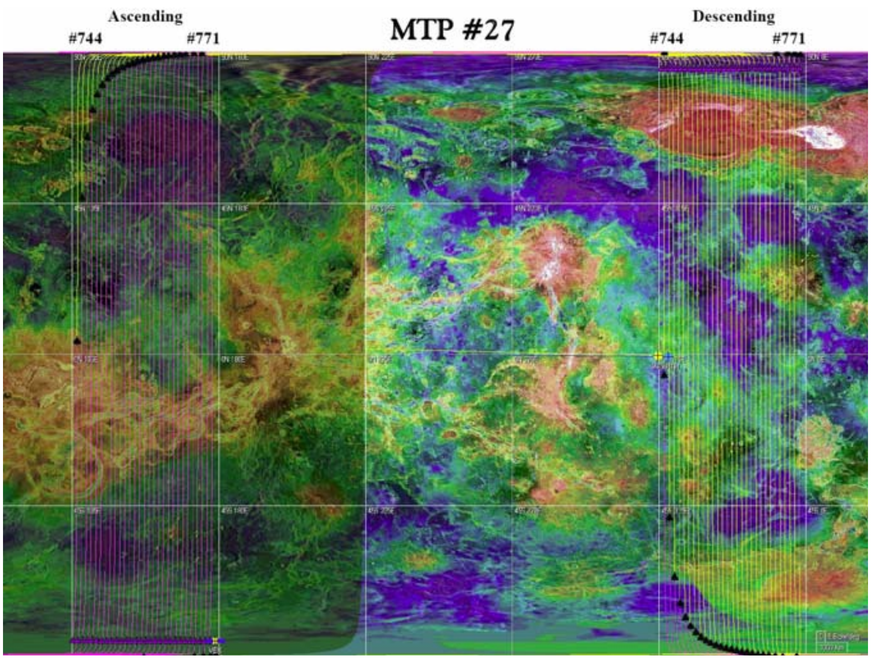

Figure 3.18. Planet coverage by orbital tracks in MTP#27 (see the note in 3.2.3).

3.11 MTP #28

3.11.1 Scientific focus

MTP #28 is by about 60% occupied by the Solar Conjunction when all science operations are suspended. The first orbit when the observations are resumed is #791 (figure 3.19). At this moment the mission is in the middle of the earth occultation season eclipse seasons. Local time at ascending node is close to mid-night thus making the rest of MTP favourable for typical night side observations before pericentre: night limb (airglow) and surface imaging. After pericentre observations will include wind tracking close to the planet and full day side monitoring.

The peculiarities of science observations of individual experiments are as follows:

SPICAV: Solar occultations (egress in every 2-d orbit);

Night side limbs before P and in plane limbs after P;

The geometry is also well suited for observations of the exosphere in the UV on the day side near noon.

VeRa: No solar corona experiments due to S-band signal loss ;

No Earth occultation experiment because of perturbations by the solar corona.

VMC: Surface imaging before P (East flank of Atla Regio, Ozza Mons, Zevana and Paga Chasma)

Wind tracking after P on the day side;

VIRTIS: night side monitoring in ascending branch

Night limbs together with SPICAV

Surface imaging before P (East flank of Atla Regio, Ozza Mons, Zevana and Paga Chasma).(together with VMC)

3.11.2 Environmental conditions

- Local Time at Ascending Node (LTAN): ~21-24 h
- Cold period

- Night side targets: east flank of Atla Regio (Ozza Mons, Zevana and Paga Chasma)
- Science data dump: very low (~700 Mbits/day)

3.11.3 Timeline

Dates: 1.06-28.06.2008.

Orbits # 772-799.

Current SAP combines case #2 observations in ascending branch and alternating of the following two types of orbits in pericentre vicinity:

Type 1: Night-side limbs before pericenter, followed by an in-plane limb after pericenter.

Type 2: Night side nadir, egress solar occultation, followed by pure nadir or a spot tracking on the day side.

Figures 3.19-3.20 show observations timeline and planet coverage by orbital tracks in MTP #28.

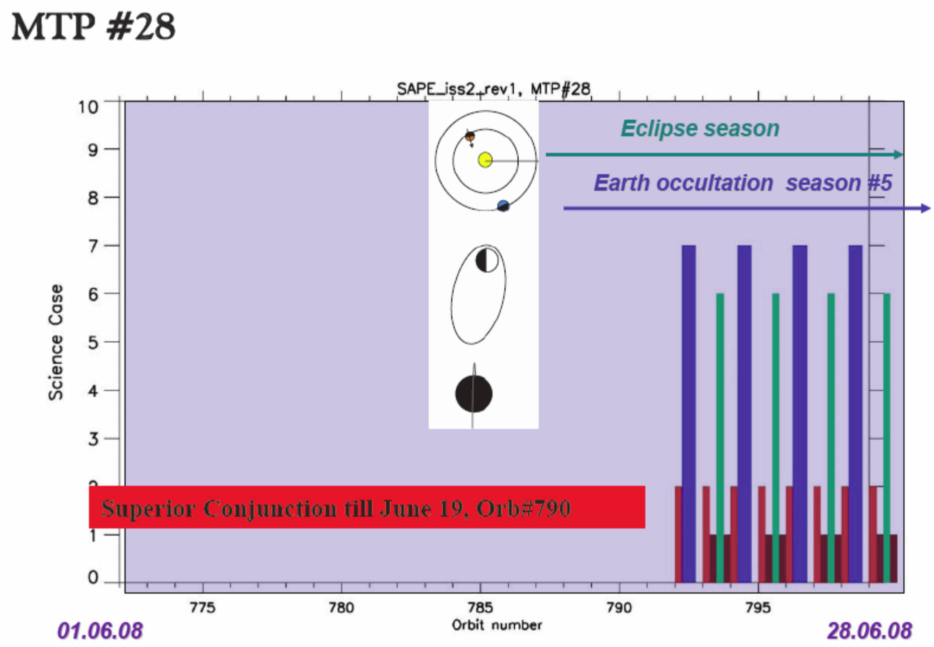

Figure 3.19 *MTP#28 timeline.*

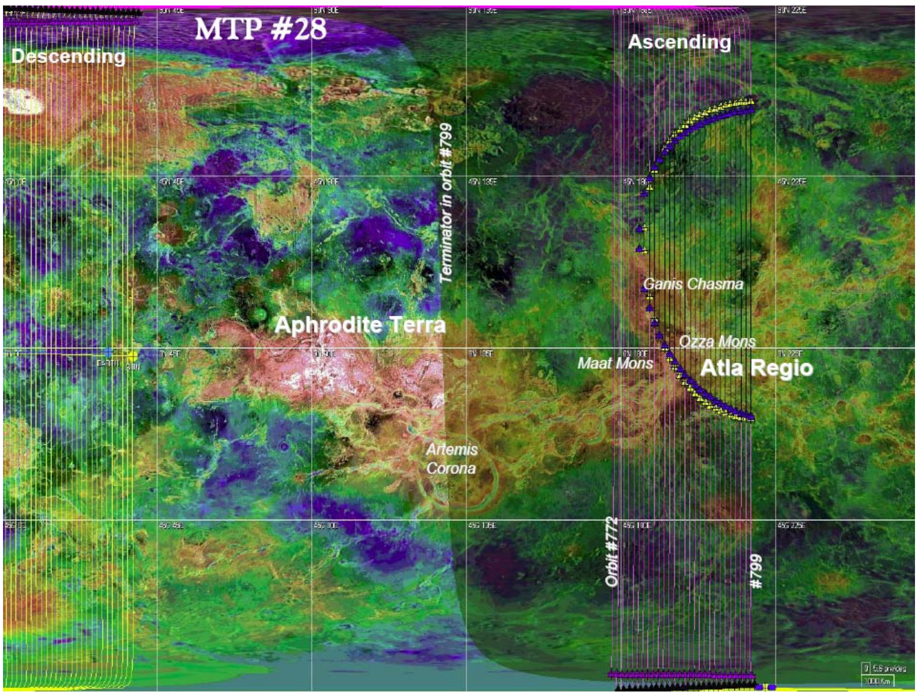

Figure 3.20. Planet coverage by orbital tracks in MTP#28 (see the note in 3.2.3).

3.12 MTP #29

3.12.1 Scientific focus

MTP #29 includes both Earth occultation and eclipse seasons. Local time at ascending node is between mid-night and 3am. Solar occultation will be alternated with night limbs. After pericentre observations will include wind tracking close to the planet, day side monitoring, and sounding of the exosphere on the day side. The main limitation will result from very low data rate. Starting with orbit #817 VeRa will resume Earth occultations. The pericentre lowering campaign will start in this MTP. The pairs of manoeuvres will be performed in orbits 814, 815 and 821,822 (see Annex 4).

The peculiarities of science observations of individual experiments are as follows:

SPICAV: Solar occultations (egress in every 2-d orbit) till orbit #810;

Both ingress & egress solar occs in orbits #811-819

Night side limbs before P and in plane limbs after P;

The geometry is also well suited for observations of the exosphere in the UV on the day side near noon.

Possibly sub-solar point tracking with SOIR near end of MTP

Case #5 coordinate with VeRa (combined T profile)

Dayglow observations at pericentre when flying perpendicular to terminator.

VeRa: Earth occultation experiments start in orbit #817.

VMC: Surface imaging before P (East flank of Atla Regio, Zewana and Paga Chasma)

Wind tracking after P on the day side (evening sector);

VIRTIS: night side monitoring in ascending branch

Limb obs together with SPICAV

Surface imaging together with VMC.

3.12.2 Environmental conditions

- Local Time at Ascending Node (LTAN): ~24-3 h
- Cold period
- Night side targets: west flank of Atla Regio (Zewana and Paga Chasma)
- Science data dump: low (~1000 Mbits/day) (tbc)

3.12.3 Timeline

Dates: 29.06-26.07.2008.

Orbits # 800-827.

Current SAP combines case #2 observations in ascending branch and following types of orbits alternating in pericentre vicinity:

For orbits before and including #810

Type 1: Night-side limbs before pericenter, followed by an in-plane limb after pericenter.

Type 2*:* Night side nadir, egress solar occultation, followed by pure nadir or a spot tracking on the day side.

For orbits after #810 till the end of eclipse season:

Type 1: Ingress & Egress solar occultation every orbits (if eclipse duration and data rate allow) combined with nadir in between.

Type 2: Ingress & Egress radio occultation

For orbits after end of eclipse season till the end of MTP:

Type 1: Ingress & Egress radio occultation

Type 2: Night-side limbs before pericenter followed by day-side limbs (left of the orbit) after pericenter.

Type 3: Night-side case 5 before pericenter followed by nadir or spot tracking after pericenter.

Figures 3.21-3.22 show observations timeline and planet coverage by orbital tracks in MTP #29.

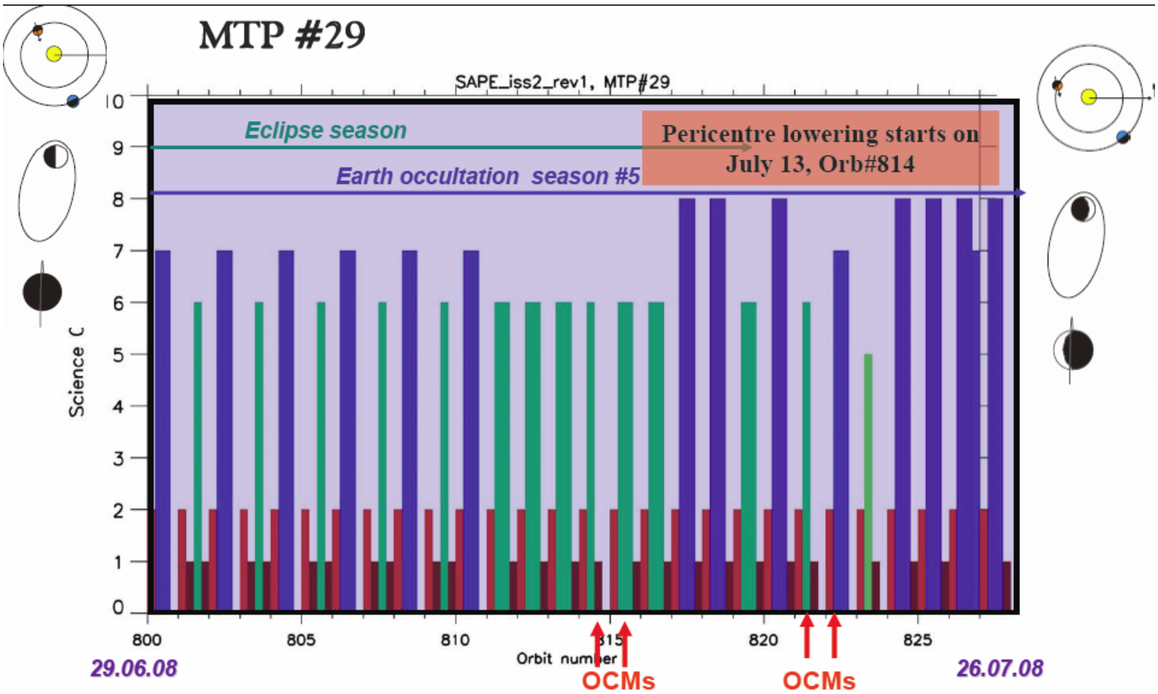

Figure 3.21 ***MTP#29 timeline.***

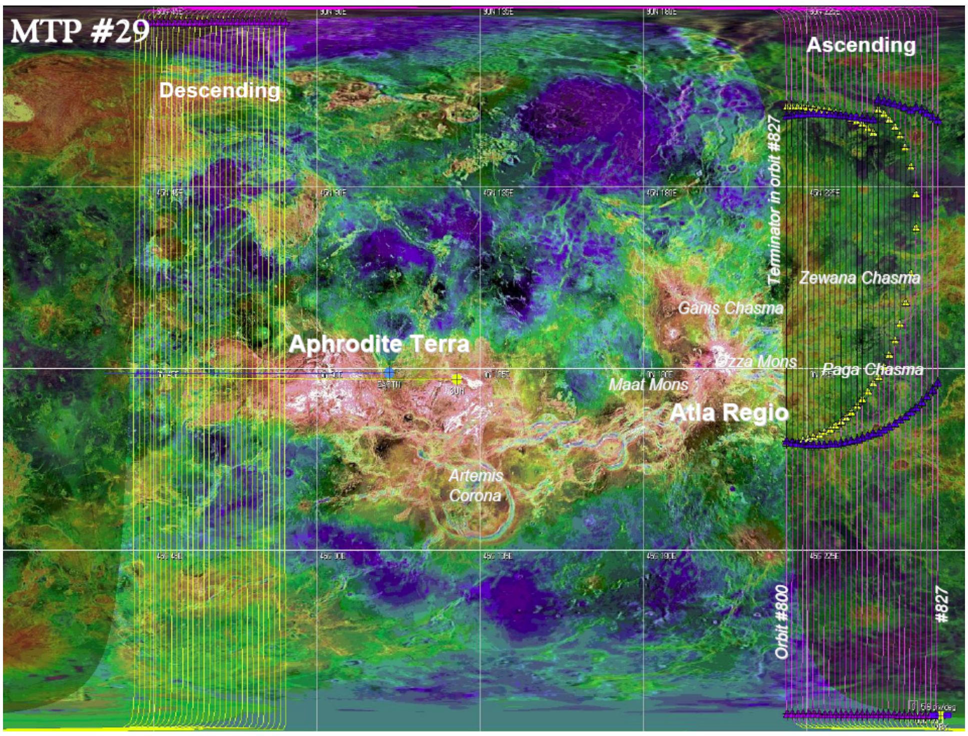

Figure 3.22. Planet coverage by orbital tracks in MTP#29 (see the note in 3.2.3).

3.13 MTP #30

3.13.1 Scientific focus

MTP #30 includes the end of the Earth occultation seasons. Also pericentre lowering campaign ends in orbit #836. Local time at ascending node is between 3am and 6am. Two pairs of manoeuvres will be performed in orbits 829, 830 and 836, 837 (see Annex 4). Natural lowering of the pericentre altitude will continue during ~10 days after the last maneouver. Pericentre altitude will reach its minimum on August 20. DSN station (CAN-34 m) was requested for 2.5 hours on August 18-22.

The peculiarities of science observations of individual experiments are as follows:

SPICAV: Night side limbs before P and in plane limbs after P;
Stellar occs (Case #5) coordinated with VeRa (combined T profile)

VeRa: Earth occultation experiments in orbits 829, 831, 832.

VMC: Wind tracking after P on the day side (evening sector);

VIRTIS: night side and terminator monitoring in ascending branch
Limb obs together with SPICAV

3.13.2 Environmental conditions

- Local Time at Ascending Node (LTAN): ~3-6 h
- Cold period
- Science data dump: low (~1000 Mbits/day) (tbc)

3.13.3 Timeline

Dates: 27.07-23.08.2008.

Orbits # 828-855.

Current SAP combines case #2 observations in ascending branch and following types of orbits alternating in pericentre vicinity:

For orbits before and including #847

Type 1: Night-side limbs before pericenter, followed by day side tangential limb after pericenter.

Type 2: Night side stellar occ before P, followed by nadir or a spot tracking on the day side.

For orbits after #847 till the end of MTP:

Day side limbs before pericenter followed by nadir or spot tracking after pericenter.

Figures 3.23-3.24 show observations timeline and planet coverage by orbital tracks in MTP #30.

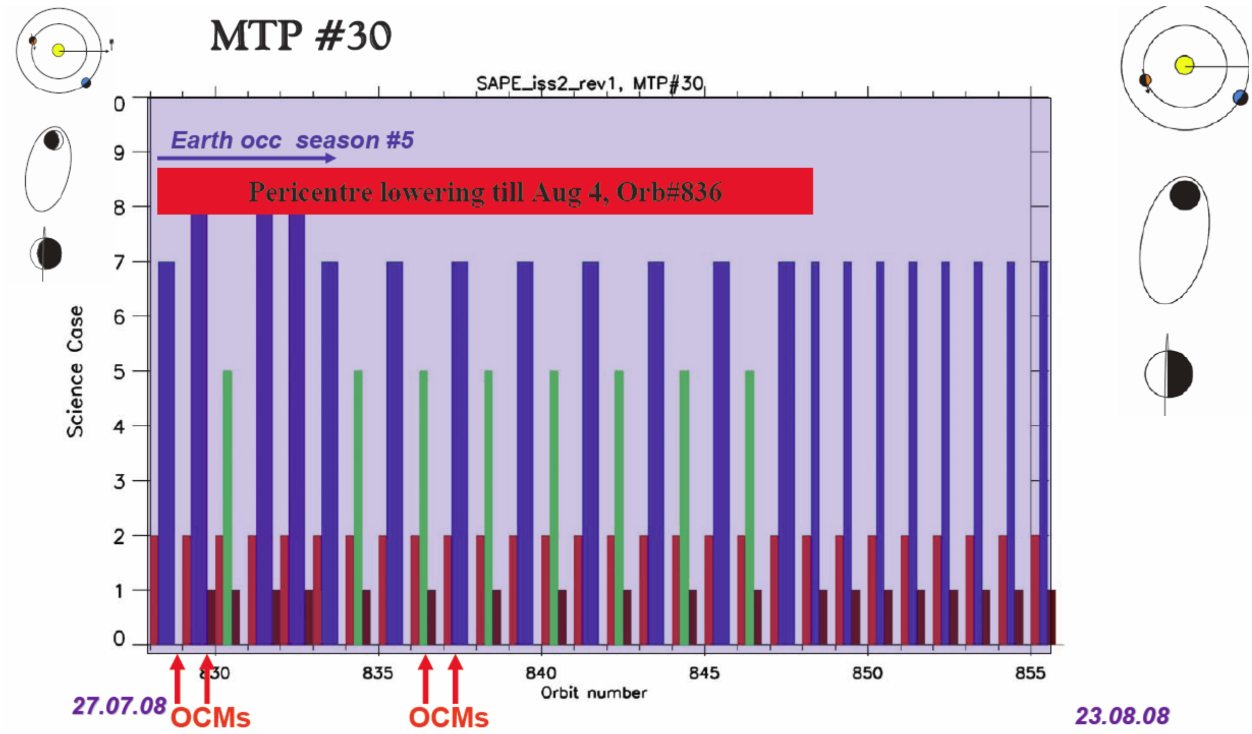

Figure 3.23 ***MTP#30 timeline.***

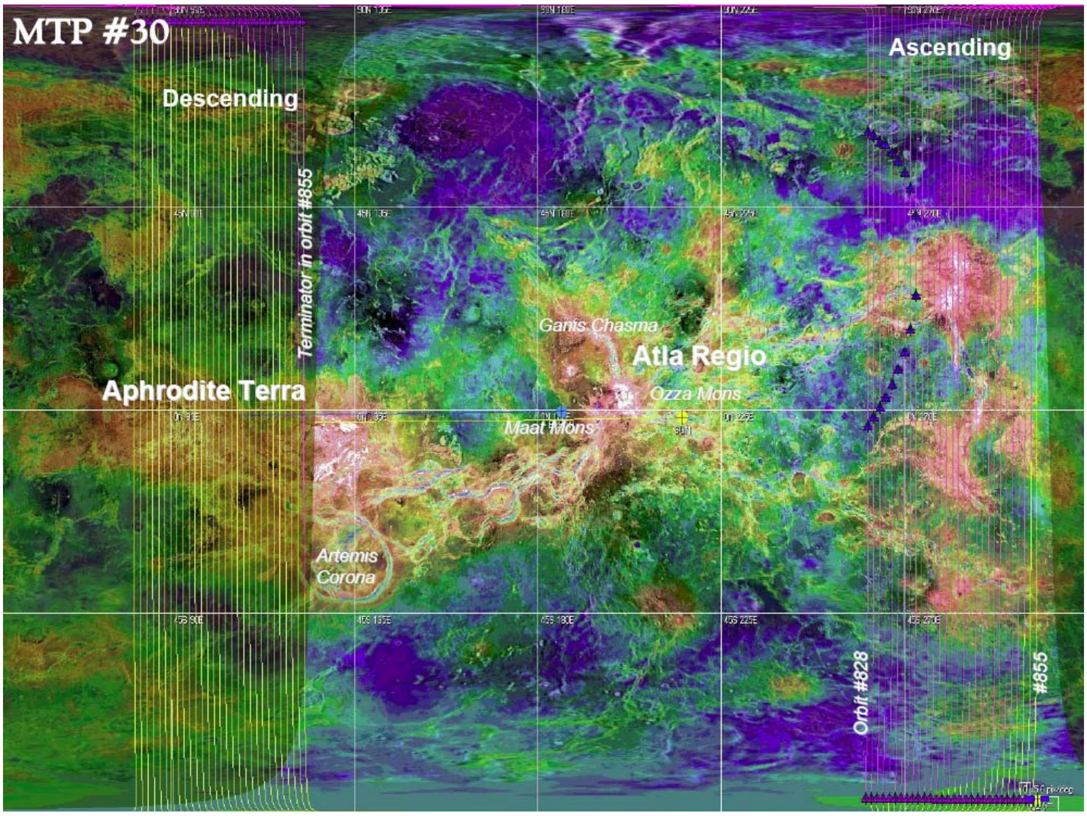

Figure 3.24. Planet coverage by orbital tracks in MTP#30 (see the note in 3.2.3).

3.14 MTP #31

3.14.1 Scientific focus

MTP #31 has no occultation or eclipse seasons. Local time at ascending node is between 6 am and 9 am. This is the first MTP with possibility for altitude specification in limb tracking. In the beginning of MTP observations of the morning terminator region. By the end of MTP – possibility of pendulum observations. This MTP is hot.

The peculiarities of science observations of individual experiments are as follows:

SPICAV: Day side limbs before P and after P;
Stellar occs (Case #5)

VMC: Wind tracking before P on the day side (morning sector);

VIRTIS: day side and terminator monitoring in ascending branch

Limb obs together with SPICAV

3.14.2 Environmental conditions

- Local Time at Ascending Node (LTAN): ~6-9 h
- Hot period
- Science data dump: low (~1200 Mbits/day) (tbc)

3.14.3 Timeline

Dates: 24.08-20.09.2008.

Orbits # 856-883.

Current SAP combines case #2 observations in ascending branch and following types of orbits alternating in pericentre vicinity:

In orbits before and including #870

Type 1:Nadir or spot tracking before P followed by day limb after pericenter.

Type 2*:* Day limbs before P, followed by night limbs after P (tbc).

In orbits after #870 till the end of MTP:

Nadir (including pendulum closer to the end of MTP) before pericenter followed by combination of limb (#5) and stellar occs (#7).

Figures 3.25-3.26 show observations timeline and planet coverage by orbital tracks in MTP #31.

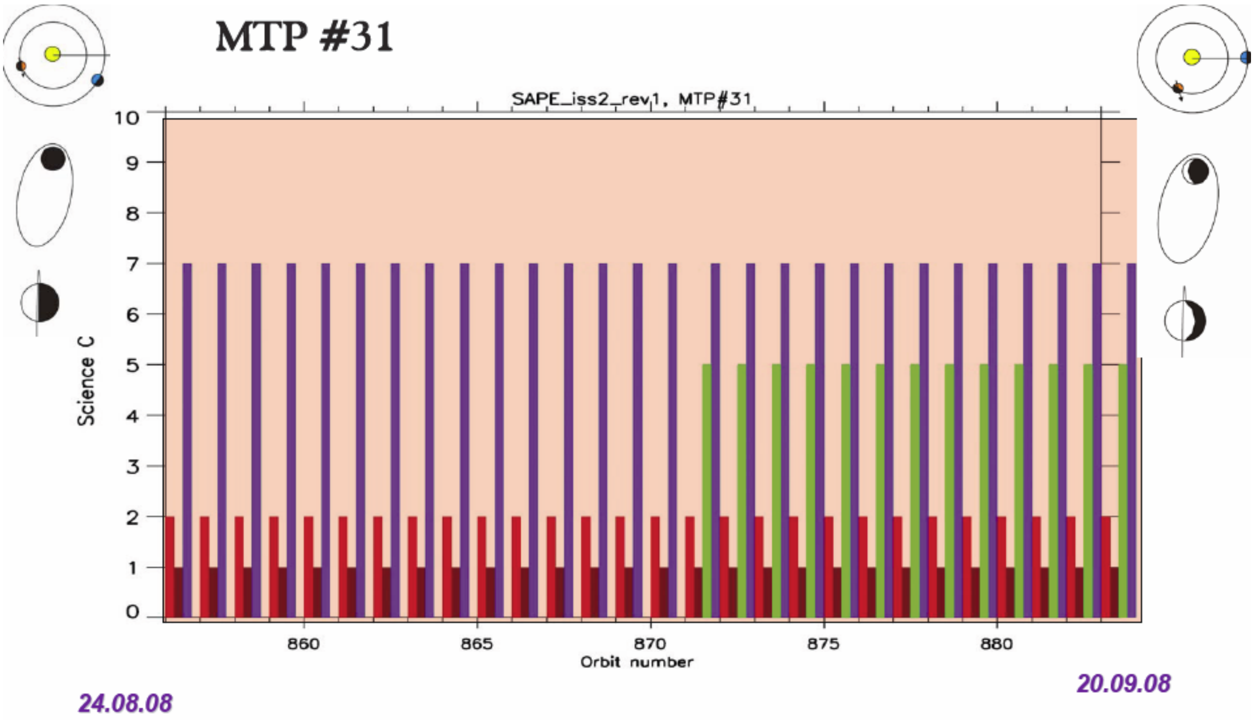

Figure 3.25 ***MTP#31 timeline.***

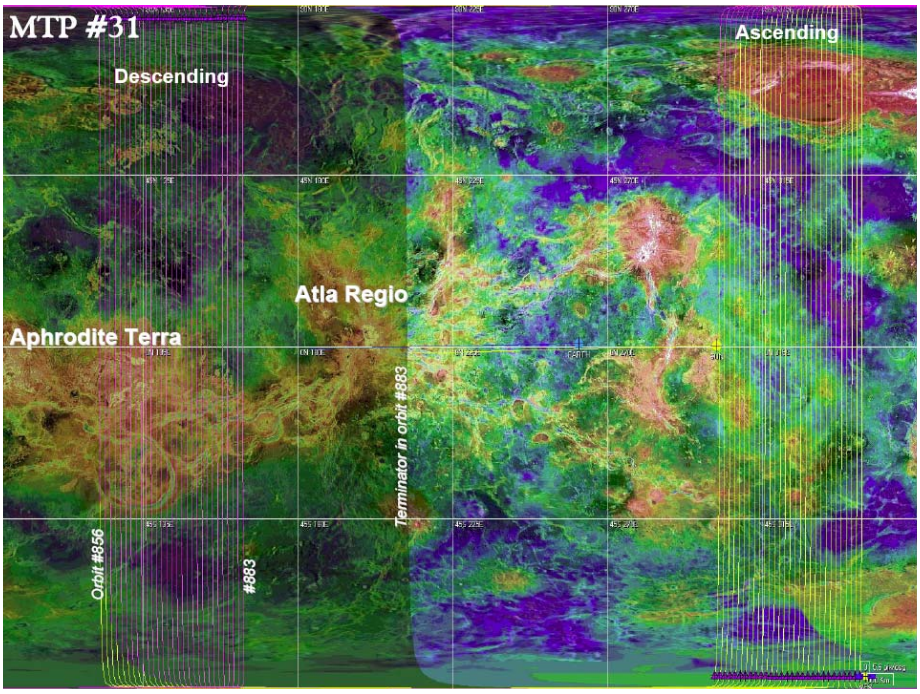

Figure 3.26. Planet coverage by orbital tracks in MTP#31 (see the note in 3.2.3).

3.15 MTP #32

3.15.1 Scientific focus

MTP #32 has eclipse season. Mosaic season starts on orbit #903, but mosaics will be performed later in MTP 34 when the downlink will be higher. Local time at ascending node is between 9 am and 12 am. Pendulum observations at ascending branch will be frequently used. This MTP is hot. Joint VIRTIS-SPICAV campaign of the night side nadir airglow obs in equatorial zone btw 22 and 2h (after Pericentre). From October 7 till Oct 18 the NNO will be on maintenance and CEB will be shared with MEX. CEB downlink with VEX will begin ~2 hours later than usual. It was concluded that no DSN support is required for the period of NNO maintenance.

The peculiarities of science observations of individual experiments are as follows:

SPICAV: Solar occultation after Pericentre
Night and day limbs

VMC: Monitoring (incl pendulum) and wind tracking on the day side;
Surface imaging after P between solar occs

VIRTIS: day side monitoring in ascending branch
Night and day limb obs together with SPICAV

3.15.2 Environmental conditions

- Local Time at Ascending Node (LTAN): ~9-12 h
- Hot period
- Science data dump: relatively high (~2000 Mbits/day) (tbc)

3.15.3 Timeline

Dates: 21.09-18.10.2008.

Orbits # 884-911.

Current SAP combines case #2 observations in ascending branch (including pendulum) and following types of orbits alternating in pericentre vicinity:

In orbits #884-885

Case#1 before P and #5 after P.

In orbits #886-890

Case#1 before pericentre and Case #6 (both ingress & egress) after P;

In orbits #891-898

Type 1: solar occs (both ingress & egress) with night nadir in between.

Type 2*:* solar occs (both ingress & egress) with night limb in between.

In orbits #898-911

Type 1: day nadir + ingress solar occs + night nadir after P.

Type 2*:* in plane limb + ingress solar occs + night nadir after P.

Figures 3.27-3.28 show observations timeline and planet coverage by orbital **t**racks in MTP #32.

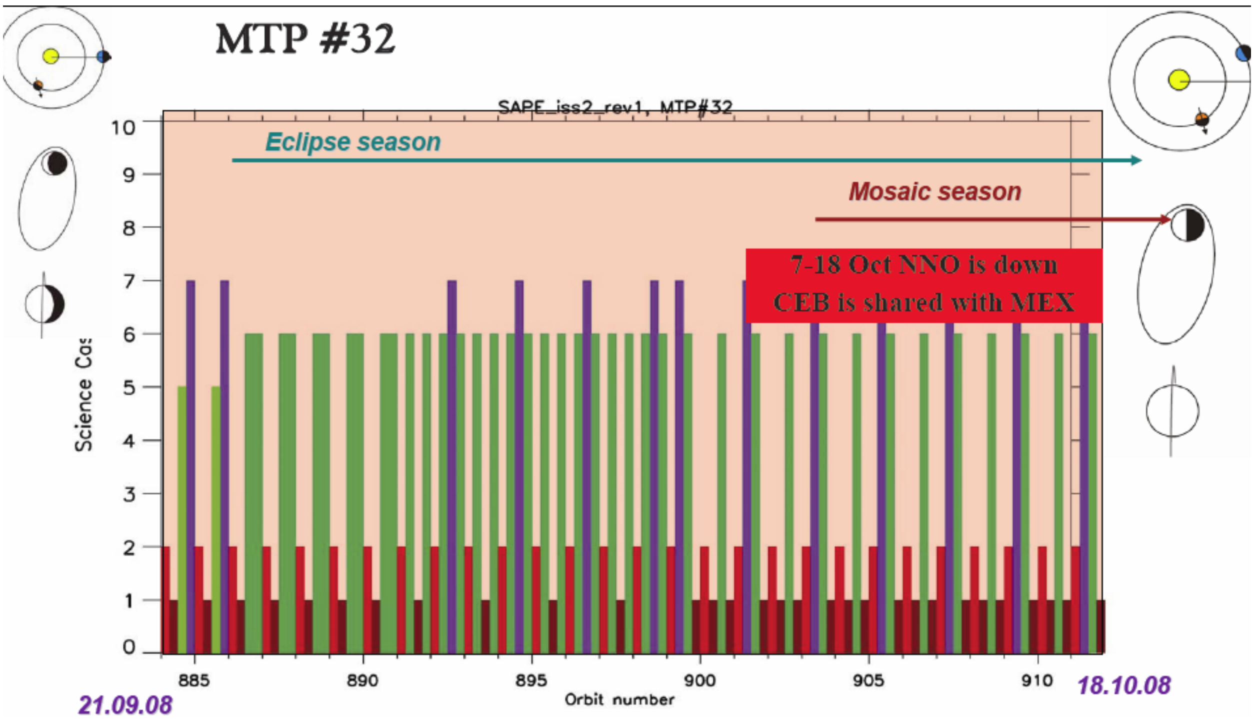

Figure 3.27 ***MTP#32 timeline.***

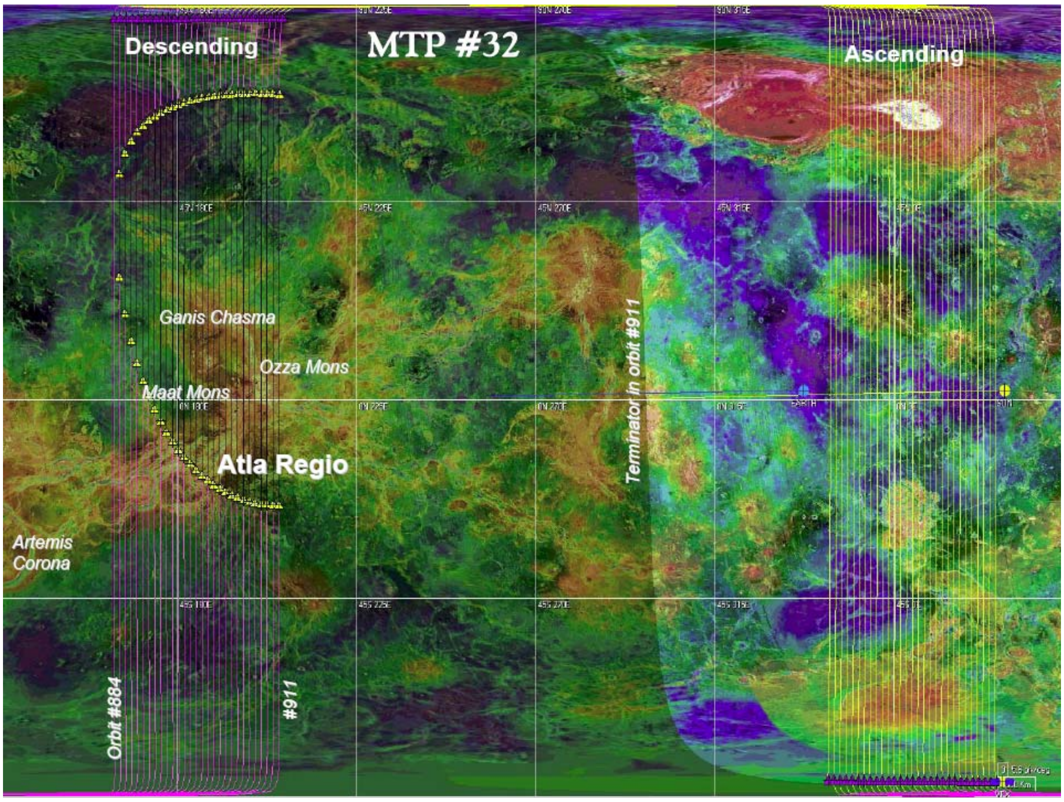

Figure 3.28. Planet coverage by orbital tracks in MTP#32 (see the note in 3.2.3).

3.16 MTP #33

3.16.1 Scientific focus

MTP #33 contains the second half of eclipse season. There is also a possibility for mosaics (early end of CEB), but mosaics will be performed later in MTP 34 when the downlink will be higher. Local time at ascending node is between 12 am and 3 pm. Pendulum observations at ascending branch will be frequently used. Also good opportunity for SOIR nadir observations if earlier attempts were successful. The Earth occultation season #6 begins in orbit 923. The MTP is hot.

The peculiarities of science observations of individual experiments are as follows:

SPICAV: Solar occultation after Pericentre
Night and day limbs

VMC: Monitoring (incl pendulum) and wind tracking on the day side;

Surface imaging after P between solar occs in the first half of MTP

VIRTIS: day side monitoring in ascending branch

Night and day limb obs together with SPICAV

VeRa: Radio –occultations (check if VeRa and SOIR sound the same place)

3.16.2 Environmental conditions

- Local Time at Ascending Node (LTAN): ~12-15 h
- Hot period
- Science data dump: relatively high (~3000 Mbits/day) (tbc)

3.16.3 Timeline

Dates: 19.10-15.11.2008.

Orbits # 912-939.

Current SAP combines case #2 observations in ascending branch (including pendulum) and following types of orbits alternating in pericentre vicinity:

In orbits #912-925 alternate:

Type 1: case #7 (in-plane day limb before P) + #6 ***(ingress)*** + #1(night nadir)

Type 2(twice): case #1 (day nadir or spot-pointing) + #6***(ingress)***+ #1(night nadir)

In orbits #925-939 alternate:

Type 1: case#1 (day nadir or spot pointing before P) + 2 radio occultations after P

Type 2*:* case #7(day tangential towards sub-solar point) + #6 (ingress) +#1 (night nadir)

Type 3*:* case #7(day tangential towards sub-solar point) + #1 (night nadir) + #6 (egress)

Figures 3.29-3.30 show observations timeline and planet coverage by orbital **t**racks in MTP #33.

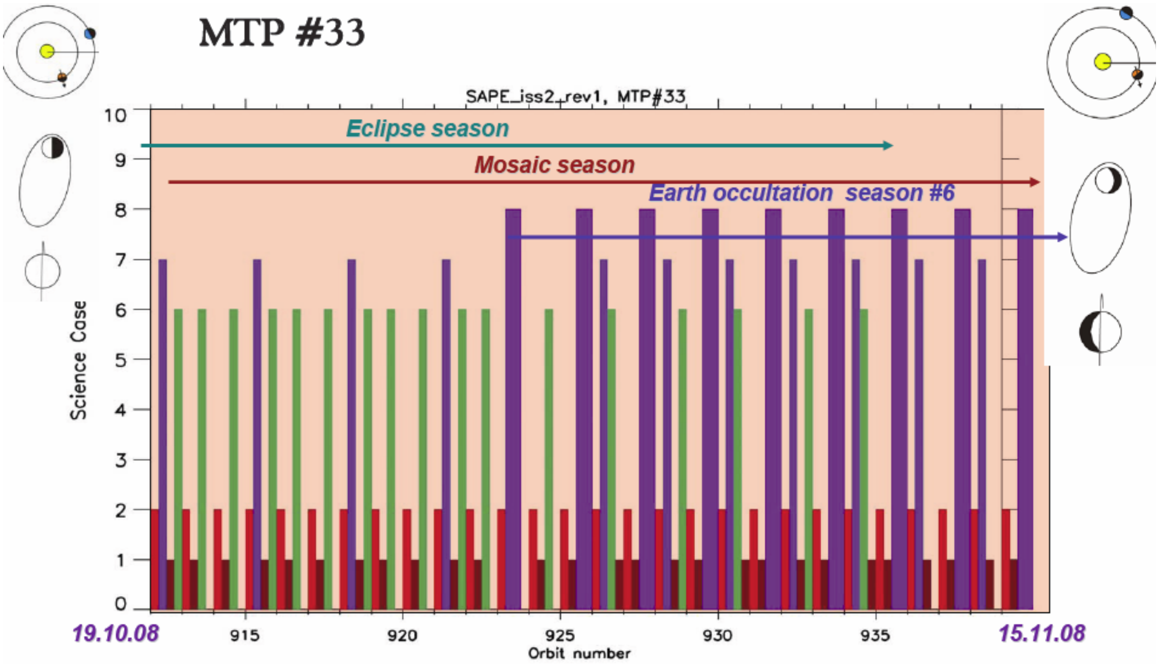

Figure 3.29 ***MTP#33 timeline.***

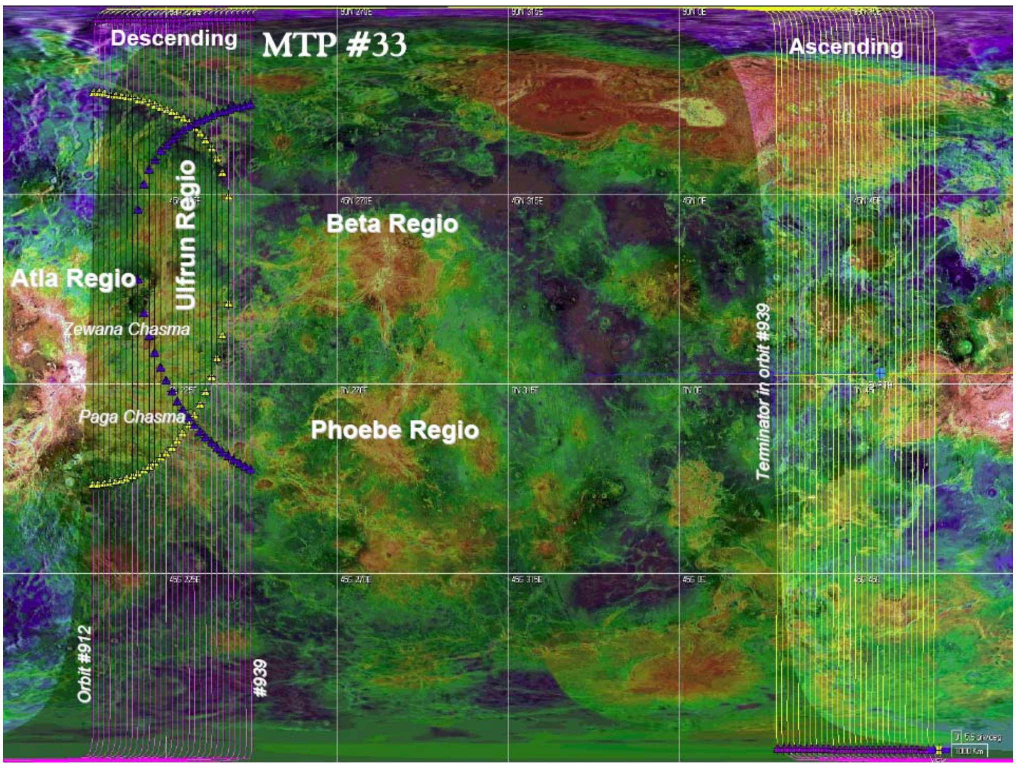

Figure 3.30. Planet coverage by orbital tracks in MTP#33 (see the note in 3.2.3).

3.17 MTP #34

3.17.1 Scientific focus

In the first part of MTP (orbits #941-954) the CEB station is down for maintenance. The downlink will be performed via NNO station in **ascending** branch of the orbit btw about -6:30 and -1:30 h pericentre time. It was concluded that no DSN support for the downlink is required in the period of CEB maintenance. MTP #34 contains the second half of the Earth occultation season #6. Also there are good conditions for mosaics for two reasons: 1. high downlink rate; 2. free apocentre during CEB maintenance. Local time at ascending node is between 3 and 6 pm. Good opportunity for Earth observations. The MTP is hot till orbit ~ 962.

The peculiarities of science observations of individual experiments are as follows:

SPICAV: Day side tangential limbs

VMC: Monitoring (incl pendulum in the beginning of MTP) and wind tracking on the day side (evening terminator);

In the last 10 orbits before terminator (~#967) night side imaging of the Aphrodite Terra (Ovda Regio) at -1h…-0:30

VIRTIS: mosaics from apocentre

VeRa: Radio –occultations.

3.17.2 Environmental conditions

- Local Time at Ascending Node (LTAN): ~15 – 18 h
- Hot period till orbit 962
- Science data dump: very high (~4000 Mbits/day) (tbc)
- In orbits 941-954 CEB station is down for maintenance. NNO station is available in ascending branch for 5 hours (-6:30….-1:30).

3.17.3 Timeline

Dates: 16.11- 13.12.2008.

Orbits # 940-967.

Current SAP combines case #2 and **case #3 (mosaic)** observations in apocentre and the following types of orbits alternating in pericentre vicinity:

In orbits #940-955 alternate:

Type 1: case #1 (nadir day before P) + #5(star occs)

Type 2: case #1 (nadir day before P) + #8(Earth occs both ingress and egress)

In orbits #956-967 alternate:

Type 1: case#7 (day side tangential limbs before and after P

Type 2*:* case #1 (nadir day before P) + #8(Earth occs both ingress and egress)

Figures 3.31-3.32 show observations timeline and planet coverage by orbital **t**racks in MTP #34.

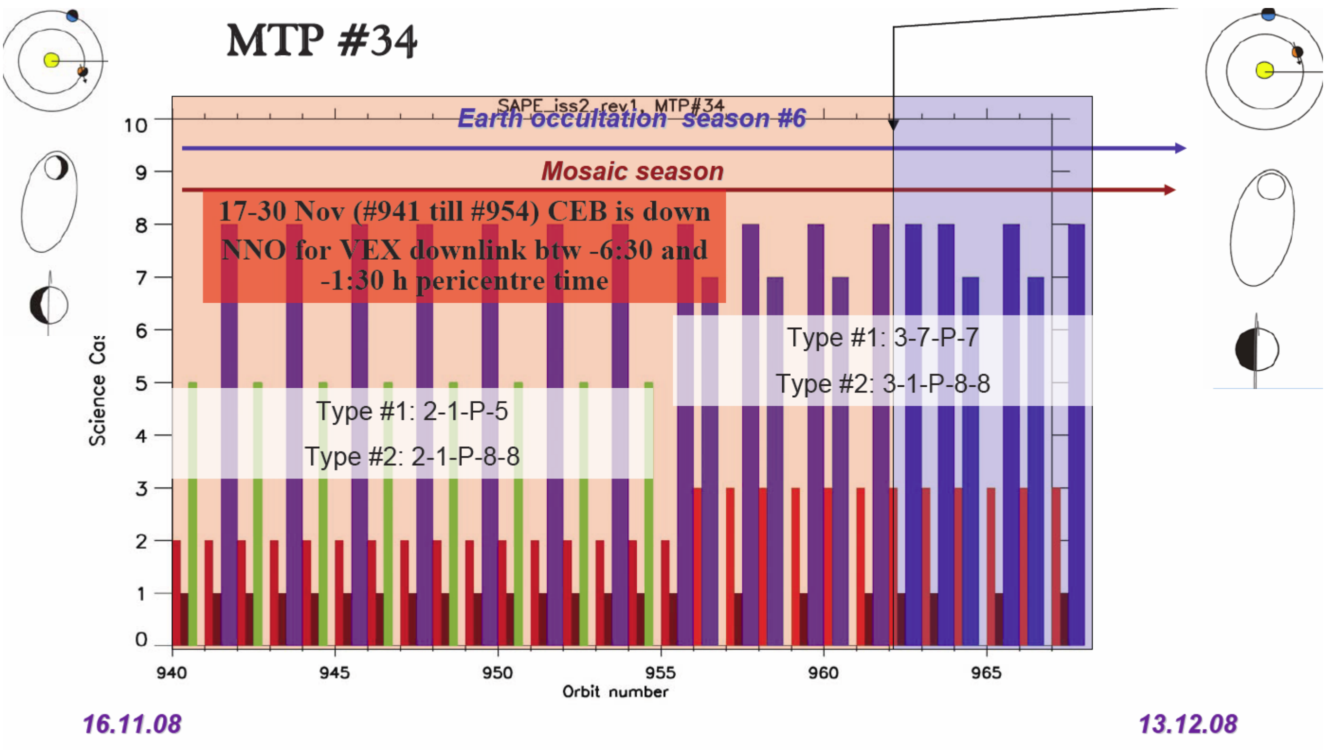

Figure 3.31 ***MTP34 timeline.***

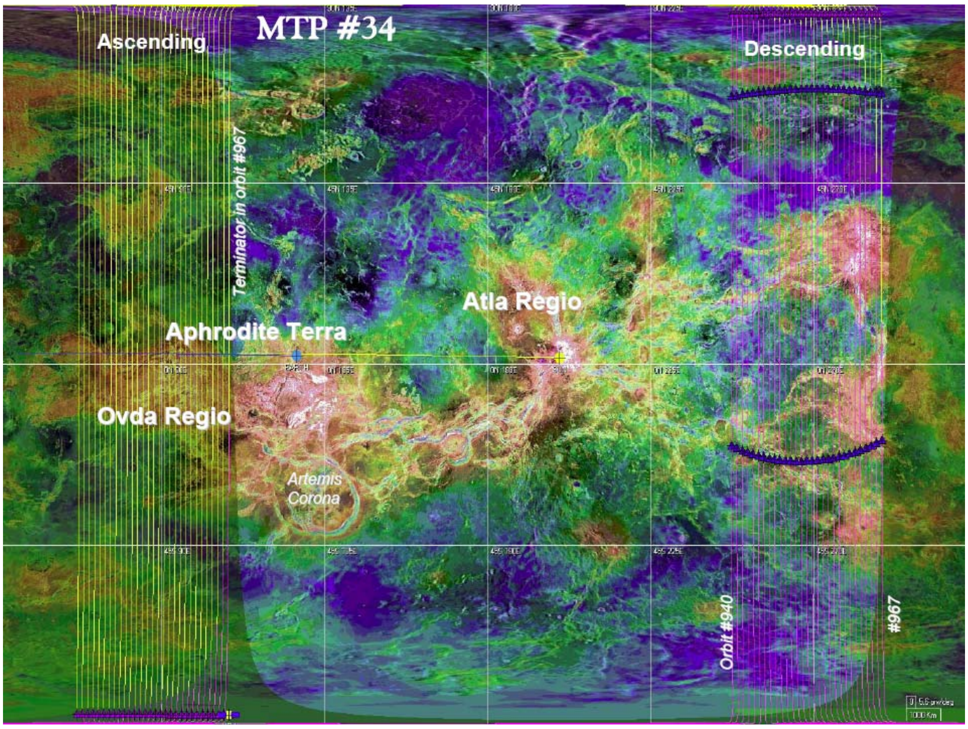

Figure 3.32. Planet coverage by orbital tracks in MTP#34 (see the note in 3.2.3).

3.18 MTP #35

3.18.1 Scientific focus

In the beginning of the MTP (orbit #972) the mission enters quadrature period meaning, meaning that the telecommunications will be hot on +Y due to VMC sun avoidance requirement. As in the quadrature periods before every 2-d CEB pass will be skipped in order to keep VIRTIS cold. VIRTIS will observe at every 2-d orbit. The orbits with skipped CEB closer to the second part of MTP can be used for observations of the day side on descending branch. The downlink rate is maximum until the HGA1 switched to HGA2 in the very end of MTP (orbit #994).
This MTP contains the end of the radio occultation season.

The peculiarities of science observations of individual experiments are as follows:

SPICAV: Day and night side limbs

VMC: In the first several orbits night side imaging of the Aphrodite Terra (Ovda Regio) at -1h…-0:30;

In the end of MTP day side observations on the descending branch in the orbits with skipped CEB passes

VIRTIS: observations in every 2-d orbit

VeRa: Radio –occultations

3.18.2 Environmental conditions

- Local Time at Ascending Node (LTAN): ~18 – 21 h
- Cold period
- From orbit #972 quadrature season meaning that telecoms are hot
- Science data dump: very high (~4000 Mbits/day) (tbc)
- Geometry is similar to MTP#31

3.18.3 Timeline

Dates: 14.12 .2008- 10.01.2009.

Orbits # 968-995.

Current SAP combines case#2 observations at ascending branch and the following types of orbits alternating in pericentre vicinity:

In orbits #968-984 alternate:

Type 1: case #1 (nadir night or day before P) + #8(radio occs ingress & egress)

Type 2: case #7 (day limbs before P) + #7(day/night limbs after P)

In orbits #985-995 alternate:

Type 1: case#1 + case#5 (after P) + case#7 (after P if possible)

Type 2*:* case #8 (radio occs ingress & egress) + #2(in descending branch in the orbits with skipped CEB pass))

Figures 3.33-3.34 show observations timeline and planet coverage by orbital tracks in MTP #35.

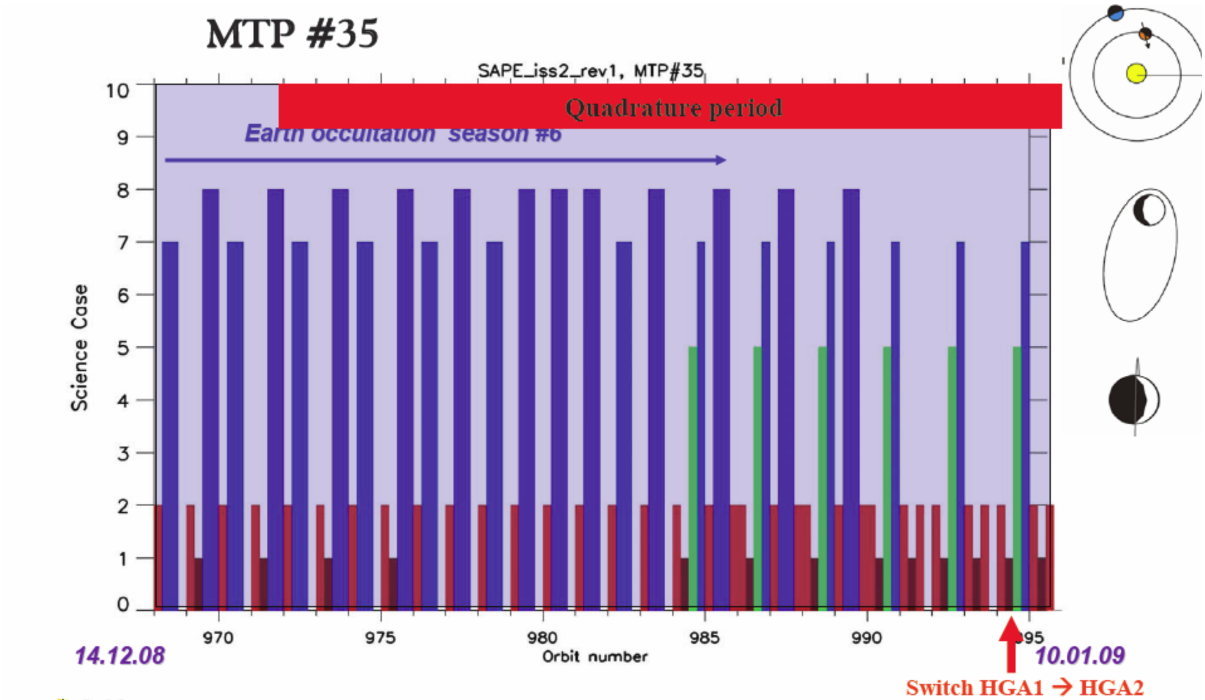

Figure 3.33 ***MTP35 timeline.***

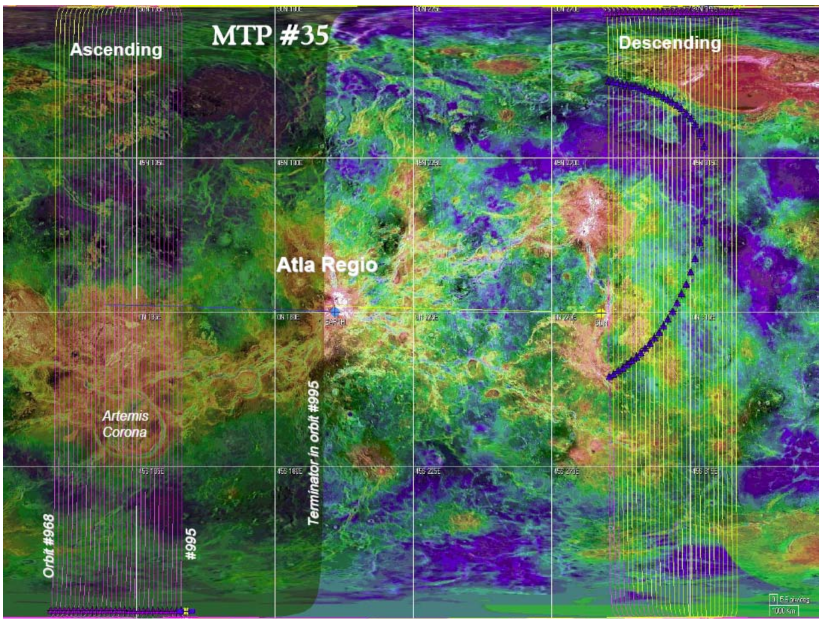

Figure 3.34. Planet coverage by orbital tracks in MTP#35 (see the note in 3.2.3).

3.19 MTP #36

3.19.1 Scientific focus

In the beginning of the MTP till orbit #1005 - quadrature period meaning, meaning that the telecommunications will be hot on +Y due to VMC sun avoidance requirement. As in the quadrature periods before every 2-d CEB pass will be skipped in order to keep VIRTIS cold. VIRTIS will observe in every 2-d orbit. The orbits with skipped CEB pass can be used for observations of the day side on descending branch. The downlink rate is very low since telecoms are via HGA2. In orbit 1001 eclipse season starts.

The peculiarities of science observations of individual experiments are as follows:

SPICAV: Solar occultations

Day and night side limbs

VMC: In the second part of MTP night side imaging of the Aphrodite Terra (Atla Regio, Sapas Mons, Ganis Chasma) and Rusalka Planitia west from Atla.

In the beginning of MTP day side observations on the descending branch in the orbits with skipped CEB passes

VIRTIS: in the beginning of MTP observations in every 2-d orbit

3.19.2 Environmental conditions

- Local Time at Ascending Node (LTAN): ~21 – 24 h
- Cold period
- Till orbit #1005 quadrature season meaning that telecoms are hot
- Science data dump: very low (~1000 Mbits/day) (tbc)

3.19.3 Timeline

Dates: 11.01-7.02.2009.

Orbits # 996-1023.

Current SAP combines case#2 observations at ascending branch and the following types of orbits alternating in pericentre vicinity:

In orbits #996-1000 alternate:

Type 1: case #1 (nadir before P) + #5(possibly hot after P) + #7(right from the orbit, deep night side) + CEB pass

Type 2: case #1 (nadir before P) + #5(possibly hot after P) + #1(day side, long obs) + NO CEB pass

In orbits #1001-1014:

Type 1: case#6 (ingress & egress before P) + case#1 (after P) (when in quadrature period only in orbits with skipped CEB pass)

In orbits #1015-1023:

Type 1: case#1 (night before P) + case#6 (egress) + case#1 (day nadir after P)

Type 2: case#1 (night before P) + case#6 (egress) + case#7 (day in-plane limb after P)

Figures 3.35-3.36 show observations timeline and planet coverage by orbital tracks in MTP #36.

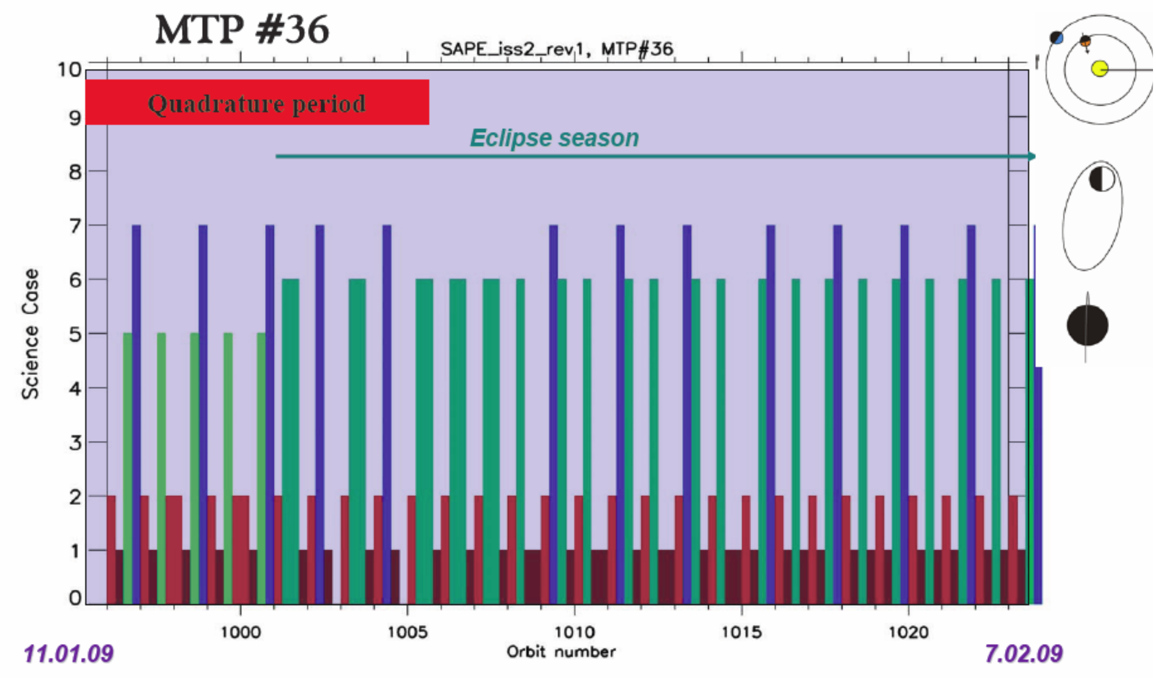

Figure 3.35 ***MTP36 timeline.***

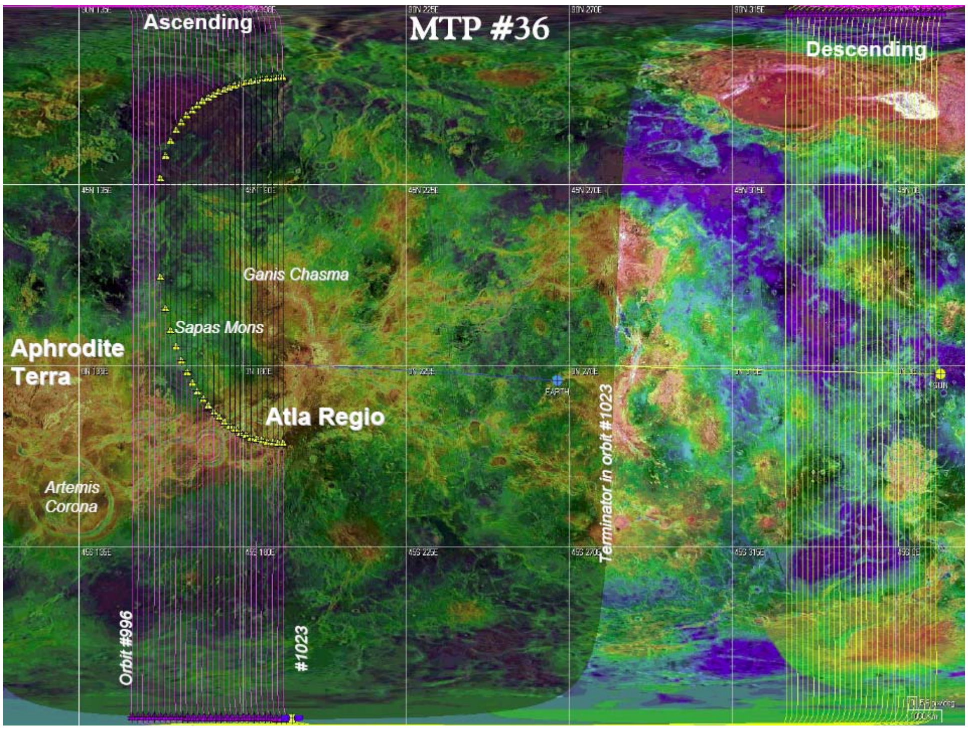

Figure 3.36. Planet coverage by orbital tracks in MTP#36 (see the note in 3.2.3).

3.20 MTP #37

3.20.1 Scientific focus

The MTP includes second part of the eclipse season. The MTP is close to inferior conjunction, so the downlink is with HGA2 and between low and moderate. In the first half of MTP#37 5 consecutive DSN passes are requested to support the night side observations in this period of low data rate. This will provide a gain of a factor of 4.

The peculiarities of science observations of individual experiments are as follows:

SPICAV: Solar occultations

Day and night side limbs

VMC: Before P night side imaging of the Aphrodite Terra (east of Atla Regio, Ozza Mons)

After P full day side and wind tracking

VIRTIS:

3.20.2 Environmental conditions

- Local Time at Ascending Node (LTAN): ~24 - 3h
- Cold period
- Science data dump: (~1000 -2000 Mbits/day) (tbc)

3.20.3 Timeline

Dates: 8.02-7.03.2009.

Orbits # 1024-1051.

Current SAP combines case#2 observations at ascending branch and the following types of orbits alternating in pericentre vicinity:

In orbits #1024-1037 alternate:

Type 1: case #6 (egress) before P + #1(nadir or spot pointing) after P

Type 2: case #5 (stellar occ) before P + #7(day in-plane limb) after P

In orbits #1038-1045:

Type 1: case#6 (ingress & egress before P) + case#1 (after P)

Type 2: case#6 (ingress & egress before P) + case#7 (day in-plane limb) after P

In orbits #1046-1051:

Type 1: case#5 (stellar occs) before P + case#1 (day nadir or spot pointing) after P

Type 2: case#5 (stellar occs) before P + case#7 (day tangential limb) after P

Figures 3.37-3.38 show observations timeline and planet coverage by orbital tracks in MTP #37.

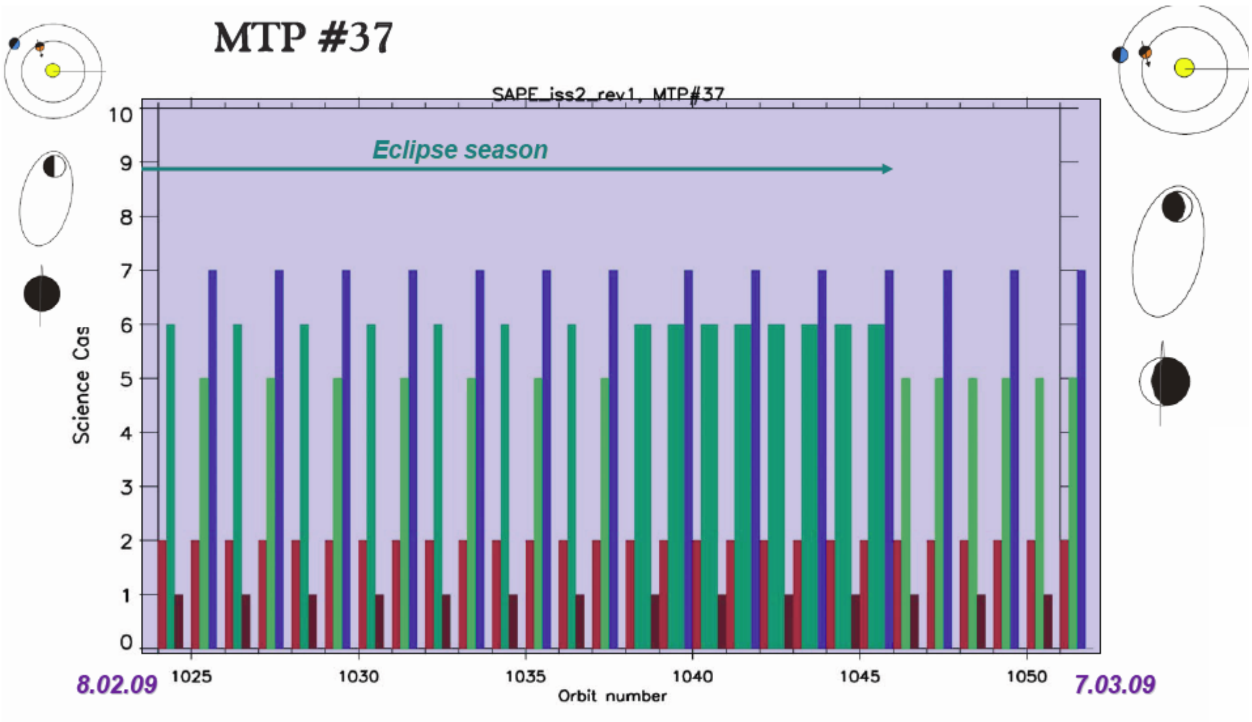

Figure 3.37 ***MTP37 timeline.***

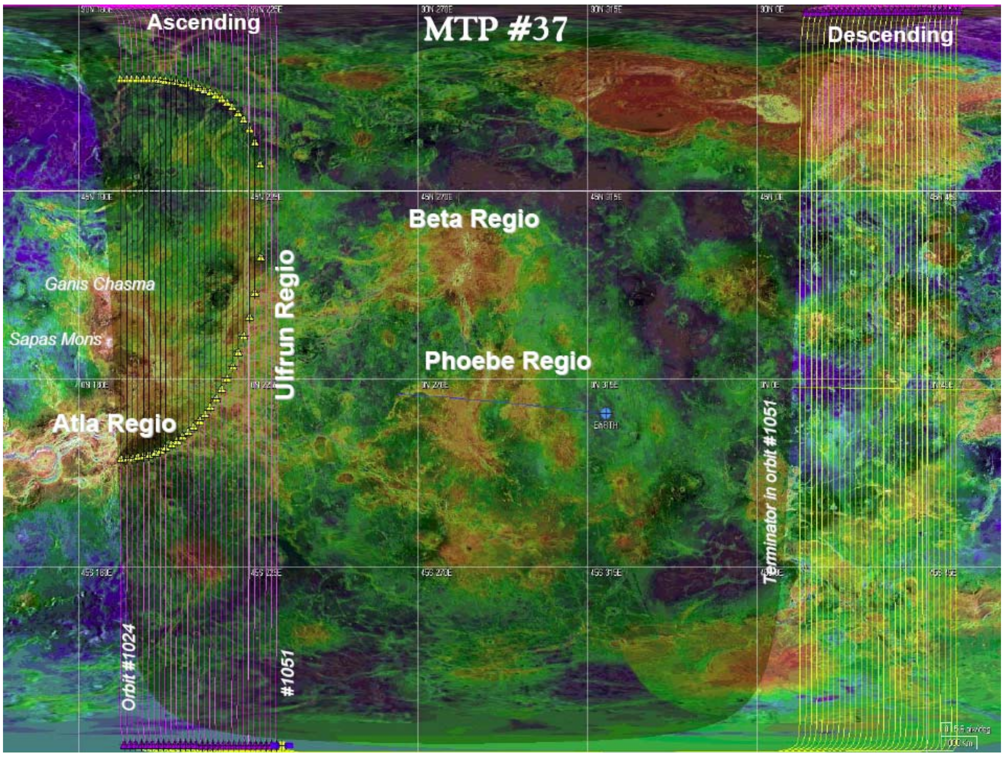

Figure 3.38. Planet coverage by orbital tracks in MTP#37 (see the note in 3.2.3).

3.21 MTP #38

3.21.1 Scientific focus

The MTP includes inferior conjunction. The downlink is performed with HGA2 and is maximum. Venus is 10 deg from the Sun so telecoms are not affected. No specific seasons (Earth occultations, eclipses). Terminator orbit at the end of MTP.

The peculiarities of science observations of individual experiments are as follows:

SPICAV: Stellar occultations
Day side tangential limbs

VMC: After P, in the beginning of MTP, wind tracking in the evening sector

After P, in the last ~10 orbits before the terminator orbit, night side imaging of the Western part of Aphrodite Terra (Ovda Regio, Monatum and Tellus Tessera, Tahmina and Aino Planitia))

VIRTIS: Terminator studies from ascending branch
Limb observations together with SPICAV
Night side surface obs with VMC

VeRa: Gravity experiment (minimum tracking time +/- 20 min wrt Pericentre)

3.21.2 Environmental conditions

- Local Time at Ascending Node (LTAN): ~3-6 h
- Cold period
- Science data dump: (~3000 Mbits/day) (tbc)

3.21.3 Timeline

Dates: 8.03-4.04.2009.

Orbits # 1052-1079.

Current SAP combines case#2 observations at ascending branch and the following types of orbits alternating in pericentre vicinity:

In orbits #1052-1065 alternate:

Type 1: case #5 (stellar occ) before P + #1(nadir or spot pointing) after P

Type 2: case #10 (gravity experiment): spacecraft trtacking btw -1 and +1 h

In orbits #1065-1079:

Type 1: case#7 (day tangential limb before P) + case#7 (day tangential limb after P)

Type 2: case#7 (day tangential limb before P) + case#1 (night side surface after P)

Type 3: case #10 (gravity experiment): spacecraft trtacking btw -1 and +1 h

Figures 3.39-3.40 show observations timeline and planet coverage by orbital tracks in MTP #38.

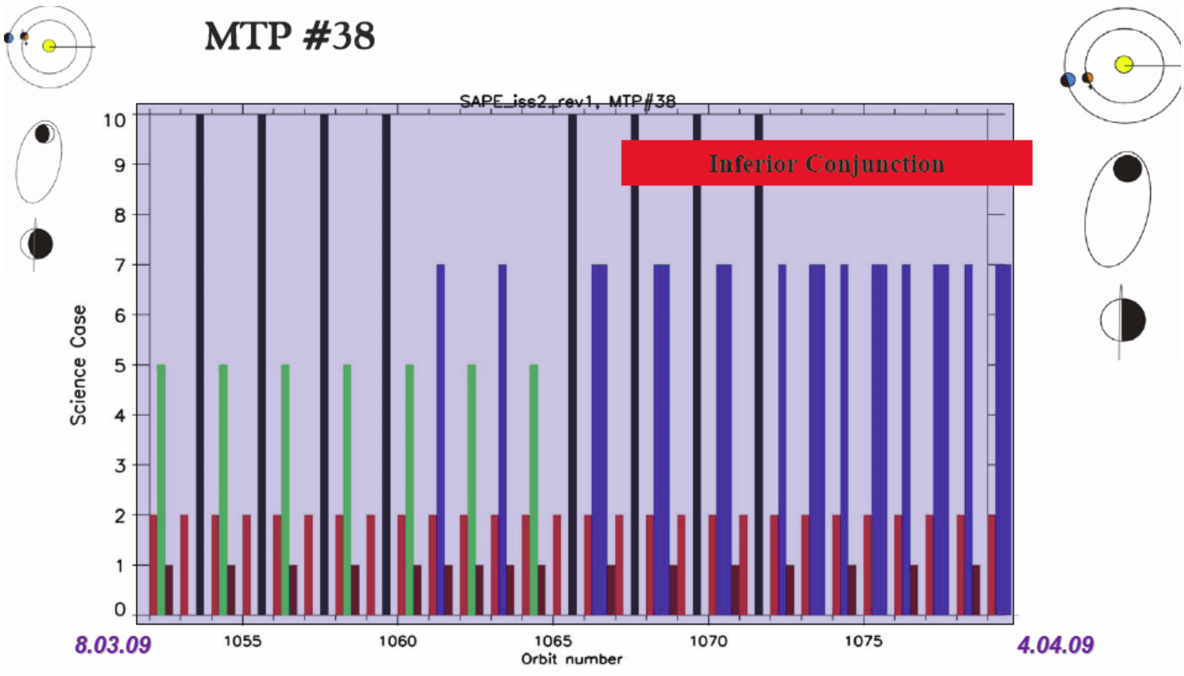

Figure 3.39 ***MTP38 timeline.***

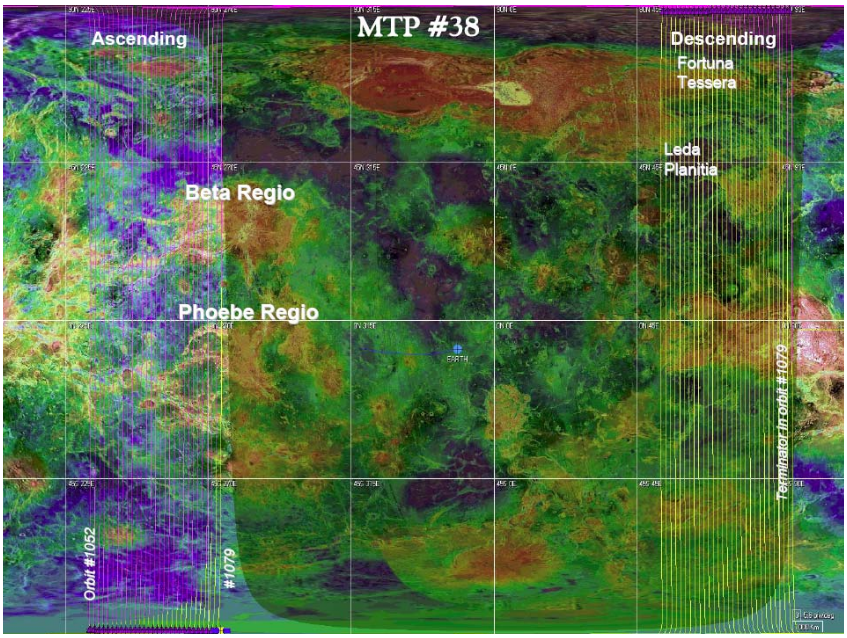

Figure 3.40. Planet coverage by orbital tracks in MTP#38 (see the note in 3.2.3).

3.22 MTP #39

3.22.1 Scientific focus

The MTP includes second part of inferior conjunction. The downlink is performed with HGA2 and is maximum. Venus is 10 deg from the Sun so telecoms are not affected. No specific seasons (Earth occultations, eclipses). Terminator orbit at the end of MTP.

The peculiarities of science observations of individual experiments are as follows:

SPICAV: Stellar occultations

Day side tangential limbs

VMC: After P, in the first ~10 orbits after the terminator orbit, night side imaging of the Western part of Aphrodite Terra (Ovda Regio, Monatum and Tellus Tessera, Tahmina and Aino Planitia)

Before P, in the end of MTP, wind tracking in the morning sector

VIRTIS: Terminator studies from ascending branch

Limb observations together with SPICAV

Night side surface obs with VMC

VeRa: Gravity experiment (minimum tracking time +/- 20 min wrt Pericentre)

3.22.2 Environmental conditions

- Local Time at Ascending Node (LTAN): ~6-9 h
- Hot period
- Science data dump: (~3000 Mbits/day) (tbc)

3.22.3 Timeline

Dates: 5.04 – 2.05.2009.

Orbits # 1079-1107.

Current SAP combines case#2 observations at ascending branch and the following types of orbits alternating in pericentre vicinity:

In orbits #1080-1094 alternate:

Type 1: case#7 (day tangential limb before P) + case#7 (day tangential limb after P)

Type 2: case#7 (day tangential limb before P) + case#1 (night side surface after P)

Type 3: case #10 (gravity experiment): spacecraft trtacking btw -1 and +1 h

In orbits #1095-1107:

Type 1: case #1(day nadir or spot pointing) before P + case #5 (stellar occ) after P

Type 2: case #1(day nadir or spot pointing) before P + case #5 (stellar occ) after P

Type 3: case #10 (gravity experiment): spacecraft trtacking btw -1 and +1 h

Figures 3.41-3.42 show observations timeline and planet coverage by orbital **t**racks in MTP #39.

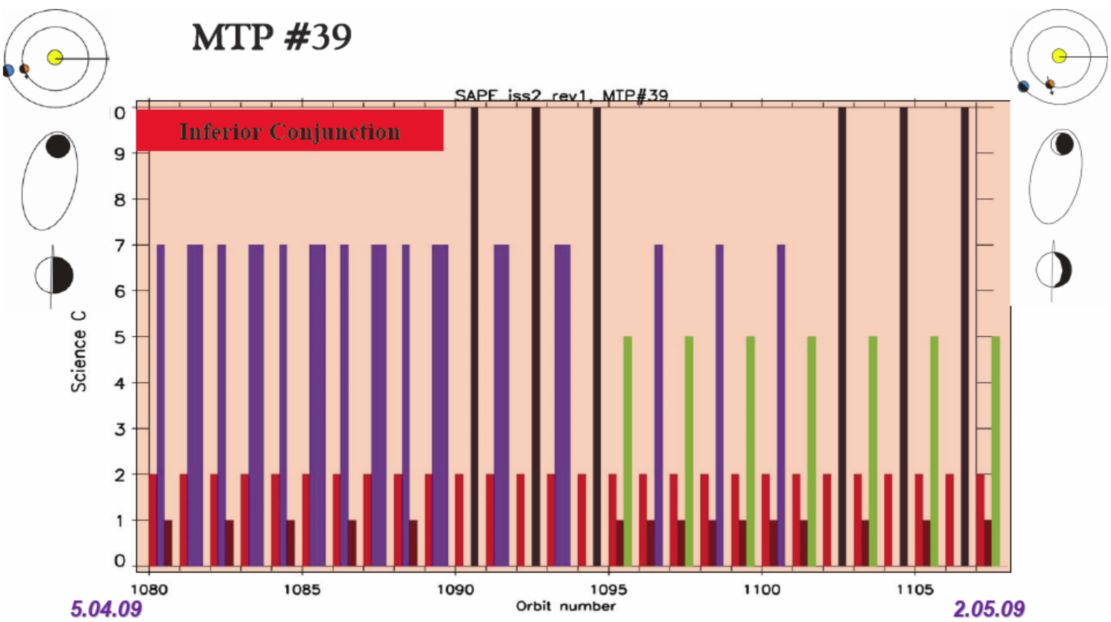

Figure 3.41 ***MTP39 timeline.***

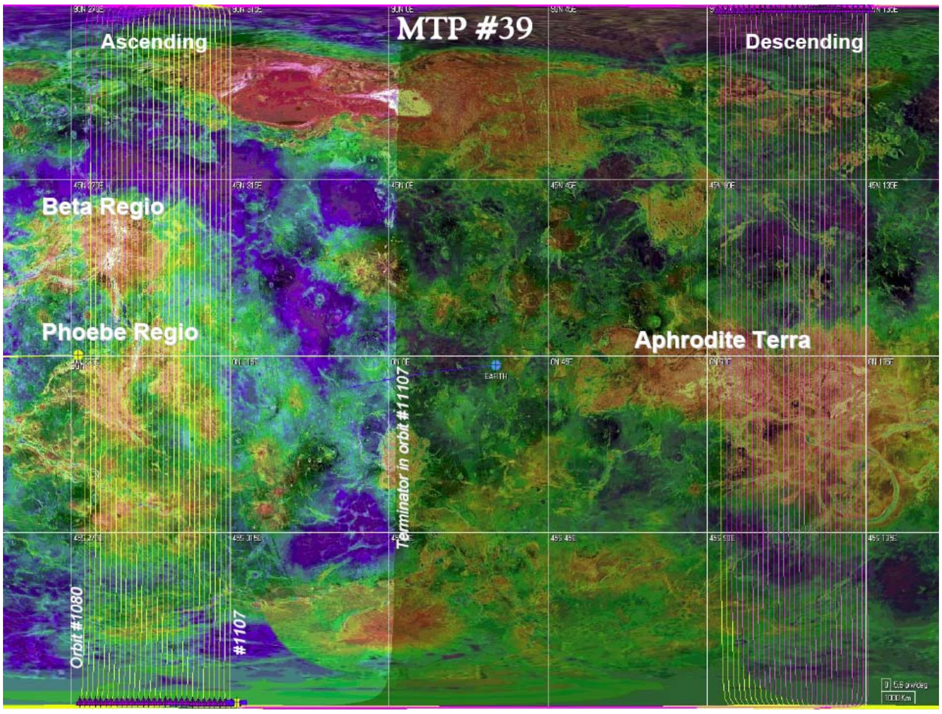

Figure 3.42. Planet coverage by orbital tracks in MTP#39 (see the note in 3.2.3).

3.23 MTP #40

3.23.1 Scientific focus

The MTP includes the eclipse season. The downlink is performed with HGA2 and is rather low. Noon orbit at the end of MTP. Good conditions for the day side observations by the end of MTP including case#2 "pendulum".

The peculiarities of science observations of individual experiments are as follows:

SPICAV: Solar occultations
Stellar occultations
Day side tangential limbs

VMC: Before P day side observations using "pendulum" by the end of MPT

After P in eclipse – nadir night side imaging of the Atalanta and Rusalka PLanitia, Atahensik corona

VIRTIS: Full day side observations at ascending branch
Limb observations together with SPICAV

3.23.2 Environmental conditions

- Local Time at Ascending Node (LTAN): ~9-12 h
- Hot period
- Science data dump: (~1000 Mbits/day) (tbc)

3.23.3 Timeline

Dates: 3.05 – 30.05.2009.

Orbits # 1108-1035.

Current SAP combines case#2 observations at ascending branch and the following types of orbits alternating in pericentre vicinity:

In orbits #1108-1123 alternate:

Type 1 (first two orbits): case#1 (day nadir before P) + case#5 (after P)+ case#7 (after P)

Type 2: case#1 (day nadir before P) + #6 (egress occ after P) + #1 (nadir night in eclipse)

Type 3: case #1 (day nadir before P) +#7(night side limb after P) + #6(ingress occ)

In orbits #1124-1135:

Type 1: case #1(day nadir or spot pointing) before P + case #6 (egress occ) after P + #1 (nadir night in eclipse)

Type 2: case #7(day in-plane limb before P) + case #6 (egress occ) after P + #1 (nadir night in eclipse)

Figures 3.43-3.44 show observations timeline and planet coverage by orbital tracks in MTP #40.

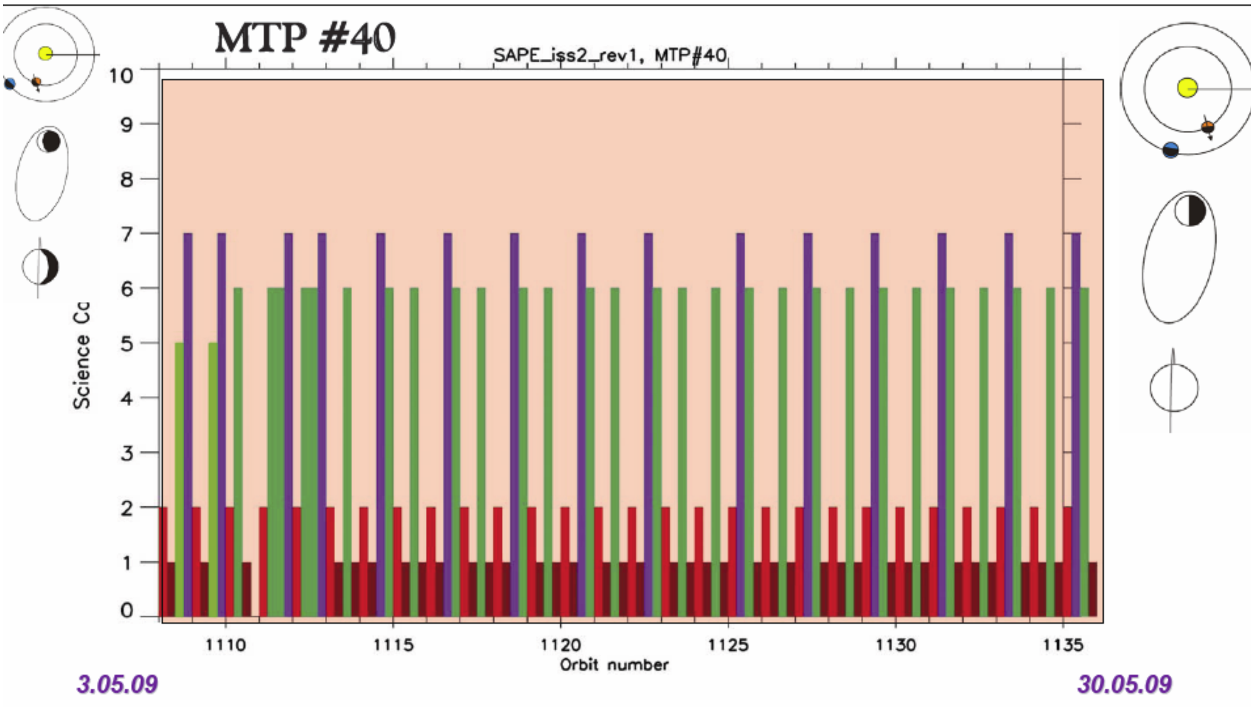

Figure 3.43 ***MTP40 timeline.***

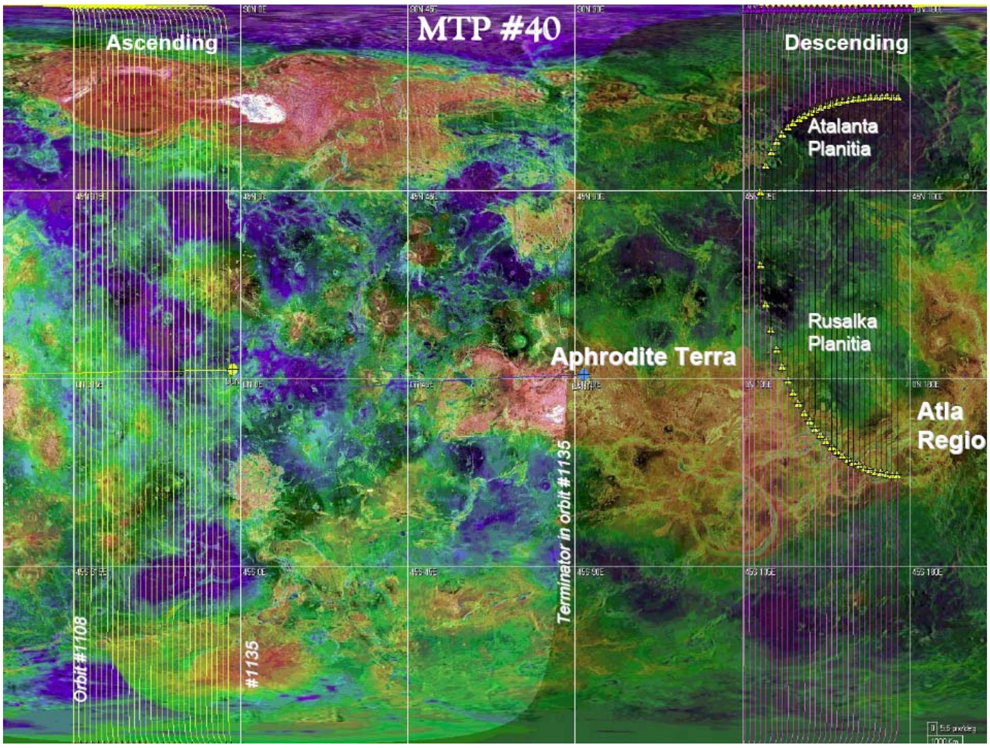

Figure 3.44. Planet coverage by orbital tracks in MTP#40 (see the note in 3.2.3).

3.24 Preliminary plans for the rest of Extended Mission

3.24.1 Pericentre lowering

It was tentatively agreed that after the superior conjunction the pericentre will be lowered and later maintained in the altitude "corridor" 170-270 km (instead of 250-350 km during the nominal and beginning of extended missions). Science benefit from this pericentre lowering is two fold. 1). In situ study of the plasma environment will be extended to lower altitudes. 2). Atmospheric density in this altitude range will be high enough to conduct drag experiment to determine density/temperature of the upper atmosphere remaining low enough to avoid aerobraking.

3.24.2 Apocentre lowering (aerobraking)

Later in the extended mission the aerobraking campaign is planned. It will result in lowering the apocentre and circularization of the orbit that would decrease the sun gravity effect on the pericentre altitude and prolong the mission. Lowering the pericentre will also give an opportunity to observe the Southern hemisphere with higher resolution (at the expense of spatial coverage, however). This phase will take about one year. Although the Venus Express spacecraft is designed for moderate aerobraking, preparation of the campaign would require thorough analysis of the thermal conditions on the spacecraft, as well as operational consequences.

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.

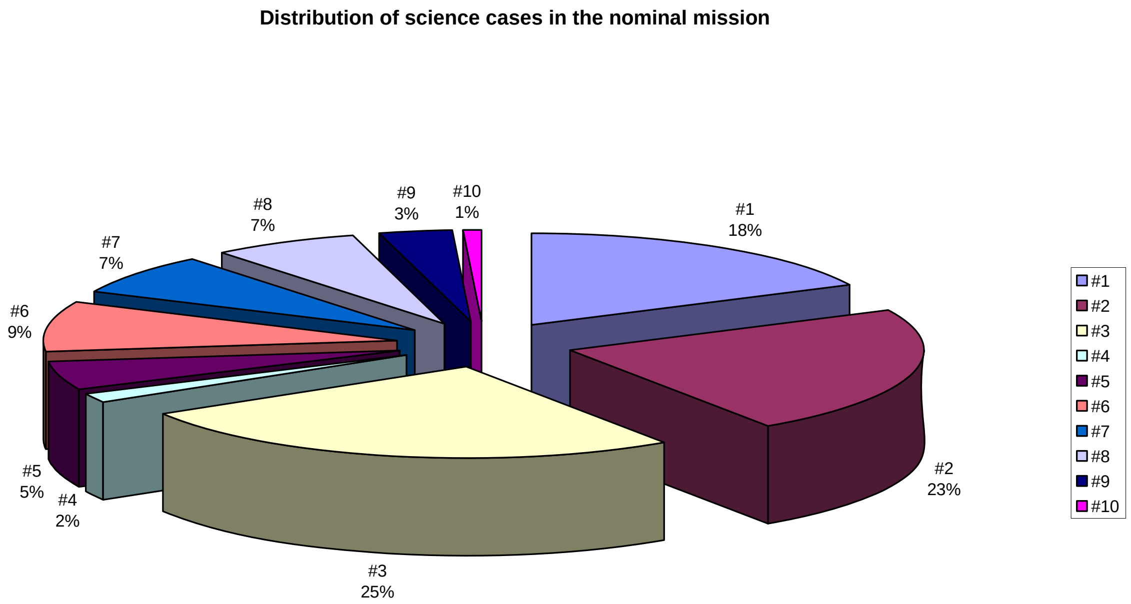

Figure 4.1. *Distribution of the science cases in the nominal mission.*

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.

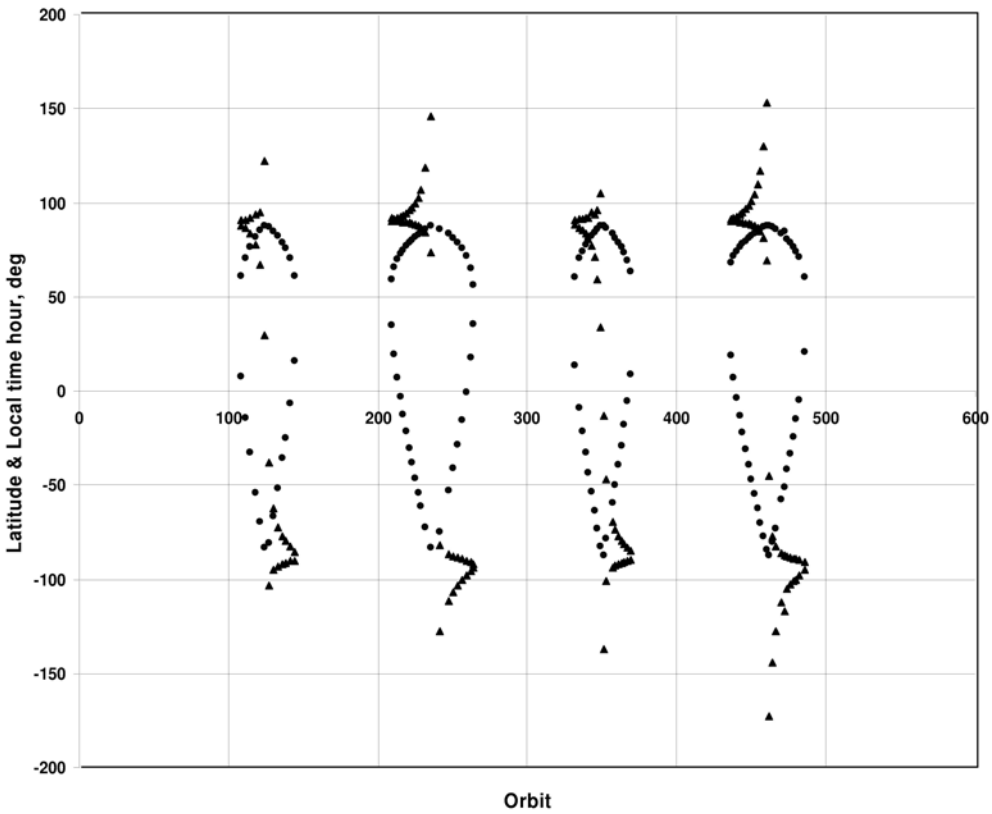

Figure 4.2 Latitude (solid circles) and local time hour (triangles) coverage in the SPICAV/SOIR solar occultation experiment during the nominal mission. The local hour angle of 0° corresponds to the noon, positive (negative) local hour angles correspond to the afternoon (morning) hours.

<u>*Case #7 (limb observations)*</u> 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).

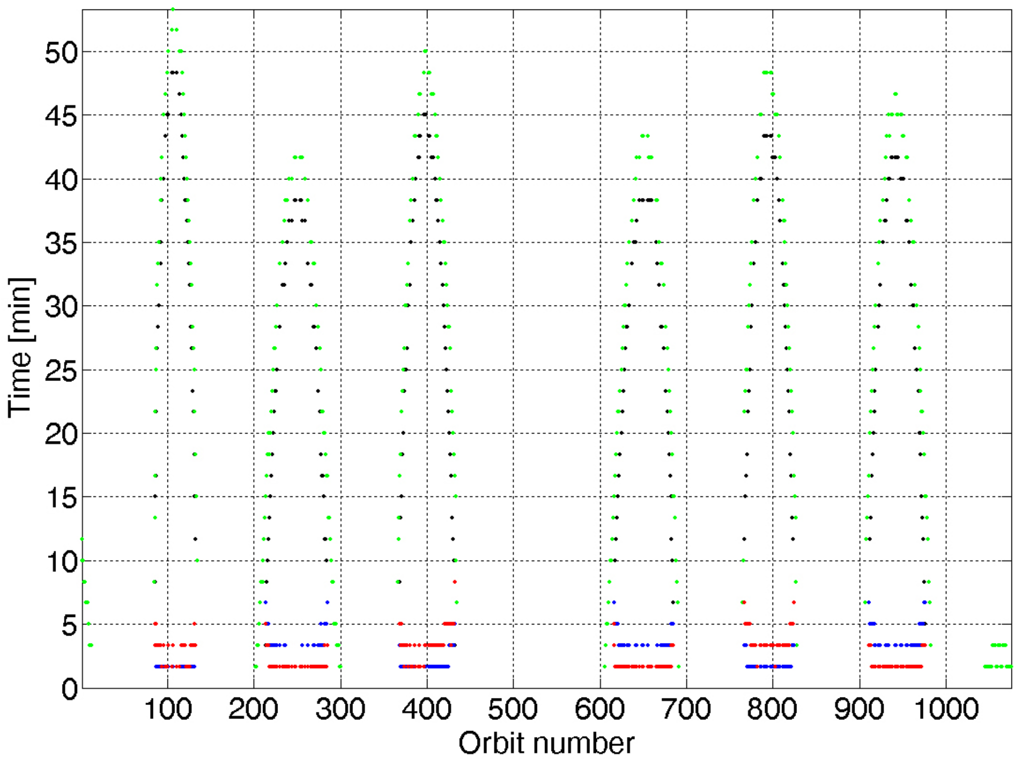

Figure 4.3. *Occultation seasons for VeRa for the nominal (orbit number < 500) and extended mission (orbit number > 500). Black dots indicate the duration of a pure planetary occultation,*

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

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.

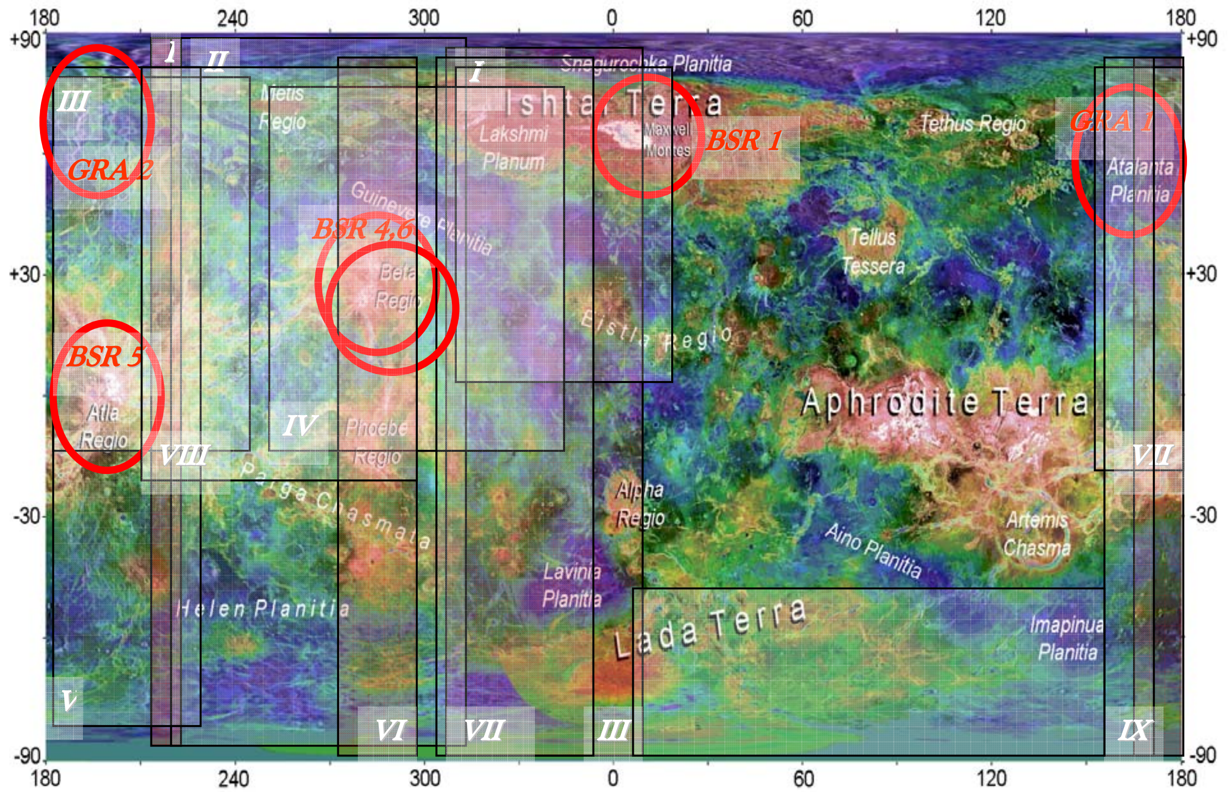

Figure 4.4. *Venus surface coverage by investigations onboard Venus Express: red circles – bi-static radar (BSR) and gravity (GRA), semi-transparent rectangles – locations covered by the night side thermal mapping. Mission phases are marked by white roman numbers.*

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.

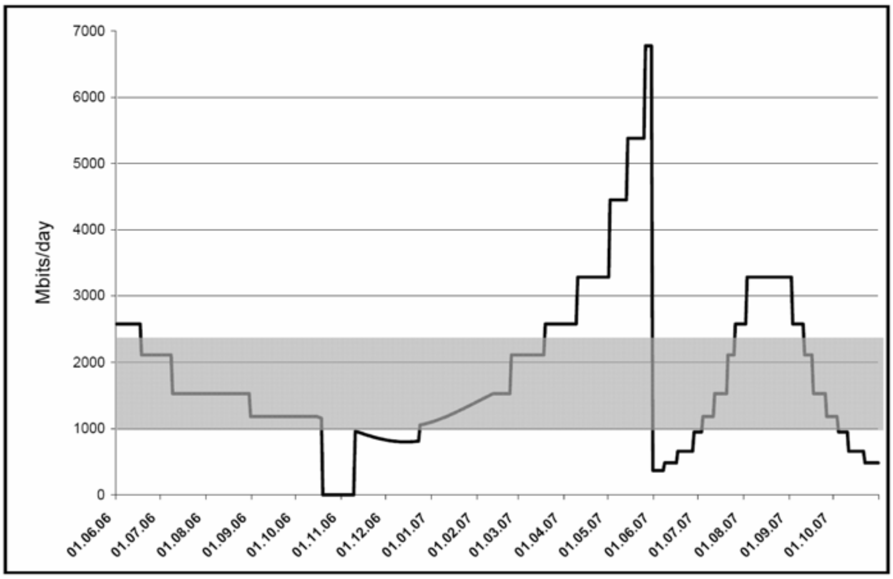

Figure 4.5. *Daily downlink of the scientific data to Cebreros antenna. Grey belt shows nominal level of daily data production by the payload.*

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.

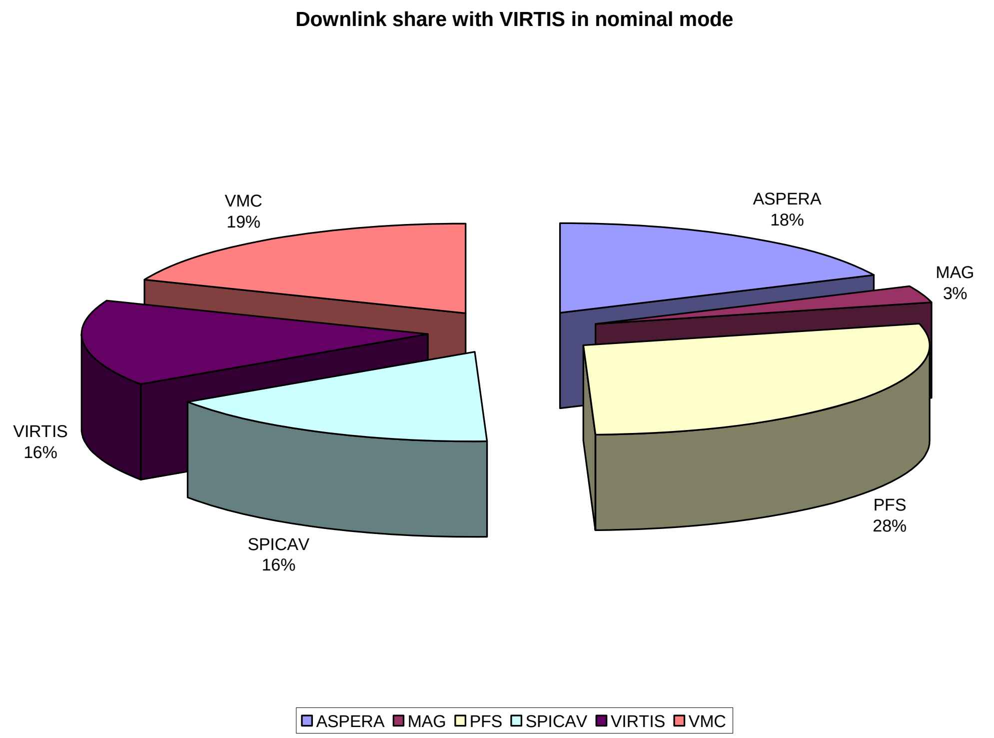

Figure 4.6. *Downlink share with VIRTIS in nominal mode.*

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.

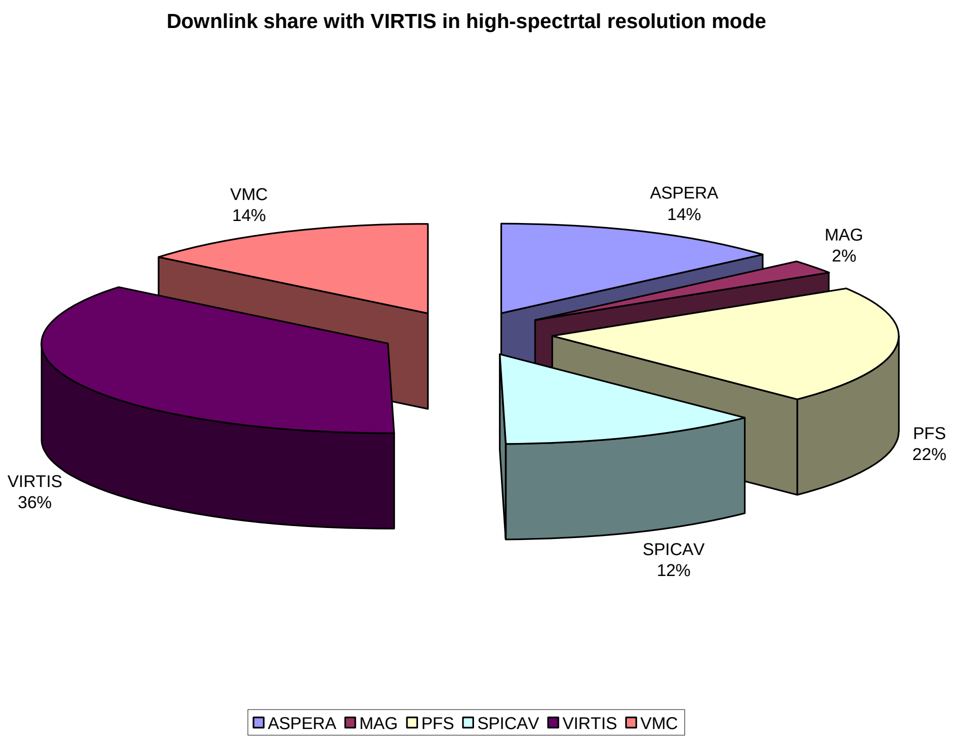

Figure 4.7. *Downlink share with VIRTIS in the high-spectral resolution mode.*

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. 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.

6. FUTURE WORK AND RECOMMENDATIONS

6.1 Overview

6.2 Missing inputs and future work

6.3 Action Items

6.4 Recommendations

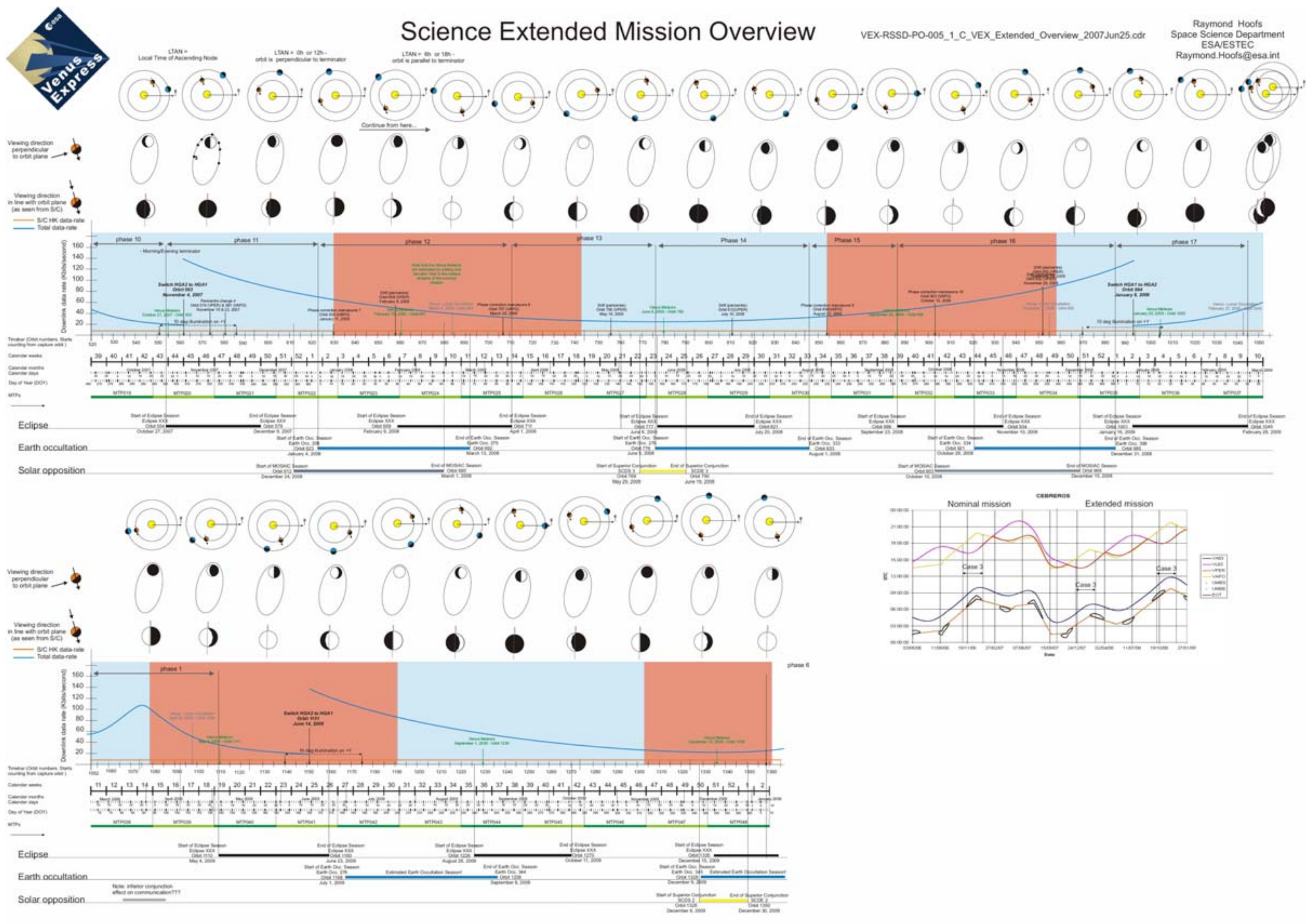
Science Extended Mission Overview
VEX-RSSD-PO-005_1_C_VEX_Extended_Overview_2007Jun25.cdr
Raymond Hoofs
Space Science Department
ESA/ESTEC
Raymond.Hoofs@esa.int
Venus Express
Eclipse
Earth occultation
Solar opposition
Nominal mission
Extended mission
CEBREROS

Figure 6.1

Figure 1.2

7. 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	

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

9. ANNEX 3. TABLE OF THE VERA EXPERIMENTS

Scheduling of the VeRa experiments in the Extended Mission (October 2007 – May 2009).

Extended Mission							
Time Period Extended Mission	Orbit No.	VeRa Experiment	Distance Earth-Venus [AU]	Surface Target	Station	Number of Passes	Orbits coordinated not yet finally granted
25.09.07-01.10.07	**522-528**	**Bistatic Radar 6a**	**0.5**	**Maxwell Montes**	**DSN**	**3**	**Cancelled**
26.09.2007	523	#1	0.5	Maxwell Montes	DSN	1	**DOY 269 target hit at 01:30 UTC cancelled due to sun illumination constraints**
28.09.2007	525	#2	0.5	Maxwell Montes	DSN	1	**DOY 271, target hit at 01:30 UTC cancelled due to sun illumination constraints**
30.09.2007	527	#3	0.5	Maxwell Montes	DSN	1	**DOY 273, target hit at 01:30 UTC cancelled due to sun illumination constraints**
02.11.07-14.11.07	**560-572**	**Bistatic Radar 7**	**0.8**	**Sapas, Ozza Montes**	**DSN**	**2**	**Cancelled**

08.11.2007	566	#1			DSN		**DOY 312 target hit at 01:09 UTC** **cancelled due to weak S-Band signal**
10.11.2007	568	#2					**DOY 314 target hit at 01:09 UTC** **cancelled due to weak S-Band signal**
12.11.07-20.11.07	**570-578**	**Bistatic Radar 8**	**0.8**	**Sapas, Ozza Montes**	**DSN**	**2**	**Cancelled**
12.11.2007	570	#1					**DOY 316 target hit at 01:09 UTC** **cancelled due to weak S-Band signal**
14.11.2007	572	#2					**DOY 318 target hit at 01:09 UTC** **cancelled due to weak S-Band signal**
19.12.07-25.12.07	**607-613**	**Bistatic Radar 9**	**1.1**	**Theia, Rhea Mons**	**DSN**	**2**	**Cancelled**
21.12.2007	609	#1	1.1	Theia, Rhea Mons	DSN	1	**DOY 355 target hit at 03:00 UTC** **cancelled due to weak S-Band signal**
23.12.2007	611	#2	1.1	Theia, Rhea Mons	DSN	1	**DOY 357, target hit at 03:06 UTC** **cancelled due to weak S-Band signal**
27.12.07-02.01.08		**Gravity 3**	**1.3**	**Atalanta Planitia, Coronae**	**NNO**	**4**	
27.12.2007	615	#1	1.3	Atalanta Planitia, Coronae	NNO	1	DOY 361 target hit at 03:35 UTC BOT: 2:41 EOT: 3:55
29.12.2007	617	#2	1.3	Atalanta Planitia, Coronae	NNO	1	DOY 363 target hit at 03:39 UTC BOT: 2:45 EOT: 3:59
31.12.2008	619	#3	1.3	Atalanta Planitia, Coronae	NNO	1	DOY 365 target hit at 03:43 UTC BOT: 2:49 EOT: 4:03
02.01.2008	621	#4	1.3	Atalanta Planitia, Coronae	NNO	1	DOY 2 target hit at 03:47 UTC BOT: 2:52 EOT: 4:07

04.01.08-13.03.08	623-692	Earth Occultation 4	1.3		NNO	35+4	Each second orbit
05.01.2008	624	#1	1.3		NNO	1	DOY 5 BOT: 3:28 EOT: 4:37
07.01.2008	626	#2	1.3		NNO	1	DOY 7 BOT: 3:31 EOT: 4:44
08.01.2008	627	#3	1.3		NNO	1	DOY 8 BOT: 3:33 EOT: 4:47
11.01.2008	630	#4	1.3		NNO	1	DOY 11 BOT: 3:38 EOT: 4:57
13.01.2008	632	#5	1.3		NNO	1	DOY 13 BOT: 3:42 EOT: 5:03
15.01.2008	634	#6	1.3		NNO	1	DOY 15 BOT: 3:46 EOT: 5:10
17.01.2008	636	#7	1.3		NNO	1	DOY 17 BOT: 3:50 EOT: 5:16
19.01.2008	638	#8	1.3		NNO	1	DOY 19 BOT: 3:54 EOT: 5:22
20.01.2008	639	#9	1.3		NNO	1	DOY 20 BOT: 3:55 EOT: 5:25
21.01.2008	640	#10	1.3		NNO	1	DOY 21 BOT: 3:57 EOT: 5:28
22.01.2008	641	#11	1.3		NNO	1	DOY 22 BOT: 3:59 EOT: 5:30
23.01.2008	642	#12	1.3		NNO	1	DOY 23 BOT: 4:01 EOT: 5:33
24.01.2008	643	#13	1.3		NNO	1	DOY 24 BOT: 4:03 EOT: 5:36

25.01.2008	644	#14	1.3		NNO	1	DOY 25 BOT: 4:05 EOT: 5:39	Light T (ca. mr
31.01.2008	650	DSN #6	1.3		DSN	1	**DOY 31** **BOT: 4:20 EOT: 5:50** **Confirmed DSN path**	
02.02.2008	652	DSN #8	1.3		DSN	1	**DOY 33** **BOT: 4:24 EOT: 5:55** **Confirmed DSN path**	
04.02.2008	654	DSN #10	1.3		DSN	1	**DOY 35** **BOT: 4:28 EOT: 6:00** **Confirmed DSN path**	
06.02.2008	656	DSN #12	1.3		DSN	1	DOY 37 BOT: 4:32 EOT: 6:04 Confirmed DSN path **cancelled**	
09.02.2008	659	#15	1.3		NNO	1	DOY 40 BOT: 4:32 EOT: 6:11	
10.02.2008	660	#16	1.3		NNO	1	DOY 41 BOT: 4:31 EOT: 6:11	
11.02.2008	661	#17	1.3		NNO	1	DOY 42 BOT: 4:31 EOT: 6:10	
12.02.2008	662	#18	1.3		NNO	1	DOY 43 BOT: 4:30 EOT: 6:09	
13.02.2008	663	#19	1.3		NNO	1	DOY 44 BOT: 4:29 EOT: 6:08	
14.02.2008	664	#20	1.3		NNO	1	DOY 45 BOT: 4:28 EOT: 6:07	
15.02.2008	665	#21	1.3		NNO	1	DOY 46 BOT: 4:27 EOT: 6:06	

16.02.2008	666	#22	1.3		NNO	1	DOY 47 BOT: 4:26 EOT: 6:04
18.02.2008	668	#23	1.3		NNO	1	DOY 49 BOT: 4:25 EOT: 6:02
20.02.2008	670	#24	1.3		NNO	1	DOY 51 BOT: 4:23 EOT: 5:59
22.02.2008	672	#25	1.3		NNO	1	DOY 53 BOT: 4:22 EOT: 5:56
23.02.2008	673	#26	1.3		NNO	1	DOY 54 BOT: 4:21 EOT: 5:55
26.02.2008	676	#27	1.3		NNO	1	DOY 57 BOT: 4:19 EOT: 5:50
28.02.2008	678	#28	1.3		NNO	1	DOY 59 BOT: 4:17 EOT: 5:47
01.03.2008	680	#29	1.3		NNO	1	DOY 61 BOT: 4:15 EOT: 5:43
03.03.2008	682	#30	1.3		NNO	1	DOY 63 BOT: 4:14 EOT: 5:39
05.03.2008	683	#31	1.3		NNO	1	DOY 64 BOT: 4:13 EOT: 5:37
07.03.2008	686	#32	1.3		NNO	1	DOY 67 BOT: 4:11 EOT: 5:31 **cancelled**
09.03.2008	688	#33	1.3		NNO	1	DOY 69 BOT: 4:10 EOT: 5:26 **cancelled**
11.03.2008	690	#34	1.3		NNO	1	DOY 71 BOT: 4:09 EOT: 5:21 **cancelled**
13.03.2008	692	#35	1.3		NNO	1	DOY 73 BOT: 4:09 EOT: 5:16
09.06.2008		**Superior**	**1.7**				

		Solar Conjunction					
02.05.2008-15.07.2008		Solar Corona	1.7		DSN	30	Cancelled because of S-Band problem
16.07.08-01.08.08	**818-833**	**Earth Occultation 5**	**1.3**		**NNO**	**11-3+2**	**During First Part of Occ. Season 5 no measurements possible (SCO influence)**
16.07.2008	817	#1	1.3		NNO	1	
17.07.2008	818	#2	1.3		NNO	1	
19.07.2008	820	#3	1.3		NNO	1	
20.07.2008	821	#4	1.3		NNO	1	**Deleted: conflict** with pericenter lowering **pericenter OCM**
22.07.2008	823	#5	1.3		NNO	1	**Deleted: conflict** with pericenter lowering **FD tracking**
23.07.2008	824	#6	1.3		NNO	1	
24.07.2008	825	#7	1.3		NNO	1	**Added** because of conflicts with orbit lowering
25.07.2008	826	#8	1.3		NNO	1	
26.07.2008	827	#9	1.3		NNO	1	
28.07.2008	829	#10	1.3		NNO	1	
29.07.2008	830	#11	1.3		NNO	1	**Deleted: conflict** with pericenter lowering **FD tracking**
30.07.2008	831	#12	1.3		NNO	1	**Added** because of conflicts with orbit

							lowering
31.07.2008	832	#13	1.3		NNO	1	
28.10.2008-31.12.08	**921-985**	**Earth Occultation 6**	**1.1**		**NNO**	**35**	**Each second orbit**
30.10.2008	923	#1			NNO	1	
01.11.2008	925	#2			NNO	1	
03.11.2008	927	#3			NNO	1	
04.11.2008	928	#4			NNO	1	**Cancelled:** NNO Maintenance Orbit added because of conflicts with orbit lowering in Occ#5
05.11.2008	929	#5			NNO	1	
07.11.2008	931	#6			NNO	1	
09.11.2008	933	#7			NNO	1	
11.11.2008	935	#8			NNO	1	
13.11.2008	937	#9			NNO	1	
15.11.2008	939	#10			NNO	1	
17.11.2008	941	#11			NNO	1	
19.11.2008	943	#12			NNO	1	

21.11.2008	945	#13			NNO	1	
23.11.2008	947	#14			NNO	1	
25.11.2008	949	#15			NNO	1	
27.11.2008	951	#16			NNO	1	
29.11.2008	953	#17			NNO	1	
01.12.2008	955	#18			NNO	1	
03.12.2008	957	#19			NNO	1	
05.12.2008	959	#20			NNO	1	
07.12.2008	961	#21			NNO	1	
08.02.2008	962	#22			NNO	1	Orbit **added** because of conflicts with orbit lowering in Occ#5
09.12.2008	963	#23			NNO	1	
11.12.2008	965	#24			NNO	1	
13.12.2008	967	#25			NNO	1	
15.12.2008	969	#26			NNO	1	
17.12.2008	971	#27			NNO	1	
19.12.2008	973	#28			NNO	1	

21.12.2008	975	#29			NNO	1	
23.12.2008	977	#30			NNO	1	
25.12.2008	979	#31			NNO	1	
26.02.2008	980	#32			NNO	1	Orbit **added** because of conflicts with orbit lowering in Occ#5
27.12.2008	981	#33			NNO	1	
29.12.2008	983	#34			NNO	1	
31.12.2008	985	#35			NNO	1	

Source: ESA Orbit File: ORVF_FDLVMA_DA______________00009.VEX

Source: ESA Orbit File: ORVF_FDLVMA_DA______________00052.VEX

15.04.2005 B.H./J.S.
Modified B.H. 14.07.2005
Orbit No added J.S.
15.07.2005

Modified B.H. 06.02.2006

Modified B.H. 09.04.2006

Modified B.H./P.Sch. 13.04.06

Modified R.M. 02.10.06 - SCO #1 Updates

Modified R.M - B.H. 03.01.07 - SCO #1 Reference: delivered CP's

Modified R.M 09.01.07 - SCO #1Survey based on MOR's

Modified R.M - S.R. 28.03.07 - OCC #3 updates

Modified R.M - B.H. - S.R. 28.03.07 - Extended Mission BSR updates

Modified DT 9.05.07

Modified SR 9.08.07

Modified SR 15.10.07 DSN passes OCC4

Modified SR 09.11.07 DSN passes OCC4, OCC#6 added
Modified SR 10.Jan.08 DSN passes OCC4 mod, OCC5 conflicts with FD marked, OCC6 3 orbits added

Modified SR 11.Jan.08 OCC5 2 orbits added, OCC6 1 orbit cancelled

10. ANNEX 4. MEMO ON PERICENTRE LOWERING CAMPAIGN

NOTE: The schedule of pericentre lowering (see table below) should be corrected by shifting all activities by 1 week earlier as compared to the original Memo.

f MEMO

date/*date* 14-Nov-07	ref./*réf.* FCT-VEX-010	page/*page* 1/4

from/*de* I. Tanco visa/*visa*

to/*à* VEX FCT, VSOC, V. Companys, VEX FD,

copy/*copie* F. Jansen, P.Ferri, H. Swedhem, O.Witasse, D. Titov

This note presents a preliminary proposal for the conduction of pericenter reduction operations during the summer of 2008.

1. Reference documents

[RD1] – VEX-RSSD-TN-041 Extended Mission Orbit Modifications 19/07/2007 [RD2] – VEX-ESC-MN-2059 Pericenter reduction discussion 20/07/2007

2. Background

As described in [RD1], Phase 1 of the Orbit Modifications Campaign focuses on lowering the pericenter altitude down to a target value of ~185 km.

[RD2] documents the discussion and decision taken to the effect, that this orbit modification would be permanent (i.e., the pericenter control band would be changed from the present 250-400 km to 185-300 km. This change would be implemented as soon as safely possible, after the end of the superior conjunction period in June 2008. It was tentatively concluded that a period of four weeks would be necessary to execute such an orbit modification.

3. Operational Approach

The rationale guiding this proposal is to fulfil the objective of reducing the pericentre minimising the risk to the spacecraft and the impact on the conduction of routine operations as currently implemented. This means, in particular:

- Adapting, as far as possible, the pericenter reduction activities to the weekly Short-Term-Planning cycle.
- Using a step-by-step approach to pericenter lowering.
- Increasing visibility of the S/C by booking additional NNO passes at the time of the pericenter lowering manoeuvres, and by extending the CEB passes beyond apocenter passage.

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MEMO

date/*date* 14/11/2007 | ref./*réf.* FCT-VEX010 | page/*page* 2 / 2

With these principles in mind, the following guidelines are proposed for the execution of the activities:

- Pericenter lowering manoeuvres will be performed in pairs (one at pericenter, then another at apocenter), both of which will be executed within the same STP cycle.
- In order to avoid adverse effects of Sun activity on the Doppler signal, the necessary sun clearance angle is estimated to be 10 deg. This implies that the earliest date

for beginning apocenter-lowering operations would be 15 July, 2008.

- A Drift correction manoeuvre scheduled for 11 July (DOY 193) will be cancelled due to its proximity to the Orbit Lowering campaign. The effect of this cancellation will be evaluated as part of the analysis to be done in the next months.
- The first manoeuvre, at pericenter, will be executed immediately before the Cebreros pass on the Sunday of the relevant STP cycle.
- The second manoeuvre, at apocenter, will be executed immediately after the Cebreros pass on the Monday of the relevant STP cycle.
- A WOL will be executed within the slot assigned to each manoeuvre. The order in which these two activities (OCM, WOL) will be conducted is TBD.
- The CEB pass prior to the second manoeuvre will be extended to LOS, which thus will cover apocenter passage +3hrs. The pass will be temporarily interrupted for the OCM, regaining the signal once the S/C slews back to Earth.
- A New Norcia pass will be booked for the maximum available duration following the second manoeuvre, to increase visibility of the S/C and tracking data. Two of the passes (on DOY 204 and 211) will be affected by occultations.
- Flight Dynamics will run their OD activities on Tuesday and deliver the required products to continue orbit lowering in the next STP cycle within Wednesday of the relevant STP cycle.
- The four steps to be performed will lower the pericenter altitude to the following values: first 210 km, then 200 km, then 190 km, and finally 185 km. Of these steps, the final two are identified as incurring a higher risk for the S/C, and therefore special safety activities will be implemented to protect against possible contingencies.
- In principle, there will be no restrictions to Science Operations during this phase. The only effective limitation will be the increase in Earth contact times, which will necessarily prevent certain types of science observations.

S MEMO

date/date 14/11/2007	ref./réf. FCT-VEX010	page/page 3

4. Operational Schedule

NOTE: The table below should be corrected by shifting all activities by 1 week earlier as compared to the original Memo.

The operational schedule resulting from these guidelines would be as follows:

EventDate	DOY	Weekday	Groundstation	AOS_HM	AOS_10	EOT	Remark
15-Jul-08	197	Tue	CEB	6:03	6:48	16:48	Sun-Earth-SC Angle goes above 10 deg.
16-Jul-08	198	Wed	CEB	6:05	6:50	16:50	TM BRC to 76182.5051 FCT STP process complete
17-Jul-08	199	Thu	CEB	6:07	6:52	16:52	
18-Jul-08	200	Fri	CEB	6:09	6:54	16:54	
19-Jul-08	201	Sat	CEB	6:12	6:57	16:57	
20-Jul-08	202	Sun	CEB	6:14	6:59	16:59	Apo lowering OCM #1 at Peri before CEB AoS
21-Jul-08	203	Mon	CEB	6:16	7:01	19:24	Peri lowering OCM #1 at Apo during CEB pass.
22-Jul-08	204	Tue	NNO		00:50:00	07:03:00	NNO passes requested, to be scheduled.
22-Jul-08	204	Tue	CEB	6:18	7:03	17:03	FDYN runs Orbit Det. Process
23-Jul-08	205	Wed	CEB	6:20	7:05	17:05	FDYN products submitted
24-Jul-08	206	Thu	CEB	6:23	7:08	17:08	FCT STP

							process complete
25-Jul-08	207	Fri	CEB	6:25	7:10	17:10	
26-Jul-08	208	Sat	CEB	6:27	7:12	17:12	
27-Jul-08	209	Sun	CEB	6:29	7:14	17:14	Apo lowering OCM #2 at Peri before CEB AoS
28-Jul-08	210	Mon	CEB	6:31	7:16	19:23	Peri lowering OCM #2 at Apo during CEB pass.
29-Jul-08	211	Tue	NNO		00:49:00	07:16:00	NNO passes requested, to be scheduled.
29-Jul-08	211	Tue	CEB	6:34	7:19	17:19	FDYN runs Orbit Det. Process
30-Jul-08	212	Wed	CEB	6:36	7:21	17:21	FDYN products submitted
31-Jul-08	213	Thu	CEB	6:38	7:23	17:23	FCT STP process complete
01-Aug-08	214	Fri	CEB	6:40	7:25	17:25	
02-Aug-08	215	Sat	CEB	6:43	7:28	17:28	
03-Aug-08	216	Sun	CEB	6:45	7:30	17:30	Apo lowering OCM #3 at Peri before CEB AoS
04-Aug-08	217	Mon	CEB	6:47	7:32	19:19	Peri lowering OCM #3 at Apo during CEB pass.
05-Aug-08	218	Tue	NNO		00:46:00	07:32:00	NNO passes requested, to be scheduled.
05-Aug-08	218	Tue	CEB	6:49	7:34	17:34	FDYN runs Orbit Det. Process

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MEMO

date/*date* 14/11/2007
ref./*réf.* FCT-VEX010

page/*page* 4

date/*date* 14/11/2007 ref./*réf.* FCT-VEX010 page/*page* 4

06-Aug-08	219	Wed	CEB	6:52	7:37	17:37	FDYN products submitted
07-Aug-08	220	Thu	CEB	6:54	7:39	17:39	FCT STP process complete
08-Aug-08	221	Fri	CEB	6:56	7:41	17:41	
09-Aug-08	222	Sat	CEB	6:58	7:43	17:43	
10-Aug-08	223	Sun	CEB	7:01	7:46	17:46	Apo lowering OCM #4 at Peri before CEB AoS
11-Aug-08	224	Mon	CEB	7:03	7:48	19:14	Peri lowering OCM #4 at Apo during CEB pass.
12-Aug-08	225	Tue	NNO		00:43:00	07:48:00	NNO passes requested, to be scheduled.
12-Aug-08	225	Tue	CEB	12:00	12:45	19:13	FDYN runs Orbit Det. Process
13-Aug-08	226	Wed	CEB	7:07	7:52	17:52	FDYN products submitted
14-Aug-08	227	Thu	CEB	7:10	7:55	17:55	FCT STP process complete

5. Open Points

The following issue is currently left open to further discussion:

- Contingency strategy: on call\dedicated support during NNO passes; pre-processing of emergency pericenter raising OCMs.

6. Delivery of Products

- Update of FD products including the pericenter reduction until end of current mission extension: End of 2007.
- All files affected by the FD products will be updated as soon as possible in

January 2008.