European Space Agency

Research and Scientific Support Department

Planetary Missions Division

Venus Express

Science Activity Plan for
Extended Mission
SAP-E-4, Part 1
MTPs 88-100

VEX-SCIOPS-PL-035

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24 July 2012	0	1	All	All sections. MTPs 88-90 are based on orbit file v425 MTPS 91-100 based on synthetic orbit v20001	
22 August 2012	0	2		Updates to MSPs following new orbit file delivery	
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Revisions are indicated by a vertical bar at the outside border.

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	ASPERA		
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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 ended on October 2, 2007. However the mission extension till the end of 2014 has been approved (fourth extension). 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 Fourth Extended Mission (SAP-E-4) describes in a structured way the scientific activities to be carried out throughout the third extended mission (January 2013 – January 2015). To create more manageable SAP documents, the SAP is subdivided in 2 parts, as follow

SAP number	PART	MTP	Period	SAP document
SAP#4	Part 1	88-100	Jan'13 – Jan'14	VEX-SCIOPS-PL-035
	Part 2	101-113	Jan'14 – Jan'15	VEX-SCIOPS-PL-036 (TBC)

This document describes the SAP-E-4 Part 1 (MTP#88-100, January 2013 – Jan 2014). 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 (Medium 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-4 Part 1 contains preliminary MTP timelines (sequences of science cases) based on science priorities 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.

At the time of writing (July 2012), it has been decided that the VEx orbit will not be changed to a lower orbital period through use of aerobraking during 2013. Therefore this SAP document has been formulated based on the assumption that the orbit remains a 24-hour period.

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 mission to date;
-
- Perform pericentre lowering down to the altitude that allows measurement of atmospheric density using torque and drag measurements, without appreciably changing the orbital period of the spacecraft. (~165 km);
- Start conducting observation campaigns, each lasting up to four months, to study particular science objectives with high temporal resolution.

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.

AD14: VEX-SCIOPS-LI-046_1_16 Consolidated observations table version 16 (2 Apri 2012)

AD15: VEX-MPS-LI-001_VMC_surface_targets_20120827

AD16: Stofan et al. "Large topographic rises on Venus: Implications for mantle upwelling" J. Geophys. Res. 1985. doi:10.1029/95JE01834

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

TBW

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 two computer based planning tools: 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.

Each science case has several different observation types; these are described below and listed in the 'consolidated observations table' (AD14).

2.3 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.

2.4 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].

2.5 Venus Express orbit and visibility of the ground stations

The Venus Express was inserted in a polar orbit with a period of 24 hours. The pericentre altitude was maintained between 250 km and 350 km during the first 8 months of the Extended Mission. In July-August, 2008 the pericenter was lowered to the corridor 170-270 km to allow plasma observations in this altitude range. This pericentre lowering does not require any changes in observations strategy or special spacecraft operations. The apocenter altitude is kept at about 66,000 km. In September 2009 the pericentre latitude reached the Northern pole. During the period of this document (Jan 2013 – Jan 2014), the pericentre latitude will drift from approximately 79.3°N to approximately 75.9°N (TBC pending final orbit file).

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.

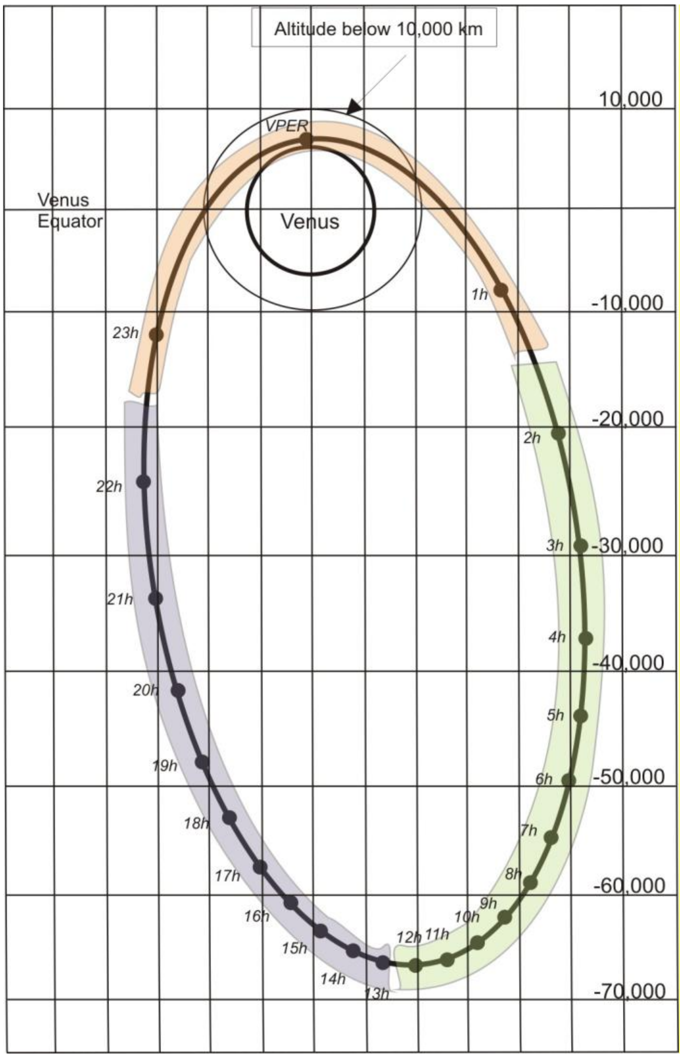

Figure 2.1 *The Venus Express orbit and orbital phases: orange: pericentre observations; blue: off-pericentre observations in ascending branch; green – telecommunications with Cebreros.*

Communication with Earth takes place in each orbit after the pericentre passage, i.e. in the descending part of the orbit, marked in green in Figure 2.2. The orbit period is tuned such that the communication window always falls in daytime at the primary ground station at Cebreros. Figure 2.3 shows visibility of the Cebreros station from the spacecraft. 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 provide favorable conditions for the Case 3 apocentric mosaic.

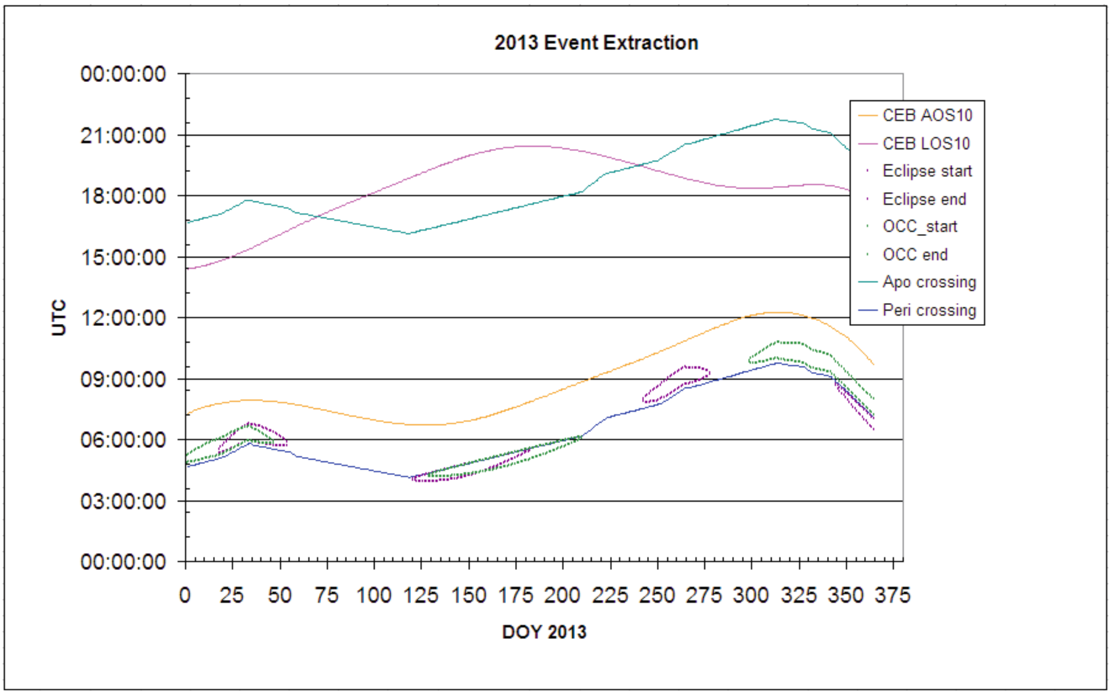

Figure 2.3 *Visibility of the Cebreros ground station from the satellite.*

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 radio occultations as well as the support for the data downlink in the periods of low data rate is agreed between ESA and NASA.

Note that ESA's newest ground station in Malargüe, Argentina, is expected to be operational by the beginning of Jan 2013. However, the baseline assumed in this document remains the use of Cebreros ground station for all communications passes.

3. THE SAP-E-4 PART-1 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 the period covering MTP#88-100 (January 2013 – January 2014). Depending on environmental conditions (occultation, illumination conditions etc.), the science will focus on different mission objectives.

3.1 Science Activity Plan overview

3.1.1 Coverage

The SAP-E-4 Part 1 (SAP for 4th extension) will cover in detail the period from January 2013 until Jan 2014, or MTP range from #88 to #100.

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

A poster summarising this mission extension period is given in Annex 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 overall operational requests are listed.

3.1.5.2 ASPERA

ASPERA is typically operated twice per orbit, once near apocenter and once in the ascending branch as the spacecraft crosses the space/atmosphere boundry. 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 parts 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 will 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 several attempts to unblock the scanning mechanism.

3.1.5.5 SPICAV

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; further modes include nadir and limb pointing. The use of the near IR channel (0.7-1.7µm) compensates partially for the loss of VIRTIS-M, with a better spectral resolution but a lower sensitivity and spatial resolution (2°).
SPICAV observing modes include:

- Stellar occultation
    - This is performed only on the nightside (with few exceptions). Bright stars are chosen to maximize coverage in latitude and local solar time.
    - Orbits where the orbital plane is near the terminator are slightly less favourable for stellar occultation.
- Solar occultation (SOIR)
    - Occurs in eclipse seasons.
    - Allocation of orbits to SOIR is generally chosen to maximise latitude coverage. This requirement leads to use of consecutive orbits at the beginning and end of a solar occultation season, with typically one solar occultation every 2-3 orbits in the middle of eclipse season, alternating ingress and egress to observe both North and South hemispheres.
    - In addition to the above requirement, the SOIR team request repeated ingress or repeated egress observations on 4-5 consecutive orbits in order to study day-to-day variability at the same location, to be carried out occasionally (not necessarily in every eclipse season).
    - Due to thermal limitations of the SPICAV instrument, the maximum operation time for the instrument is 35 minutes; this means that the instrument can perform ingress + egress solar occulations only when the eclipse duration is less than 25 minutes (at the beginning and end of each eclipse season). When the eclipse duration is more than 25 minutes (in the middle of each eclipse season), the SOIR team has to choose either ingress or egress occultations.
- Solar occultation (SPICAV UV)
    - Due to the imperfect co-alignment of SOIR and SPICAV UV in the solar occultation mode, SPICAV UV is looking at the sun at a place of the focal plane for which the spectral resolution is degraded. Spicav wishes to perform some solar occultations optimized for UV spectral resolution, in particular to confirm the absorption by SO.
    - Once per MTP in occultation.

- Nadir observation on dayside using SOIR boresight
  - This is a new request for SAP Ext 3 part 3. SOIR intends to observe light reflected from the dayside cloud-top. Observation should be chosen to maximize the signal, without illuminating the –X face.
  - In order to probe the atmosphere to the lowest possible altitude, it is desired that this observation be carried out in near-nadir geometry.
- Nadir observation dayside using SPICAV boresight.
  - The goals of this observation include mapping of unknown UV absorbers, mesospheric SO_2 and H_2O abundance, and cloud top altitude retrieval with CO2 band at 1.43 µm.
- Nadir observation nightside using SPICAV boresight
  - The main goal of this observation is mapping of the lower atmosphere and surface, in the 0.7 – 1.7 µm range. This includes H2O in the lower atmosphere.
  - This is usually carried out in eclipse.
- NO observation campaign
  - For the SAP Ext 3 Pt 3 SPICAV has added a new request for observations in eclipse of the NO airglow using inertial mode. In this mode, the spacecraft is held in an inertial pointing mode such that the observed point sweeps a wide range of latitudes while the spacecraft is in eclipse.
  - In this SAP for 2013, we propose a specific NO mapping campaign. In this time the NO observation will be carried out on alternate orbits, in order to build up and map of NO emission evenly spaced in local solar time. See technical note VEX-SPICAV-TN-120.
- MEx-VEx joint observations
  - In this observation, SPICAV is pointed in the direction of Mars for one acquisition, and in the opposite direction for another acquisition. SPICAM/MEx performs the same observation. These are combined to make a study of dust interstellar/interplanetary Hydrogen atoms in the inner solar system by looking at the Lyman alpha emission of these

atoms illuminated by the sun, and to intercalibrate SPICAV, SPICAM and SWAN on SOHO at the Lyman alpha frequency.

  - This observation is performed near apocentre, with a duration of ~ 1 hr, to avoid Lyman alpha contamination by the hydrogen corona of Venus.
  - Since it requires VEX to look into two strictly opposite directions, it can be done only when the elongation of Mars as seen from Venus is at 90°, plus or minus a few degrees, requiring the illumination of the – Z face by a few degrees. This is to be performed ~ 3 times at each opportunity, which dates for 2011-2012 are: 2012/06/17, and 2011/08/06.

- VEx-SOHO joint observations
  - Same as above, but using SWAN/SOHO, near the Earth. Therefore, there is one opportunity at each quadrature, when the solar elongation of the Earth as seen from Venus is near 90°. This occurs over the 2011-2012 period around 2011/01/10, 2012/03/28 and 2012/08/16.
- Zodiacal light observation
  - It is important to look at small solar elongations (less than 30°), not well explored up to now. In order to avoid solar stray light contamination, it is performed in eclipse during a few minutes before exit of shadow, inertial viewing. A slew maneuver to increase the solar elongation is started one minute before exit of eclipse.
  - This is to be performed once per favourable MTP. The favourable MTPs are those when VEX is in eclipse before pericenter.
- Dayside airglow limb observation
  - The science goal is to look for dayside non-LTE emissions (‘airglow’). Their decreased brightness with altitude yields the thermospheric / exospheric temperature. Target species including H, O, CO, CO_2^+ ion and O at 297.2 nm in the UV, and O_2 in the IR. This is performed with the SPICAV-UV slit arranged perpendicular to the limb, to minimise stray light from the bright limb. The current procedure is to align the

spacecraft with the large part of the slit towards the limb, resulting in some +X illumination. The SPICAV team has requested that the spacecraft be 'flipped' such that the narrow portion of the slit is towards the bright limb, to reduce stray light and increase the spectral resolution. This is not allowed under current flight rules (as of May 2011), but a revision of this rule is under study. If allowed, this observation should be performed at regular intervals e.g. 5-10 times per MTP, OR in campaigns of alternate orbits during half of a Venus day (120 days). See technical note VEX-SPICAV-TN-121.

- Dayside hydrogen corona observation
    - One preferred mode is to observe the H Lyman alpha emission in an inertial direction, letting Vex orbital motion perform the scan in altitude. In the same orbit (±1), the same pointing is required near the apocenter, in order to measure the interplanetary background in the same celestial direction, for a good subtraction from the data obtained at lower latitudes. In some instances, several ON-OFF observations by SPICAV may be done in the same direction, to scan a larger altitude range (the instrument cannot work more than 35 minutes in continuous duration because of potential over-heating.
- Observations of Mercury/comets/other targets
    - Occasional.
- Galactic scan
    - The science goal is to study diffuse UV radiation in some planetary nebulae (scattering of stellar light by interstellar dust) and to attempt to detect galactic Lyman alpha radiation (at 121.6 nm), which is suggested by Recent Voyager observations at 100 AU. Observation requires periods of ~2 hours near apocentre. A number of interesting sky areas have been identified. They can be observed when their solar elongation is between 60 and 90° (to minimize solar stray light). This usually requires a series of apocenters to be dedicated to a particular region in the sky, with about 3 to 6 apocentres per MTP.

- Solar UV imaging
    - The goal is to obtain a map of the sun in UV wavelengths (190-310 nm). This will be done by letting the FOV of SPICAV-UV (solar port) drift across the Sun, therefore building up a hyperspectral image of the sun. Spatial reolution will be 1.5 arcmin.
    - Observation duration is <30 minutes, and can be performed when VEx is away from Venus (e.g. near apocentre).
    - The long-term intention is to perform regular monitoring of the sun twice per MTP. However, as of late 2011 this observation type is not yet fully validated so it has not yet been included in the SAP.

In addition to the above scientific observations, there are occasional calibration observations, which include:

- SPICAV-SOIR ‘mini-scans’
    - Performed near apocentre, approximately twice per MTP. The purpose of the mini-scan calibrations is to get precise relationships between the applied RF frequency and the wave number and also to obtain the bandpass curve of the electrically tuneable order sorting filter (AOTF).
- SPICAV-SOIR alignment calibration
    - Performed near apocentre, approximately once per MTP. The main goal of the alignment scans is to define the exact alignment of the instrument boresight with respect to the spacecraft axes.
- SPICAV ‘polarisation’ calibration
    - Sunlight reflected at 0° phase angle should exhibit no net polarisation. Therefore it requires that boresight +Z be pointed exactly opposite to the sun (inertial pointing), and the –Z face be illuminated at 90° angle. The observed point is preferably at a low SZA angle (<30°). This point is observed with SPICAV in order to intercalibrate the photometry of the two channels sensitive to the two polarization components of back-scattered light. Duration is 5 to 10 minutes, to be made twice per year..

- Measurement of Dark Charge of the SPICAV UV CCD. This is to monitor the DCNU (Dark Charge Non-Uniformity) of the CCD detector, which is changing with time because of high energy particles. Those coming from the Sun are increasing in flux with the climb of the solar cycle. They may be performed anywhere in the orbit. Approximately 4 times per MTP (this is because of the many ways the CCD may be read, each mode requiring a dedicated measurement). At least one in Z mode (internal parameter of SPICAV) may be done.

3.1.5.6 VeRA

The VeRa experiment will perform four kinds of *“environment dependent”* observations.

(1) Earth occultation with *as good as possible* latitude and local time coverage of Venus. The 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. These observations are abandoned since autumn 2007 due to power loss in the S-band.

(4). Gravity anomaly. This investigation consists of precise tracking of the spacecraft while it passes over global geological formations on the Venus solid body. These observations are abandoned since the end of the nominal mission due to a judgment that the added scientific value with respect to previous observations was very small.

The VeRa experiment is mainly performed using the ESA New Norcia station. Support from the DSN antennae for the VeRa experiments as well as for the data downlink is agreed between ESA and NASA. A list of requested New Norcia and DSN passes for VeRa experiments is included as Annex 4, and the latitude and solar zenith angle coverage are shown in Annex 5.

3.1.5.7 VIRTIS

The 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 VIRTIS-M-IR channel is no longer operational after a failure of the cooler in late 2007. The VIRTIS-H-cooler failed in June 2011 and will no longer be scheduled for future operations.

Specific observation types are:

- Case 1 VIRTIS-M-VIS N hemisphere nightside – 18 sec exposure time
  - Goal is to map thermal emission from surface at ~1.0 µm.
  - To be performed when data volume allows; VEx does not need to be in eclipse.
- Case 1 dayside phase function coverage.
  - The goal is to achieve coverage of the dayside at a range of latitudes, local solar times, incident and emergent angles, and phase angles. In particular, few observations at low phase angles (<45°) have been obtained to date.
  - Could be performed using spot pointing or inertial modes (TBD).
- Case 2 – hi-res images of cloud morphology
  - The goal is to obtain images at the highest possible spatial resolution. VMC has found many instances of gravity waves at high latitudes; VIRTIS could complement this by high resolution at low latitudes.
  - Will be performed at 1-2 hr from pericentre. Although push-broom imaging is possible, acquiring images using the scan mirror while VEx is in spot-tracking mode enables high-resolution images with consistent pixel aspect ratio. Spatial resolution will be < 5 km.
  - focus at first on low latitudes (e.g. 0, ±10°, ±20°, ±30°), during one dayside ‘season’ (four MTPs), at Local Solar Time = 7h, 9h, 11h, 13h, 15h, 17h (TBC).
- Case 2 – cloud tracking

    - The science goal is to enable cloud tracking of the upper clouds. This requires repeated images on the dayside using spot-tracking to target a specific latitude.
    - Carried out in campaigns of 3-5 consecutive orbits at each latitude
    - Double offset day + night
        - Depending on data volume
- Case 2 Nightside observations : surface thermal emission mapping
    - As for Case 1 surface observation above.
    - consecutive orbits not required
    - Typically, spot tracking is used to ensure latitude coverage.
- Case 3
    - Formally, this is a full or half mosaic acquired from near apocentre.
    - VIRTIS team suggest using this mode in 3 consecutive orbits, twice per MTP.
- Case 7- limb observation of O_2 visible airglow (nightside) with VIRTIS-M-VIS
    - Coverage in the past has been sporadic.
    - VIRTIS team now suggests campaign of every 3rd orbit during 120 days to ensure even coverage of nightside hemisphere.
    - Use limb track. Along-track or tangential limb. Slit almost perpendicular to limb.
- Case 7 Dayside limb imaging
    - The science goal is the study of vertical cloud structure, e.g. search for detached layers.
    - Observation is difficult due to stray light.
    - Strategy is yet TBD.

3.1.5.8 VMC

The default operation mode for VMC is to acquire images any time that Venus is in the field of view.

- Case 3 / 2 Dayside imaging
    - Repetition rate is set to optimise cloud tracking. This ranges from 30 minutes near apocentre to 1 minute when near pericentre.
    - If VMC has control over pointing in the period 1-2 hours before or after pericentre – when the disc of Venus is still larger than the FOV –

VMC may command re-pointings to build a mosaic to cover the whole disc of Venus. (observation type 'C2VM')

- Case 1 dayside cloud morphology imaging
  - The time interval between successive images is chosen to ensure overlap between images. The degree of overlap may be 20% to 90%, depending on available data rate.
- Case 1 phase function observations
  - 'Phase function' observations in past SAPs were conducted using a spot tracking mode. This allowed a phase function to be built up for a particular cloud. Particular focus is given to 'zero phase angle' observations: these are point tracking observations designed that the phase angle (Sun-target-VEX angle) goes through zero degrees during the course of the observation. This observation is thermally demanding since solar aspect angles of 90° on the –Z panel are incurred.
- Case 1 nightside surface observation using near IR channels
  - Performed only in eclipse, using nadir geometry
- Terminator imaging campaigns
  - Within ± 2 orbits of the terminator orbit, VMC can point towards the dayside in both the ascending and descending branches of the orbit as a cold observation (no illumination on –Z). Goals include: measurement of scattered light vs. solar zenith angle at the terminator; search for waves near terminator; "astronaut's view" P.R. movies.

For calibration, VMC requests 'flat field' observations on every orbit. These are nadir observations of the dayside, conducted near pericentre. Some geometrical calibrations are also periodically requested.

3.1.6 VEx Atmospheric Drag Experiment (VExADE)

Atmospheric drag experiments are conducted when the pericentre is lowered to its minimum levels, typically down to 160 km altitude. This observation precludes other observations for typically ±2 hours around pericentre. Campaigns are typically 12 orbits long, with additional 'pre-ADE' passes. See mission overview poster for details.

Atmospheric density may be measured both using 'classic' spacecraft radio science to determine the mean drag for each pass but also using torque experiments. In these the solar panels are set in asymmetric positions to induce a torque on the spacecraft, which is measured using the reaction wheels.

For 2013, a reduced number of ADE passes will be undertaken due to workload considerations at VMOC. The agreed ADE seasons are as follows:

ADE season #11 (April 2013): No drag activities, due to superior conjunction

ADE season #12 (July-August 2013): pericentre altitude 170 km

- radio tracking and torque measurements

ADE season #11 (November 2013): Torque only, pericentre altitude 190 km.

3.1.7 Special campaigns

At the June 2012 VEx Science Working Team meeting (held in Longyearbyen, Norway), the Science Working Team agreed to put particular focus, during limited periods, on specific observation campaigns, in order to obtain high-intensity (high temporal and spatial resolution) datasets for particular scientific investigations. Some of the specific campaigns proposed under SAP Ext 4 Pt 1 are listed here.

3.1.7.1 Surface observation campaign

In eclipse season #23 (MTPs 88-89, Jan-Feb 2013), a campaign on surface observation will take place. This campaign will take place on 50% of orbits, to avoid changes to the ground station bookins for VeRa experiments which were made before the development of this SAP.

Surface targets have been chosen principally from [AD15] and [AD16]. Targets include:

- Maxwell Montes and the surrounding highlands of Ishtar Terra. Maxwell Montes is the highest feature on Venus which gives it intrinsic interest;

Surface observations of its flanks will also help to constrain gas continuum opacity in radiative transfer models.

- Bereghinia Planitia (28°E, 39°N), was the area identified as a possible cooling lava flow by Bondarenko et al (GRL, 2009) – this should be observed using SPICAV-IR nadir and VMC.
- VEx will overfly, during this campaign, various topographic rises which are interpreted as indicating upwelling mantle plumes below and are thus candidates for looking for active vulcanism. These rises include Western Eistla Regio and its volcanoes Gula Mons and Sif Mons; and, visible towards the end of MTP 89 with a slight eastwards slew, the Bell Regio highlands , where targets include Tepev Mons (29.6°N, 44.5°E) and Nyx Mons (30°N, 50°E)
- Dzalarhons Mons and Oshun Farra volcanoes, exhibit steep slopes indicative of unusually viscous lava, should also be imaged in this MTP [AD15]. Finally, an un-named tessera region at (4°S – 4°N, 36° – 46°E) was identified as possibly having non- basaltic composition, so its IR emissivity is of interest [AD15].
- Finally, an un-named tessera region at (4°S – 4°N, 36° – 46°E) was identified as possibly having non- basaltic composition, so its IR emissivity is of interest [AD15].

3.1.7.2 SPICAV Nitric Oxide (NO) nightglow mapping campaign

SPICAV has been mapping NO nightglow for several years, using a near-nadir inertial pointing; but its spatial distribution is still unclear. In particular, it is not confirmed whether the maximum emission is shifted from the antisolar point. In this campaign (MTPs 91-94), SPICAV NO observations are given priority on every second orbit in order to build up a map of NO emission on the nightside of Venus with good resolution.

3.1.7.3 SO2 campaign

The purpose of this campaign is to gain measurements of SO2 with high temporal and spatial resolution, using as many techniques as possible. The primary approach will be to perform daytime nadir observations on **consecutive or alternate orbits** during an entire dayside pass. On the nightside, SOIR measurements focusing on SO2 will be given a priority and should be undertaken on **consecutive orbits**.

This campaign is proposed for orbits MTPs 95-98 (broadly, August-October 2013).

- It is proposed that dayside nadir observations start immediately after the end of the radio occultation period, i.e. after 28 July.
- During orbits 2688-2706 (30-Aug-2013 – 17-Sep-2013), SOIR sounds the terminator visible from Earth while Venus is at maximum elongation from the Sun, which is ideal for co-ordination with ground-based observers.
- During orbits 2721-2759 (2 Oct – 9 Nov 2013), VEx will be in quadrature illumination, which means that there is a +10 deg illumination on the +Y panel during Earth-point. Due to thermal constraints, this means that no 'hot' observations are allowed during this period unless a communications pass is skipped. Dayside nadir observations and SOIR observations are both classed as 'hot' observations. In this quadrature period, the SAP proposes that every other communications pass is skipped in order to continue the SO2 measurement in alternate orbits with nadir measurements, and solar occultation measurements until the end of the eclipse season on the 6 Oct.
- The continuation of SO2 measurements on alternate orbits during quadrature (2 Oct – 9 Nov) is particularly important for co-ordination with ground-based measurements, because the nadir dayside observations will be probing the afternoon quadrant of Venus which is visible from Earth.
- Coordinated observations from Earth may include
  - IRTF/TEXES observations at 7.35 µm, which probe cloud-top SO_2 on dayside and nightside.
  - JCMT observations at 346.65 GHz, which probe cloud-top SO_2 on dayside and nightside.

In summary:

- 28 July – 28 August – dayside nadir measurements on alternate or consecutive orbits.

- 28 August – 2 October – dayside nadir, and SOIR, measurements on **all orbits**.
- 2 - 7 October - dayside nadir, and SOIR, measurements on **alternate orbits** (skipping alternate communications passes to allow these hot observations).
- 7 Oct – 7 Nov – dayside nadir on **alternate orbits** (skipping alternate communications passes to allow these hot observations).

3.1.7.4 Polar dynamics campaign

There will be a very long radio occultation season (VeRa season #16) lasting from October 2013 until Mar 2014. During a long period from orbits 2775-2860, the VeRa egress sounded location will be at high latitudes in the Southern hemisphere, on the dayside, as shown in the figure below.

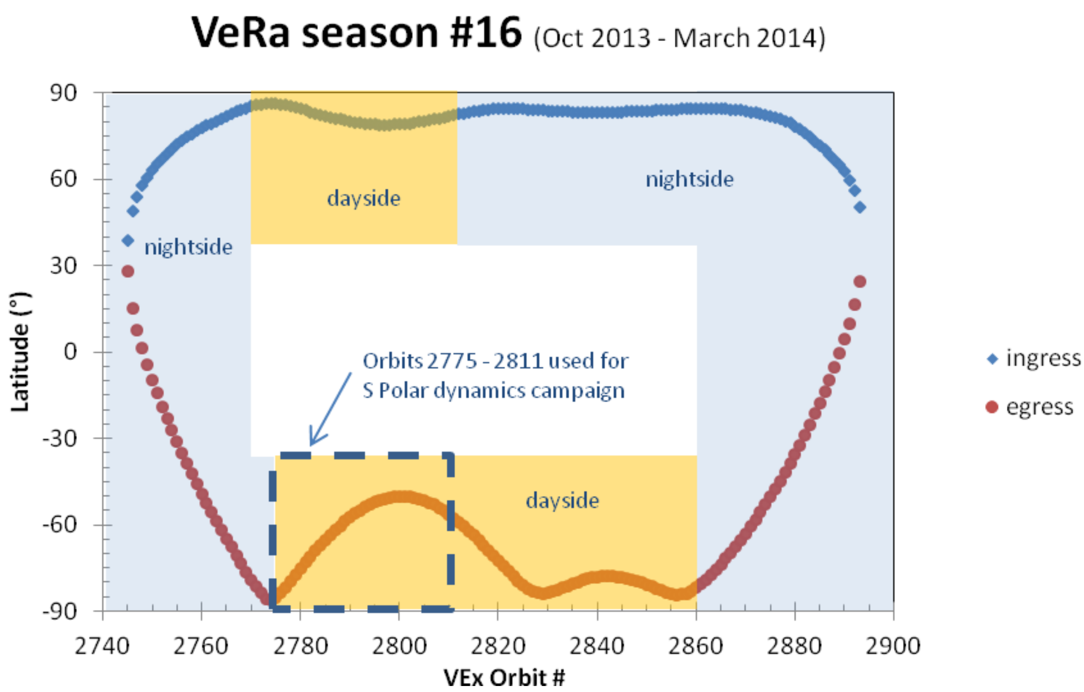

Figure above shows the occultation ***opportunities*** *in VeRa season #16. See Annex 4-5 for detailed information.*

This offers an opportunity, unique in the mission to date, to repeatedly probe high Southern latitudes; in the period where the sounded location is on the dayside, which means that co-located context imagery and cloud-tracked wind calculation can be performed.

However, at the time of writing (September 2012) it is understood that the New Norcia ground station (NNO) which is used for VeRa soundings will be fully booked from 1 Jan 2014 (VEx orbit 2012) due to Rosetta post-hibernation activities. Therefore the SAP baseline includes a VeRa egress sounding on every orbit from orbits 2775 – 2811 (25/11/2013 to 31/12/2013). Before and after the sounding, VMC and VIRTIS-M-VIS instruments will be used to obtain images at high southern latitudes for context of the VeRa soundings and for cloud-tracking. VMC flat-field images should therefore be obtained at pericentre. Otherwise, the nightside portion of the orbit and the pericentre are not used by this campaign so are left free for other observations.

3.1.7.5 Solar Occultation Mesospheric sounding campaign

The science goal is to probe, with high latitude and temporal resolution, vertical profiles of density, temperature, abundances and particulates. Solar occultations will be performed on every orbit during an eclipse season. This is scheduled to occur in Eclipse season #26 (Dec 2012 – Feb 2013), i.e. in the same period as the polar dynamics campaign discussed above. As noted above in section 3.1.5.5, SOIR will perform ingress + egress occultations at the beginning and end of the eclipse season, but ingress-only or egress-only occultations in the middle of the season. This leaves the pericentres of some orbits available for other observations (including radio occultation).

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3.2 MTP #88

3.2.1 MTP in brief

MTP #88 covers the period from 5 Jan until 2 Feb, 2013 and orbits #2452-2479.

Earth occultation season #14 continues throughout the whole MTP. This MTP includes the start of eclipse season #23 in orbit 2464 (18 Jan 2013). Eclipse and Earth occultations both occur after pericentre, so VeRa and SOIR observations are in conflict. Illumination conditions are similar to those in MTP #72 and #80. The MTP is hot. The data rate is very low. Local time at ascending node changes from 08:30h to 11:30h. Pericentre altitude is shown in Annex #2. Figures 3.7 and 3.8 show observations timeline and planet coverage by orbital tracks.

A focus on surface observation is proposed in this eclipse season once the eclipse duration is >25 minutes (starting in orbit 2468); surface observations should take place in at least 50% of orbits. Where possible, this is to be combined with a SOIR and/or VeRa occultation observations. Surface targets include Gula Mons (21.9°N, 359°E) and Sif Mons (22°N, 352°E) in the Western Eistla Regio highland, suspected to be a volcanic ‘hotspot’, i.e. a surface manifestation of a mantle upwelling (Smrekar et al. chapter in ‘Venus II’, 1997); and Carmentia Farra (12.4°N, 8°E), which is a steep-sided volcanic dome formed with unusually high-viscosity lava – this last target is from the VMC surface targets list [AD15].

3.2.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 08:45 - 11:45h (similar to MTP#80)
- Eclipse season #23 starts in orbit 2464
- Earth occultation season #14 continues throughout this MTP.
- Surface targets:
  - Maxwell Montes (65°N, 5°E)
  - Gula Mons (21.9°N, 359°E)
  - Sif Mons (22°N, 352°E)
  - Carmentia Farra (12.4°N, 8°E).
- Hot period
- Downlink is very low

3.2.3 Proposed Observations

- Near-Pericentre dayside observations should alternate between nadir observations (good for spectroscopy) and spot tracking (good for phase function observations). Dayside limb observations are included roughly once per week.

- After the start of the eclipse season, near-pericentre nightside observations should include nadir surface observations in every orbit where possible. These nadir observations can be undertaken on the same orbit as occultations (SOIR and VeRa) where thermally allowed.

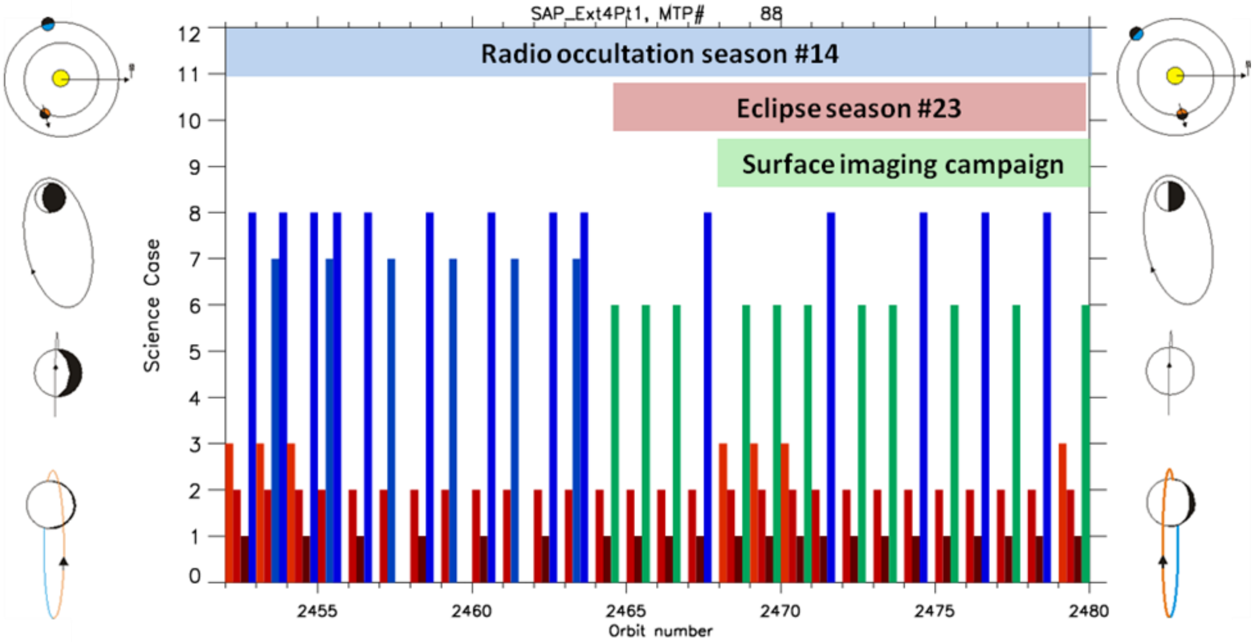


Figure 3.7 *MTP#88 timeline.*

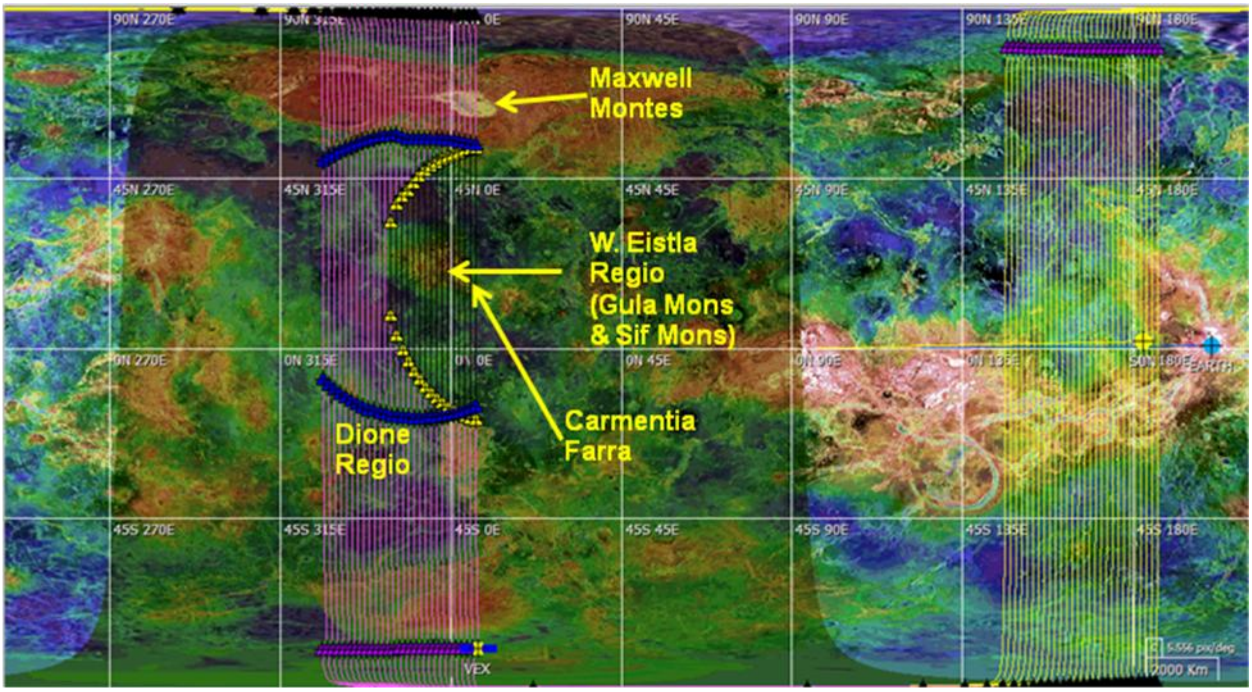


Figure 3.8 *Planet coverage by orbital tracks in MTP#88. Position of terminator, Earth and Sun correspond to the last orbit of MTP.*

3.3 MTP #89

3.3.1 MTP in brief

MTP #89 covers the period from 2 Feb until 2 March, 2013, and includes orbits #2480-2507. The Radio Occultation season #14 ends in orbit 2493, and eclipse season #23 ends in orbit 2500. The MTP is hot and has low data rate. Local time at ascending node changes from 11:45 to 14:45, thus illumination conditions are similar to those in MTP#81

The focus on surface mapping started in last MTP should continue in this MTP: Observations of the surface in eclipse should continue in at least 50% of orbits until the eclipse duration drops below 25 minutes (orbit 2493). Surface targets include Ishtar Terra at high Northern latitudes, particularly at the beginning of the MTP. Around orbit 2495, VEx will, in eclipse. fly over Bereghinia Planitia (28°E, 39°N), which was the area identified as a possible cooling lava flow by Bondarenko et al (GRL, 2009) – this should be observe using SPICAV-IR nadir and VMC. Also, towards the end of the MTP VEx will be able to image, with a slight eastwards slew, the Bell Regio highlands , which have been identified as 'hotspots', i.e. a surface manifestation of a mantle upwelling (Smrekar et al. chapter in 'Venus II', 1997). Particular targets to image, which have been identified as potentially active volcanic vents are Tepev Mons (29.6°N, 44.5°E) and Nyx Mons (30°N, 50°E). Dzalarhons Mons and Oshun Farra volcanoes, which exhibit steep slopes indicative of unusually viscous lava, should also be imaged in this MTP [AD15]. Finally, an un-named tessera region at (4°S – 4°N, 36° – 46°E) was identified as possibly having non-basaltic composition, so its IR emissivity is of interest [AD15].

Figures 3.9 and 3.10 show observations timeline and surface coverage in MTP#89.

3.3.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 11:45 - 14:45 h (similar to MTP#81)
- Hot season
- Eclipse season #23 ends in orbit 2500.
- Earth occultation season #14 ends in orbit 2493.
- Quadrature throughout entire MTP (10° illumination on +Y panel during communications pass). No hot observations allowed during quadrature, unless CEB passes are skipped for cooling.
- Surface targets:
    - Ishtar Terra, (55° - 75°N, 310° - 60°E)
    - Bell Regio (e.g. Tepev Mons), (27° - 37°N, 44° - 52°E)
    - E. Eistla Regio (10° - 20°N, 36° - 52°E)
    - Bereghinia Planitia (28°E, 39°N),
    - Oshun Farra (4.2°N, 9.3°N)
    - Dzalarhons Mons (0.5°N, 34°E)
    - Un-named Tessera (4°S – 4°N, 36° – 46°E).
- Very low data rate
- Note there is an OCM (orbit control manoeuvre) at pericentre in orbit 2501 (24 Feb 2013), this precludes observations from VPER – 01h30 to VPER + 01h30.

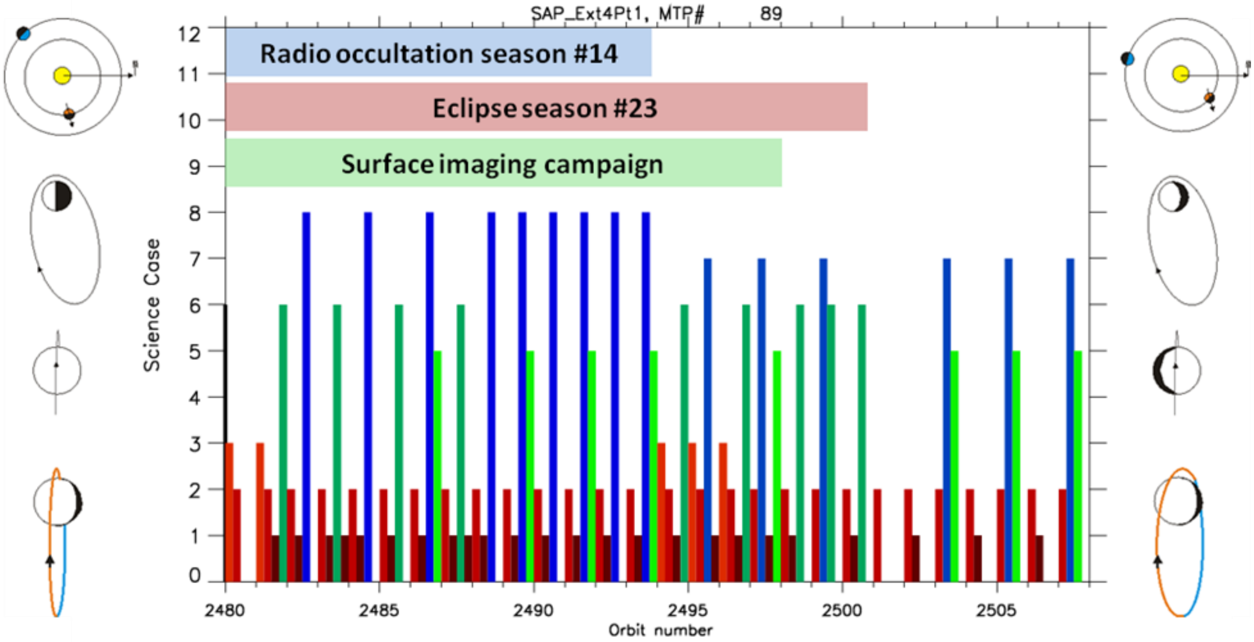


Figure 3.09 *MTP#89 timeline*

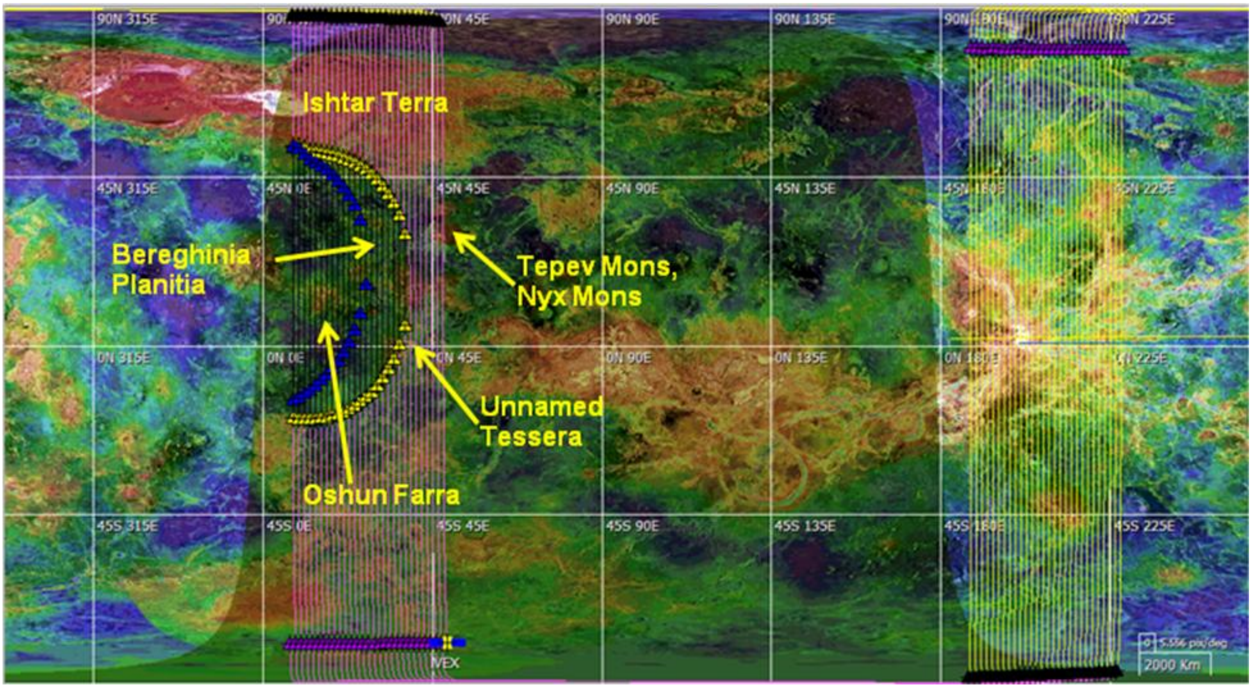


Figure 3.10 *Planet coverage by orbital tracks in MTP#89. Position of terminator, Earth and Sun correspond to the last orbit of MTP.*

3.3.3 Proposed Observations

- Near-Pericentre dayside observations should alternate between nadir observations (good for spectroscopy) and spot tracking (good for phase function observations). Dayside limb observations are included roughly once per week.
- Near-pericentre nightside observations should include nadir surface observations in every orbit where possible. These nadir observations can be undertaken on the same orbit as occultations (SOIR and VeRa) where thermally allowed.

3.4 MTP #90

3.4.1 MTP in brief

MTP #90 covers the period from 2 March until 30 March 2013, and includes orbits #2508 - 2535. There are no eclipse, occultation, or drag activities in this MTP. This MTP therefore offers an opportunity to catch up on observation types including stellar occultations and limb tracks, as well as VMC wind tracking in morning and evening sectors of the planet. Data rate is very low, as VEx approaches superior conjunction on 28 March 2013. There will be a communication outage for 20 days starting on orbit 2522 (17 March 2013).

The MTP is hot and has very low data rate.

Local time at ascending node changes from 14:45 to 17:45

Figures 3.11 and 3.12 show observations timeline and surface coverage for this MTP.

3.4.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 14:45 to 17:45 h (similar to MTP#62)
- Hot season
- No eclipse, no occultation season
- Very low data rate – VEx reaches superior conjunction in orbit 2532.

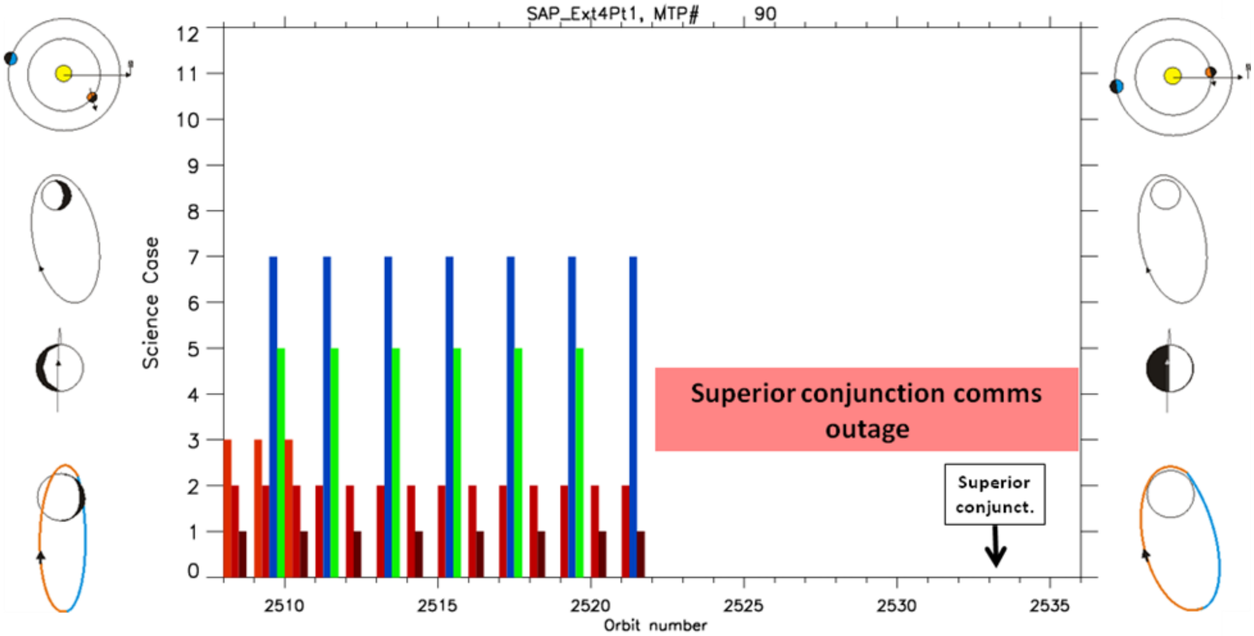


Figure 3.11 *MTP#90 timeline*

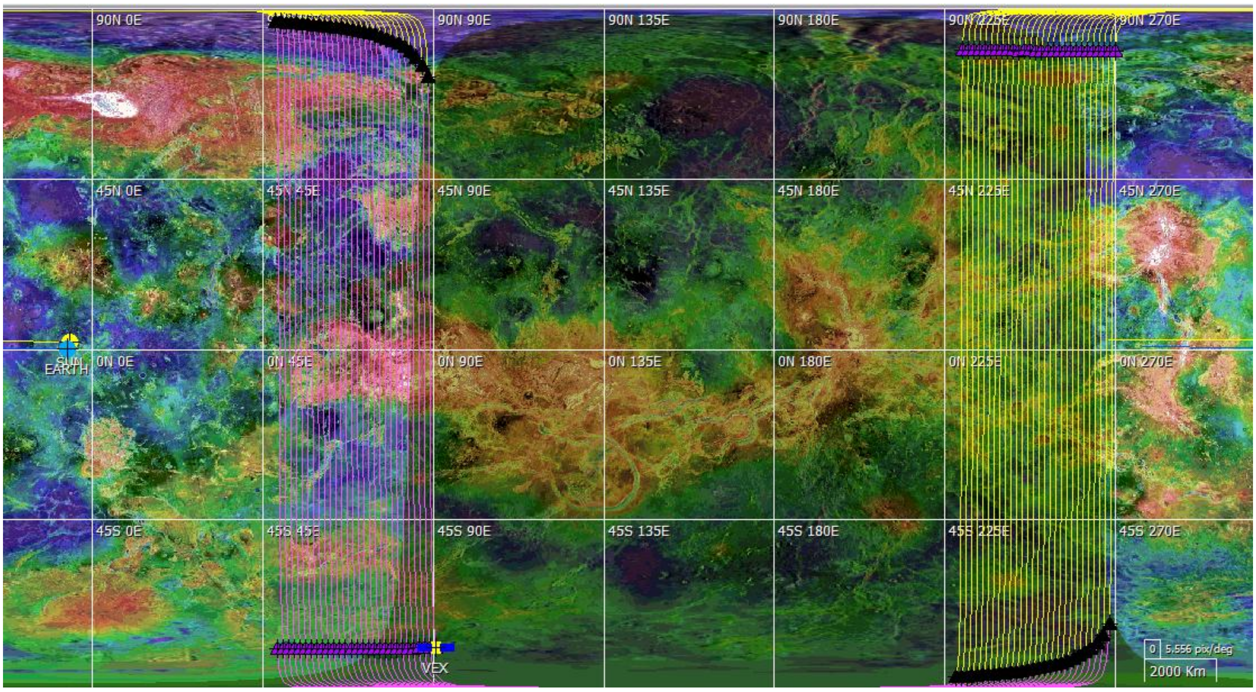


Figure 3.12 *Planet coverage by orbital tracks in MTP#90. Position of terminator, Earth and Sun correspond to the last orbit of MTP.*

3.4.3 Proposed Observations

- Near-Pericentre dayside observations should alternate between nadir observations (good for spectroscopy) and dayside limb observations.
- Near-pericentre nightside observations should include limb observations and stellar occultations.

3.5 MTP #91

3.5.1 MTP in brief

MTP #91 covers the period from 30 March 2013 until 27 April 2013, and includes orbits #2536 - 2563. MTP 91 sees VEx emerge from the communication outage at superior conjunction in orbit 2544. There are no further eclipse or occultation observations during the MTP.

The MTP starts with near-terminator orbits, but there are no drag measurements being conducted due to superior conjunction. This is therefore an opportunity for SPICAV stellar occultations to probe the variation of the nightside mesospheric density as a function of distance from the terminator. This would involve, starting in orbit 2543, a series of stellar occultations using the same star in consecutive orbits (if a suitable star can be found). Following this stellar occultation campaign, nightside observations can be devoted to the NO observation campaign proposed for MTPs 91-94 – 50% of orbits should be assigned to this campaign.

Priority on the dayside should be given to VMC cloud-tracking observations in this MTP.

Figures 3.13 and 3.14 show observations timeline and surface coverage for this MTP.

3.5.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 17:45 to 20:45 h (similar to MTP#83)
- Cold season

- No eclipse or earth occultation in this MTP.
- Very low data rate – VEx is immediately after superior conjunction.
- Note there is an OCM (orbit control manoeuvre) at pericentre in orbit 2557 (21 Apr 2013), this precludes observations from VPER – 01h30 to VPER + 01h30.

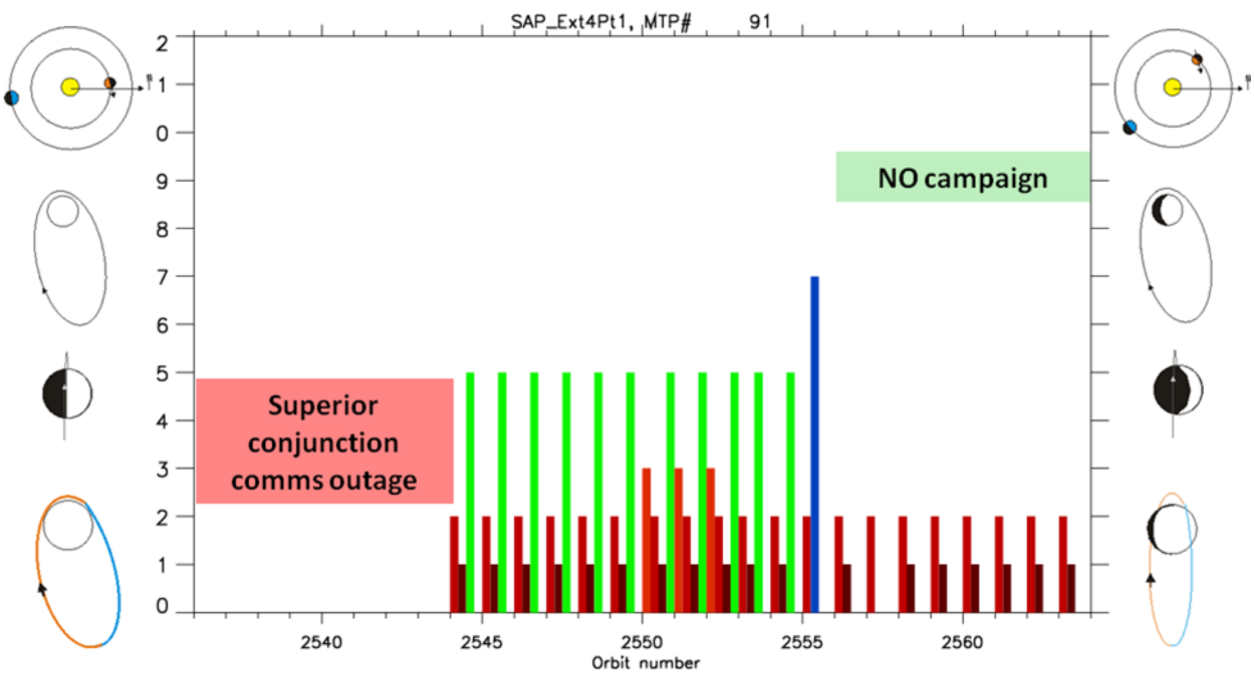


Figure 3.13 *MTP#91 timeline*

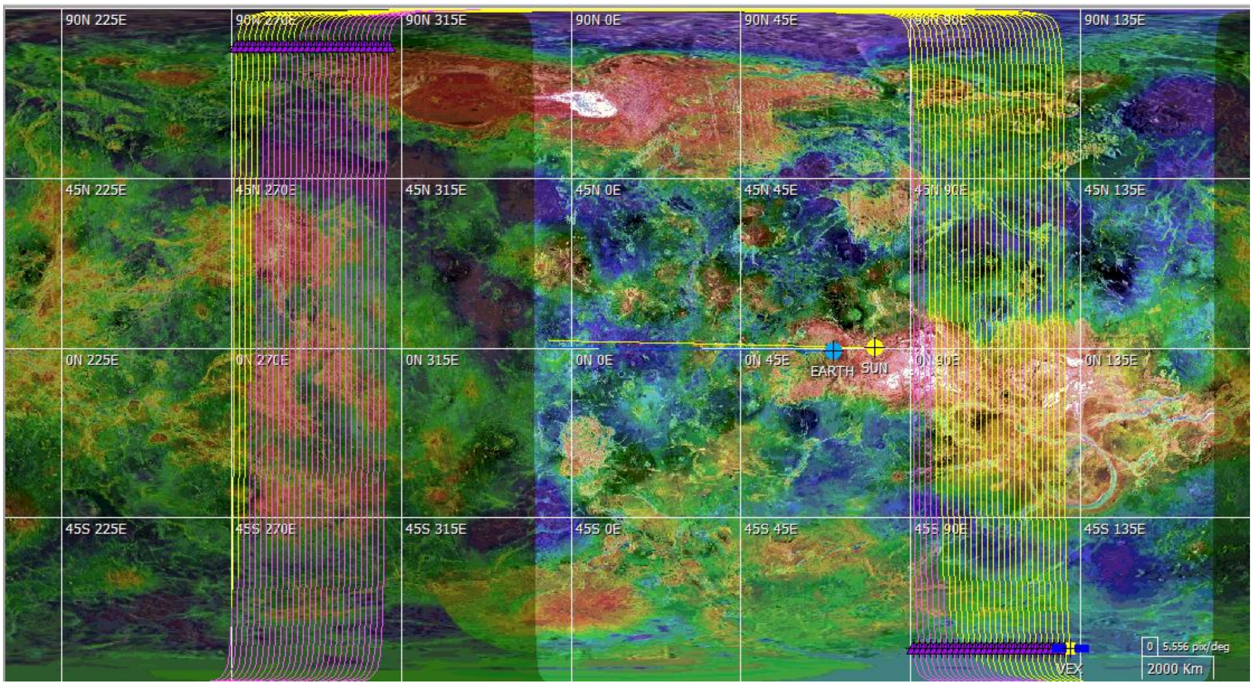


Figure 3.14 *Planet coverage by orbital tracks in MTP#91. Position of terminator, Earth and Sun correspond to the last orbit of MTP.*

3.5.3 Proposed Observations

- Near-Pericentre dayside observations should alternate between nadir observations (good for spectroscopy) and dayside limb observations.
- Near-pericentre nightside observations should include stellar occultations (to probe density variations as function of distance from terminator) in the first week of operations, and thereafter should have SPICAV NO observations in at least 50% of orbits.

3.6 MTP #92

3.6.1 MTP in brief

MTP #92 covers the period from 27 April 2013 until 25 May 2013, and includes orbits #2564-2591. VEx is still far from Earth, having recently passed superior conjunction, so the data rate is still very low. This MTP sees the start of eclipse season #24 in orbit 2567, and the start of earth occultation season #15 in orbit 2575.

The MTP is cold. Local time at ascending node changes from 20:45 to 23:45, thus illumination conditions are similar to those in MTP#84. Accessible surface targets in this MTP are similar to those imaged in MTP #88: Ishtar Terra, W. Eistla Regio, and Dione Regio in the S hemisphere. However, due to the focus on surface observation in the last eclipse season, it is proposed instead in this eclipse season to **focus on nightside NO observations**. NO observations in inertial or nadir mode should occur on alternate orbits throughout the eclipse season. Note that these must fit around the radio occultation schedule, which occurs on alternate orbits from orbit 2575. Solar occultations should be combined with other observations where possible.

Surface targets include Dione Regio, one of the nine hotspots identified by Smrekar et al as a candidate region for active vulcanism; and Comnena crater, which exhibits a radar-dark parabola suspected to be fine-grained and relatively unweathered ejecta from a young impact crater.

Figures 3.15 and 3.16 show observations timeline and surface coverage for this MTP.

3.6.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 20:45 – 23:45 h
- Cold season
- Eclipse season #24 starts in orbit 2567;
- Earth occultation season #15 starts in orbit 2575.
- Surface targets:
    - Dione Regio (lat 10°S to 40°S, lon 320° to 335°E), including:
        - Innini Mons (34.6°S, 328.5°E)
        - Hathor Mons (38.7°S 324.7°E)
    - Comnena crater (1.17°N, 343.72°E)
- Very low data rate

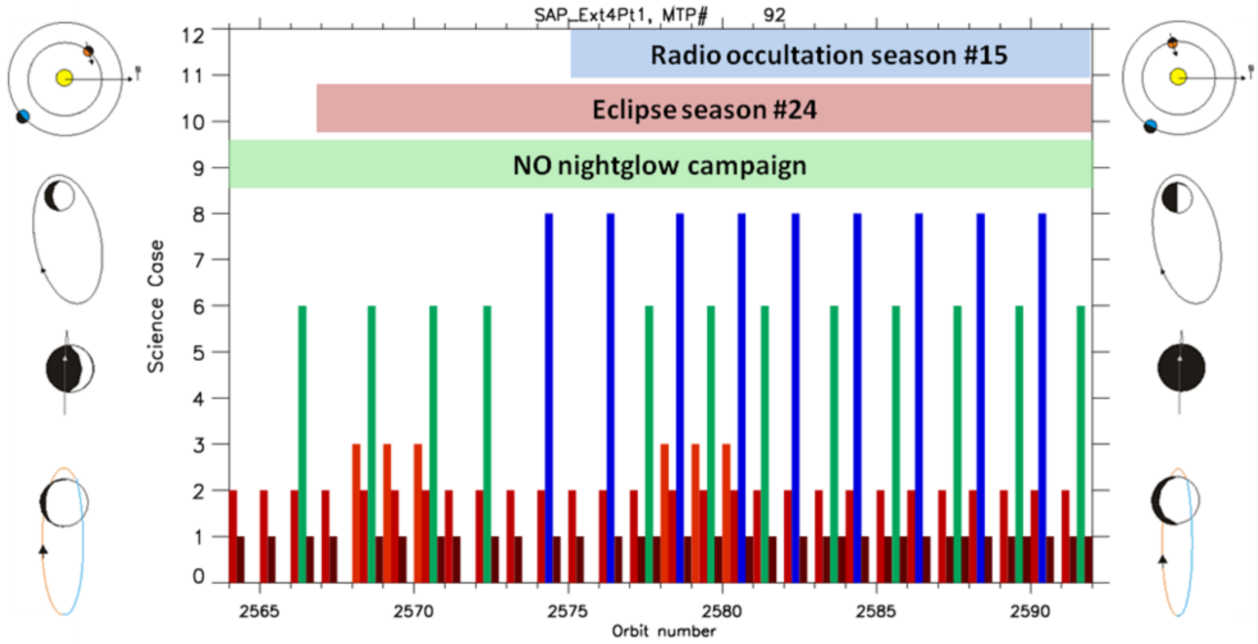


Figure 3.15 *MTP#92 timeline*

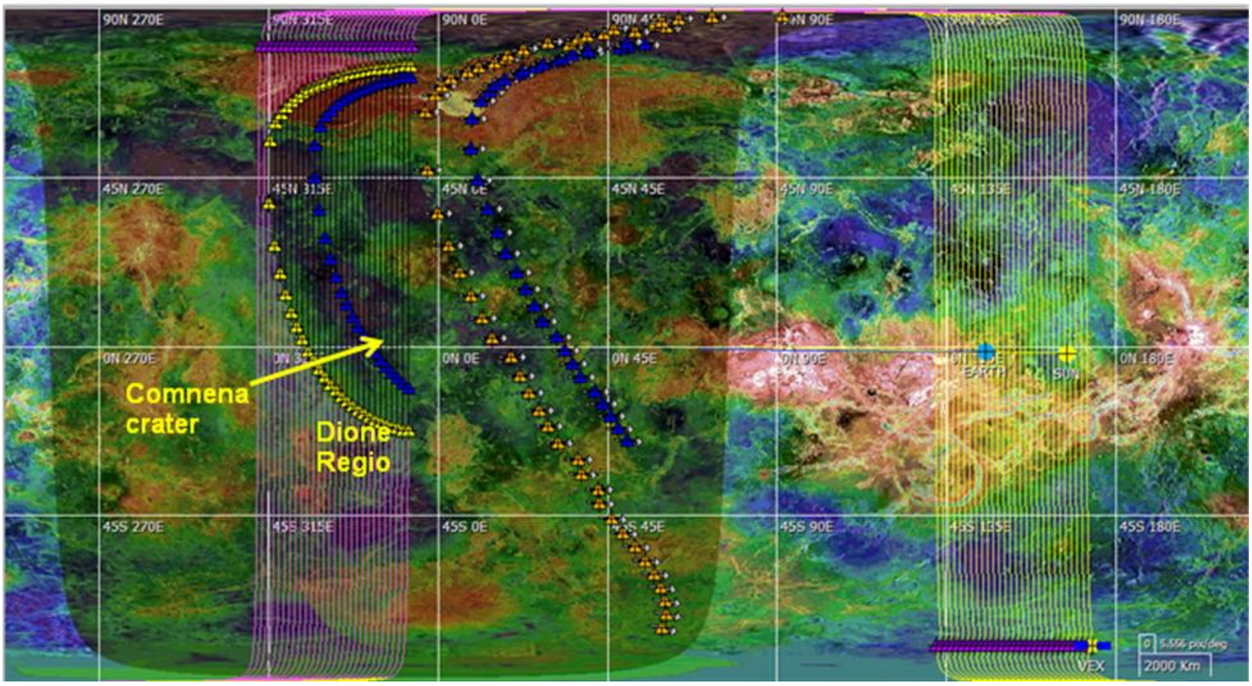


Figure 3.16 *Planet coverage by orbital tracks in MTP#92. Position of terminator, Earth and Sun correspond to the last orbit of MTP.*

3.6.3 Proposed Observations

- Near-Pericentre dayside observations should alternate between nadir observations (good for spectroscopy) and spot tracking (good for phase function observations). Dayside limb observations are included roughly once per week.
- Near-pericentre nightside observations should prioritise SPICAV inertial observations of NO (on 50% of orbits). These should be combined, where possible, with SOIR observations (whether ingress or egress).
- In the draft timeline, radio science passes are skipped in orbits 2573 and 2575 in order to ensure regular coverage for SPICAV NO mapping.

3.7 MTP #93

3.7.1 MTP in brief

MTP #93 covers the period from 25 May 2013 until 22 June 2013, and includes orbits #2592 - 2619. Earth occultation season #16 and Eclipse season #24 continues throughout the whole of this MTP. The MTP is cold. Local time at ascending node changes from 23:45h to 02:45h, thus illumination conditions are similar to those in MTP#85. Data rate is still low.

Accessible surface targets include many of those imaged in MTP#89: Maxwell Montes, Eistla Regio, and Oshun and Carmentia Farra (steep-sided volcanic features). However, it is proposed in this MTP to continue the focus on NO observations started in last MTP. VeRa and SOIR observations should also continue throughout the MTP.

Figures 3.17 and 3.18 show observations timeline and surface coverage for this MTP.

3.7.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 23:45 to 02:45 (similar to MTP#85)
- Cold season
- Earth occultation season #15 during whole MTP.
- Eclipse season #24 during whole MTP.
- Surface targets:

- Maxwell Montes (65°N, 5°E)
- Oshun Farra (4.2°N, 9.3°N)
- Carmentia Farra (12.4°N, 8°E).
- E. Eistla Regio (10° - 20°N, 36° - 52°E)
  - Gula Mons (21.9°N, 359°E)
  - Sif Mons (22°N, 352°E)
- Bereghinia Planitia (28°E, 39°N),

- Low data rate

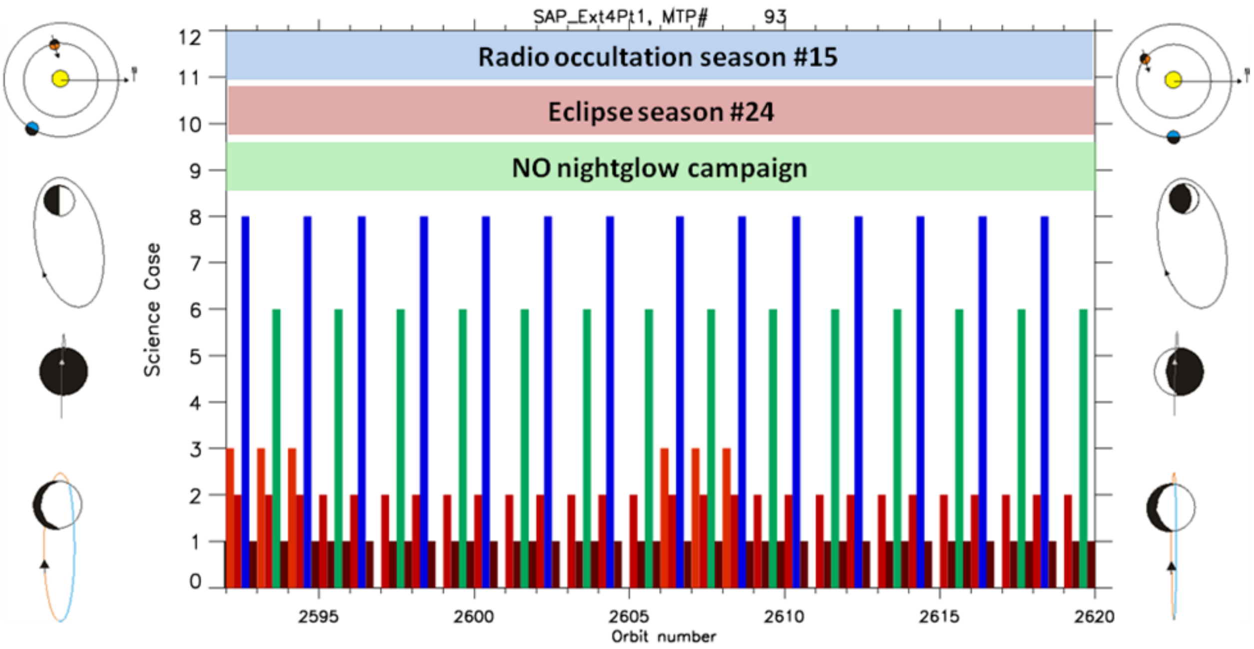


Figure 3.17 *MTP#93 timeline*

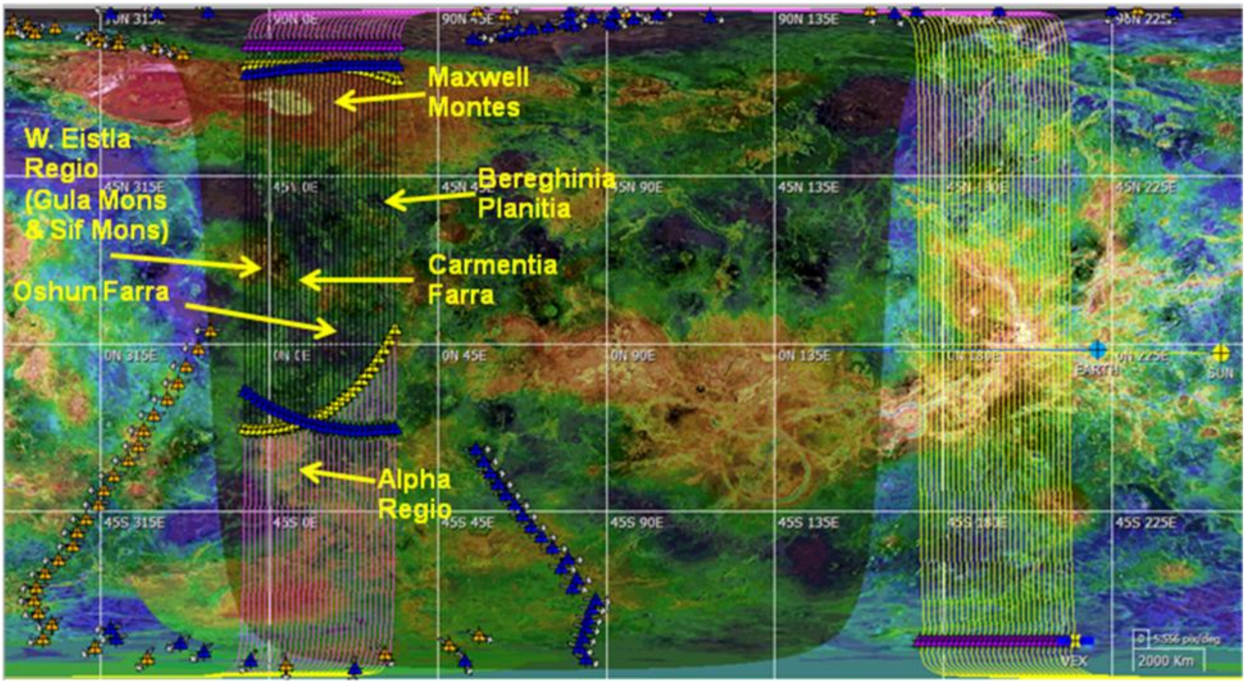


Figure 3.18 *Planet coverage by orbital tracks in MTP#93. Position of terminator, Earth and Sun correspond to the last orbit of MTP.*

3.7.3 Proposed Observations

- Near-Pericentre dayside observations should alternate between nadir observations (good for spectroscopy) and spot tracking (good for phase function observations). Dayside limb observations are included roughly once per week.
- Near-pericentre nightside observations should focus on SPICAV inertial observations of NO. These should be combined, where possible, with SOIR observations (whether ingress or egress). This applies to orbits where VeRa occultations are not scheduled.

3.8 MTP #94

3.8.1 MTP in brief

MTP #94 covers the period from 22 June 2013 until 20 July 2013, and includes orbits #2620 - 2647. Earth occultation season #15 continues throughout the whole of this MTP, and Solar occultation season #24 ends on orbit 2629. High priority will be given to drag campaign period #12: the drag passes will occur in orbits 2643 – 2654, with pre-ADE passes beforehand. The drag campaign will reach pericentre altitudes of 170 km, and will include radio tracking from New Norcia Ground station as well as torque measurements onboard.

The main science priority for this MTP continues to be the SPICAV NO mapping campaign, which should be carried out in 50% of orbits. There is some limited scope at the beginning of this MTP to observe the two surface targets listed below. After the end of the eclipse season, priority should be given to VMC cloud-tracking observations to ensure good coverage with respect to local solar time.

Data rate is still low but starting to rise again.

Figures 3.19 and 3.20 show observation timelines and surface coverage for this MTP.

3.8.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 02:45 to 05:45 h (similar to MTP#82)
- Cold season
- Earth occultation season #15 continues during whole MTP
- Eclipse season #24 ends in orbit 2629.
- Drag season #12 starts orbit 2643.
- Surface targets:
    - Dzalarhons Mons (0.5°N, 34°E)
    - Un-named Tessera (4°S – 4°N, 36° – 46°E).
- Low-medium data rate
- Note there is an OCM (orbit control manoeuvre) at pericentre in orbit 2627 (30 June 2013), this precludes observations from VPER – 01h30 to VPER + 01h30.
- Pre-ADE passes will be required staring as early as orbit 2620. Pre-ADE passes before orbit 2630 should be scheduled by skipping VeRa orbits (e.g. orbits 2622, 2630), to avoid interrupting the regularity of the NO observation campaign; after orbit 2630, SINO orbits can be skipped as needed for pre-ADE passes.

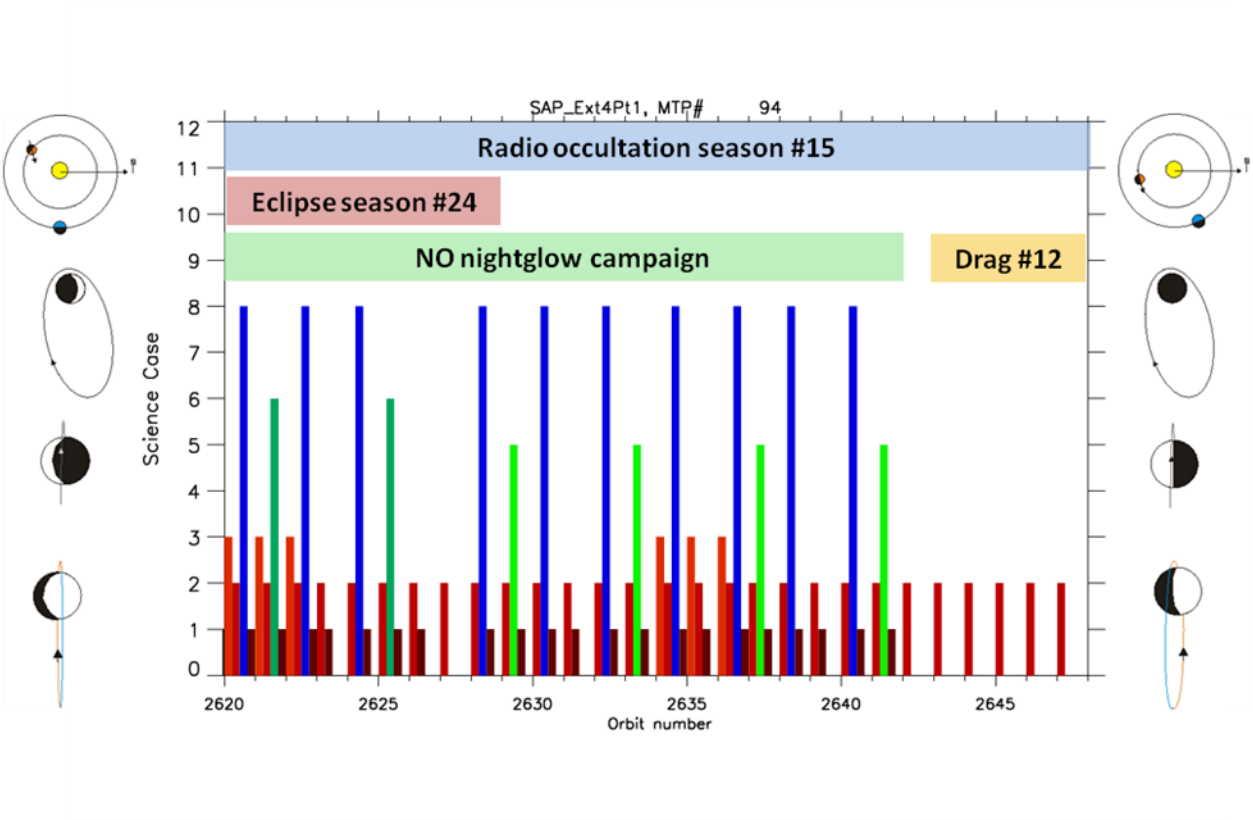


Figure 3.19 *MTP#94 timeline*

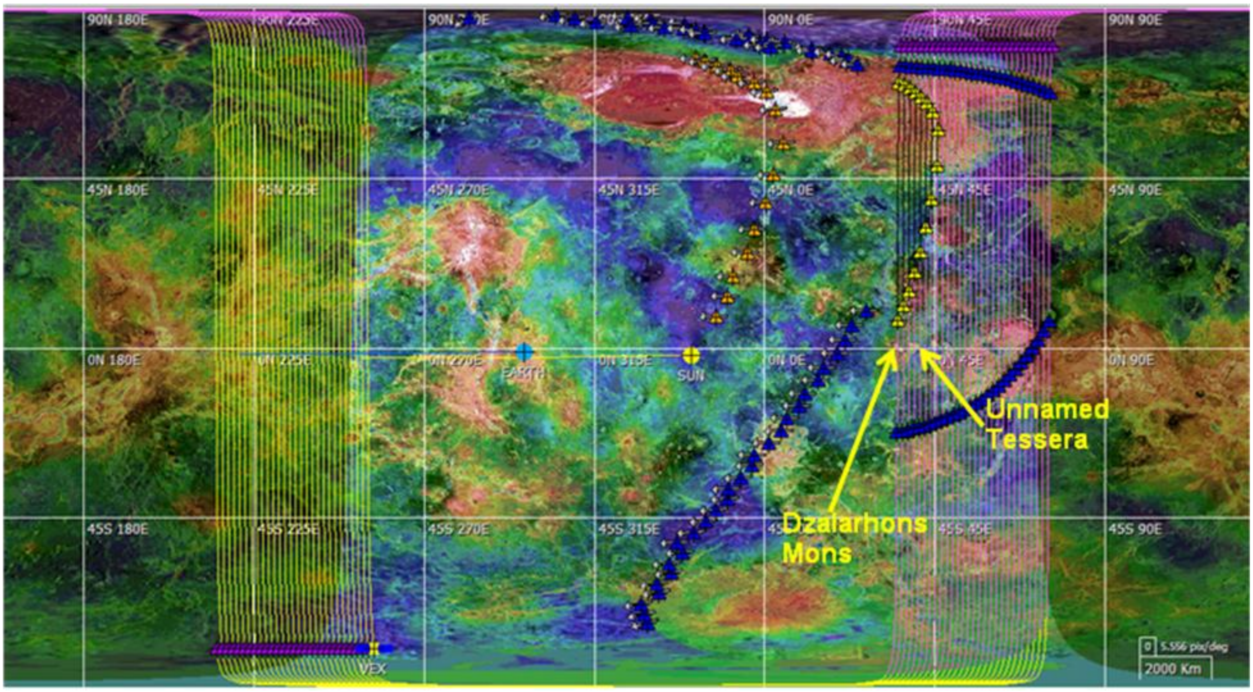


Figure 3.20 *Planet coverage by orbital tracks in MTP#94. Position of terminator, Earth and Sun correspond to the last orbit of MTP.*

3.8.3 Proposed Observations

- Near-Pericentre dayside observations should alternate between nadir observations (good for spectroscopy) and spot tracking (good for phase function observations). Dayside limb observations are included roughly once per week.
- Near-pericentre nightside observations should focus on SPICAV inertial observations of NO. These should be combined, where possible, with SOIR observations (whether ingress or egress). This applies to orbits where VeRa occultations are not scheduled.

3.9 MTP #95

3.9.1 MTP in brief

MTP #95 covers the period from 20 July 2013 until 17 August 2013, and includes orbits #2648 - 2675.

The MTP starts with drag season #12 (orbits 2643-2654), which include tracking and torque measurements with a plateau altitude of 170 km.

After the drag season, there are two orbits left before the end Earth occultation season #16 (orbit 2655-2656), so VeRa occultations should be performed on these orbits. There are no further eclipse or occultation seasons in this MTP.

Local time at ascending node changes from 05:45 to 08:45, thus the season is hot after the first few orbits. Data rate is still low-medium but is starting to rise. After the drag passes have finished, the science priority for VEx for MTPs 95-98 will be SO2 measurements. Therefore, following the drag campaign, a dayside SO2 nadir observation should be performed at least on every other orbit. These may be preceded by VMC cloud-tracking observations. SPICAV UV dayglow observations may be carried out on the orbits in which SO2 measurements are not performed.

Figures 3.21 and 3.22 show observation timelines and surface coverage for this MTP.

3.9.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 05:45 to 08:45 h (similar to MTP#87)
- Starts as Cold season; Hot season from orbit 2652.
- Earth occultation season ends in orbit 2656.
- VExADE campaign #12, orbits 2643-2654.
- Surface targets: No particular targets for this MTP.
- Low-medium data rate.
- Note there is an OCM (orbit control manoeuvre) at pericentre in orbit 2669 (11 Aug 2013), this precludes observations from VPER – 01h30 to VPER + 01h30.

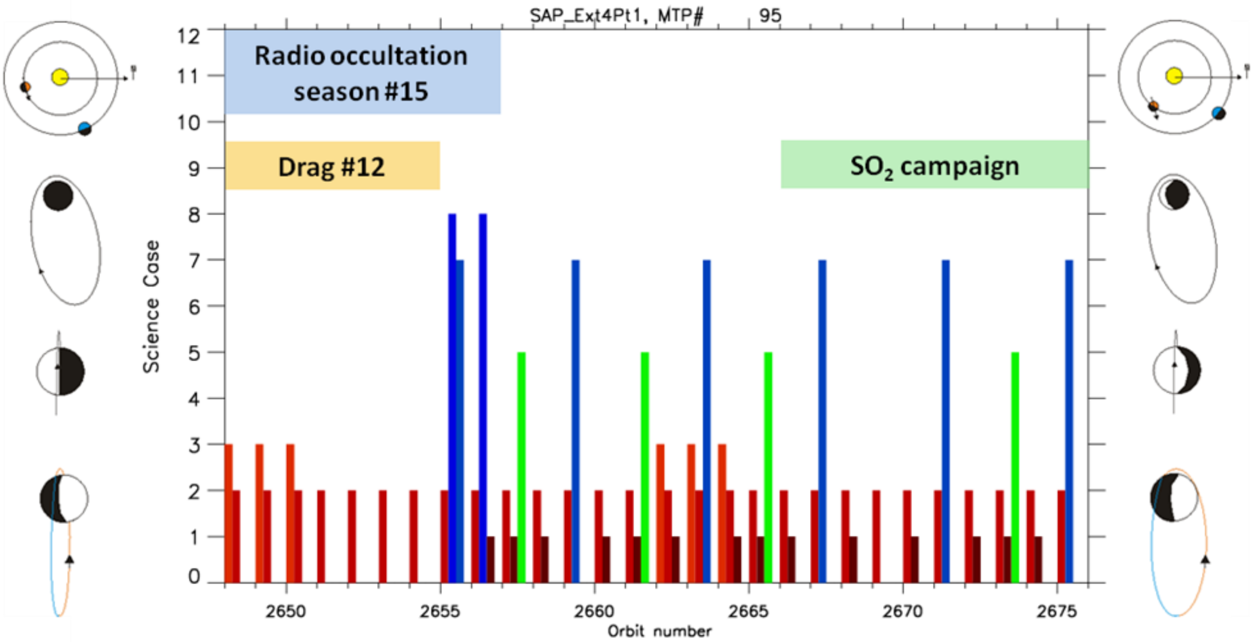


Figure 3.21 *MTP#95 timeline*

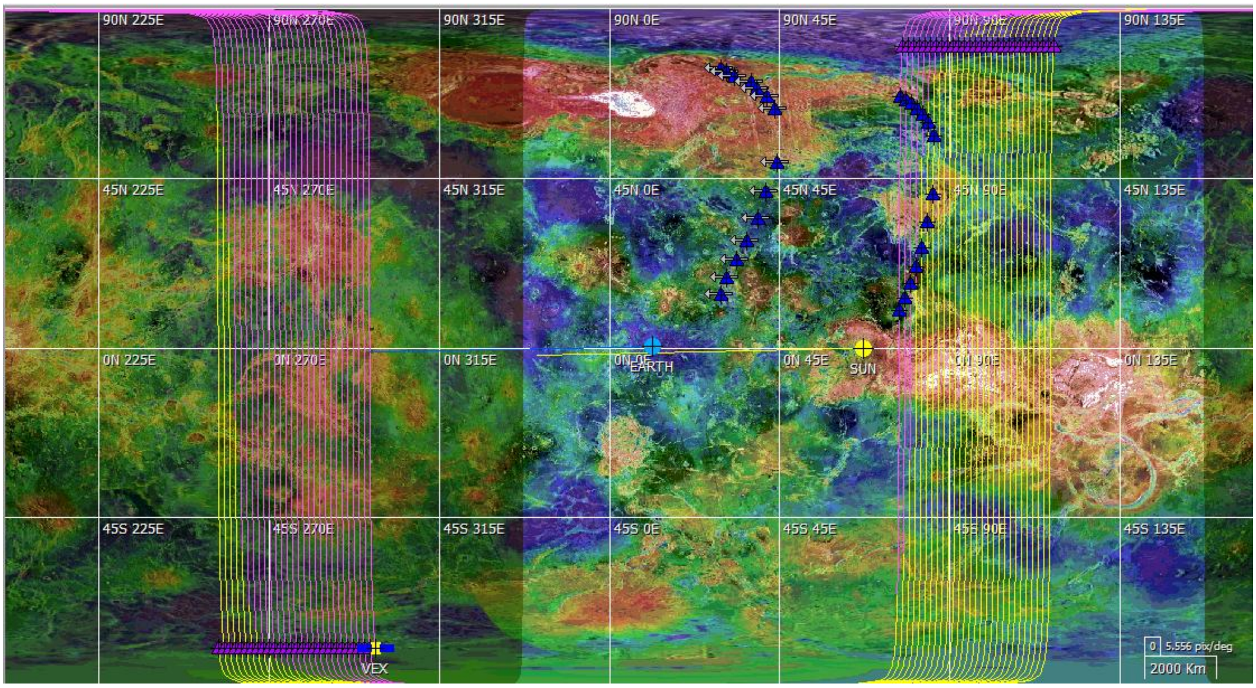


Figure 3.22 *Planet coverage by orbital tracks in MTP#95. Position of terminator, Earth and Sun correspond to the last orbit of MTP.*

3.9.3 Proposed Observations

- Near-Pericentre dayside observations should include nadir observations on at least every other orbit, as part of the SO2 campaign. Other orbits can have either spot tracking (good for phase function observations) or dayside limb observations.
- There is no particular focus for near-pericentre nightside observations in this MTP; these observations can include stellar occultations, limb tracks and cross-terminator VMC cloud tracking observations.

3.10 MTP #96

3.10.1 MTP in brief

MTP #96 covers the period from17 August 2013 until 14 September 2013, and includes orbits #2676 - 2703. Eclipse season #25 starts in orbit 2689. Local time at ascending node changes from 08:40 to 11:40, thus the season is hot. Data rate is medium and increasing, as VEx nears maximum elongation.

Priority in this MTP is given to SO_2 measurement campaign. In the first two weeks of the MTP there should be **SPICAV dayside nadir observations at least on alternate orbits**. After the beginning of eclipse season in orbit 2689, there should be dayside nadir and SOIR observations **preferably in every orbit**, or at a minimum in 3 out of every 4 orbits. SOIR observations in the period 2688-2706 are given high priority, because the terminator sounded by SOIR is visible from Earth. Due to the long duration of the eclipses, though, surface observations in eclipse may be combined with SOIR observations.

Surface targets include Dione Regio, which is identified as a rift-dominated topographic rise which is a candidate for recent vulcanism [AD16]. Inninni and Hathor Montes, in the southern latitudes of this region, were identified as having anomalously dark surface emissivities by VIRTIS-M-IR mapping so are good candidates for targeted imaging.

Figures 3.23 and 3.24 show observation timelines and surface coverage for this MTP.

3.10.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 08:40 - 11:40 h
- Hot season
- Eclipse season #25 start in orbit 2689.
- Surface targets: Dione Regio (lat 10°S to 40°S, lon 320° to 335°E):
    - e.g. Innini Mons (34.6°S, 328.5°E) & Hathor Mons (38.7°S 324.7°E)
- Medium data rate

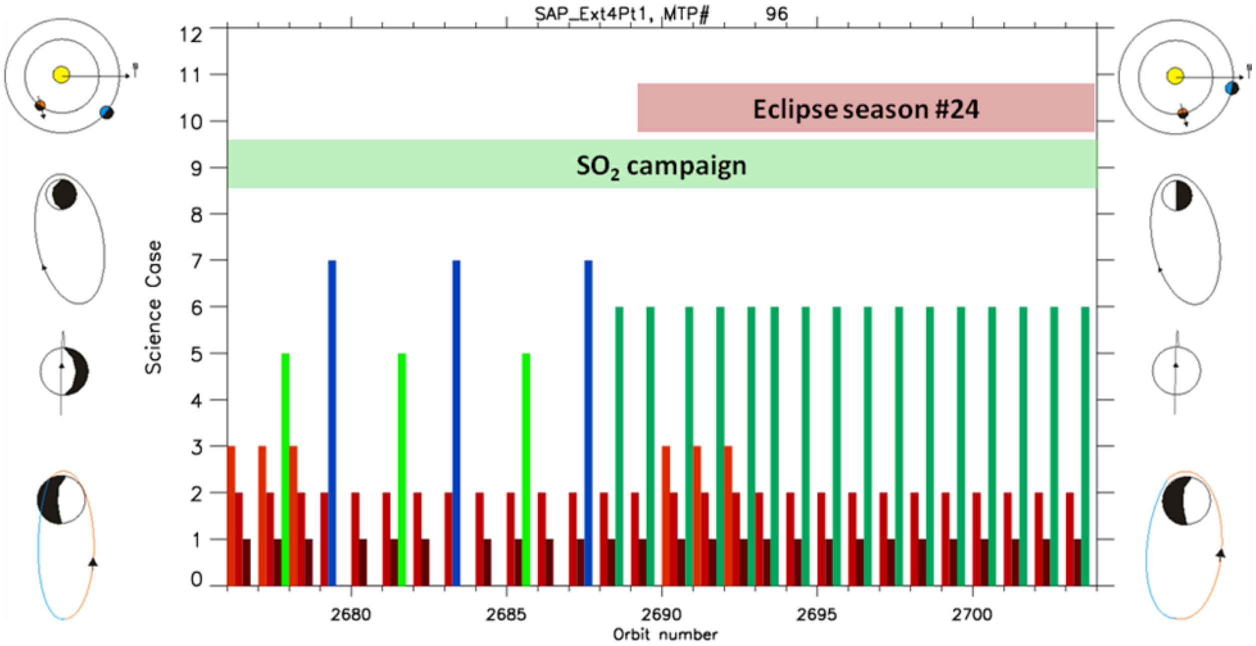


Figure 3.23 *MTP#96 timeline*

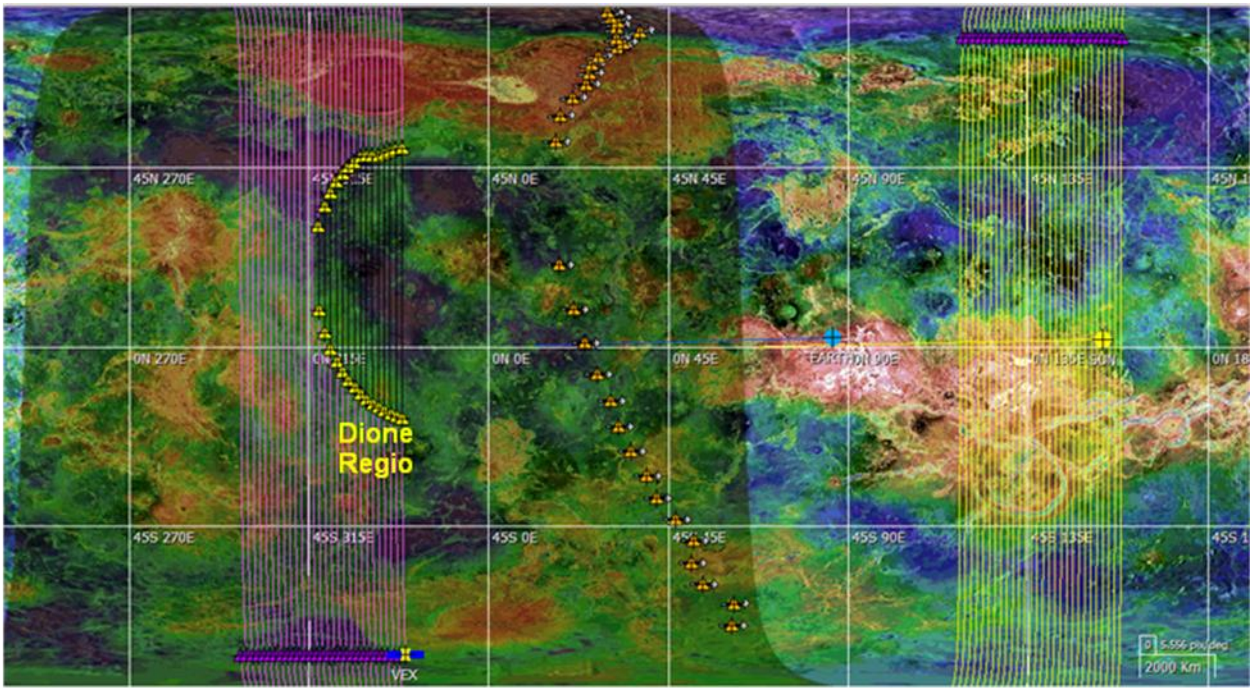


Figure 3.24 *Planet coverage by orbital tracks in MTP#96. Position of terminator, Earth and Sun correspond to the last orbit of MTP.*

3.10.3 Proposed Observations

- Dayside: Near-Pericentre dayside observations should include nadir observations as part of the SO_2 campaign. At the beginning of the MTP these are scheduled on alternate orbits, in order to leave some orbits with hot apocentres; after the beginning of the eclipse season these dayside nadir observations should occur on every orbit (or at least on >3/4 of orbits).
- Nightside: Stellar occultations and limb tracks should be performed at the beginning of the MTP, because priority is given to SOIR observations once the eclipse season starts (orbit 2689). After this time, there should be a SOIR observation on every orbit, or at least on 3 out of 4 orbits, as part of the SO2 campaign. Once the eclipse duration is long enough, nadir observations in eclipse can be combined with SOIR observations.

3.11 MTP #97

3.11.1 MTP in brief

MTP #97 covers the period from 14 Sep 2013 until 12 October 2013, and includes orbits #2704 - 2731. Eclipse season #25 ends in orbit 2724. Quadrature illumination starts towards the end of the MTP, in orbit 2721.Local time at ascending node changes from 11:40 to 14:40, thus the season is hot.

Science priority in this MTP is on SO2 observations, as in the last MTP. Until the beginning of quadrature, there should be dayside nadir observations on every orbit, as well as SOIR observations in at least 3 out of every four orbits. The terminator sounded by SOIR in orbits 2706-2725 is not the one visible from Earth, so they are not relevant for co-ordinated ground-based observations and thus have a lower priority than SOIR observations in the previous MTP. Due to the long duration of the eclipses, surface observations in eclipse may be combined with SOIR observations.

From orbit 2721, VEx will be in quadrature illumination, which means that there is a +10 deg illumination on the +Y panel during Earth-pointing. Due to thermal constraints, this means that no 'hot' observations are allowed during this period unless a communications pass is skipped. Dayside nadir observations and SOIR observations are both classed as 'hot' observations. In this quadrature period, **2 to 3 communications passes per week should be skipped in order to allow the continuation, on a 2-4 day interval, of the SO2 measurement campaign** until the beginning of the drag season on 29 Oct 2013.

The continuation of SO2 measurements in this MTP is particularly important for co-ordination with ground-based measurements, because the nadir dayside observations will be probing the afternoon quadrant of Venus which is visible from Earth.

Figures 3.25 and 3.26 show observation timelines and surface coverage for this MTP.

3.11.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 11:40 – 14:40 h (similar to MTP#76)
- Hot season.
- Eclipse season #25 until orbit 2724
- Quadrature illumination from orbit 2721.
- Surface targets:
    - Comnena crater (1.17°N, 343.72°E)
    - Gula Mons (21.9°N, 359°E)
    - Sif Mons (22°N, 352°E)
- Medium-high data rate
- Note there is an OCM (orbit control manoeuvre) at pericentre in orbit 2711 (22 Sep 2013), this precludes observations from VPER – 01h30 to VPER + 01h30.

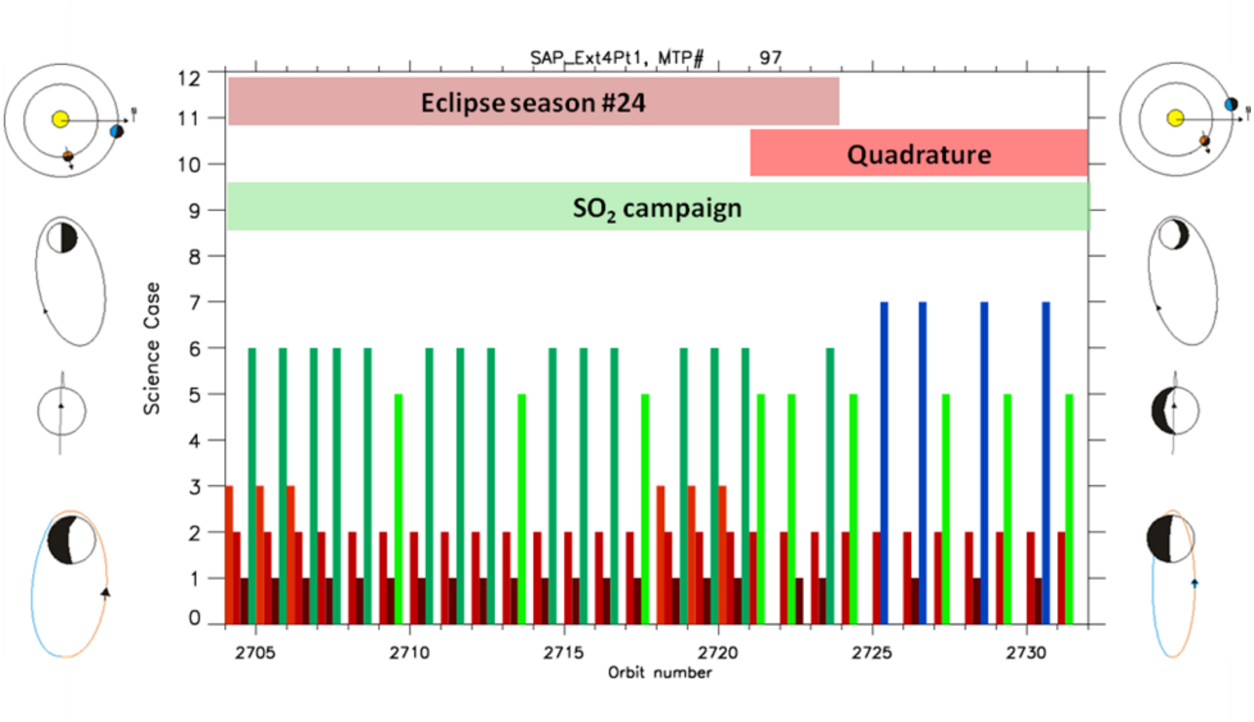
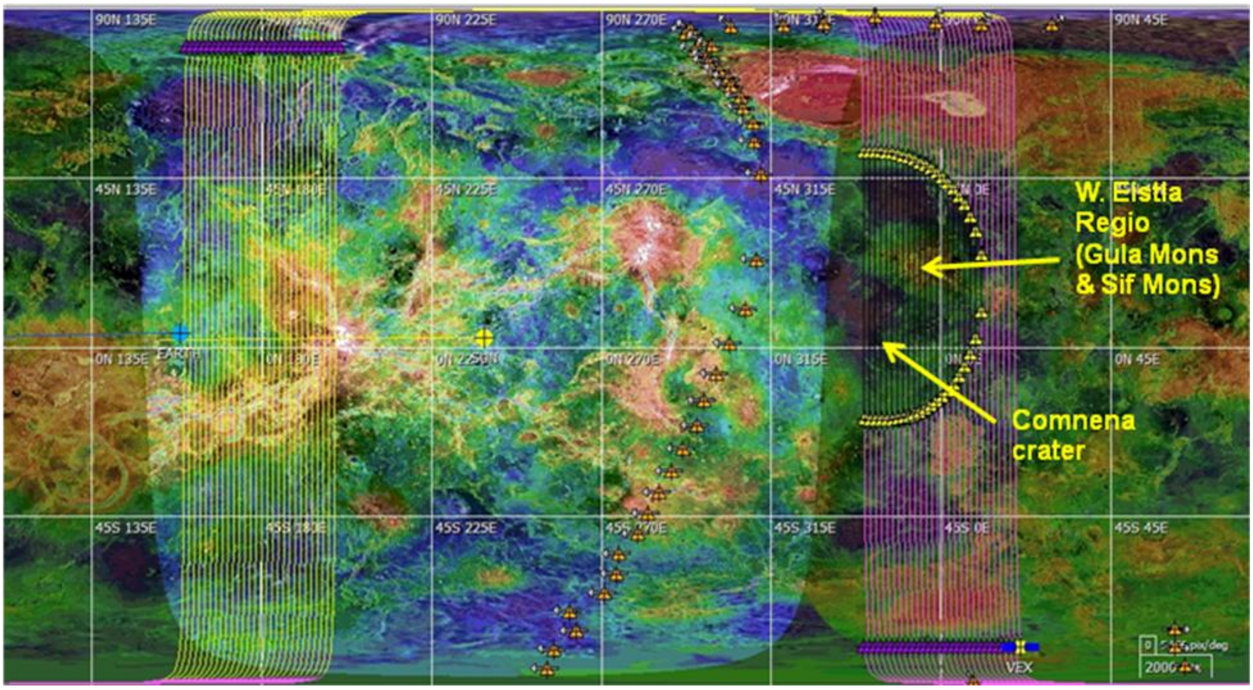


Figure 3.25 *MTP#97 timeline*



- **Figure 3.26** *Planet coverage by orbital tracks in MTP#97. Position of terminator, Earth and Sun correspond to the last orbit of MTP.*

3.11.3 Proposed Observations

- Dayside: Near-Pericentre dayside observations should include nadir observations as part of the SO2 campaign. These are scheduled on every orbit until the beginning of the quadrature period, and on at least 3 orbits per week, skipping communications passes, after the beginning of the quadrature period.
    - At MTP planning level, in consultation with ground-based SO2 observers, it may be decided to reduce the number of skipped communications passes – in this case some of the hot SO2 observations in quadrature may be replaced by cold observations such as UV dayglow limb observations, in order to permit the communications pass to take place.
- Nightside: SOIR observations still have a high priority and should occur on at least every other orbit. When the eclipse duration is long enough (>25 minutes), they can be combined with surface observations in eclipse.

3.12 MTP #98

3.12.1 MTP in brief

MTP #98 covers the period from12 October 2013 until 9 November 2013, and includes orbits #2732 - 2759.

Local time at ascending node changes from 14:40 to 17:40, thus the season is hot. Also, quadrature illumination continues throughout this entire MTP, so hot observations can only be carried out if a communications pass is skipped. Radio occultation season #16 starts in orbit 2744. Data rate is very high until the HGA1 > HGA2 swap in orbit 2748 (29 Oct 2013), and very low thereafter.

In this MTP, science priority is given to the SO2 campaign started in the last MTP. In this quadrature period, **2 to 3 communications passes per week should be skipped in order to allow the continuation, on a 2-4 day interval, of the SO2 measurement campaign** until the beginning of the drag season on 29 Oct 2013.

. These nadir measurements of SO2 by SPICAV-UV are important for co-ordination with ground-based observers, because the afternoon sector sounded by the nadir observations is the one visible from Earth, and a co-ordinated ground-based campaign is planned.

At the end of this MTP (orbits 2748-2759), there will be drag season #13. This will be a torque-only measurements (i.e. no radio tracking from ground), with a pericentre altitude of 190 km.

Figures 3.27 and 3.28 show observation timelines and surface coverage for this MTP.

3.12.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 14:40 – 17:40 h
- Hot season
- Quadrature illumination applies throughout entire MTP.
- Earth occultation season #16 starts in orbit 2744.
- Drag season #13 (190 km, torque only) occurs in 2748-2759.
- Surface targets: No particular surface targets specified for this MTP.
- High data rate until HGA1 > HGA2 swap in orbit 2748; low data ate afterwards.

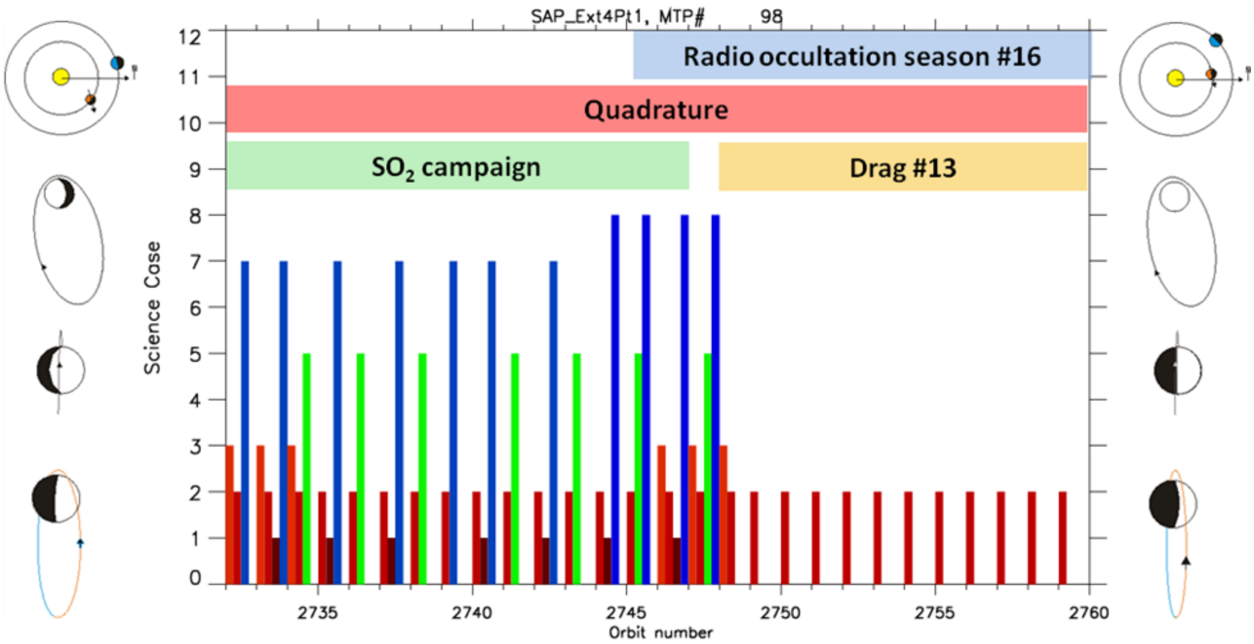


Figure 3.27 *MTP#98 timeline*

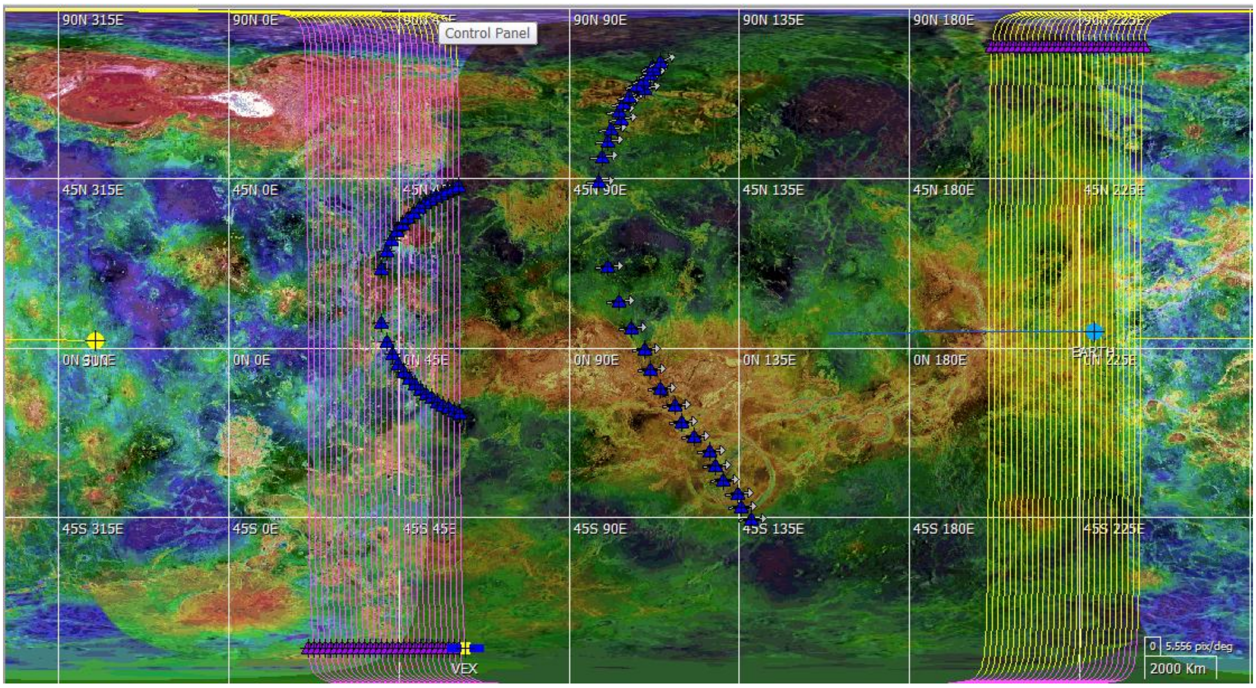


Figure 3.28 *Planet coverage by orbital tracks in MTP#98. Position of terminator, Earth and Sun correspond to the last orbit of MTP.*

3.12.3 Proposed Observations

- Dayside: Near-Pericentre dayside observations should include nadir observations as part of the SO2 campaign. These are scheduled on 3 orbits/wk until the end of the MTP. Because VEx is in quadrature illumination, a communications pass will need to be skipped after each of these hot pericentre observations.
    - At MTP planning level, in consultation with ground-based SO2 observers, it may be decided to reduce the number of skipped communications passes – in this case some of the hot SO2 observations in quadrature may be replaced by cold observations such as UV dayglow limb observations, in order to permit the communications pass to take place.
- Nightside near-pericentre observations: can be devoted to stellar occultations, limb track observations, and/or cross-terminator VMC wind-tracking observations.

3.13 MTP #99

3.13.1 MTP in brief

MTP #99 covers the period from 9 November until 7 December 2013, and includes orbits #2760 - 2787.

Local time at ascending node changes from 17:40 to 20:40, thus the MTP starts with a terminator orbit and thereafter the season is cold. Data rate is low, because HGA2 is in use. The long earth occultation season #16 continues throughout this MTP.

There is no particular science priority early in this MTP, so activities should include VMC cloud-tracking observations, SPICAV stellar occultations and limb observations.

Starting in orbit 2775 (25 Nov 2013), VEx will start a South polar dynamics campaign, which combines radio occultation with imaging for context and wind velocity determination. A VeRa egress occultation is scheduled on every orbit, and priority is also given to VMC and VIRTIS cloud-tracking observations of the polar region. VIRTIS observations can take place near apocentre (in which case they will be hot and will need 9 hr recovery time), or after VPER -07h00 in the ascending branch, when they will be cold. VMC cloud tracking observations of S Polar region can occur in ascending branch (in which case they will be cold, and should also be scheduled after the VeRa pass (from ~VPER +01h00 until the communications pass), when they will be hot. In addition to VeRa egress observations, VeRa ingress occultations are scheduled with a cadence of one ingress per four orbits. Figures 3.29 and 3.30 show observation timelines and surface coverage for this MTP.

3.13.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 17:40 – 20:40 h
- Cold season
- Earth occultation season #16 continues throughout the MTP.
- Surface targets: none for this MTP.
- low data rate (HGA2 in use).
- Note there are OCMs (orbit control manoeuvres) at pericentre in orbits 2760 (10 Nov 2013) and 2774 (24 Nov 2013), this precludes observations from VPER – 01h30 to VPER + 01h30.

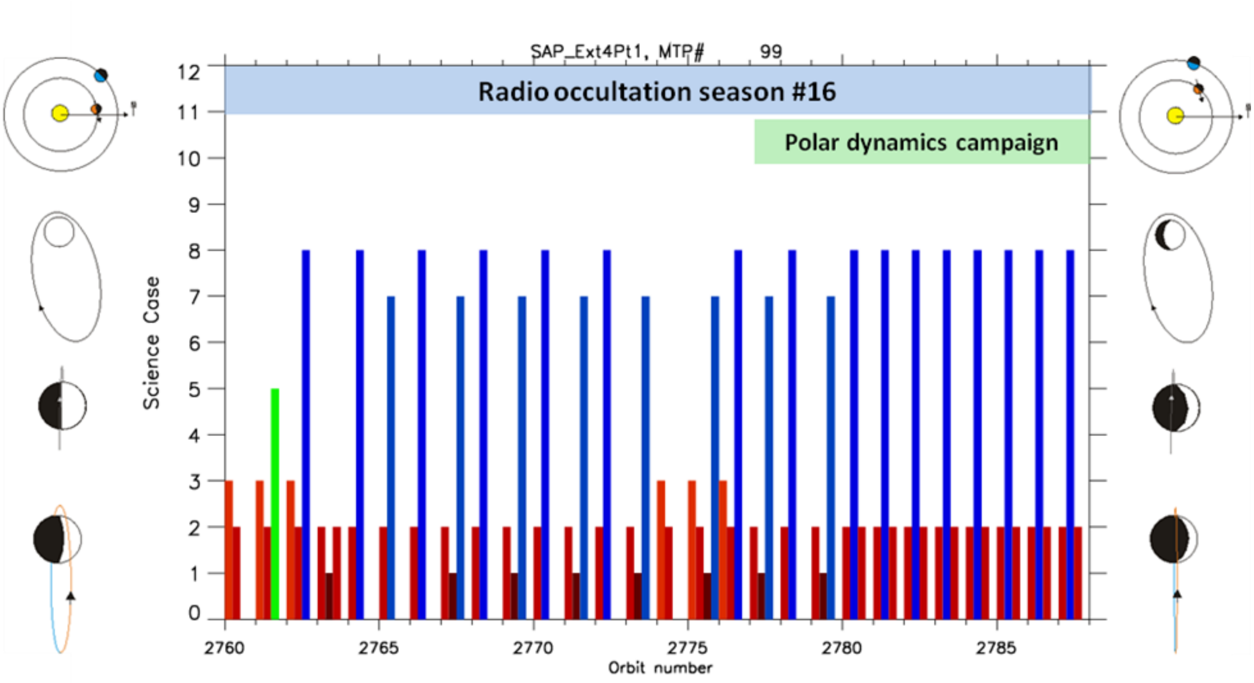


Figure 3.29 *MTP#99 timeline*

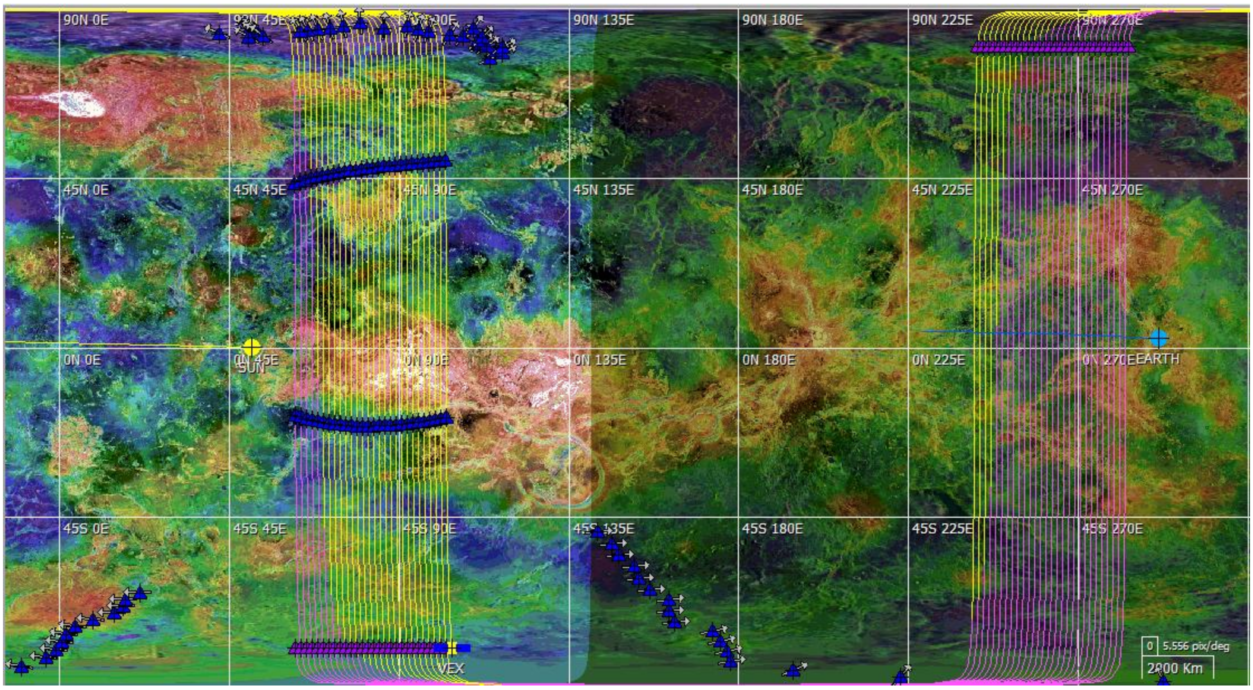


Figure 3.30 *Planet coverage by orbital tracks in MTP#99. Position of terminator, Earth and Sun correspond to the last orbit of MTP.*

3.13.3 Proposed Observations

- Dayside: Before the start of the polar dynamics campaign in orbit 2780, priority is given to VMC cloud-tracking observations in morning and evening sectors.
- Dayside: After the start of the polar dynamics campaign in orbit 2780, priority is given to VIRTIS tracking of dayside polar regions (hot observations near apocentre and/or cold observations in ascending branch), VeRa egress occultation (VPER +00h30 – VPER +01h00), and VMC tracking of polar regions (VPER +01h00 until communications pass, as well as cold observations in ascending branch),

3.14 MTP #100

3.14.1 MTP in brief

MTP #100 covers the period from 7 December 2013 until 4 Jan 2013, and includes orbits #2788 - 2815.

Local time at ascending node changes from 20:40 to 23:40, thus the season is cold. Data rate starts low but rises quickly during this MTP as Venus approaches inferior conjunction. The long earth occultation season #16 continues throughout this MTP, and eclipse season #26 starts in orbit 2791 (11 Dec 2013).

The polar dynamics campaign started in the last MTP continues throughout this MTP, ending on the 31 Dec 2013. Thus, a VeRa egress campaign is scheduled for **every orbit**, and priority is also given to VMC and VIRTIS cloud-tracking observations of the S polar region. VMC cloud tracking observations will take place after the VeRa pass (from ~VPER +01h00 until the communications pass). VIRTIS observations can take place near apocentre (in which case they will be hot), or after VPER -07h00 in the ascending branch, when they will be cold.

Eclipse season #26 (MTPs 100-102, Dec-Feb) will be a dedicated SOIR campaign, with SOIR occultations scheduled on every orbit. As SOIR observations occur before pericentre, these are still compatible with the continuation of the S polar dynamic campaign with a VeRa egress on each orbit and imaging of the S polar region. Once the eclipse duration is longer than 25 minutes, SOIR can longer conduct both ingress and egress on the same orbit, so there is more flexibility to schedule other observations at pericentre between the SOIR ingress and VeRa egress observations. At this time, pericentres may be divided up between SOIR egress, VeRa ingress, and other observations. As always, any hot observations at apocentre (such as VIRTIS polar wind tracking observations) will have to be thermally recovered before the SOIR observations.

Figures 3.29 and 3.30 show observation timelines and surface coverage for this MTP.

There is one surface target to try to image in this MTP: An un-named steep-sided volcanic dome at 11°N, 301°E. Steep-sided volcanic domes result when lava is unusually viscous and may thus have unusual composition. Surface observations are not prioritised in this MTP, but it should be possible to image this target at least once when the eclipse period is long enough, around orbit 2803.

Figures 3.31 and 3.32 show observation timelines and surface coverage for this MTP.

3.14.2 Environmental conditions

- Local Time at Ascending Node (LTAN): 20:40 – 23:40 h (similar to MTP#76)
- Cold season
- Earth occultation season #16 continues throughout the MTP.
- Eclipse season #26 starts in orbit 2791.
- Medium data rate
- Surface targets: Un-named steep-sided volcanic domes (11°N, 301°E)
- Note there is an OCM (orbit control manoeuvre) at pericentre in orbit 2788 (8 Dec 2013), this precludes observations from VPER – 01h30 to VPER + 01h30.

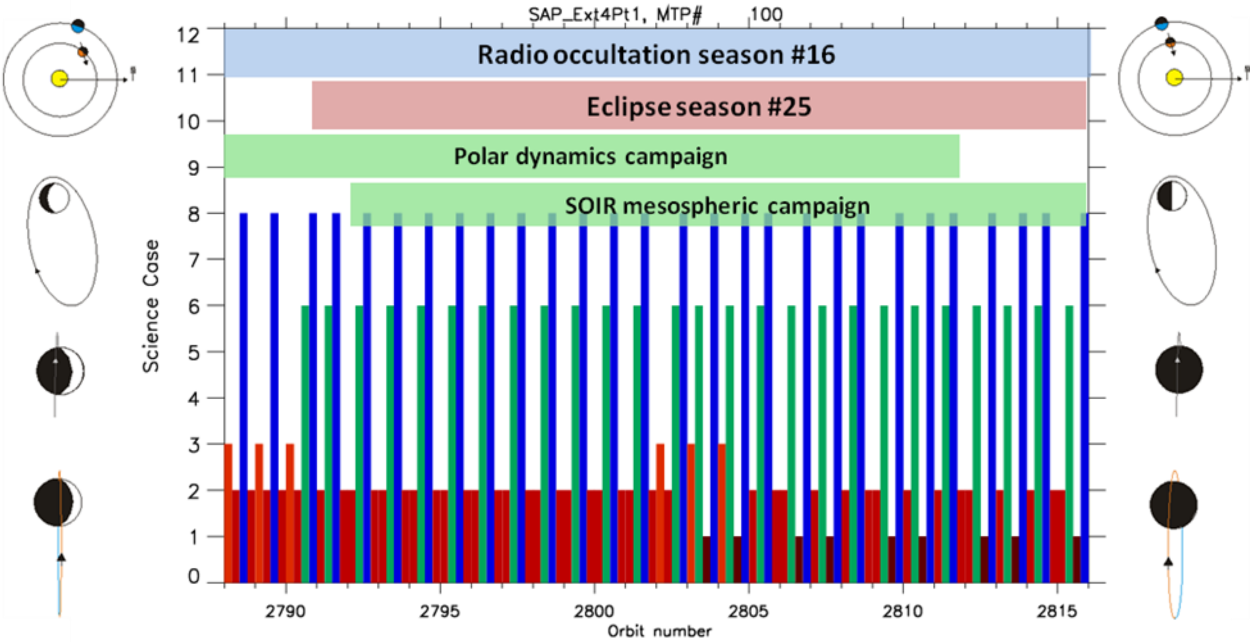


Figure 3.31 *MTP#100 timeline*

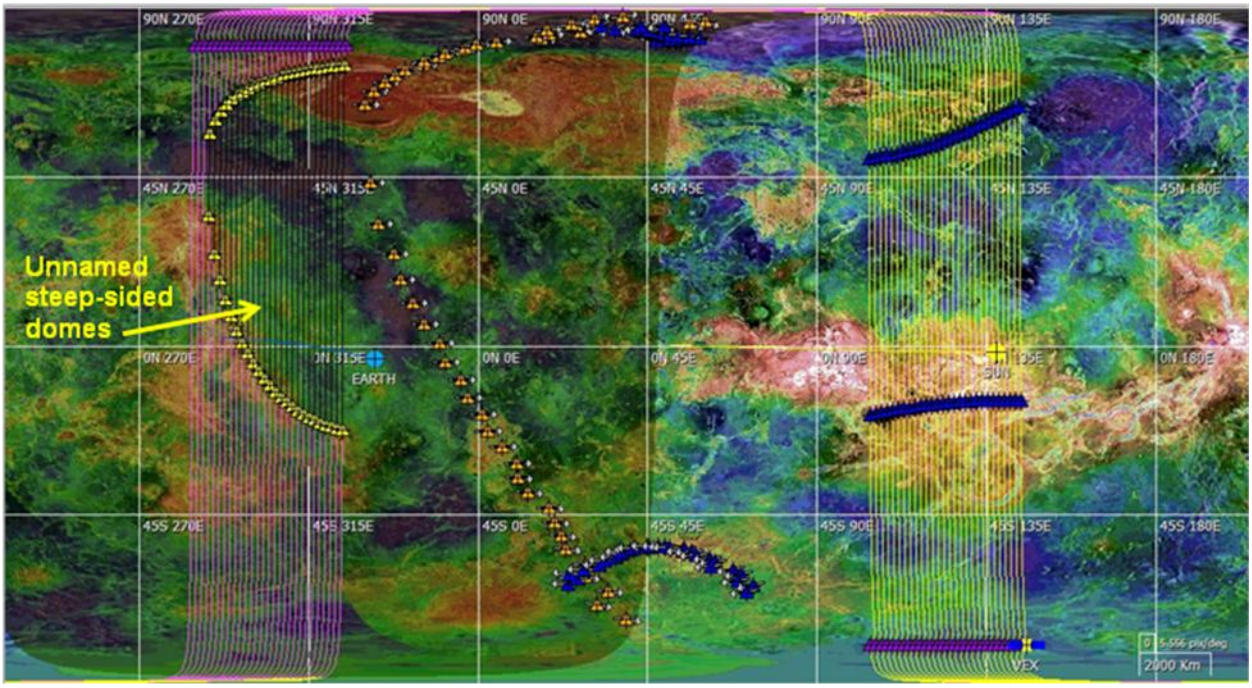
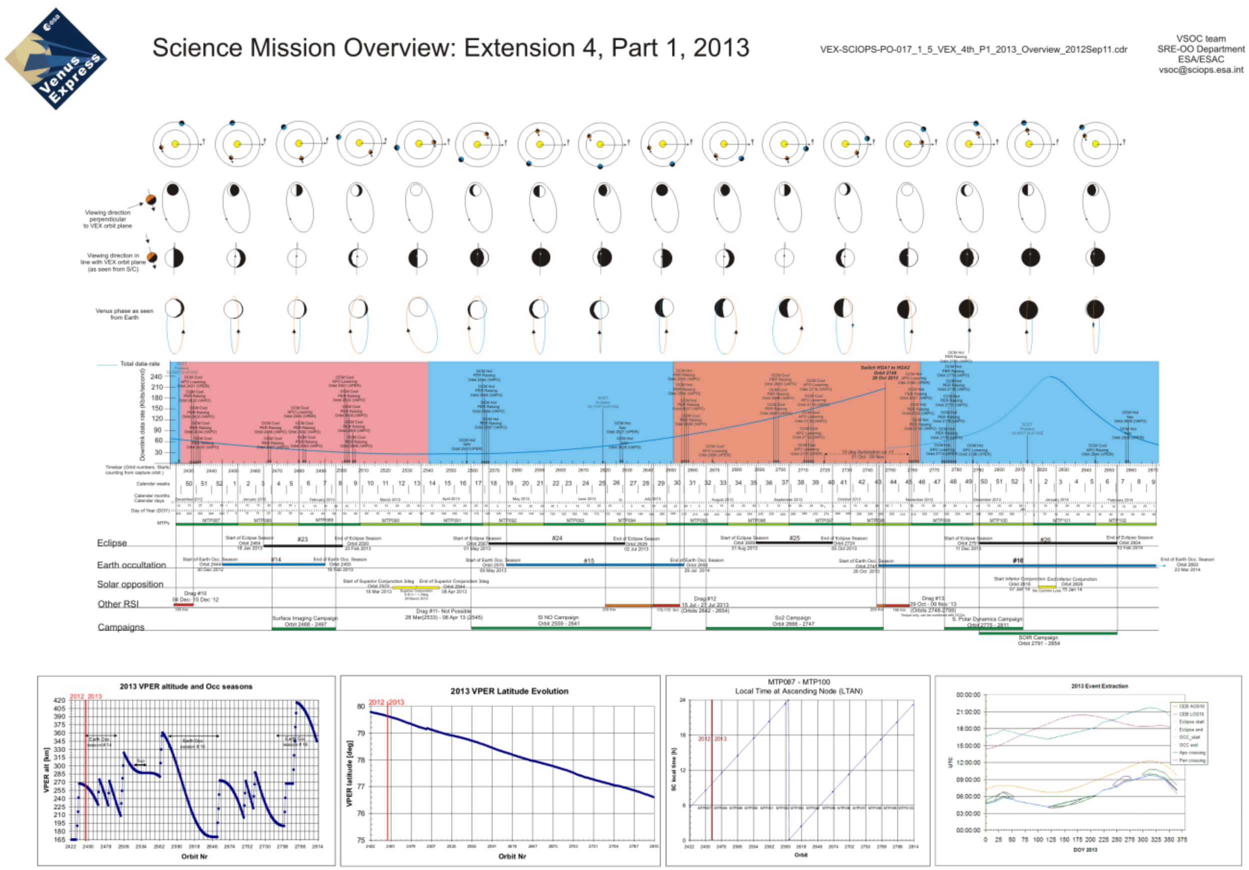


Figure 3.32 *Planet coverage by orbital tracks in MTP#100. Position of terminator, Earth and Sun correspond to the last orbit of MTP.*

3.14.3 Proposed Observations

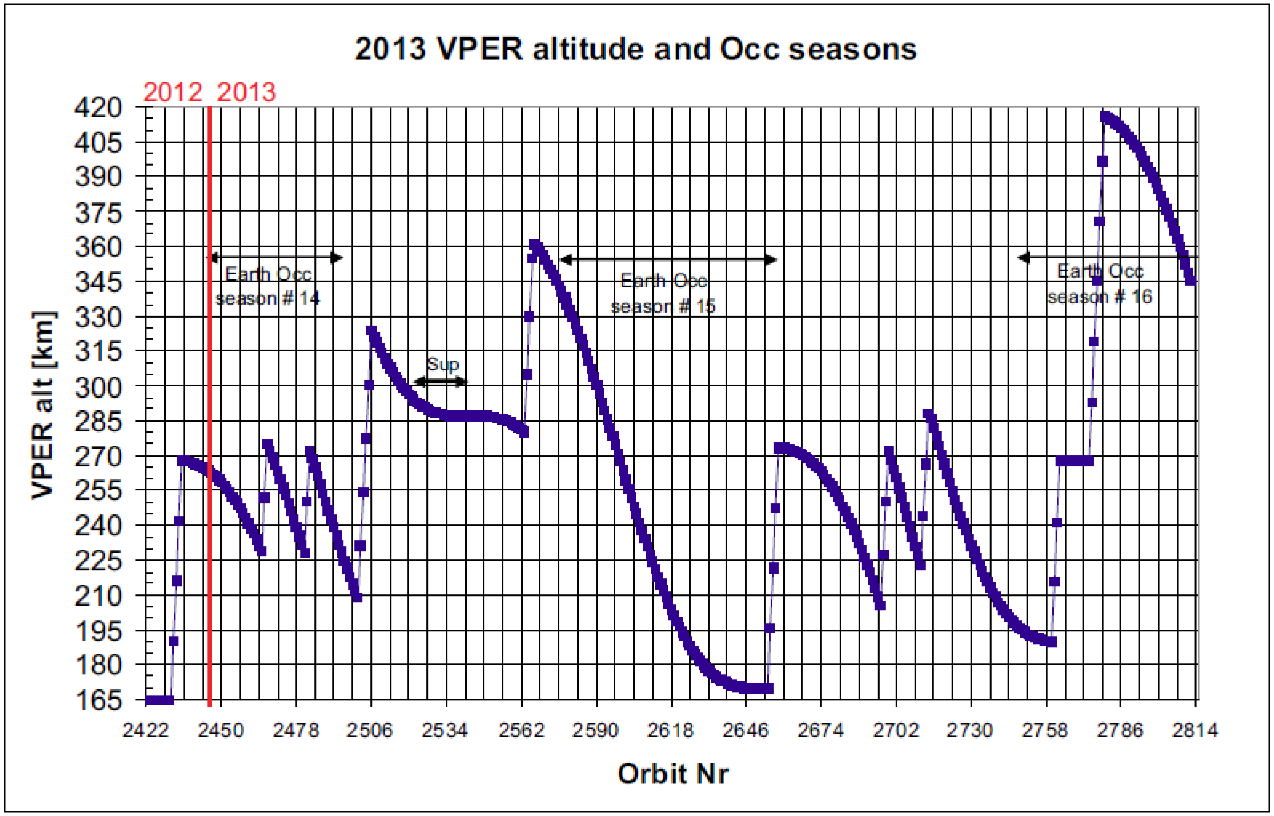
- Nightside: priority is given to SOIR on every orbit for a dedicated campaign. Before the SOIR occultations, VMC/VIRTIS imaging of the S polar region for wind tracking should be given priority.
- Dayside: a VeRa egress sounding is scheduled on every orbit. Where thermally allowed, imaging of the dayside S polar region for wind tracking should also be carried out.

4. ANNEX 1. EXTENDED-4 PART 1 MISSION OVERVIEW POSTER



This is file VEX-SCIOPS-PO-017_1_5_VEX_4th_P1_2013_Overview_2012Sep11.pdf

5. ANNEX 2. PERICENTRE ALTITUDE IN EXTENDED MISSION



ANNEX 3. LIST OF STARS FOR STELLAR OCCULTATION OBSERVATIONS

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	

ANNEX 4. COVERAGE OF VERA EXPERIMENT

See also VeRa Synoptic Table:

(VEX-SCIOPS-LI-500_53_VeRa_Synoptic_Table_2012Sep11.xls)