Venus Express
VENUS EXPRESS RADIO SCIENCE
VeRa

FLIGHT OPERATIONS MANUAL
EXPERIMENT USER MANUAL

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1 Introduction

1.1 Purpose

This document presents the Experiment User Manual and Flight Operations Manual for the Venus Express Radio Science experiment (VeRa). It is intended as a reference for the implementation of VeRa science operations during the Venus Express mission.

1.2 Scope

The document defines the science objectives, describes the observational methods, and the configuration and operational modes of the VeRa experiment, with regard to the space and ground station segments.

Section 2 describes the science objectives, the experiment operations and pointing requirements. Section 3 covers characteristics of the experiment, section 4 covers operations. In section 5 functions are explained. An interface definition is given in section 6, in section 7 a detailed description of functional procedures and an estimate of the total data volume is given. In section 8 a timeline including operation procedure tables for the individual procedures is given. References are listed in section 9.

1.3 Applicable Documents

	Reference Number	Title	Issue	Date
[1]	VEX-VRA-IGM-IS-3007	Archive Generation, Validation and Transfer Plan	4.5	11.02.2004
[2]	VEX-VRA-IGM-IS-3009	Radio Science File Naming Convention and Radio Science File Formats	6.8	17.02.2004
		Archival Tracking Data File ATDF TRK 2-25 Original Data Record ODR RSC 11-13 Radio Science Receiver RSR 0189-Science		
	MEX-MRS-IGM-RS-3014	IFMS User Requirement Document		
	VEX-VeRa-IGM-RS-3001	VeRa PID-B	1	02.11.1999
	RO-RSI-IGM-TN-3057			
	GRST-TTC-GS-ICD-0518-TOSG	IFMS-to-OCC Interface Control Document	1.0	14.07.2000
	VEX-ESC-RP-5500 I1	Venus Express: Consolidated Report on Mission Analysis	1	April 2003

1.4 Referenced Documents

Reference Number	Title	Issue	Date
[1] VEX-VERA-UBW-TN-3006	VERA Science Performance Analysis	2.1	16.12.2002
[2] VEX-VERA-UBW-TN-3040	VERA Reference Systems and Techniques used for the Simulation and Prediction of Atmospheric and Ionospheric Sounding Measurements	2.4	12.12.03
[3] VEX-T.ASTR.-TCN-00665	Science Cases Definition and Study assumptions	2.0	26.08.2003

1.5 Abbreviations

ADEV Allan Deviation
AGC Automatic Gain Controll
ATDF Archival Tracking Data File
AVAR Allan Variance
BVA High performance, low phase noise type of quartz oscillator
CNES Centre National d'Etude Spatiale
DSN Deep Space Network
DTM Digital Topographic Model
DUT Device under test
EM Engineering Model
EPS Experiment Planning System
EQM Electrical Qualification Model
ESA European Space Agency
ESOC European Space Operations Centre
FM Flight Model
FOM Flight Operations Manual
FS Flight Spare
G/S Ground Station
HDEV Hadamard Deviation
HGA High Gain Antenna
HRSC High Resolution Stereo Camera
HVAR Hadamard Variance
IFMS Intermediate Frequency Modulation System
IGM Institut für Geophysik und Meteorologie, Universität zu Köln
JPL Jet Propulsion Laboratory
LCP Left Circular Polarization
LGA Low Gain Antenna
LHC Left Handed Circulated Polarization
LOS Line-of-Sight
MaRS Mars Express Orbiter Radio Science Experiment
MPTS Multi-Protocoll Transport Service
NASA National Aeronautics and Space Administration
ONES One-way single-frequency mode
ODR Original Data Record
PA Power Amplifier

PFM Proto Flight Model
PLL Phase-lock loop
PSD Power Spectral Density
RAIUB Radioastronomisches Institut der Universität Bonn
RCP Right Circular Polarization
RF Radio Frequency
RHC Right Handed Circulated Polarization
RSI Radio Science Investigation
RSR Radio Science Receiver
RX Receiver
S/C Spacecraft
SFDU Standard formatted data unit
SGICD Surface Ground Interface Control Document
SNR Signal-Noise-Ratio
STAT Science Time Analysis Tool
S-TX S-Band Transmitter
TCXO Temperature controlled crystal oscillator
TT&C Telemetry Tracking & Comanding
TWOD Two-way dual-frequency mode
TWOS Two-way single-frequency mode
TWTA Travelling wave tube amplifier
UniBW Universität der Bundeswehr
USO Ultra Stable Oscillator
VCXO Voltage controlled crystal oscillator
X-TX X-band Transmitter

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2 An Introduction to Radio Science

2.1 Introduction

Although initially conceived as an exploratory tool, radio science techniques have provided considerable detail—originally unanticipated—regarding the atmospheres and gravity of the planets. Previous experiments at Venus with the Pioneer Venus and Magellan S/C have provided substantial insight into the physics and dynamics of the atmosphere and have contributed to the understanding of the planetary surface. It is anticipated that due to the integration of an ultrastable reference frequency source onboard the S/C this performance can be duplicated or bettered for occultation immersion and bistatic radar measurements with Venus Express.

2.2 Background

Radio Science is the general study of phenomena affecting the propagation, scattering, and reception of electromagnetic transmissions in the wavelength regime longward of roughly 0.1 millimeters. A broad array of phenomena and the techniques used in studying them fall in this category, including much of electromagnetism in the natural world. The distinction between 'radio science' and 'electromagnetics,' as used especially in an engineering sense, is the emphasis in the former on study of phenomena observed in nature. In the context of planetary study and exploration, however, the term radio science has come generally to indicate a focus on the use of radio signals traveling between spacecraft and an Earth terminal for scientific investigation of planets and their environs. This specialized usage arises from the historical development of space applications. Thus, for example, topside sounding and passive reception of natural emissions properly would be 'radio science' in a terrestrial context, but these topics likely would be identified in terms of the specific techniques when applied in space. In the context of planetary studies the term radio science also includes the scientific application of radio tracking data in the precise determination of a spacecraft's orbit and scientific information that can be derived from such information. Radio signals provide an extremely precise measurement of the radio path between the ground station and the spacecraft, and such measurements in turn are employed to infer important characteristics of planetary systems.

Radio Science techniques are applied to the study of planetary atmospheres (including the ionosphere), cometary atmospheres, the solar corona, rings, surfaces, and gravity. Much of our modern fundamental knowledge of these subjects has been derived from radio science observations. Early flight missions incorporating radio science investigations include the Mariners, Pioneers, and Viking, as well as Soviet projects. Examples of recent and current radio science investigations include those conducted with Voyager (Eshleman et al. 1977; Tyler 1987), Ulysses (Bird et al., 1994; Pätzold et al., 1995), Giotto (Pätzold et al., 1991a; 1991b; 1993), Galileo (Howard et al. 1992), Mars Observer (Tyler et al. 1992), Mars Global Surveyor (Tyler et al. 2000), Pioneer Venus (Kliore et al. 1980), and Magellan (). Missions carrying radio science investigations currently en route or planned include Cassini (Bird et al., 1995), Rosetta (Pätzold et al., 2000a), and Mars Express (Pätzold et al., 2000b).

Radio science investigations fall into three broad categories of experimentation and observation. First, for the study of planetary environments, the orbit or trajectory of the spacecraft is arranged so that the spacecraft passes behind the planetary body as seen from the tracking station on the Earth. In this instance the spacecraft is said to be 'occulted' by the planet during those intervals when the atmosphere or body of the planet lies between the radio source and receiver. In a typical occultation experiment conducted with an orbiter, the spacecraft sequentially passes behind the ionosphere, the neutral atmosphere, and body of the planet as seen from the tracking station, and then reemerges in the reverse sequence. During an occultation event one 'senses' the media of interest—atmosphere and ionosphere—by the effect of the gas on the radio signal. The method can be extended to any one of several separable 'atmospheres' including the planetary rings and magnetospheres, as well as the relativistic gravitational effects of stars (Eshleman 1973). In conducting such observations the geometry and other experimental conditions must be controlled so that the only significant unknown factors are the properties of the medium along the radio path.

The modern value for the surface pressure of Mars was first determined in 1965 by use of the radio occultation method with Mariner 4 providing the signal source (Kliore et al. 1965). Prior to the Mariner 4 experiment, the scientific literature and popular literature indicated a consensus that the surface pressure was in the range of 100 mb, or about 10 percent of that of Earth, based on difficult spectroscopic observations from the ground. Further, many believed that oxygen was a major atmospheric constituent. In a time when Mt. Everest had been conquered many believed that it would be possible to live on Mars without mechanical aids after a period of adjustment! The science fiction stories of Edgar Rice Burroughs reflect this earlier view.

At the beginning of the space age, however, a precise value became important in the context of designs for entry craft and landers destined for the surface of Mars then under study by teams lead by Werner von Braun. In the time of the Mariner 4 launch and cruise new ground based observations of the atmosphere had begun to cast doubt on the 100 mb value, suggesting that the true value could be substantially lower. As a result of this situation an accurate determination became critical in an engineering sense. After considerable debate in which one side declared that the loss of data during an occultation event could lead to a spacecraft catastrophe, mission managers at NASA elected to direct Mariner 4 to fly behind the body of Mars for the purpose of performing radio occultation measurements. Although the early analysis methods were primitive compared with current techniques, it was immediately clear that atmospheric pressure at the occultation point was approximately 4 mb, a factor of 20 less than the consensus value; dramatically and very significantly less that many expected! Further, since spectrographic studies indicated that the partial pressure of CO2 on Mars was in this range, the atmosphere was almost entirely carbon dioxide with little if any oxygen. Radio occultation measurements have been included on all planetary mission flown since that time. Similarly, a radio occultation experiment conducted with Voyager 2 was able to determine for the first time that the surface pressure of Neptune's satellite Triton is 14 microbars (Tyler et al. 1989; Gurolla 1995).

Second, oblique incidence scattering investigations using carom paths between spacecraft, a planetary or satellite surface, and an Earth station can be used to explore the surface properties through study of the microwave scattering function. Such investigations are referred to a 'bistatic radar' after the military nomenclature for radar systems in which the transmitter and receiver are separated by significant angular distances or ranges. In this instance the first experiment in space was

conducted on the moon. The oblique scattering geometry afforded by the Explorer 35 spacecraft, which orbited the moon in 1967, provided the signal source. Recording of signals transmitted to Earth by that satellite also contained echos of the transmissions from the lunar surface. As it happened, the plane of the spacecraft spin axis and the antenna polarization made it possible to measure the Brewster angle of the lunar crust, leading to an unambiguous value for the relative dielectric constant of lunar soil between 2.9 and 3.1, and thereby confirming that a future landing spaceship would be on firm (lunar) ground.
Third, when the radio path is well-clear of occulting material, the spacecraft can be treated as a classical 'test particle' falling in the gravity field of the planetary system with the component of its velocity along the line-of-sight to the tracking station measured by the Doppler effect. In contrast to occultation experiments, which sense the effect of the medium along a path between two known points, gravity experiments are based on determining the motion of the spacecraft in response to the variations in mass distribution within a planet or its satellites. This is a classical physics laboratory experiment carried out on planetary scales. Our global knowledge of Earth's gravity comes from such studies. In space, our only knowledge of the gravity field of Mercury is from the two flybys of Mariner 10 (Howard et al., 1974). Similarly, recent inferences as to the internal structures of the Galilean satellites, for example that there is an ocean on Europa, are based on the behavior of the trajectory of Galileo spacecraft during close flybys. A precise determination of the total mass of Uranus and Neptune has led to the conclusion that there is no need for a 'Planet X' to explain the orbits of these bodies (Standish, 1993), although some important mysteries in the motions of the out planets and very remote spacecraft remain. The method has been extended to small bodies as well, for example in the mass determination of asteroid Mathilde (Yeomans et al., 1997) and gravity field of asteroid Eros (Yeomans et al., 2000). At Mars, techniques similar to those used for asteroids can be applied to a precise determination of the masses of Phobos and Diemos. For Venus the spherical harmonic gravity field was determined to degree and order 60 by Konopliv and Sjogren 1994 and even higher by Barriot et al.( ).
These three techniques—radio occultation, bistatic radar, and determinations of gravity from radio tracking—have roots and counterparts in classical astronomy: (I) Classical stellar occultation observations make use of the chance passage of a planet between Earth and a star. Such an occurrence permits determination of the existence or absence of an atmosphere by observing the extinction of starlight as the planet obscures the star (*v., e.g.,* Elliot et al. 1989). When an atmosphere is present some of its properties can be determined. Stellar occultation has been extended to the study of planetary rings by observing the degree extinction as a function of radius (*v., e.g.,* Elliot and Nicholson 1984). Sometimes the unexpected occurs; the rings of Uranus were discovered by this technique by investigators attempting to understand the planet's upper atmosphere. (ii) Measurements of the classical scattering phase function, *i.e.*, the angular distribution of scattered energy flow, are the optical predecessor of bistatic radar, in which the source typically is the sun and observations are made with terrestrial telescopes. (iii) Early determinations of the small-scale properties of the lunar surface, for example, were carried out in this manner. Classical Earth-based measurements of the motions of natural satellites are used to determine the low-order gravity fields of planets. When available, radio science methods provide much greater accuracy and dynamic range than these classical approaches. The power of radio science methods as compared with the

classical techniques arises from the use of coherent radio signals that permit the measurement of radio frequency phase and deterministic polarization as precise tools for probing planetary environments. An additional, fundamental distinction between the classical approaches and those of radio science is the ability of the investigation geometry to be controlled through manipulation of the spacecraft relative to the Earth, thereby considerable flexibility in the selection of the geometric experimental parameters. Future missions in which such experiments are organized utilizing transmission between or among multiple satellites in orbit about the same planet would permit complete control of experimental conditions. An early such occultation experiment, GPS/MET, has been conducted in Earth orbit using the GPS constellation of satellites as signal sources with reception on a low-Earth orbiter (Kursinski et al. 1996; Ware et al. 1996).
Short of in situ measurements by entry probes, radio occultation studies of atmospheres provide the most detailed information available on the vertical structure of the neutral atmosphere, the ionosphere, and atmospheric waves. In principle, vertical structure as fine as a few meters can be discerned, and a resolution as fine as 100 m has been demonstrated for Mars. Recent analyses of MGS radio occultations at Mars have shown that a sequence of radio occultation measurements can provide adequate sampling and accuracy to provide a useful determination of atmospheric fields; wind velocity, temperature, and pressure can all be determined as a function of altitude. An unusual aspect of this is the use of the occultation determination of the atmospheric parameters in terms of the absolute radius, thereby enabling the use of new techniques to address problems in atmospheric dynamics. For example, the gradient wind equation can be used to determine absolute winds vs. altitude across a path connecting two nearby occultation points ((Hinson 1999).
Although atmospheric effects result from integrated effects over long distances along the ray path, Abel inversion of the observations (see section 2.4.1) yields a vertical resolution of 0.5-1 km, limited by diffraction. Atmospheric disturbances will be detected by variations in temperature at the 1 K level. Specifically for Venus, the results are also expected to reveal the vertical structure of localized buoyancy waves, and the presence and properties of planetary waves.
Signal intensity variations will provide information on the structure of H2SO4 vapor in the Venusian atmosphere, which can be seen as a tracer for atmospheric motions. Scintillation effects caused by diffraction of the radio wave within the atmosphere provide information of small scale turbulence effects in the atmosphere.

Radio occultation measurements strongly complement and extend other spacecraft and Earth-based remote sensing techniques, such as infrared spectroscopy, which provide detailed information on atmospheric constituents and low vertical resolution structure over wide regions by instrumental scanning. The best results are obtained when radio occultation and these other observations are combined.

Bistatic radar observations of the Moon, Venus, and Mars extend and complement Earth-based radar astronomy studies of these objects. For example, the fundamental nature of the lunar surface as a consolidated soil was first demonstrated by a combination of terrestrial radar astronomy and bistatic radar methods. Likewise, determination of the particle sizes in the rings of Saturn was based on a forward scattering experiment for observing the diffraction pattern of the ring particles; refined experiments of this type are planned for Cassini when it reaches Saturn. With Pioneer Venus Orbiter regions on the surface of Venus (mostly located at relatively

high altitudes) could be found which exhibited unexpectedly high values of radar reflectivity (up to 0.4) (Pettengil et al. 1982). It was later found that these regions were also associated with low values of surface emissivity (~ 0.54) (Ford et al. 1983). Identified elevated regions were Ovda Regio, Thetis Regio, Maat Mons, Ozza Mons, Theia Mons, and Rhea Mons (Tyler et al. 1991).
Additional observations of Venus were made in 1983 from Earth, using the Very Large Array (VLA) in New Mexico resolved areas as small as 200 km. The latter data confirmed the existence of regions having radio emissivities as low as 0.58 (Pettengil et al. 1988).
The Magellan spacecraft provided detailed, near global measurements of both radar reflectivity and the radiothermal emission of the surface at a wavelength of 12.6 cm (2.4 GHz). Similarly, the existence of exotic phase changes in materials at the upper levels of Cytherian mountains was demonstrated by observing variations in polarization from Maxwell Montes with a bistatic scattering experiment conducted with the Magellan spacecraft (Pettengil et al. 1996).
Radio tracking studies of gravity are uniquely suited to determine the interior structure of planets, for those cases for which the appropriate geometrical conditions can be obtained. To date, the intense radiation field of Jupiter's magnetosphere and the hazard of planetary rings at Saturn and Uranus have prevented close approaches to these planets by spacecraft, thereby limiting the utility of this technique at the outer planets. While in these cases the best information to date is obtained by classical methods, suggested missions that would fly interior to the radiation belts of Jupiter, say, hold considerable promise for solving the puzzle of that planet's interior organization. When practical, spacecraft methods are superior in all instances for determination of total system mass, the internal distribution of mass of various bodies, and the masses of individual satellites.
The absence of a planetary magnetic field leads to important differences between the structures of the Earth´s and Venus´ ionosphere. The upper atmosphere of Venus is not protected by the magnetic field from direct interaction with the solar wind which then can lead to strong atmospheric escape processes.
The solar radiation also creates a hot neutral atmosphere which extends into the solar wind. The ionospheric pressure, consisting of both thermal and magnetic components, balances the dynamic pressure of the solar wind. The neutral atmosphere that extends into the solar wind becomes ionised and adds to the solar wind flow, further decelerating it by mass loading since the high altitude neutral atmosphere consists mainly of hot oxygen and not hydrogen (Russell and Vaisberg 1983).
At Venus, the magnetosheath stops at the altitude where the ionospheric plasma pressure is equal to the incident pressure. Venera-9, Venera-10, and Pioneer Venus data also demonstrate a clear dependence of the altitude profile on the solar zenith angle (Ivanov-Kholodny, G.S. et al. 1979, Bauer et al. 1985). The upper boundary of the ionosphere where the plasma density shows a deep gradient is called ionopause. The extent of the thermal ionosphere is dictated by the ionopause altitude. VEX will give an opportunity to measure the ionospheric structure also during solar minimum conditions. These studies will also lead to an understanding of the Earth´s environment during the epochs of weak magnetic field.

2.3 Technique

Radio science instrumentation combines equipment on the ground with on-board spacecraft hardware required to create and maintain a highly stable and precise radio link. Most commonly, two-way radio signals have been generated on the ground and transmitted 'uplink' through the large antennas of the NASA Deep Space Network. These transmissions are received by the spacecraft transponder, shifted in frequency, and then re-transmitted 'downlink' to the Earth where they are received either at the original site or at a second site, possibly located on another continent. Transponder design is such that the frequency of the downlink signal is coherently related to the received uplink frequency by a known integer ratio. Because the downlink signal frequency is derived precisely from that of the uplink, it is possible to measure changes in the radio path length by comparison of the received, downlink signal with the ground oscillator that generated the uplink signal originally. An increase in the radio path length decreases the phase of the received downlink signal relative to the ground oscillator, while a decrease in path length has the opposite effect. As hydrogen maser clocks are used for the fundamental frequency reference on the ground, measurement of the downlink phase provides an extremely precise method of determining changes in the round trip propagation time to the spacecraft. A one-Hertz difference between the frequencies of the uplink and downlink signals means that the total radio path length is changing at the rate of one wavelength per second; larger or smaller frequency differences correspond to proportionally larger or smaller rates of path length change. Overall, the short term accuracy of the measurement procedure depends on the signal-to-noise ratio achieved and, ultimately, on the stability of the ground station oscillator over the round trip flight time of the radio signals to the spacecraft and back (Eshleman and Tyler 1975; Lipa and Tyler 1979).

On the ground, stations for communication over interplanetary distances are built around the large antennas of 20–100 m diameter. These stations are used primarily for uplink transmission of commands and downlink reception of spacecraft data (Yuen 1983). On spacecraft, however, typical antenna sizes are limited to only a few meters at most, and the transmitted downlink signal power ranges from about 1 to less than 100 W. As mentioned, hydrogen maser atomic clocks are used for the ground station frequency reference, while microwave frequencies in the 2 (S-band) and 8 (X-band) Gigahertz range, corresponding to 12–13 cm and 3–4 cm wavelengths, respectively, are used for the radio signals. Either band can be used separately or both used simultaneously. Use of dual frequencies is advantageous since this permits direct separation of the effects of neutral and ionized gases on the basis of differences in the dispersive characteristics of the two media. Frequency changes as small as about 0.001 Hertz can be measured, corresponding to a fractional accuracy in the range of a few parts in 10^{14} (Tyler et al. 1992). In the absence of other effects, this leads to an accuracy in the measurement of spacecraft velocity, for example, in the range of 30 micrometers/second when the 8 gigahertz band is used. Under the best conditions accuracies better than 10 micrometers/second have been achieved. Similar or slightly lower accuracies are anticipated for Venus Express (see also chapter 9.2 of this document). The use of a two-way, uplink/downlink radio path is suitable for study of gravity and for spacecraft navigation purposes.. The strong atmosphere of Venus has also the effect of a bending of the microwave ray (to be discussed below). In consequence the

spacecraft HGA has to vary its pointing attitude in order to compensate for the ray bending effect.
Occultation observations exhibit considerable signal dynamics, with simultaneous variations in signal frequency and amplitude, as well as the presence of near-forward scattering and diffraction when the radio path passes near a planet's surface. In the case of Mars diffraction from the planetary limb is observed on all occasions while near-forward scattering occurs in roughly 80 percent of occultation events.
Observed signals obtained from bistatic scattering experiments are characteristically broadened relative to the illuminating signal as a result of the combination of angular spreading of the waves by the scattering process and the relative motion of the spacecraft and ground station with respect to the planet's surface. Unlike occultation observations, much of the information regarding the surface properties is in the polarization and amplitude of the scattered signal; typically there is no coherent component in the scattered fields.
Thus, both occultation and bistatic scattering observations produce dynamic signals occupying a considerably greater bandwidth than the transmitted illuminating waveform. For this reason, the measurement of these signal characteristics requires capture of the time-sampled waveform at a sufficient sampling rate to avoid frequency aliasing effects. This is accomplished with open-loop receivers pre-programmed to track the expected spectral window. The dynamical characteristics of the occultation and scattered signals preclude reliable use of phase-locked loop techniques for reliable radio occultation measurements.

2.4 Applications to Venus

2.4.1 Atmosphere

Radio occultation studies of atmospheres can be understood in terms of 'geometric' or 'ray' optics refraction of signals traveling between spacecraft and ground stations. In a spatially varying medium wherein the wavelength is very short compared with the scale of variation in refractive index, the direction of propagation of an electromagnetic wave always curves in the direction of increasing refractivity. Consequently, in a spherically symmetric atmosphere with gas refractivity (which is proportional to density) constantly decreasing with height, the radio path remains in a plane and bends about the center of the system. The degree of bending depends on the strength of the refractivity variation. This simple model approximates a real atmosphere and is useful for understanding the basic phenomena of radio occultation.

The geometry is illustrated in Fig. 2.4-1, where the atmosphere is represented by the refractivity as a function of radius from the center, r_o , and the bending can be described in terms of a bending angle, α , and a ray asymptote, a . The variation of the bending angle, ray asymptote, and refractivity are linked elegantly through an Abel transform relationship (Fjeldbo and Eshleman 1971); viz.,

$$\alpha(a) = -2a \int_{r=r_o}^{r=\infty} \frac{1}{n}\frac{\partial n}{\partial r}\frac{dr}{\sqrt{(nr)^2 - a^2}} \tag{2-1}$$

where $r_o = \dfrac{a}{n(r_o)}$, from Bouguer's Rule, is the ray periapse, and

$$\ln\left(n(r_o)\right) = \frac{1}{\pi}\int_{a_o}^{\infty} \frac{\alpha(a)\,da}{\sqrt{a^2 - a_o^2}} \tag{2-2}$$

In this last expression, r_o represents the asymptotic miss distance for a ray whose radius of closest approach is r_0. Thus, for spherical atmospheres, if $\alpha(a)$ is known, then the corresponding refractivity profile can be found exactly. For non-spherical geometry alternative numerical solutions are available.

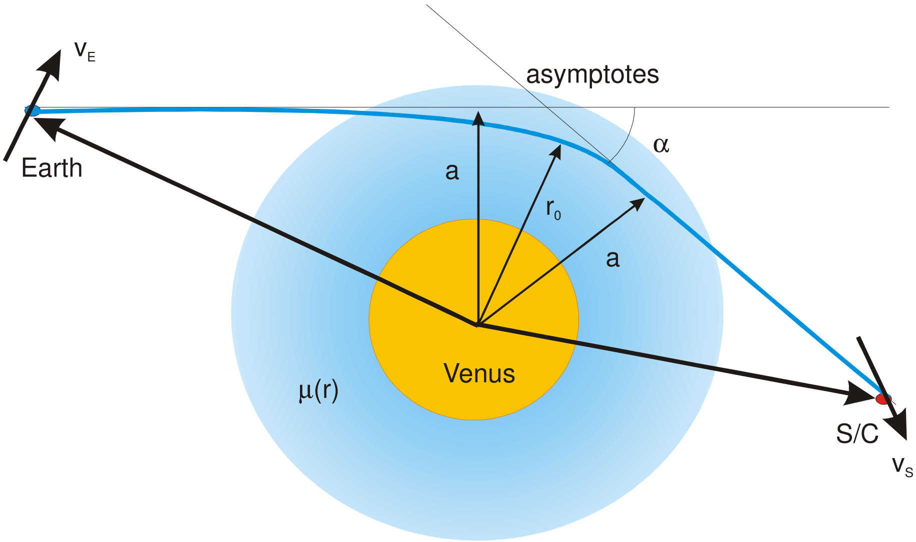

Fig. 2.4.1 Ray Bending in Atmosphere

Figure 2.4-1: Occultation ray path geometry. Signals passing between spacecraft and Earth are refracted by a planetary atmosphere. Refraction angle is α. Position and velocity of spacecraft and Earth station are known from tracking data.

The bending angle and the ray asymptote can be determined accurately by radio occultation measurements to create an experimentally derived table of α versus *a*, or $\alpha(a)$. This is accomplished as follows: Referring again to Fig. 2.4-1, the position and velocity of spacecraft with respect to the Earth tracking station and the planet's center can be found from tracking data during periods when the radio path is well-clear of the atmosphere. Given knowledge of the geometry, a measurement of the Doppler shift over the spacecraft-to-ground path is sufficient to find α and a, from which $\alpha(a)$ then can be determined. It was possible with Voyager to measure α to an accuracy of about 1 x 10^{-8} radians, and at least equal accuracy is expected for Venus Express; the impact parameter a is known typically to about 1 km, and will be known to about 100 m or better for Venus Express. These high levels of measurement accuracy in turn permit determination of an accurate refractivity profile N(r), as outlined above.

In order to interpret the refractivity in terms of gas parameters, the pressure and temperature are calculated assuming hydrostatic equilibrium, for example, from

$$p(\rho) = kn_t(\rho)T(\rho) \tag{2-3}$$

and

$$p(\rho) = \frac{\overline{m}}{kv(\rho)} \int_{\rho}^{\infty} v(\rho)\, g(\rho)\, d\rho$$

$$T(\rho) = \frac{\bar{m}}{kv(\rho)} \int_{\rho}^{\infty} v(\rho)\, g(\rho) d\rho \tag{2-4}$$

$$T(\rho) = \frac{v(\rho_{top}) \cdot T(\rho_{top})}{v(\rho)} + \frac{\bar{m}}{kv(\rho)} \int_{\rho}^{\rho_{top}} v(\rho)\, g(\rho) d\rho$$

In the above

- $p(\rho)$ is the atmospheric pressure
- $g(\rho)$ is the acceleration due to gravity
- k is Boltzmann's constant
- $\bar{m}$ is the mean molecular mass
- $n_t(\rho)$ is the total number density
- ρ is distance along the local vertical, and
- ρ_{top} is an adopted 'top' of the atmosphere.

Formal use of these equations requires *a priori* knowledge of the atmospheric composition.

2.4.2 Atmospheric Defocusing Effect

Atmospheric defocusing is caused by the gradient in refractivity with respect to radius. This distorts the shape of the beam by spreading it in the plane of the occultation and compressing it in the orthogonal direction. The refractive defocusing τ (dB) does not depend on frequency and is estimated from the ray path parameters and the occultation geometry by [Jenkins et al., 1994]:

$$\tau = 10\log\left(\cos\alpha - D\frac{d\alpha}{da}\right) \quad \text{(dB)} \qquad (2\text{-}5)$$

D being the distance from S/C to the crossing of the asymptotes (Fig. 2.4-1)

The defocusing effect was analyzed in [1], at minimum probed altitudes of ~38 km it can amount to approximately –30 dB [1].

2.4.3 Atmospheric Absorbtion

The Venusian lower atmosphere consists mainly of CO_2 and N_2 with small amounts of other gases. It has been shown, however, that the H_2SO_4 (g) abundance can become significant below an altitude of 50 km, reaching peaks between 18 and 24 ppm near 39 km before dropping precipitously below 38 km [Jenkins et al. 1994, 1995; Kolodner and Steffes 1998]. It was suggested that this sharp decrease confirms a thermal decomposition of sulfuric acid vapor below 39 km. Also, significant variations were found with Magellan from orbit to orbit indicating the presence of dynamical processes between 33 and 200 km.
The atmospheric absorption shows a frequency dependence ~ f^2 (S- vs. X-band). It can amount to approximately 2.2 dB (S-band)/15 dB (X-band) at a minimum probed altitude of ~38 km [1].
For the derivation of the proper atmospheric profiles it is intended to record the amplitude variations of the received radio signal, to correct it against orbital effects, ACS and defocusing effects. The corrected profiles will allow the estimation of the abundance and distribution of sulfuric acid vapor in the Venusian atmosphere.

2.4.4 Surface

There are several current mysteries regarding surface processes on Mars that can be addressed by bistatic radar study of the centimeter scale surface morphology, the variation in surface electrical properties, and/or a combination of these characteristics (Simpson 1993).
Observations of obliquely incident VeRa signals specularly reflected from the surface of Venus can provide insight into the surface roughness properties, and also clarify our understanding of its anomalous radio wave scattering properties, particularly the source of the apparent phase changes of materials in higher terrain. Three bistatic S-band measurements were carried out with Magellan 5 June 1994 [4.12] with a wavelength of 13 cm to illuminate a surface that traversed much lowland terrain, but

also passed over the high altitude low emissivity regions in the southeast of Maxwell Montes. Because of its high latitude, the angle of incidence (67°) was close to the Brewster angle (64°) for material having a dielectric constant of ~ 4.5 (Pettengil et al. 1996). As the footprint moved into the low-emissivity regions in Maxwell, however, the plane of the received polarization suddenly rotated through nearly 45°.The polarization angle was determined to be 3±6.9° at the edge of crater Cleopatra, implying a surface dielectric constant there of order 100. A particularly surprising result was the appearance over Maxwell of a component of right circularly polarized power corresponding to about 10 % of the total reflected signal. The amount of this component, the observed polarization angle, and the previously measured emissivity of ~ 0.33 place constraints on the electrical properties of the reflecting surface of the Maxwell Montes. The polarization results obtained with BSR (and not possible with the altimeter) lead to the conclusion that a thin coating of semi-conductor material could explain the observations. Pettengilll et al. 1996 noted that elemental tellurium has the necessary electrical properties to explain the radar results; its melting point (723 K) matches the altitude (6054 km) above which high reflectivity surfaces have been observed, suggesting that this trace component of volcanic eruptions on Earth may be cold-trapped on Venus peaks causing the to ‘glisten’ when illuminated by radar.

The geometry is illustrated in Fig. 2.4-2.

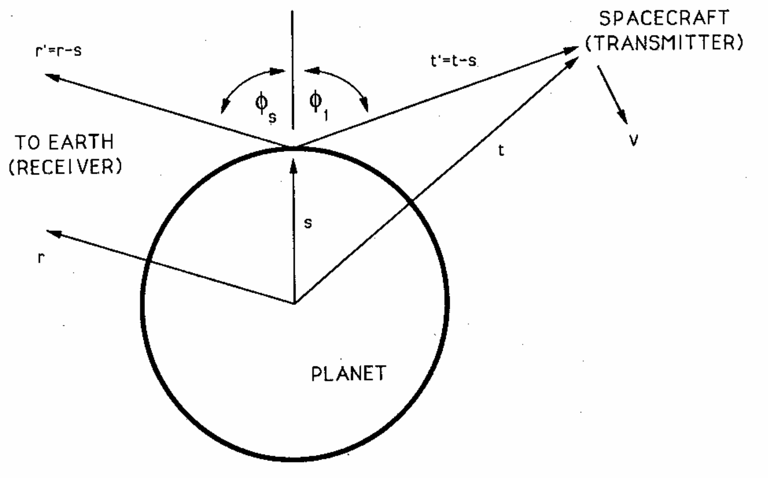

Figure 2.4.2: Bistatic Radar Scattering Geometry.

Radio transmissions from an orbiting spacecraft at T are directed towards the surface of Venus. In the experiment shown, the antenna direction (i.e. the S/C attitude) is manoeuvered so that the location on the surface is such that the angles of incidence and reflection are the same, as indicated. This choice resulting in a scanning action as the spacecraft source at T moves. An alternative choice is to direct the incident illumination towards a fixed location on the surface so that the angle of incidence is constantly changing, although the angle of reflection and the direction to the receiver on Earth is fixed. Scanning the surface at the angle of specular reflection (first choice) produces comparative data of areas along the track scanned with a geometry that allows separation of surface electrical properties and gross morphology. Fixed point observations allow observation of the scattering pattern over a range of incident geometries. “C/C” refers to the location of the center of curvature of Venus’ surface in the illuminated region.

3 Mission Characteristics

3.1 Science Objectives of the Venus Express Radio Science Experiment (VeRa)

As part of the Venus Express Orbiter payload, the Venus Express Radio Science experiment (VeRa) will perform the following experiments:

a) radio sounding of the neutral Venusian atmosphere (occultation experiment) to derive vertical density, pressure and temperature profiles as a function of height (height resolution better than 100 meter) above 35 km altitude,
b) radio sounding of the ionosphere (occultation experiment) to derive vertical ionospheric electron density profiles and to derive a description of the global behavior of the Venusian ionosphere through its diurnal and seasonal variations depending also on solar wind conditions,
c) determination of dielectric and scattering properties of the Venusian surface in specific target areas by a bistatic radar experiment,
d) radio sounding of the solar corona during the superior and inferior conjunction of the planet Venus with the Sun.

The radio links of the spacecraft TT&C subsystem between the orbiter and the Earth will be used for these investigations. A simultaneous and coherent dual-frequency downlink at X-band and S-band via the High Gain Antennas (HGA1) is required to separate the contributions from the classical Doppler shift and the dispersive media effects caused by the motion of the spacecraft with respect to the Earth and the propagation of the signals through the dispersive media, respectively.
The experiment relies on the observation of the phase, amplitude, polarisation and propagation times of radio signals transmitted from the spacecraft and received at ground station antennas on Earth. The radio signals are affected by the medium through which the signals propagate (atmospheres, ionospheres, interplanetary medium, solar corona), by the gravitational influence of the planet on the spacecraft and finally by the performance of the various systems involved both on the spacecraft and on ground.

3.2 Overview of the Instrument – Space Segment

3.2.1 General

The Venus Express Radio Science (VeRa) experiment will make use of the radio link between the orbiter and the ground station(s) on Earth. Frequency, amplitude and polarisation information will be extracted from the radio signal received in the ground station.

3.2.2 Block Diagram of the VEX Radio Subsystem

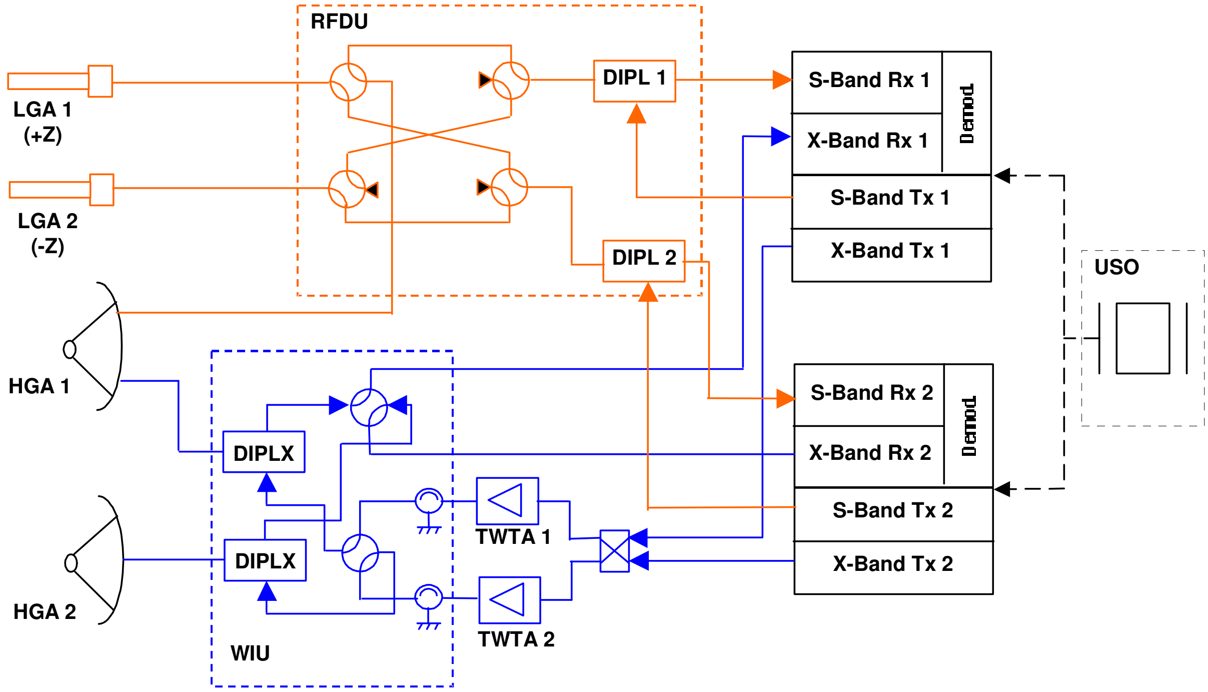

Figure 3.2.1: Principal block diagram of the VEX radio subsystem(In flight the USO is connected to TRSP 2 only)

The S-band uplink is received via the Low Gain Antennas (LGA) or the High Gain Antenna 1 (HGA 1). The HGA 2 will only be used during inferior solar conjunction phase when thermal constraints prohibit the use of HGA 1. HGA 2 can only receive and transmit at X-band.
The X-band uplink is received via both HGAs only. In the coherent two-way mode the received frequency is used to derive the downlink frequencies by using the constant transponder ratios 880/749 and 240/749 for X-band and S-band downlink, respectively. An X-band uplink will enhance the performance of the experiment because X-band is less sensitive to the interplanetary plasma along the propagation path.
The simultaneous and phase coherent dual-frequency downlink at X-band and S-band is transmitted via the HGA 1.The X-band and S-band frequencies are related by a factor of 11/3. If an uplink exists, the downlinks are also coherent with the uplink

by their respective transponding ratios. The dual-frequency downlink is required in order to separate the classical Doppler shift, due to the relative motion of the spacecraft and the ground station, from the dispersive media effects, due to the propagation of the radio waves through the ionosphere and interplanetary medium. It is also required that both frequencies are transmitted via the High Gain Antenna to maximise the signal-to-noise ratio.

An Ultrastable Oscillator (USO) is synchronizing both transponders to serve as a highly stable frequency reference source for operations in the one-way radio link mode which will be applied during atmospheric/ionospheric sounding and the bistatic radar observations.

3.2.3 Definition of Radio Links

3.2.3.1 Two-way radio link

The two-way dual-frequency radio link (Figure 3.2.3-1) is used for the gravity observations and coronal investigations. The radio link benefits from the superior frequency stability of the ground station provided by hydrogen masers.
The dual-frequency downlink at X-band and S-band is used to separate classical and dispersive Doppler shifts and therefore to correct the observed frequency shift by the plasma contribution due to the propagation through the interplanetary medium.

Two-way mode:

- X-band uplink
- S-band uplink as requested during solar conjunctions
- simultaneous and coherent S- and X-band downlink via the HGA 1
- S-band downlink only operational if radio science experiments are performed
- No telemetry and no ranging modulation at S-band; full RF power on carrier
- No telemetry and no ranging modulation at X-band; full RF power on carrier
- Dual-frequency ranging at S-band and X-band as requested

3.2.3.2 One-way radio link

The dual-frequency one-way radio link (Figure 3.2-2) at X-band and S-band will be used for the occultations and bistatic radar observations. It is driven by the Ultrastable Oscillator (USO) as a highly stable frequency reference source available to both transponders.

One-way mode:

- X-band downlink via the HGA1
- S-band downlink via the HGA 1
- simultaneous and coherent S- and X-band downlink via the HGA 1
- No telemetry and no ranging modulation at X-band; full RF power on carrier
- No telemetry and no ranging modulation at S-band; full RF power on carrier

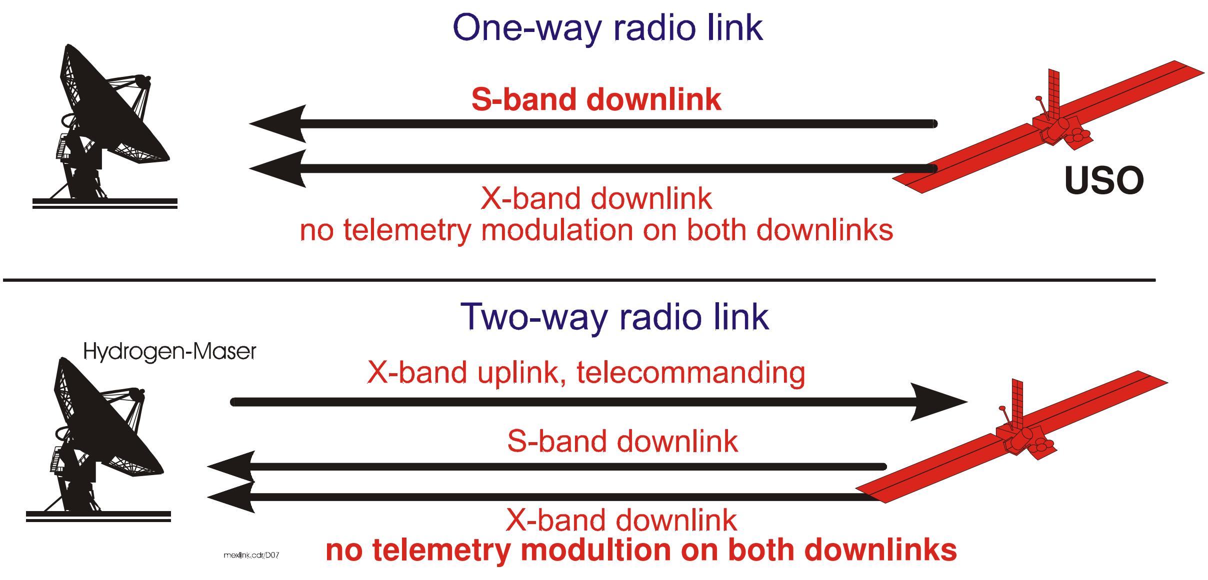

Figure 3.2-2: Proposed radio links between the orbiter and the ground station on Earth. Upper panel: one-way X-band downlink for bistatic radar. Lower panel: Two-way radio link where the uplink is transponded back phase-coherently at a dual-frequency downlink. The frequency stability is governed by an hydrogen maser located at the ground station.

3.2.3.3 Radio Link Budgets

The radio link budgets for VeRa are shown in chapter 10.1 (Appendix) for S- Band and in chapter 10.2 (Appendix) for X-band using NNO as ground station and the modified HGA1 as S/C antenna. We assumed a distance of 1.7 AU (worst case). A distance of 0.5 AU will result in a C/N improvement of ~ 10.6 dB.The use of DSS 63 (NASA) as ground station will contribute with an additional C/N improvement of 11.3 dB (S-band) and 10.8 dB (X-band) [1].
The anticipated Doppler and Range accuracies based on the link budget calculations assuming thermal noise contributions only are given in the following table.

Distance 1.7 AU	S-band NNO	X-band NNO	S-band DSS 63	S-band DSS 63
C/N_0 (dB Hz) No modulation	30.4	52.1	41.7	62.9
Doppler (t=1s) σ_v (m/s)	6.2 E-4	4.4 E-5		
Range (t=10s) σ_v (m)	1.2	3.5 E-2		

Table 3.2-1 : Doppler and range uncertainties to be expected for VEX/VERA when considering thermal noise contributions only (Distance 1.7 AU) (no atmospheric absorption or defocusing effect included)
Groundstation either NNO or NASA.

3.3 Overview of the Instrument – Ground Segment

3.3.1 Overview

Ground stations include antennas, associated equipment and operating systems in the tracking complexes of New Norcia (ESA, 35 m), Australia, and the Deep Space Network (NASA, 70m and 34 m) in California, Spain and Australia. A tracking pass consists of typically eight to ten hours of visibility, radio science activities last for typically one hour (occultations), two hours (bistatic radar) or up to six hours as requested for solar conjunctions. Measurements of the spacecraft range and carrier Doppler shift can be obtained whenever the spacecraft is visible. In the two-way mode the ground station transmits an uplink radio signal at S-band (if requested for solar conjunctions) or at X-band (nominal case) and receives the dual-frequency simultaneous downlink at X-band and S-band. The information about signal amplitude, received frequency and polarization is extracted and stored as a function of ground receive time.

3.3.2 Ground Stations

3.3.2.1 European Ground Stations

ESA has installed a new 35 m ground station at its complex in New Norcia, Australia. The current station baseline calls for an X-band or S-band uplink and a dual-frequency downlink at S-band and X-band capability. The station equipment consists of two regular ESA IFMS receivers (IFMS 1 and IFMS 2) and one dedicated IFMS radio science receiver (IFMS RS or IFMS 3).
The IFMSs are fully compatible with the requirements for one-way and two-way closed-loop recordings and will be upgraded in 2004 for dual-frequency ranging and open-loop recordings.

3.3.2.2 Deep Space Network

The DSN ground stations provide uplinks at S-band or X-band and a full scale radio science equipment used for most of the NASA missions.
It should be emphasized that the feasibility of the two-way measurements do not depend on the uplink frequency. The two data types, closed-loop and open-loop, can be generated simultaneously regardless of the radio link configuration, one-way or two-way.
The open-loop equipment is capable to receive one frequency at two polarizations (LCP and RCP) or two frequencies at one polarization (LCP or RCP). The reception of two frequencies at two polarization (four channels) each is only feasible at the 70-m ground stations.

3.3.3 Required Ground Station Capabilities

The following required ground station capabilities are supported by the new IFMS systems at Perth and the DSN:

1. X-band uplink transmission
2. S-band uplink transmission
3. S-band downlink reception
4. X-band downlink reception
5. S,X-band downlink simultaneous reception
6. Doppler sample rates: 1000, 100, 10, 1, 0.1 samples/sec. (to be selected by VeRa)
7. OL sampling of RHC and LHC X-band signals
8. OL sampling of RHC and LHC S-band signals
9. X/S ranging
10. X/X ranging
11. S/X ranging
12. S/S ranging
13. X/S and X/X simultaneous ranging (starting in 2004)
14. S/S and S/X simultaneous ranging (starting in 2004)
15. ranging sample rates: 1..120 sec., 1 sec. Steps
    Monitoring and recording of S, X-band AGC, sample rates 60, 10, 1, 0.1 samples/s
16. Digitally recording of RHC and LHC signals at S-band or X-band (starting in 2004)
17. Digitally recording of RHC signals at S-band and X-band (starting in 2004)

3.4 Data Products

3.4.1 Introduction

A thorough description of the VeRa data products from level 1a to level 2 can be found in the Rosetta/Mars Express/Venus Express Archive Plan [1] and the Rosetta/Mars Express/Venus Express File Naming Convention Document [2].

3.4.2 Data types

3.4.2.1 Closed-loop data

Closed-loop data acquisition is done with a phase-locked loop receiver at the ground station. Two-way Doppler shifts are extracted by comparing each measure of the downlink carrier frequency from the phase-locked loop with a reference from the ground station frequency reference source, e.g. a hydrogen maser with a frequency stability in the order of 10^{-15} to 10^{-16} . Because this frequency reference source is also used for the generation of the uplink carrier, the accuracy of the frequency determination is as good as the reference source. The Doppler integration time needed to achieve a certain signal to noise ratio controls the time between successive frequency determinations. The amplitude of the radio signal is estimated by the Automatic Gain Control (AGC).

3.4.2.2 Open-loop data

Open-loop data recording is done by filtering and down-converting the received radio carrier signal to baseband where it is A/D converted and stored for subsequent analysis. The open-loop receiver is tuned by a local oscillator. The frequency of the local oscillator onboard the S/C is defined ~~given~~ by the best available estimate of the carrier frequency transmitted by the spacecraft and applying Doppler corrections due to the relative S/C-to-Earth motion. The drift of the USO output frequency will be known by long term measurements on ground and will be controlled by inflight calibration.

The specification of the Open Loop Data recording is given as below (Table 3.4.-1)

Radio Science Parameters (Venus) Open Loop Recording
(see VeRa Flight user Manual for more details such as Closed Loop Recordings)

Experiment		Frequencies uplink	Frequencies downlink		Doppler X-Band (caused by Venusian atmospheric effects) *	Open Loop Sample rate	Received Polarisations
Occultation	One Way	-	S and X		ca. ± 45 kHz**	200 ksamples/s *4	RCP
	Two Way	X	S and X	coherent	ca. ± 90 kHz ***	400 ksamples/s *4	RCP
Bistatic Radar	One Way	-	S and X			50 ksamples/s	RCP, LCP at S_and X-Band
Gravity *5	Two Way	X	S and X	coherent		-	
Solar Corona*5	Two Way	S	S and X	coherent		5 ksamples/s	RCP, LCP at S_and X-Band

Table 3.4-1: Possible Transmission and Receiving modes for Open Loop recording

* ± means: + for occultation start (ingress) and – for occultation end (egress)
This effect does not include the Doppler effect caused by orbital motion only (vacuum case)

** Estimated maximum Doppler contribution
S-Band Doppler has to be scaled by 3/11.

*** Estimated maximum Doppler contribution
X up S down: $\Delta f \approx 45$ kHz + 3/11 * 45 kHz = 57.3 kHz
This mode is presently not foreseen for VeRa

*4 Occultation sample rate can be extremely reduced if the Doppler predict in the ground station includes the Doppler caused by the atmospheric effects at Venus (assuming the Magellan standard atmosphere)

*5 only closed loop recording

3.4.3 Data required from ESOC

3.4.3.1 Observation data from the IFMS

The radio science observation data are recorded in the ground station by the IFMS systems. Depending on the ground station configuration up to three IFMS may record radio science data.
The Radio Science IFMS is an integral part of the receiving system at the ESA ground station. Its configuration has to fulfill the requirements of the Radio Science experiments, it can however serve also as a complementary and redundant unit for ESA´s prime receiving units.
The following tables show the likely configuration scenarios for the IFMS system. All Doppler and ranging measurements must be performed by the standard ESA IFMS units with two downlink frequencies (TWOD) in order to allow compensation for the ionospheric/interplanetary TEC contribution.
In all cases requiring the Radio Science IFMS in OL mode operation, no telemetry modulation shall be applied to the downlink carrier analysed by the Radio Science IFMS in order to preserve spectral cleanliness as much as possible.
Also, as a highly desirable option, scenarios are suggested which require in addition to the Radio Science IFMS either IFMS A or IFMS B.

IFMS Configurations

As agreed with ESOC the three IFMS in Perth are configured as:

- IFMS A: X-band uplink, X-band downlink coherent, closed-loop (standard configuration)
- IFMS B: serves primarily as baxk up for IFMS A, can be configured operational as requested by VeRa
- IFMS RS:as requested by VeRa

For the solar corona observations, the uplink at IFMS-A is requested as S-band and IFMS-A and IFMS-B downlink receivers are configured as S-band. IFMS-RS is then configured for X-band.
If IFMS A is not operational, IFMS B is set in standard configuration and is then not available for specific requested configurations by VeRa.
IFMS configurations for the various radio links are listed in section 4.2.

3.4.3.2 IFMS Data files

Closed-loop data:

Receiver system	Data type	
IFMS-A	Doppler 1 Doppler 2 AGC 1 AGC 2 Range Meteo	
IFMS-B	Doppler 1 Doppler 2 AGC 1 AGC 2	
IFMS-RS	Doppler 1 Doppler 2 AGC 1 AGC 2 Range (starting in 2004)	
Sample rate	To be selected by VeRa	s^{-1}

Before and after the pass a range calibration of the IFMS equipment is requested.

Open-loop data:

Receiver system	Data type	
	Tbd (starting in 2004)	V V
Sample rate	100 ksamples/s	s^{-1}

3.4.3.3 IFMS file names

The requested data file names from each operating IFMS at the NNO 35 m ground station have the following format:

NN1n_ssss_ddd_dk_dt_hhmmss_xxxxx

Identifier	Explanation	Options
n	Number of the operating IFMS	1 uplink providing IFMS 2 back-up IFMS 3 RS IFMS
ssss	Spacecraft acronym	VEX1 = Venus Express
ddd	Day of year	
dk	Data kind	OP = operational CL = calibration TS = test
dt	Data type	D1 = Doppler 1 D2 = Doppler 2 RG = ranging G1 = AGC 1 G2 = AGC 2 MT = meteo
hhmmss	Start time in hours, minutes, seconds	
xxxxx	Data set sequence ID	Starting with 00001

3.4.3.4 Observation data from the DSN

3.4.3.4.1 Archival Tracking Data Files (ODF)

TBD

3.4.3.4.2 Radio Science Receiver Data (RSR)

TBD

3.4.3.5 Anciliary Data

The required and requested ancillary data are listed in the Rosetta/Mars Express/ Venus Express File Naming Convention Document [2].

3.4.3.6 Spacecraft Housekeeping Data

To be specified

3.4.3.7 Data Volume

Estimate of the data volume (order of magnitude numbers):

closed-loop:

IFMS	Calculation (bytes)	One hour data recording @ 1 second sampling time
Overhead		18 kBytes
Ranging	110 x number of samples /hour	396 kBytes
Doppler	220 x number of samples/hour	792 kBytes
Meteo	100 x number of samples/hour	6 kbytes (1 min sampling time)

DSN ODF	Calculation (bytes)	One hour data recording @ 1 second sampling time
Ranging Doppler	288 x number of samples/hour	1036 kBytes

Open-loop (I+Q Channels):

IFMS	Calculation (bytes)	Event volume
	36 Mbyte/min	2.2 Gbyte/1 hour

DSN RSR	Calculation (bytes)	Event volume (tracking pass)
Bistatic radar	36 Mbyte/min	2.2 Gbyte total (duration 1 hour)
Solar corona	3.6 Gbyte/min	864 Mbytes total 4 hours

3.4.4 End-to-end performance

Tbd
Will be updated after the analysis of the Venus Express commissioning data.

3.4.4.1 Doppler accuracy for longer integration times

Tbd
Will be updated after the analysis of the Venus Express commissioning data.

4 Experiment Operations

4.1 Overview of Experiment Observation Modes

4.1.1 Science Operations

Radio science operations can only be requested when ground station coverage is available. Ground station visibility will be correlated with spacecraft orbits using request files as defined in section 7. Radio science ops requests will focus on those orbits which are covered by ground station availability. Radio Sounding of the atmosphere and ionosphere, bistatic radar experiments, and gravity measurements shall not take place during epochs of superior conjunctions. Further, no gravity measurements shall be performed while being in an Earth occultation.

4.1.2 Radio Sounding of the Atmosphere and Ionosphere

The sounding of the neutral and ionized atmosphere is performed before the spacecraft enters the occultation with the planet. The High Gain Antenna 1 (HGA 1) is pointed toward the Earth an adequate time (approx. 10 to 15 minutes) before entering occultation. The radio link is twoone-way dual-frequency downlink (ONETWOD) with unmodulated carriers. For deep occultations where the S/C, the Earth and the planet are located nearly in one plane, the radio frequency ray performs a vertical swath through the atmosphere from an altitude of approximately 1000 km towards low atmospheric altitudes (minimum altitude ~ 33 km, “height of superrefraction”) and a slew around the planet before leaving the atmosphere in the opposite hemisphere. For “grazing” occultations the ray describes a conical motion through the atmosphere. In both cases the HGA 1 must be pointed such that the ray bending effects are compensated.

4.1.3 Gravity Field

Orbit perturbations by the Venusian gravity field can be extracted from precise two-way dual-frequency radio tracking (TWOD) during pericenter passes. For this configuration, the HGA 1 is pointed toward the Earth.

4.1.4 Bistatic Radar

The bistatic radar configuration is distinguished from the monostatic configuration (e.g. the onboard radar is monostatic) by the spatial separation of the transmitter (the spacecraft via the HGA) and the receiver on the ground (Earth). The HGA is inertially pointed toward the surface of Venus and a one-way X-band signal without modulation (full power on carrier) is transmitted (ONES). Several passes above specific targets are requested. It is recommended to use one of the DSN ground station for the recording of the echo signal because of their higher SNR.

4.1.5 Solar Corona

From tbd to tbd and from tbd to tbd, Venus is within 10° elongation about the solar disk in the plane-of-sky at superior and inferior solar conjunction, respectively. The operational radio link for the sounding of the solar corona is the two-way dual-frequency radio link (TWOD) when ever the spacecraft is tracked for data return.

4.2 Definitions and Configurations

4.2.1 Spacecraft and Ground Station configurations

Two main spacecraft and ground station configurations are used: ONE and TWO describing one-way radio downlink(s) and two-way radio links, respectively. Further details are added to the acronyms as:

- S = single frequency downlink
- D = dual-frequency downlinks
- TCXO = driven by the transponder oscillator
- USO = driven by the onboard Ultrastable Oscillator
- -S = S-band uplink
- -X = X-band uplink

The present plan foresees the test of the VeRa experiment using seperatially both transponders. In case the USO will be connected only to one transponder, the test duration will be shortened accordingly.

4.2.2 ONES

This configuration acronym describes the X-band one-way downlink driven by the TXCO or the USO, ONES-TCXO or ONES-USO, respectively.

4.2.2.1 ONES-TCXO

Spacecraft

Mode	Uplink	downlink	RNG	TM	Driven by
One-way	n/a	X-band	OFF	selectable	TCXO

Ground station

IFMS	Uplink	downlink	Sample rates (sec^{-1})					
			RNG	DOP1	DOP2	AGC1	AGC2	METEO
1	n/a	X-band	OFF	10	10	10	10	0.016
2	-	X-band	-	10	10	10	10	
3	-	X-band	-	10	10	10	10	

4.2.2.2 ONES-USO

Spacecraft

Mode	Uplink	downlink	RNG	TM	Driven by
One-way	n/a	X-band	OFF	selectable	USO

Ground station

IFMS	Uplink	downlink	Sample rates (sec^{-1})					
			RNG	DOP1	DOP2	AGC1	AGC2	METEO
1	n/a	X-band	OFF	10	10	10	10	0.016
2	-	X-band	-	10	10	10	10	
3	-	X-band	-	10	10	10	10	

4.2.3 ONED

4.2.3.1 ONED-TCXO

Spacecraft

Mode	Uplink	downlink	RNG	TM	Driven by
One-way	n/a	X-band S-band	OFF OFF	Selectable Selectable	TCXO TCXO

Ground station

IFMS	Uplink	downlink	Sample rates (sec^{-1})					
			RNG	DOP1	DOP2	AGC1	AGC2	METEO
1	n/a	X-band	OFF	10	10	10	10	0.016
2	-	X-band	-	10	10	10	10	
3	-	S-band	-	10	10	10	10	

4.2.3.2 ONED-USO

Spacecraft

Mode	Uplink	downlink	RNG	TM	Driven by
One-way	n/a	X-band S-band	OFF OFF	Selectable Selectable	USO USO

Ground station

IFMS	Uplink	downlink	Sample rates (sec^{-1})					
			RNG	DOP1	DOP2	AGC1	AGC2	METEO
1	n/a	X-band	OFF	10	10	10	10	0.016
2	-	X-band	-	10	10	10	10	
3	-	S-band	-	10	10	10	10	

4.2.4 TWOS

Spacecraft

Mode	Uplink	downlink	RNG	TM	Driven by
Two-way coherent	X-band	X-band	ON	Selectable	G/S

Ground station

IFMS	Uplink	downlink	Sample rates (sec^{-1})					
			RNG	DOP1	DOP2	AGC1	AGC2	METEO
1	X-band	X-band	ON	1	1	1	1	0.016
2	-	X-band	-	1	1	1	1	
3	-	X-band	-	1	1	1	1	

4.2.5 TWOD

4.2.5.1 TWOD-X

Spacecraft

Mode	Uplink	downlink	RNG	TM	Driven by
Two-way coherent	X-band	X-band S-band	ON ON	Selectable Selectable	G/S

Ground station

IFMS	Uplink	downlink	Sample rates (sec^{-1})					
			RNG	DOP1	DOP2	AGC1	AGC2	METEO
1	X-band	X-band	ON	1	1	1	1	0.016
2	-	X-band	-	1	1	1	1	
3	-	S-band	-	1	1	1	1	

4.2.5.2 TWOD-S

Spacecraft

Mode	Uplink	downlink	RNG	TM	Driven by
Two-way coherent	S-band	X-band S-band	ON ON	Selectable Selectable	G/S

Ground station

IFMS	Uplink	downlink	Sample rates (sec^{-1})					
			RNG	DOP1	DOP2	AGC1	AGC2	METEO
1	S-band	S-band	ON	1	1	1	1	0.016
2	-	S-band	-	1	1	1	1	
3	-	X-band	-	1	1	1	1	

4.3 Operations

4.3.1 TVT Tracking Verification Test

Purpose: Check-out of the space and ground segment at various configurations and geocentric distances; determination of the radio link quality

S/C Configuration: TWOS; TWOD
ONES; ONED
Ground Seg. Config.: TWOS-CL; TWOD-OL
ONES-CL; ONES-OL
ONED-CL; ONED-OL
open-loop in RCP and LCP
Execution: Commissioning phase (after launch and at Venus arrival)
Requirements: No S/C orbit correction within TVT

4.3.2 UCT USO Commissioning Test

Purpose: USO check out

S/C Configuration: ONES; ONED
Ground Segment Config.: ONES-CL; ONED-CL
ONES-OL ; ONED-OL
Execution: During S/C Commissioning Phase after launch and repeated periodically (TBD) during cruise
Requirements: No S/C orbit correction within UCT
Logging of thruster activities

4.3.3 GRA Gravity Mapping of Anomalies

Purpose: Venus Local Gravity Field Anomalies

S/C Configuration: TWOD[1]
Ground Seg. Config.: TWOD-CL
Execution: during nominal observation phase (pericenter passes)
Requirements: HGA Earth pointing
No S/C orbit correction within GRA
Minimum thruster activity and logging of thruster activity

4.3.4 OCC Occultation Procedures

Purpose: sounding of neutral and ionized atmosphere prior to entering occultation and after exiting occultation

S/C Configuration: ONED when entering occultation

---

[1] TWOS acceptable in case of power problems

ONED when exiting occultation
Ground Seg. Config.: ONED-CL when entering occultation
ONED-OL when entering occultation
ONED-OL when exiting occultation
ONED-CL when exiting occultation
Execution: prior to occultation entry and after occultation exit
Constraint: executed once per orbit if occultation entry is within nominal observation phase
executed every orbit if occultation entry is within nominal communication phase
execution must be correlated with ground station visibility

Requirements:

No telemetry modulation at both downlinks
No orbit correction within OCC

4.3.5 BSR Bistatic Radar procedure

Purpose: Venus surface properties

S/C Configuration: ONED
Ground Seg. Config.: ONED-OL at RCP and LCP
Execution: Planned bistatic radar procedure
Repeated periodically (TBD) during mission
Requirements: Pointing of HGA toward the planetary surface
Recording of RHC and LHC radio signals at the ground station
No orbit correction during BSR

4.3.6 SCP Solar Conjunction Procedures

Purpose: Radio sounding of the solar corona at inferior and superior solar conjunction

S/C Configuration: TWOD; S-band uplink
Ground Seg. Config.: TWOD-CL; TWOD-OL
Execution: tbd
Executed during nominal communication phase
Requirements: Daily tracking passes
S-band uplink

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Functions

5.1 Functions: Space Segment

5.1.1 Design and Functional Description of the RF Subsystem

Block diagrams of the characteristic elements of the Venus Express radio subsystem are shown in Figure 5.1-1.

Venus Express is capable of receiving and transmitting radio signals via two dedicated antenna systems:1. High Gain Antenna 1 (HGA 1), a body-fixed parabolic dish of 1.30 m diameter (X+S band)2. High Gain Antenna 2 (HGA 2), a body fixed parabolic dish of tbd m diameter to be used during inferior solar conjunction phase (X-band only)

3. Two Low Gain Antennas (LGA), front and rear, S-band only

The two transponders consist of an S-band and X-band receiver and transmitter each. The spacecraft is capable of receiving one uplink signal at S-band (2100 MHz) via the LGAs, or at either X-band (7100 MHz) or S-band via the HGA. The spacecraft can transmit via the HGA simultaneously two downlink signals at S-band (2300 MHz) and X-band (8400 MHz) or one downlink signal at S-band via the LGAs.

Both HGAs are the main antennas for receiving telecommands from and transmitting telemetry signals to ground. The LGAs are used during the commissioning phase after launch and for emergency operations.

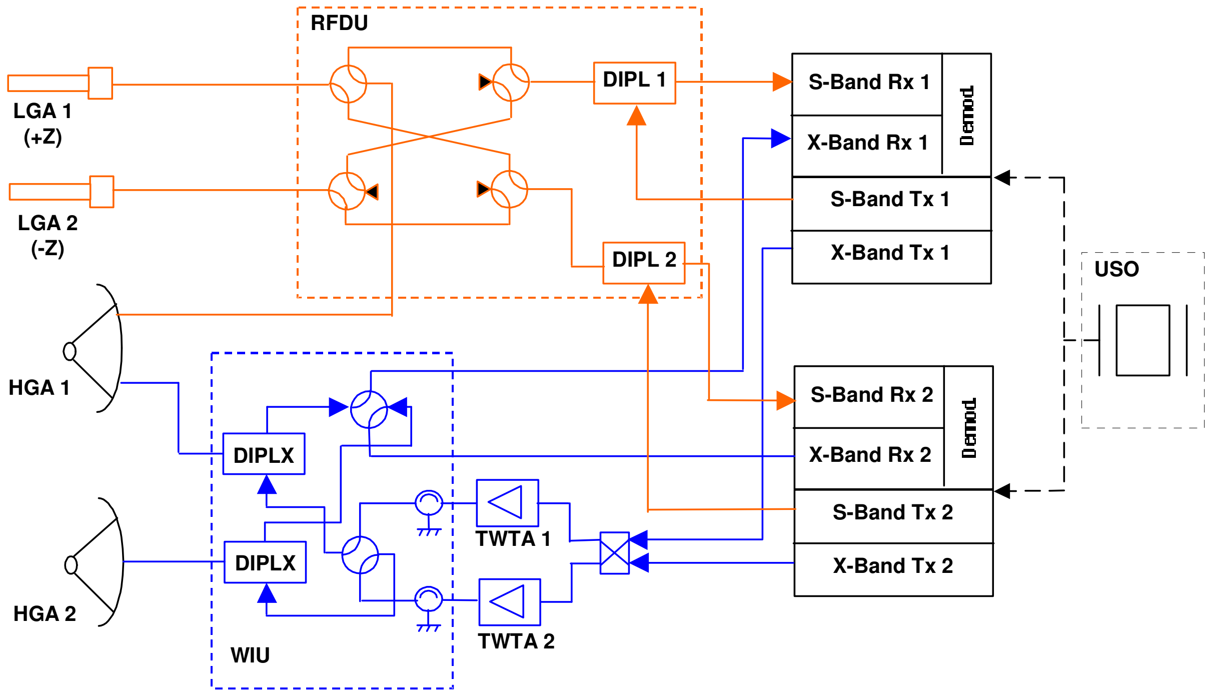


Figure 5.1-1: Principal block diagram of the VEX radio subsystem.
(In flight the USO is disconnected from TRSP 1)

The S-band uplink is received via the Low Gain Antennas (LGA) or the High Gain Antenna 1 (HGA 1). In the coherent two-way mode the received frequency is used to derive the downlink frequencies by using the constant transponder ratios 880/221 and 240/221 for X-band and S-band downlink, respectively.
The X-band uplink is received via the HGA 1 or HGA 2 only. In the coherent two-way mode the received frequency is used to derive the downlink frequencies by using the constant transponder ratios 880/749 and 240/749 for X-band and S-band downlink, respectively. An X-band uplink will enhance the performance of the experiment because X-band is less sensitive to the interplanetary plasma along the propagation path.

5.1.2 New Norcia Ground Station (NNO)

5.1.2.1 Overview IFMS

The dedicated Radio Science IFMS is an integral part of the receiving system at the ESA ground station. Its configuration has to fulfill the requirements of the Radio Science experiments, it can however serve also as a complementary and redundant unit for ESA´s prime IFMS receiving units.

5.1.2.2 System Description

According to MEX-MRS-IGM-RS-3014 the following assumptions can be made with regard to the IFMS systems in the ground station:

1. The New Norcia ground station near Perth, Australia, is equipped with two standard (operational) IFMSs and a third IFMS unit dedicated to the Radio Science observations
2. Two polarizations can be analyzed by one IFMS
3. Two downlink carriers at S-band and X-band can be received simultaneously, only one carrier will be modulated with telemetry
4. One, alternatively also two downlink carriers, modulated with ranging signals can be received
5. Radio science open-loop measurements will be carried out simultaneously at S- and X-band with one polarization.[2]

The IFMS block diagram is shown in
Figure 5.1-2. The configuration change from standard CL configuration to OL configuration will not involve any hardware changes. A schematics including the digital signal processing part relevant for VeRa is shown in Figure 5.1-4.

[2] There is the certain risk that there is no G/S equipment redundancy when performing radio science observations. The IFMS can quickly be reconfigured in the case of problems, so that that risk can be tolerated.

Figure 5.1-2: IFMS block diagram

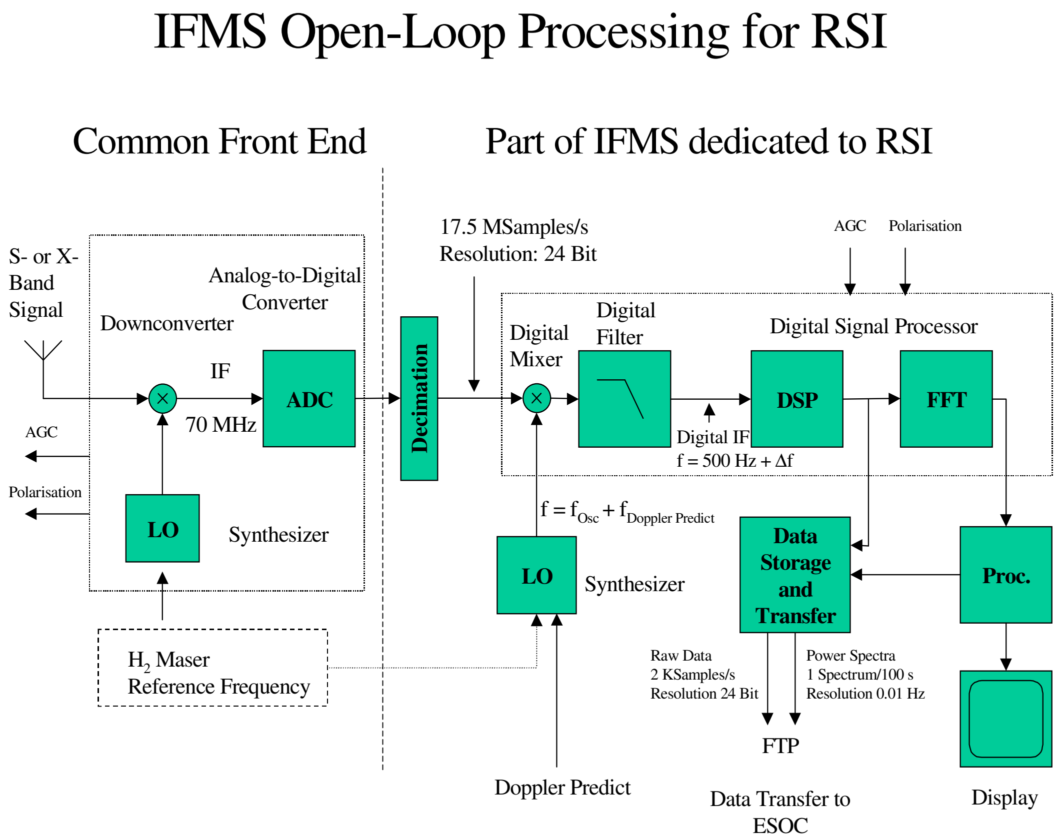


Figure 5.1-3: IFMS Open-Loop Digital Data Processing Part for VeRa

It is assumed that the IFMS operates on a 17.5 Msps 24-bit complex baseband stream (containing 12 bit words each for the I and Q channels) and resulting from filtering and decimating the 280 Msps 8-bit stream output by the Common Front End (CFE) Analogue to Digital converter. These channels are provided for both RCP and LCP polarisations.
The Radio Science raw data can be directly transferred to a mass storage device and/or processed by a Fast Fourier routine.
Data transfer rates from DSP to Data Storage (disk) is presently limited to 10 samples/s. Data Transfer to ESOC shall be done via FTP with a rate of 2 ksps.
The Doppler predict has to be accurate enough to allow carrier signal analysis in the desired narrow frequency band.
The internally generated raw data stream consists of I and Q signals which are distributed on 8 parallel bits each for both left- and right-hand polarized signals which can be processed further and routed to a data dump and storage device.
("PC" configured for MaRS/RSI, see also Fig. 5.1-4) in order to obtain higher data rates. Here, the absolute maximum data rate is limited to 10 Mb/s. The incoming signals will be further processed in a diversity combiner providing the combined output together with an estimate for the electrical phase angle (MEX-MRS-IGM-RS-3014).

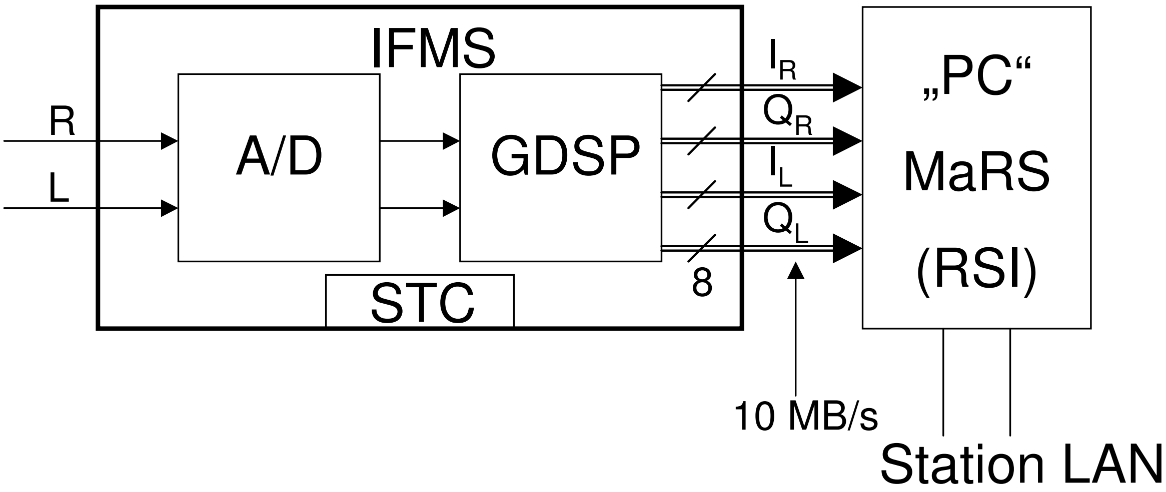


Figure 5.1-4: IFMS internal signal processing. The 8 bit resolution will be replaced by a 12 resolution

VeRa requires both the preservation of raw data for later data retrieval and the near real time data processing and conversion. These requests are further specified in section6.

5.1.2.3 IFMS Configurations

The following tables show the likely configuration scenarios for the IFMS system when Radio Science experiments will be conducted. All dual-frequency Doppler and ranging measurements must be performed by the standard ESA IFMS units together with the radio science IFMS RS with two downlink frequencies (TWOD) in order to allow compensation for the ionospheric/interplanetary TEC contribution.
The listed scenarios show that for all radio science operational cases , no telemetry modulation shall be applied to the downlink carrier analysed by the IFMS in order to preserve spectral cleanliness as much as possible.

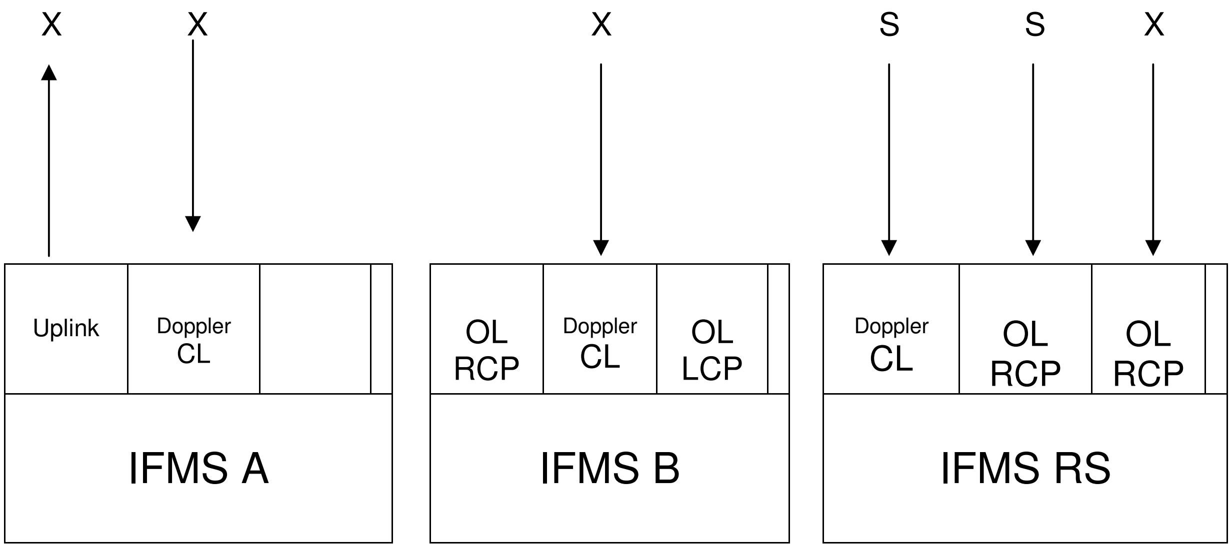
The following standards have been agreed with ESOC:

- IFMS A is always in the standard configuration: X-band uplink; X-band downlink; two-way coherent; single frequency ranging
- IFMS B is receiving X-band downlink and can be reconfigured quickly as uplink provider in case of the failure of IFMS A
- IFMS RS can be configured as requested by VeRa

Table 5.1-1: IFMS receiver system scenario 1

Functional use: occultations (atmosphere/ionosphere sounding)

Scenario1	IFMS A	IFMS B	Radio Science IFMS
Uplink Frequency	-	-	-
Downlink frequency	X-CL	X-CL RCP	S-CL S-OL, X-OL RCP
Telemetry modulation	Off	Off	Off
Observational parameters	Doppler AGC Meteo	Doppler AGC	Doppler, AGC Open loop samples RHC

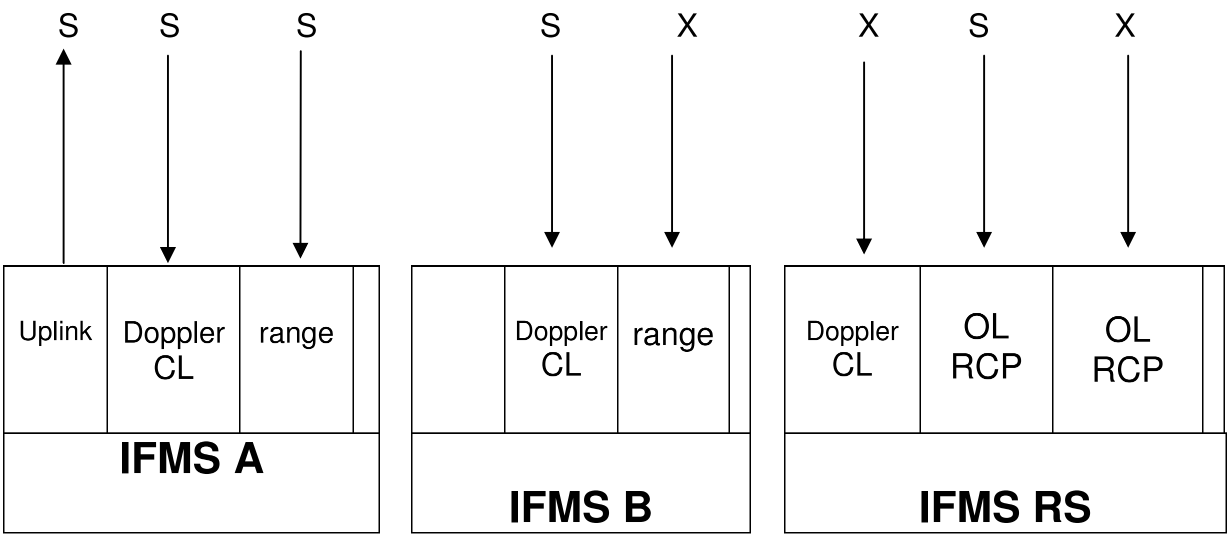


IFMS configurations for occultations (atmospheric/ionospheric sounding)

Table 5.1-2: IFMS receiver system scenario 2

Functional use: solar corona sounding

Scenario 2	IFMS A	IFMS B	Radio Science IFMS
Uplink Frequency	S	-	
Downlink frequency	S-CL	S-CL	X-CL S-OL & X-OL RCP
Telemetry modulation	Off (TBC)	Off (TBC)	Off (TBC)
Observational parameters	Doppler, Ranging AGC Meteo	Doppler AGC	Doppler, Ranging open-loop samples



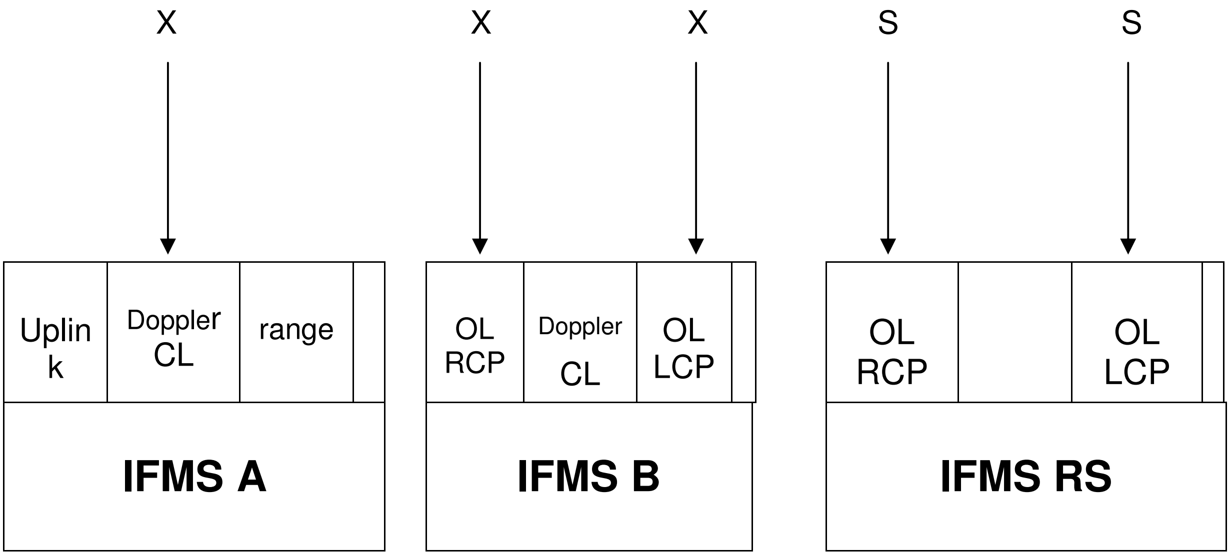
IFMS configurations for solar corona sounding

Note: Presently, the dual frequency ranging capability is not installed at NNO.

Table 5.1-3: IFMS receiver system scenario 3

5.1.2.3.1.1.1.1.1 Functional use: bistatic radar

Scenario 3	IFMS A	IFMS B	Radio Science IFMS
Uplink Frequency	-	-	-
Downlink frequency	X-CL	X-CL RCP and LCP	S-OL RCP and LCP
Telemetry modulation	Off	Off	Off
Observational parameters	Doppler AGC Meteo	Amplitudes RCP and LCP	Amplitudes RCP and LCP



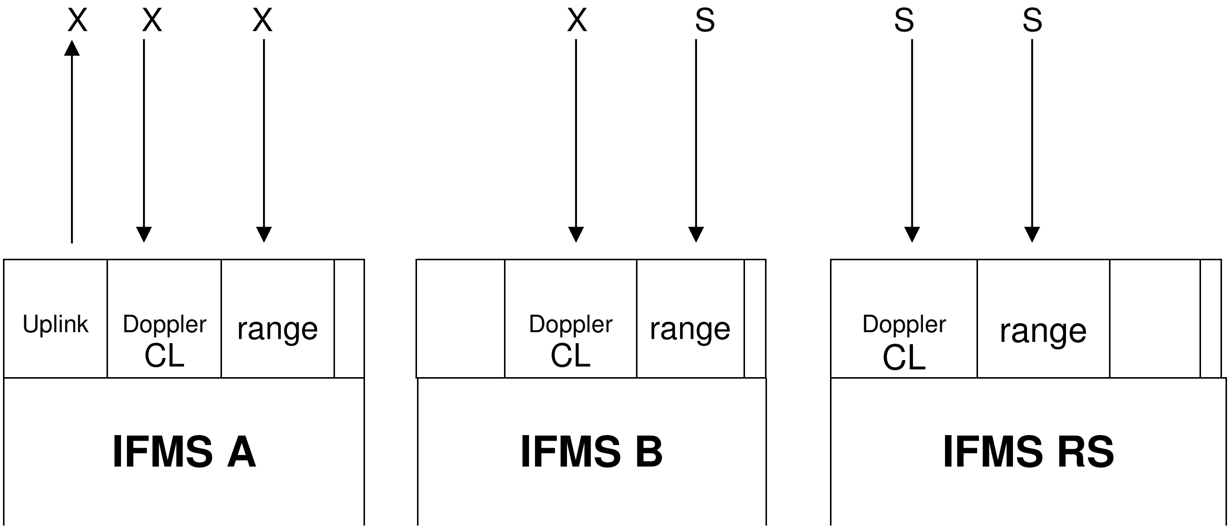
IFMS configurations for bistatic radar

Note: Open loop recording for both frequencies and both polarizations presently not installed at NNO.

Table 5.1-4: IFMS receiver system scenario 4

Functional use: planetary gravity field

Scenario 4	IFMS A	IFMS B	Radio Science IFMS
Uplink frequency	X	-	-
Downlink frequency	X-CL	X-CL	S-CL
Telemetry modulation	Off	Off	Off
Observational parameters	Doppler, Ranging AGC Meteo	Doppler AGC	Doppler, Ranging AGC



IFMS configurations for gravity (ranging to be performed shortly befor and after the gravity measurements)

Note: Presently, the dual frequency ranging capability is not installed at NNO.

5.1.3 Deep Space Network

5.1.3.1 Overview

Three Deep Space Communications Complexes (DSCCs) (near Barstow, CA; Canberra, Australia; and Madrid, Spain) comprise the DSN tracking network. Each complex is equipped with several antennas [including at least one each 70-m, 34-m High Efficiency (HEF), and 34-m Beam WaveGuide (BWG)], associated electronics, and operational systems. Primary activity at each complex is radiation of commands to and reception of telemetry data from active spacecraft. Transmission and reception is possible in several radio-frequency bands, the most common being S-band (nominally a frequency of 2100-2300 MHz or a wavelength of 14.2-13.0 cm) and X-band (7100-8500 MHz or 4.2-3.5 cm). Transmitter output powers of up to 400 kW are available

Ground stations have the ability to transmit coded and uncoded waveforms which can be echoed by distant spacecraft. Analysis of the received coding allows navigators to determine the distance to the spacecraft; analysis of Doppler shift on the carrier signal allows estimation of the line-of-sight spacecraft velocity. Range and Doppler measurements are used to calculate the spacecraft trajectory and to infer gravity fields of objects near the spacecraft.

Ground stations can record spacecraft signals that have propagated through or been scattered from target media.

The Deep Space Network is managed by the Jet Propulsion Laboratory of the California Institute of Technology for the U.S. National Aeronautics and Space Administration.

For more information on the Deep Space Network and its use in radio science see reports by Asmar & Renzetti (1993), Asmar & Herrera (1993), and Asmar et al (1995). For design specifications on DSN subsystems see [DSN810-5].

5.1.3.2 DSN Radio Science Equipment

The Deep Space Communications Complexes (DSCCs) are an integral part of Radio Science instrumentation, along with the spacecraft Radio Frequency Subsystem. Their system performance directly determines the degree of success of Radio Science investigations, and their system calibration determines the degree of accuracy in the results of the experiments. The following paragraphs describe the functions performed by the individual subsystems of a DSCC. This material has been adapted from Asmar & Herrera (1993) and [JPLD-14027]; for additional information, consult [DSN810-5]. Each DSCC includes a set of antennas, a Signal Processing Center (SPC), and communication links to the Jet Propulsion Laboratory (JPL). The general configuration is illustrated in Figure 5.1-5; antennas (Deep Space Stations, or DSS—a term carried over from earlier times when antennas were individually instrumented) are also listed in the figure.

```
   --------   --------   --------   --------   --------
| DSS 25 | | DSS 27 | | DSS 14 | | DSS 15 | | DSS 16 |
|34-m BWG| |34-m HSB| |  70-m  | |34-m HEF| |  26-m  |
   --------   --------   --------   --------   --------
       |            |     |             |          |
       |            v     v             |          v
       |           ---------            |      ---------
        --------->|GOLDSTONE|<----------      |EARTH/ORB|
                  | SPC  10 |<--------------->|   LINK  |
                   ---------                   ---------
                  |   SPC   |<--------------->|   26-M  |
                  |  COMM   |          ------>|   COMM  |
                   ---------         |         ---------
                       |             |             |
                       v             |             v
     ------        ---------         |         ---------
    | NOCC |<--->|   JPL   |<-------          |         |
     ------      | CENTRAL |                  |   GSFC  |
     ------      |   COMM  |                  | NASCOMM |
    | MCCC |<--->| TERMINAL|<---------------->|         |
     ------        ---------                   ---------
                                                ^     ^
                                                |     |
            CANBERRA (SPC 40) <-----------------      |
                                                      |
```

MADRID (SPC 60) <----------------------

Antenna	GOLDSTONE SPC 10	CANBERRA SPC 40	MADRID SPC 60
26-m	DSS 16	DSS 46	DSS 66
34-m HEF	DSS 15	DSS 45	DSS 65
34-m BWG	DSS 24	DSS 34	DSS 54

DSS 25

DSS 26
34-m HSB DSS 27

DSS 28

70-m	DSS 14	DSS 43	DSS 63
Developmental	DSS 13		

Figure 5.1-5: DSN Network

Subsystem interconnections at each DSCC are shown in figure Figure 5.1-6, and they are described in the sections that follow. The Monitor and Control Subsystem is connected to all other subsystems;

```
 -----------   ------------------   ---------   ---------
|TRANSMITTER| |                  | | TRACKING| | COMMAND |
| SUBSYSTEM |-| RECEIVER/EXCITER |-|SUBSYSTEM|-|SUBSYSTEM|-
 -----------  |                  |  ---------   ---------  |
      |       |     SUBSYSTEM    |       |           |     |
 -----------  |                  |  ---------------------  |
| MICROWAVE | |                  | |      TELEMETRY      | |
| SUBSYSTEM |-|                  |-|      SUBSYSTEM      |-
 -----------   ------------------   ---------------------  |
      |                                                    |
 -----------    -----------    ---------   --------------  |
|  ANTENNA  |  |  MONITOR  |  |   TEST  | |    DIGITAL   | |
| SUBSYSTEM |  |AND CONTROL|  | SUPPORT | |COMMUNICATIONS|-
 -----------   | SUBSYSTEM |  |SUBSYSTEM| |   SUBSYSTEM  |
                -----------    ---------   --------------
```

Figure 5.1-6: DSN subsystem schematics

DSCC Monitor and Control Subsystem

The DSCC Monitor and Control Subsystem (DMC) is part of the Monitor and Control System (MON) which also includes the ground communications Central Communications Terminal and the Network Operations Control Center (NOCC) Monitor and Control Subsystem. The DMC is the center of activity at a DSCC. The DMC receives and archives most of the information from the NOCC needed by the various DSCC subsystems during their operation. Control of most of the DSCC subsystems, as well as the handling and displaying of any responses to control directives and configuration and status information received from each of the subsystems, is done through the DMC. The effect of this is to centralize the control, display, and archiving functions necessary to operate a DSCC. Communication among the various subsystems is done using a Local Area Network (LAN) hooked up to each subsystem via a network interface unit (NIU).

DMC operations are divided into two separate areas: the Complex Monitor and Control (CMC) and the Link Monitor and Control (LMC). The primary purpose of the CMC processor for Radio Science support is to receive and store all predict sets transmitted from NOCC such as Radio Science, antenna pointing, tracking, receiver, and uplink predict sets and then, at a later time, to distribute them to the appropriate subsystems via the LAN. Those predict sets can be stored in the CMC for a maximum of three days under normal conditions. The CMC also receives, processes, and displays event/alarm messages; maintains an operator log; and produces tape labels for the DSP. Assignment and configuration of the LMCs is done through the CMC; to a limited degree the CMC can perform some of the functions performed by the LMC. There are two CMCs (one on-line and one backup) and three LMCs at each DSCC. The backup CMC can function as an additional LMC if necessary.

The LMC processor provides the operator interface for monitor and control of a link—a group of equipment required to support a spacecraft pass. For Radio Science, a link might include the DSCC Spectrum Processing Subsystem (DSP) (which, in turn, can control the SSI), or the Tracking Subsystem. The LMC also maintains an operator log which includes operator directives and subsystem responses. One important Radio Science specific function that the LMC performs is reception and transmission of the system temperature and signal level data from the

PPM for display at the LMC console and for inclusion in monitor blocks. These blocks are recorded on magnetic tape as well as appearing in the Mission Control and Computing Center (MCCC) displays. The LMC is required to operate without interruption for the duration of the Radio Science data acquisition period.

The Area Routing Assembly (ARA), which is part of the Digital Communications Subsystem, controls all data communication between the stations and JPL. The ARA receives all required data and status messages from the LMC/CMC and can record them to tape as well as transmit them to JPL via data lines. The ARA also receives predicts and other data from JPL and passes them on to the CMC.

DSCC Open-Loop Receiver (RIV)

The open loop receiver block diagram shown in Figure 5.1-7 is for the RIV system at 70-m and 34-m HEF and BWG antenna sites. Input signals at both S- and X-band are mixed to approximately 300 MHz by fixed-frequency local oscillators near the antenna feed. Based on a tuning prediction file, the POCA controls the DANA synthesizer, the output of which (after multiplication) mixes the 300 MHz IF to 50 MHz for amplification. These signals in turn are down converted and passed through additional filters until they yield output with bandwidths up to 45 kHz. The output is digitally sampled and either written to magnetic tape or electronically transferred for further analysis.

```
          S-Band                                           X-Band
         2295 MHz                                         8415 MHz
          Input                                             Input
            |                                                 |
            v                                                 v
           ---     ---                               ---     ---
          | X |<--|x20|<--100 MHz         100 MHz-->|x81|-->| X |
           ---     ---                               ---     ---
            |                                                 |
         295|                                                 |315
         MHz|                                                 |MHz
            v                                                 v
           ---     --                 33.1818        ---     ---
          | X |<--|x3|<------           MHz ------>|x11|-->| X |
           ---     --        |115          |         ---     ---
            |                |MHz          |                  |
            |                |             |                  |
          50|      71.8181  ---           ---                 |50
         MHz|         MHz->| X |         | X |<-10MHz         |MHz
            v               ---           ---                 v
           ---               ^             ^                 ---
          | X |<--60 MHz     |             |       60 MHz-->| X |
           ---               |   approx    |                 ---
            |        9.9     | 43.1818 MHz |       9.9        |
            |        MHz      -------------        MHz        |
            |         |             ^               |         |
          10|         v             |               v         |10
         MHz|        ---       ----------          ---        |MHz
            |------>| X |     |   DANA   |        | X |<------|
            |        ---      |Synthesizr|         ---        |
            |         |        ----------           |         |
            v         v             ^               v         v
         -------   -------          |            -------   -------
        |Filters| |Filters|    ----------       |Filters| |Filters|
        |3,4,5,6| |  1,2  |   |   POCA   |      |  1,2  | |3,4,5,6|
         -------   -------    |Controller|       -------   -------
            |         |        ----------           |         |
          10|         |0.1                       0.1|         |10
         MHz|         |MHz                       MHz|         |MHz
            v         v                             v         v
           ---       ---                           ---       ---
10 MHz -->| X |     | X |<------ 0.1 MHz ------->| X |      | X |<--
           ---       ---                           ---       ---   |
            |         |                             |         |  10 MHz
            v         v                             v         v
         Output     Output                       Output     Output
```

Figure 5.1-7: DSN open loop receiver block diagram

Reconstruction of the antenna frequency from the frequency of the signal in the recorded data can be achieved through use of one of the following formulas. Filters are defined below.

FS_{ant}=3*SYN+1.95*10^9+3*(790/11)*10^6+F_{rec} (Filter 4)

=3*SYN+1.95*10^9+3*(790/11)*10^6-F_{samp}+F_{rec} (Filters 1-3,5,6)

FX_{ant}=11*SYN + 7.940*10^9 + F_{samp} - F_{rec} (Filter 4)

=11*SYN + 7.940*10^9 - 3*F_{samp} + F_{rec} (Filters 1,2,3,6) where FS_{ant},FX_{ant} are the antenna frequencies of the incoming signals at S and X bands, respectively, SYN is the output frequency of the DANA synthesizer, commonly labeled the readback POCA frequency on data tapes, F_{samp} is the effective sampling rate of the digital samples, and F_{rec} is the apparent signal frequency in a spectrum reconstructed from the digital samples.

NB: For many of the filter choices (see below) the Output is that of a bandpass filter. The sampling rates in the table below are sufficient for the bandwidth but not the absolute maximum frequency, and aliasing results. The reconstruction expressions above are appropriate ONLY when the sample rate shown in the tables below is used.

5.1.3.3 Operational Modes - DSN

- DSCC Antenna Mechanical Subsystem
  Pointing of DSCC antennas may be carried out in several ways.
  For details see the subsection ‘DSCC Antenna Mechanical Subsystem’ in the ‘Subsystem’ section. Binary pointing is the preferred mode for tracking spacecraft; pointing predicts are provided, and the antenna simply follows those.
  With CONSCAN, the antenna scans conically about the optimum pointing direction, using closed-loop receiver signal strength estimates as feedback. In planetary mode, the system interpolates from three (slowly changing) RA-DEC target coordinates; this is ‘blind’ pointing since there is no feedback from a detected signal. In sidereal mode, the antenna tracks a fixed point on the celestial sphere. In ‘precision’ mode, the antenna pointing is adjusted using an optical feedback system. It is possible on most antennas to freeze z-axis motion of the subreflector to minimize phase changes in the received signal.

- DSCC Receiver-Exciter Subsystem
  The diplexer in the signal path between the transmitter and the feed horns on all antennas may be configured so that it is out of the received signal path in order to improve the signal-to-noise ratio in the receiver system. This is known as the ‘listen-only’ or ‘bypass’ mode.

- Closed-Loop vs. Open-Loop Reception
  Radio Science data can be collected in two modes: closed- loop, in which a phase-locked loop receiver tracks the spacecraft signal, or open-loop, in which a receiver samples and records a band within which the desired signal presumably
  resides. Closed-loop data are collected using Closed-Loop Receivers, and open-loop data are collected using Open-Loop Receivers in conjunction with the DSCC Spectrum Processing Subsystem (DSP). See the Subsystems section for further information.
- Closed-Loop Receiver AGC Loop
  The closed-loop receiver AGC loop can be configured to one of three settings: narrow, medium, or wide. Ordinarily it is configured so that expected signal amplitude changes are accommodated with minimum distortion. The loop bandwidth is ordinarily configured so that expected phase changes can be accommodated while maintaining the best possible loop SNR.

- Coherent vs. Non-Coherent Operation
  The frequency of the signal transmitted from the spacecraft can generally be controlled in two ways—by locking to a signal received from a ground station or by locking to an on-board oscillator. These are known as the coherent (or 'two-way') and non-coherent ('one-way') modes, respectively. Mode selection is made at the spacecraft, based on commands received from the ground. When operating in the coherent mode, the transponder carrier frequency is derived from the received uplink carrier frequency with a 'turn-around ratio 'typically of **240/221 (S-band).** In the non-coherent mode, the downlink carrier frequency is derived from the spacecraft on-board crystal-controlled oscillator. Either closed-loop or open-loop receivers (or both) can be used with either spacecraft frequency reference mode. Closed-loop reception in two-way mode is usually preferred for routine tracking.
  Occasionally the spacecraft operates coherently while two ground stations receive the 'downlink' signal; this is sometimes known as the 'three-way' mode.

- DSCC Spectrum Processing Subsystem (DSP)
  The DSP can operate in four sampling modes with from 1 to 4 input signals. Input channels are assigned to ADC inputs during DSP configuration. Modes and sampling rates are summarized in the tables below:

Mode	Analog-to-Digital Operation
1	4 signals, each sampled by a single ADC
2	1 signal, sampled sequentially by 4 ADCs
3	2 signals, each sampled sequentially by 2 ADCs
4	2 signals, the first sampled by ADC #1 and the second sampled sequentially at 3 times the rate by ADCs #2-4

Table 5.1-5: DSN operational modes

	8-bit Samples Sampling Rates (samples/sec per ADC)		12-bit Samples Sampling Rates (samples/sec per ADC)
50000			
31250			
25000			
15625			
12500			
10000	10000		
6250			
5000	5000		
4000			
3125			
2500			
		2000	
1250			
1000	1000		
		500	
		400	
		250	
		200	200

Table 5.1-6: DSN sampling rates

Input to each ADC is identified in header records by a Signal Channel Number (J1 - J4). Nominal channel assignments are shown below.

Signal Channel Number	Receiver Channel
J1	X-RCP
J2	S-RCP
J3	X-LCP
J4	S-LCP

Table 5.1-7: DSN Channel assignments

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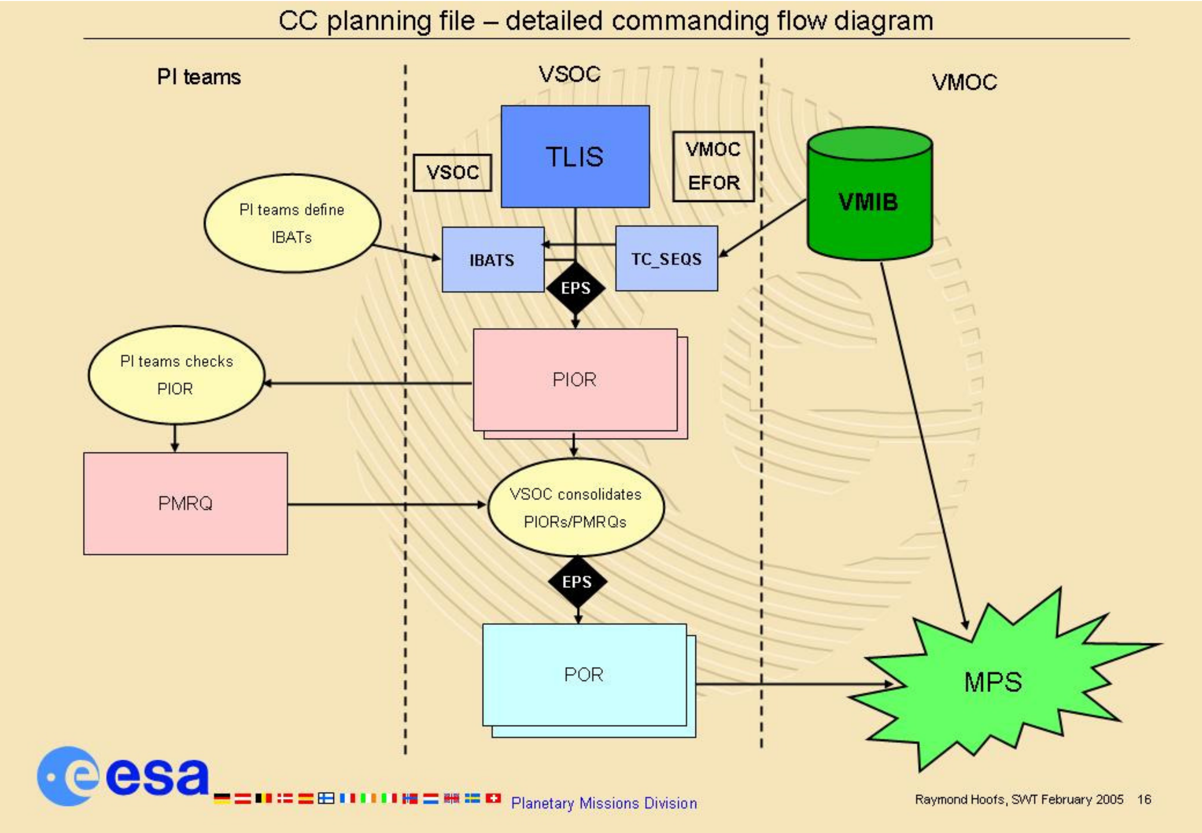
6 VeRa Interface with Ground

6.1 Interface with VSOC and VMOC

6.1.1 Flow of request files



6.2 Sequence of Events/Procedures

6.2.1 Overview

The following sequence of events have been defined. These sequences are under configuration control.

activity name	description
BSR	Bistatic radar for three pointing modes
GRV-OFF	Target gravity observation with telemetry modulation OFF
OCI-OFF	Occultation ingress with telemetry modulation OFF
OCX-OFF	Occultation ingress with X-band downlink and telemetry modulation OFF
SCS	Inferior or superior solar conjunction observation with S-band uplink
SCX	Inferior or superior solar conjunction observation with X-band uplink

6.2.2 BSR

VENUS EXPRESS			
Instrument ***VeRa***		Originator Name	**Date** **23.03.2005**
Mission Phase Routine	**Activity ID**	**Activity Name** BSR	

Description of activity:	**Bistatic Radar**
Duration of activity:	**{3 hours + ∆Tpoint} of spacecraft time [s/c operations only] includes one hour S-band warm-up** **{4.5 hours + ∆Tpoint} of ground station time includes noise calibration**
Power demand:	**S-Band transmitter power (28 W)** **USO power (5.5 W)**
Spacecraft pointing:	**BSR-INERT: surface inertial pointing** **BSR-SPOT: surface spot pointing** **BSR-SPEC: surface specular pointing** **pointing as defined in custom attitude file** **HGA-1 required**

Comments/other constrains:
HGA-1 required

DSN 70-m station required
Each BSR activity consists of these activities in sequence:
BNOISE - G/S equipment noise determination
BCAL - s/c direct signal calibration
BSLW - s/c slew
BSR-INERT or BSR-SPOT or BSR-SPEC - observation
BSLW
BCAL
BNOISE

Spacecraft configuration
ONED
X- and S-band downlink
RNG OFF
TM OFF
HGA-1 selected

IFMS DAP Settings

TBD

DSN RSR open-loop settings:

RSR1: RCP X-band; sample rate 50000 samples/sec
RSR2: LCP X-band; sample rate 50000 samples/sec
RSR3: RCP S-band; sample rate 50000 samples/sec
RSR4: LCP S-band; sample rate 50000 samples/sec

Sequence of Events

time			event
Space [S/C onboard time OBT]	**ground [Ground receive time GRT]**	**activity name**	
	T0 – 01:30 + OWLT	BNOISE	Start of noise calibration activities in the ground station No s/c signal required
	T0 + OWLT		Stop of calibration activities Pointing of G/S antenna towards s/c position
Assumption is that spacecraft is in TWOS configuration after AOS and first check of TM USO is ON but MUTE **T0 is the time of the start of radio science operation in OBT** **∆Tpoint is theduration requested for BSR-SPEC or BSR-INERT or BSR-SPOT** OWLT is the one-way light time Assumption is that commands are pre-programmed and executed automatically on board HGA-1 Selected			
T0 - 01:00		BCAL	command S-band transmitter POWER ON
T0 - 00:02			Command USO ACTIVE

T0 -00:01			command S-band d/l ON command coherency OFF
	T0 + OWLT		Stop uplink AOS of X-band and S-band non-coherent D/L
	T0 + 00:05 + OWLT		Start open-loop recordings at four RSR channels
	T0 + 00:35 + OWLT		Stop recordings
T0 + 00:35		BSLW	Start of s/c slew to requested BSR pointing
T0 + 01:05			End of s/c slew
T0 +01:05		BSR-INERT or BSR-SPOT or BSR-SPEC	Start s/c pointing sequence: inertial, spot or specular
	T0 + 01:05 + OWLT		Start open-loop recordings at four RSR channels
	T0 + 01:05 + ΔTpoint + OWLT		Stop recordings
T0 + 01:05 + ΔTpoint			End s/c pointing sequence
T0 + 01:05 + ΔTpoint		BSLW	Start s/c slew to HGA Earth pointing
T0 + 01:35 + ΔTpoint			Stop s/c slew

	T0 + 01:35 + ΔTpoint + OWLT	BCAL	Start open-loop recordings at four RSR channels
	T0 + 02:05 + ΔTpoint + OWLT		Stop recordings
T0 + 02:05+ ΔTpoint			Command S-band D/L OFF Command S-band transmitter POWER OFF
	T0 + 02:05 + ΔTpoint + OWLT		Start X-band uplink
T0 + 02:05 + ΔTpoint + 2 OWLT			s/c acquires X-band uplink command coherency ON TWOS
T0 + 02:05 + ΔTpoint + 2 OWLT			Command USO MUTE
	T0 + 02:05 + +ΔTpoint +3 OWLT		s/c transferred to other receiving antenna
	T0 + 02:05 + ΔTpoint + 3 OWLT	BNOISE	Start of noise calibration activities in ground station No spacecraft signal required
	T0 + 03:05 + ΔTpoint+ 3 OWLT		Stop activities

Accepted:	PI	VEX Project	ESOC

Configuration Control

Issue	Rev.	Date	Changes	Author
1	0	22.10.04	All	ST
2	0	23.03.2005	All	ST
2	**1**	**05.04.2005**	**Editing**	**mpa**

6.2.3 GRV-OFF Target Gravity

Instrument ***VeRa***		Originator Name	**Date** 02. November 2004
Mission Phase routine	**Activity ID**	**Activity Name** GRV-OFF	
Description of activity:	Gravity pericenter pass with TM OFF		
Duration of activity:	40 min; -20 min ≤ VPER ≤ 20 min VPER is the time of pericenter pass at GRT		
Power demand:	28 Watts S-band transmitter		
Spacecraft pointing:	HGA-1 Earth pointing		
Comments/other constrains: HGA-1 required Ground stations: NNO DSN – HEF DSN 70 m S-band reception required Sample rate: 1 sample/sec TM OFF			
Spacecraft configuration TWOD-X X-band uplink; X- and S-band downlink RNG S-band ON; RNG X-band ON TM OFF HGA-1 required			

IFMS DAP Settings:
Configure Downlink Chain 1 for X-band ops
Configure Downlink Chain 2 for S-band ops
IFMS-1 configured for Input 1 (X-band prime)
IFMS-2 configured for Input 1 (X-band)
IFMS-3 configured for Input 2 (S-band)

IFMS-1 DAP Settings X/up/down
RNG set for 1 sample per second, 3600 samples per file
(only for TWOS and TWOD)
DOP1 set for 1 samples per second, 3600 samples per file
DOP2 set for 1 samples per second, 3600 samples per file
AGC1 set for 1 samples per second, 3600 samples per file
AGC2 set for 1 samples per second, 3600 samples per file
MET set for 1 sample per 60 seconds, 100 samples per file

IFMS-2 DAP Settings X/down
DOP1 set for 1 samples per second, 3600 samples per file
DOP2 set for 1 samples per second, 3600 samples per file
AGC1 set for 1 samples per second, 3600 samples per file
AGC2 set for 1 samples per second, 3600 samples per file
MET set for 1 sample per 60 seconds, 100 samples per file

IFMS-3 DAP Settings S/down
RNG set for 1 sample per second, 3600 samples per file
(only for TWOD if available)
DOP1 set for 1 samples per second, 3600 samples per file
DOP2 set for 1 samples per second, 3600 samples per file
AGC1 set for 1 samples per second, 3600 samples per file
AGC2 set for 1 samples per second, 3600 samples per file
MET set for 1 sample per 60 seconds, 100 samples per file

time			
S/C onboard time (OBT)	**Ground receive time (GRT)**		**Event** **T0 = pericenter time at ground station = S/C ET + OWLT**

Assumption is that spacecraft is in TWOS configuration after AOS and first check of TM
T0 is the time of pericenter pass at GRT = S/C ET + OWLT
OWLT is the one-way light time
Assumption is that commands are pre-programmed and executed automatically on board
Only one IFMS file start at the start of track

T0- 01:25 - OWLT			Command S-band transmitter POWER ON
T0- 00:25 - OWLT			Command S-band d/l ON
T0- 00:25 - OWLT			Command TM OFF
	T0- 00:25	5	AOS S-band coherent
T0- 00:20- OWLT	T0- 00:20		Start of radio science activities TWOD-X Start RNG recordings: IFMS: on IFMS-1 and IFMS-3 (if available) DSN: at X-band and S-band Start recordings: IFMS : DOP1, DOP2, AGC1, AGC2, MET on all IFMS DSN: CL Doppler recording at X-band and S-band
	T0		Pericenter pass at ground station time
	T0+00:20		Stop all recordings
T0+ 00:20 -OWLT			Command TM ON
T0+ 00:20 - OWLT			Command S-band d/l OFF

Configuration Control

Issue	Rev.	Date	Changes	Author
1	0	02.11.04	All	ST
1	1	05.04.2005	Editing	mpa

6.2.4 OCC-OFF Ocultation

VENUS EXPRESS

Instrument ***VeRa***		Originator Name	**Date** **23.03.2005**
Mission Phase Routine	**Activity ID**	**Activity Name** OCC-OFF	

Description of activity:	**Occultation measurement at two frequencies with TM OFF**
Duration of activity:	**{-8 min + ΔTingress} before predicted start of occultation (= VOCS – 8 min - ΔTingress) plus 1 hour S-band warm-up** **until ΔTegress (= VOCE + ΔTegress) after occultation exit**
Power demand:	**S-Band transmitter (28 W)** **USO (5.5 W)**
Spacecraft pointing:	**as defined in custom attitude file** **HGA-1 required**

Comments/other constraints:
HGA-1 required
Dual frequency D/L at S-Band and X-band required
USO required
open loop recordings required at IFMS-3 at 2 frequencies and one polarisation (RHCP)
feasible ground stations: NNO, DSN
Note: each occultation ingress or egress has a different duration depending on time difference between occultation entry (VOCS) and occultation exit (VOCE); ΔTingress and ΔTegress are varibales depending on the occultation scenario
special local oscillator tuning at G/S required

Spacecraft configuration

HGA-1 required
ONED-USO
X- and S-band downlink
RNG OFF, TM OFF

IFMS DAP Settings
Configure Downlink Chain 1 for X-band ops
Configure Downlink Chain 2 for S-band ops

IFMS-1 DAP Settings X/down
DOP1 set for 10 samples per second, 3600 samples per file
DOP2 set for 10 samples per second, 3600 samples per file
AGC1 set for 10 samples per second, 3600 samples per file
AGC2 set for 10 samples per second, 3600 samples per file
MET set for 1 sample per 60 seconds, 100 samples per file

IFMS-2 DAP Settings X/down
DOP1 set for 10 samples per second, 3600 samples per file
DOP2 set for 10 samples per second, 3600 samples per file
AGC1 set for 10 samples per second, 3600 samples per file
AGC2 set for 10 samples per second, 3600 samples per file
MET set for 1 sample per 60 seconds, 100 samples per file

IFMS-3 DAP Settings S/down closed-loop
DOP1 set for 10 samples per second, 3600 samples per file
DOP2 set for 10 samples per second, 3600 samples per file
AGC1 set for 10 samples per second, 3600 samples per file
AGC2 set for 10 samples per second, 3600 samples per file
MET set for 1 sample per 60 seconds, 100 samples per file

IFMS-3 DAP Settings X&S/down (RCP) open-loop
Voltage samples: 100 000 samples per second

DSN RSR open-loop settings:

RSR1: RCP X-band; sample rate 50000 samples/sec
RSR2: LCP X-band; sample rate 50000 samples/sec
RSR3: RCP S-band; sample rate 50000 samples/sec
RSR4: LCP S-band; sample rate 50000 samples/sec

Sequence of Events

time			
S/C onboard time (OBT)	**Ground receive time (GRT)**		**event**
Assumption is that spacecraft is in TWOS configuration after AOS and first check of TM USO is ON but MUTE **T0 is predicted start of geometrical occultation (VOCS) at OBT !!!** **T1 is predicted end of geometrical occultation (VOCE) at OBT !!!** **ΔTingress is the duration of measurements and before VOCS** **ΔTegress is the duration of measurement after VOCE** OWLT is the one-way light time HGA-1 selected Assumption is that commands are preprogrammed and executed automatically on board			
T0 -00:08 - ΔTingress			command S-band transmitter POWER ON
T0 -00:08 - ΔTingress			Command d/l noncoherent
T0 -00:07 - ΔTingress			Command USO unmute
T0 -00:06 - ΔTingress			command S-band d/l ON
T0 - 00:05 - ΔTingress			Command TM OFF
	T0 - ΔTingress +OWLT		Start of Radio Science activities: Configuration: ONED-USO, TM OFF, RNG OFF Start recordings: IFMS1: DOP1,2; AGC 1,2; MET IFMS2: DOP1,2; AGC 1,2; MET IFMS3: voltage samples Open loop 100 000 samples/sec (X- and S-band, RHCP) DSN: voltage samples Open loop 100 000 samples/sec RHC, RHC-S
	T0+ OWLT		Expected start of occultation (VOCS) in GRT

	T1+ OWLT		Expected end of occultation (VOCE) in GRT
T1 + ΔTegress			command S-band d/l OFF command USO mute
T1 + ΔTegress			command Coherency ON
T1 + ΔTegress			command TM ON
	T1+ ΔTegress +OWLT		stop all recordings
Accepted:	PI	VEX Project	ESOC

Configuration Control

Issue	Rev.	Date	Changes	Author
1	0	02.11.04	All	ST
1	1	03.03.05	Duration of activity revised	mpa
2	**0**	**05.04.2005**	**All**	**ST**

6.2.5 OCX-OFF Occultation X-band only

VENUS EXPRESS

Instrument ***VeRa***		Originator Name	**Date** **23.03.2005**
Mission Phase Routine	**Activity ID**	**Activity Name** OCX-OFF	
Description of activity:	**Occultation measurement at X-band only with TM OFF**		
Duration of activity:	**{-8 min + ΔTingress} before predicted start of occultation (= VOCS – 8 min - ΔTingress) plus 1 hour S-band warm-up** **until ΔTegress (= VOCE + ΔTegress) after occultation exit**		
Power demand:	**USO (5.5 W)**		
Spacecraft pointing:	**as defined in custom attitude file** **HGA-1 required**		

Comments/other constraints:
HGA-1 required
USO required
open loop recordings required at IFMS-3 and one polarisation (RHCP)
feasible ground stations: NNO, DSN
Note: each occultation ingress or egress has a different duration depending on time difference between occultation entry (VOCS) and occultation exit (VOCE); ΔTingress and ΔTegress are varibales depending on the occultation scenario
special local oscillator tuning at G/S required

Spacecraft configuration

HGA-1 required
ONES-USO
X- downlink
RNG OFF, TM OFF

IFMS DAP Settings
Configure Downlink Chain 1 for X-band ops
Configure Downlink Chain 2 for S-band ops

IFMS-1 DAP Settings X/down
DOP1 set for 10 samples per second, 3600 samples per file
DOP2 set for 10 samples per second, 3600 samples per file
AGC1 set for 10 samples per second, 3600 samples per file
AGC2 set for 10 samples per second, 3600 samples per file
MET set for 1 sample per 60 seconds, 100 samples per file

IFMS-2 DAP Settings X/down
DOP1 set for 10 samples per second, 3600 samples per file
DOP2 set for 10 samples per second, 3600 samples per file
AGC1 set for 10 samples per second, 3600 samples per file
AGC2 set for 10 samples per second, 3600 samples per file
MET set for 1 sample per 60 seconds, 100 samples per file

IFMS-3 DAP Settings X/down closed-loop
DOP1 set for 10 samples per second, 3600 samples per file
DOP2 set for 10 samples per second, 3600 samples per file
AGC1 set for 10 samples per second, 3600 samples per file
AGC2 set for 10 samples per second, 3600 samples per file
MET set for 1 sample per 60 seconds, 100 samples per file

IFMS-3 DAP Settings X /down (RCP) open-loop
Voltage samples: 100 000 samples per second

DSN RSR open-loop settings:

RSR1: RCP X-band; sample rate 50000 samples/sec
RSR2: LCP X-band; sample rate 50000 samples/sec
RSR3: RCP S-band; sample rate 50000 samples/sec
RSR4: LCP S-band; sample rate 50000 samples/sec

Sequence of Events

time			
S/C onboard time (OBT)	**Ground receive time (GRT)**		**event**
Assumption is that spacecraft is in TWOS configuration after AOS and first check of TM USO is ON but MUTE **T0 is predicted start of geometrical occultation (VOCS) at OBT !!!** **T1 is predicted end of geometrical occultation (VOCE) at OBT !!!** **ΔTingress is the duration of measurements and before VOCS** **ΔTegress is the duration of measurement after VOCE** OWLT is the one-way light time HGA-1 selected Assumption is that commands are preprogrammed and executed automatically on board			
T0 -00:08 - ΔTingress			Command d/l noncoherent
T0 -00:07 - ΔTingress			Command USO unmute
T0 - 00:05 - ΔTingress			Command TM OFF
	T0 - ΔTingress +OWLT		Start of Radio Science activities: Configuration: ONES-USO, TM OFF, RNG OFF Start recordings: IFMS1: DOP1,2; AGC 1,2; MET IFMS2: DOP1,2; AGC 1,2; MET IFMS3: DOP1,2; AGC 1,2; MET voltage samples Open loop 100 000 samples/sec (X- and S-band, RHCP) DSN: voltage samples Open loop 100 000 samples/sec
	T0+ OWLT		Expected start of occultation (VOCS) in GRT
	T1+ OWLT		Expected end of occultation (VOCE) in GRT
T1 + ΔTegress			command S-band d/l OFF command USO mute

T1 + ΔTegress			command Coherency ON
T1 + ΔTegress			command TM ON
	T1+ ΔTegress +OWLT		stop all recordings
Accepted:	PI	VEX Project	ESOC

Configuration Control

Issue	Rev.	Date	Changes	Author
1	0	02.11.04	All	ST
1	1	03.03.05	Duration of activity revised	mpa
2	**0**	**25.04.2005**	**All**	**ST,mpa**

6.2.6 SCS Inferior and Superior Solar Conjunction

<table>
<tr><td colspan="2">Instrument VeRa</td><td>Originator Name</td><td>Date
02 .November 2004</td></tr>
<tr><td>Mission Phase
routine</td><td>Activity ID</td><td colspan="2">Activity Name
SCS</td></tr>
</table>

Description of activity:	Solor Corona Sounding with S-band uplink
Duration of activity:	TD ≤ 4.0 hours TD = duration of radio science activities Duration requested in MREQ
Power demand:	28 Watts S-band transmitter
Spacecraft pointing:	HGA-1 Earth pointing

Comments/other constrains:
HGA-1 required
S-band uplink
During superior or inferior solar conjunction phase as defined by radio science as superior solar conjunction ± 10° elongation from the solar disc
Ground stations: NNO
DSN – HEF
DSN 70 m
S-band reception required
Sample rate: 1 sample/sec

Spacecraft configuration
HGA-1 required
TWOD-S
S-band uplink; X- and S-band downlink
RNG S-band ON; RNG X-band ON
TM ON

IFMS DAP Settings:
Configure Downlink Chain 1 for S-band ops
Configure Downlink Chain 2 for X-band ops
IFMS-1 configured for Input 1 (S-band prime)
IFMS-2 configured for Input 1 (S-band)
IFMS-3 configured for Input 2 (X-band)

IFMS-1 DAP Settings S/up/down
RNG set for 1 sample per second, 3600 samples per file
(only for TWOS and TWOD)
DOP1 set for 1 samples per second, 3600 samples per file
DOP2 set for 1 samples per second, 3600 samples per file
AGC1 set for 1 samples per second, 3600 samples per file
AGC2 set for 1 samples per second, 3600 samples per file
MET set for 1 sample per 60 seconds, 100 samples per file

IFMS-2 DAP Settings S/down
DOP1 set for 1 samples per second, 3600 samples per file
DOP2 set for 1 samples per second, 3600 samples per file
AGC1 set for 1 samples per second, 3600 samples per file
AGC2 set for 1 samples per second, 3600 samples per file
MET set for 1 sample per 60 seconds, 100 samples per file

IFMS-3 DAP Settings X/down
RNG set for 1 sample per second, 3600 samples per file
(only for TWOD if available)
DOP1 set for 1 samples per second, 3600 samples per file
DOP2 set for 1 samples per second, 3600 samples per file
AGC1 set for 1 samples per second, 3600 samples per file
AGC2 set for 1 samples per second, 3600 samples per file
MET set for 1 sample per 60 seconds, 100 samples per file

Sequence of Events

times			
S/C onboard time (OBT)	**Ground receive time (GRT)**		**Event** **T0 = start of radio science activites in GRT**
Assumption is that spacecraft is in TWOS configuration after AOS and first check of TM **T0 is start of radio science activities in GRT = S/C ET + OWLT** OWLT is the one-way light time Assumption is that commands are pre-programmed and executed automatically on board Only one IFMS file start at the start of track			
T0- 3 OWLT -01:10			Command S-band transmitter POWER ON
T0 - 3 OWLT -00:10			Command coherency OFF
	T0 -00:10 - 2 OWLT		Stop X-band uplink
	T0 -00:10 -2 OWLT	5	AOS X-band noncoherent
	T0 - 00:05 - 2 OWLT		Start S-band uplink
T0 - 00:05 -OWLT			Command coherency ON
T0 – 00:05 - OWLT			Command S-band d/l ON
	T0 - 00:05	5	AOS X- and S-band coherent

	T0		Start of radio science activities TWOD-S Start RNG recordings: IFMS: on IFMS-1 and IFMS-3 (if available) DSN: at X-band and S-band Start recordings: IFMS : DOP1, DOP2, AGC1, AGC2, MET on all IFMS DSN: CL Doppler recording at X-band and S-band
	T0+TD		Stop all recordings
T0+ TD - OWLT			Command S-band d/l OFF
	T0 + TD	5	AOS X-band noncoherent
	T0 + TD + 00:05		Stop S-band uplink Start X-band uplink
T0 + TD + 00:05 + OWLT			Command coherency ON TWOS
	T0 + TD + 00:05 + 2 OWLT	5	AOS X-band coherent

Configuration Control

Issue	Rev.	Date	Changes	Author
1	0	02.11.04	All	ST

6.2.7 SCX Inferior and Superior Solar Conjunction X-band Uplink

Instrument ***VeRa***		Originator Name	**Date** **02 .November 2004**
Mission Phase routine	**Activity ID**	**Activity Name** SCX	
Description of activity:	Solor Corona Sounding with X-band uplink		
Duration of activity:	TD ≤ 4.0 h TD = duration of radio science activities Duration requested in MREQ		
Power demand:	28 Watts S-band transmitter		
Spacecraft pointing:	HGA Earth pointing		

Comments/other constrains:
During superior or inferior solar conjunction phase as defined by radio science as superior solar conjunction ± 10° elongation from the solar disc
Ground stations: NNO
DSN – HEF
DSN 70 m
S-band reception required
Sample rate: 1 sample/sec
TM ON

Spacecraft configuration
TWOD-X
X-band uplink; X- and S-band downlink
RNG S-band ON; RNG X-band ON
TM ON

IFMS DAP Settings:
Configure Downlink Chain 1 for X-band ops
Configure Downlink Chain 2 for S-band ops
IFMS-1 configured for Input 1 (X-band prime)
IFMS-2 configured for Input 1 (X-band)
IFMS-3 configured for Input 2 (S-band)

IFMS-1 DAP Settings X/up/down
RNG set for 1 sample per second, 3600 samples per file (only for TWOS and TWOD)
DOP1 set for 1 samples per second, 3600 samples per file
DOP2 set for 1 samples per second, 3600 samples per file
AGC1 set for 1 samples per second, 3600 samples per file
AGC2 set for 1 samples per second, 3600 samples per file
MET set for 1 sample per 60 seconds, 100 samples per file

IFMS-2 DAP Settings X/down
DOP1 set for 1 samples per second, 3600 samples per file
DOP2 set for 1 samples per second, 3600 samples per file
AGC1 set for 1 samples per second, 3600 samples per file
AGC2 set for 1 samples per second, 3600 samples per file
MET set for 1 sample per 60 seconds, 100 samples per file

IFMS-3 DAP Settings S/down
RNG set for 1 sample per second, 3600 samples per file (only for TWOD if available)
DOP1 set for 1 samples per second, 3600 samples per file
DOP2 set for 1 samples per second, 3600 samples per file
AGC1 set for 1 samples per second, 3600 samples per file
AGC2 set for 1 samples per second, 3600 samples per file
MET set for 1 sample per 60 seconds, 100 samples per file

Sequence of Events

times			
S/C onboard time (OBT)	**Ground receive time (GRT)**		**Event** **T0 = start of radio science activites in GRT**
Assumption is that spacecraft is in TWOS configuration after AOS and first check of TM **T0 is start of radio science activities in GRT = S/C ET + OWLT** OWLT is the one-way light time Assumption is that commands are pre-programmed and executed automatically on board Only one IFMS file start at the start of track			
T0-01:10 - OWLT			Command S-band transmitter POWER ON
T0-00:10 - OWLT			Command S-band d/l ON
	T0-00:05		AOS of S-band and X-band coherent
	T0		Start of radio science activities TWOD-X Start RNG recordings: IFMS: on IFMS-1 and IFMS-3 (if available) DSN: at X-band and S-band Start recordings: IFMS : DOP1, DOP2, AGC1, AGC2, MET on all IFMS DSN: CL Doppler recording at X-band and S-band
	T0+TD		Stop all recordings
T0 -OWLT +TD +00:05			Command S-band d/l OFF

Configuration Control

Issue	Rev.	Date	Changes	Author
1	0	02.11.04	All	ST

6.3 ESOC Flight Operations Procedures

ESOC prepared the following Flight Operations Procedures (FOP) which configure the spacecraft and the ground station and create command sequences for the configuration according to VeRa requirements (ATVFxxxA) and the reconfiguration after the end of activity (ATVFxxxB).

6.3.1 Format of FOP file names

TV-FCP-xxx

	description
TV	VeRa instrument acronym
FCP	Flight Control Procedure
xxx	procedure number

6.3.2 VeRa FOP procedures

FOP	**Based on VeRa SOE**	**description**
TV-FCP-001	n/a	VeRa USO ON
TV-FCP-002	n/a	VeRa USO active
TV-FCP-003	n/a	VeRa USO passive
TV-FCP-004	n/a	VeRa USO OFF
TV-FCP-010	UCS1	VeRa USO Commissioning Sequence 1 UCS1
TV-FCP-020	UCS2	VeRa USO Commissioning Sequence 1 UCS2
TV-FCP-030	TVT1	VeRa Tracking Verification Test TVT1
TV-FCP-100	OCI-OFF	VeRa Earth Occultation TM OFF
TV-FCP-200	GRA-OFF	VeRa Gravity Mapping TM OFF
TV-FCP-300	BSR	VeRa Bistatic radar
TV-FCP-400	SCS	VeRa Solar Corona S-band uplink
TV-FCP-	OCX-OFF	Not yet available
TV-FCP-	SCX	Not yet available

6.3.3 Format of Command Sequence Files

ATVFxxxQ

	description
A	Command Sequence
TV	VeRa instrument acronym
F	Flight Control Procedure
xxx	procedure number (see 6.3.2)
Q	A = start of VeRa configuration B = reconfiguration after VeRa activity

6.3.4 Command sequence files

FOP	**calls**	
	Start VeRa configuration	**reconfiguration**
TV-FCP-001	ATVF001A	ATVF001B
TV-FCP-002	ATVF002A	ATVF002B
TV-FCP-003	ATVF003A	ATVF003B
TV-FCP-004	ATVF004A	ATVF004B
TV-FCP-010	ATVF010A	ATVF010B
TV-FCP-020	ATVF020A	ATVF020B
TV-FCP-030	ATVF030A	ATVF030B
TV-FCP-100	ATVF100A	ATVF100B
TV-FCP-200	ATVF200A	ATVF200B
TV-FCP-300	ATVF300A	ATVF300B
TV-FCP-400	ATVF400A	ATVF400B
TV-FCP-	ATVFxxxA	ATVFxxxB
TV-FCP-	ATVFxxxA	ATVFxxxB

6.4 IBAT

6.4.1 VeRa IBAT File Names

TV_xxx_qqqqq

	Description
TV	VeRa instrument acronym
xxx	Procedure OCC occultation GRA gravity BSR bistatic radar SCO solar corona
qqqqq	Start = VeRa configuration End = reconfiguration after activity

6.4.2 VeRa IBAT File Listings

6.4.2.1 Occultations

File name: “TV_OCC_START”

```
Action: TV_OCC_START "IBAT commands Spacecraft and Ground Stations to
configure for Occultation"
Action_type: BLOCK
Run_type: RELATIVE
Run_actions: \
00:00:00    ATVF100A \ # Occultation Start
01:00:00    END_IBAT
```

File name: “TV_OCC_END”

```
Action: TV_OCC_End "IBAT commands Spacecraft and Ground Stations to
configure for Occultation"
Action_type: BLOCK
Run_type: RELATIVE
Run_actions: \
00:00:00    ATVF100B \ # Occultation End
01:00:00    END_IBAT
```

6.4.2.2 Gravity

File name: “TV_GRA_START”

```
Action: TV_GRA_START "IBAT commands Spacecraft and Ground Stations to
configure for Gravity"
Action_type: BLOCK
Run_type: RELATIVE
Run_actions: \
00:00:00    ATVF200A \ # Gravity Start
01:00:00    END_IBAT
```

File name: “TV_GRA_END”

```
Action: TV_GRA_End "IBAT commands Spacecraft and Ground Stations to
configure for Gravity"
Action_type: BLOCK
Run_type: RELATIVE
Run_actions: \
00:00:00    ATVF200B \ # Gravity End
01:00:00    END_IBAT
```

6.4.2.3 Bistatic Radar

File name: “TV_BSR_START”

```
Action: TV_BSR_START "IBAT commands Spacecraft and Ground Stations to
configure for Bistatic Radar”
Action_type: BLOCK
Run_type: RELATIVE
Run_actions: \
00:00:00    ATVF300A \ # Bistatic Radar Start
01:00:00    END_IBAT
```

File name: “TV_BSR_END”

```
Action: TV_BSR_End "IBAT commands Spacecraft and Ground Stations to
configure for Bistatic Radar"
Action_type: BLOCK
Run_type: RELATIVE
Run_actions: \
00:00:00    ATVF300B \ # Bistatic Radar End
01:00:00    END_IBAT
```

6.4.2.4 Solar Corona

File name: “TV_SCO_START”

```
Action: TV_SCO_START "IBAT commands Spacecraft and Ground Stations to
configure for Solar Conjunction"
Action_type: BLOCK
Run_type: RELATIVE
Run_actions: \
00:00:00    ATVF400A \ # Solar Conjunction Start
01:00:00    END_IBAT
```

File name: “TV_SCO_END”

```
Action: TV_SCO_End "IBAT commands Spacecraft and Ground Stations to
configure for Solar Conjunction"
Action_type: BLOCK
Run_type: RELATIVE
Run_actions: \
00:00:00    ATVF400B \ # Solar Conjunction End
01:00:00    END_IBAT
```

6.5 Event files (EVFs)

Three ASCII files containing information about events will be provided by ESOC (for detailed information please see [4])

ADID EVEXEVTV	most up to date event file
ADID EVEXEVTF	frozen event file consistent with orbit data from long term planning
ADID EVEXEVTP	event file for medium term planning

6.5.1 Event file format

The event files have all the same format. For each event one line of information is given. The events are listed in ascending order in time.

```
Three examples for different events are shown here:
VOCS           2  P  06-188T01:27:30.000Z       269
OCC_VENUS_START_/_RA074.35_/_DE_021.43_/_OVP_(286.02,030.80)_/_SZA_053


VOCE           2  P  06-188T01:31:59.000Z         0
OCC_VENUS_END_/_RA074.36_/_DE_021.43_/_OVP_(285.91,043.79)_/_SZA_060



VPER          81  P  06-188T01:51:34.411Z         0
PERICENTRE_PASSAGE_0081_/_SSP_(045.63,079.05)_/_SZA_086
```

The following table shows the format of the events:

Name	Format	Description	Example
EVTTID	A4	Event type identification	VPER
EVTCNT	(X2, I10)	Event count (running number for each event type; given in ascending consecutive order)	81
PREREC	(X2, A1)	single character flag indicating whether event is predicted (‘P’) or reconstituted (‘R’)	P
EVTTIM	(X2, A20)	Start time of event in the format **‘YY-DDDThh:mm:ss.ddd**	06-188T01:51:34.411Z

		Z' given in UTC, where **YY**: last two digits of the year **DDD**: day of year **hh,mm,ss,ddd**: hours, minutes, seconds and milliseconds of day	
EVTDUR	(X2, I8)	duration of event in seconds, where **0**= no duration of event or end of event **-1**=corresponding end event is not contained in file	0
EVTDES	(X2, A80)	description of event (depends on specific event)	PERICENTRE_PASSAGE_0081_/_SSP_(045.63,079.05)_/_SZA_086
LF	A1	single line feed character (ASCII 0Ahex)	TBD

The column EVTDS depends on the event and gives additional information.

Event types used by VeRa are

Event type	Definition	Information in EVTDES
VPER	PERICENTRE, this event is defined by the time when the osculating true anomaly measured from -180 degrees to +180 degrees changes sign.	PERICENTRE_PASSAGE_nnnn_/_SSP_/_(xxx.xx,yyy.yy)_/_SZA_zzz the subsatellite point (xxx.xx,yyy.yy) in planetocentric longitude (0°-360° eastwards) and planetocentric latitude (-90°-+90°) and the solar zenith angle (zzz) nnnn refers to the current orbit
VAPO	APOCENTRE, this event is defined by the time when the osculating true anomaly measured from -180 degrees to +180 degrees changes sign	APOCENTRE_PASSAGE_nnnn nnnn refers to the current orbit, orbit number are incremented by one with each apocenter passage.
VOCS	OCCULTATION START: the line-of-sight from the center of earth to the S/C starts to be occulted by Venus	OCC_VENUS_START_/_RA_rrr.rr_/_DE_ddd.dd_/_OVP_(xxx.xx,yyy.yy)_/_SZA_zzz (rrr.rr,ddd.dd) give right ascension from (0°-360°) and declination from (-90°-+90°) of the line-of-sight from

		the center of earth to the S/C; (xxx.xx,yyy.yy) define the planetocentric longitude (0°-360° eastwards) and planetocentric latitude (-90°-+90°) zzz is the solar zenith angle
VOCE	OCCULTATION END: the line-of-sight from the center of earth to the S/C ends to be occulted by Venus	OCC_VENUS_END_/ _RA_rrr.rr_/_DE_ddd.dd_/ _OVP_(xxx.xx,yyy.yy)_/_SZA_zzz same as for VOCS
VO1S	Line of sight altitude is 1000 km above surface before VOCS	OCC_VENUS_1000KM_START_/ _RA_rrr.rr_/_DE_ddd.dd_/ _OVP_(xxx.xx,yyy.yy)_/_SZA_zzz
VO1E	Line of sight altitude is 1000 km above surface after VOCE	OCC_VENUS_1000KM_END_/ _RA_rrr.rr_/_DE_ddd.dd_/ _OVP_(xxx.xx,yyy.yy)_/_SZA_zzz

6.6 VeRa EDF File

6.6.1 Introduction

Experiment Description Files (EDFs) describe the operational capabilities of an instrument. The EDFs are defined as templates with the following structure:

- Global characteristics
  - Including global actions and global constraints
- Experiment modes
- Experiment actions
- Experiment modules
- Experiment constraints

6.6.2 Global Characteristics

The global characteristics for VeRa include global actions and global constraints. Global actions and constraints are allowed in all experiment modes.

6.6.2.1 Global actions

All epxeriment operations are reffered to as actions.
All actions are defined in the experiment template as follows:

```
Nr_of_actions: <q>
#
   Action: <label> <description>
```

```
   Action_level: <LEVEL1|LEVEL2|LEVEL3>
   Duration: <action duration (seconds)>
   Power_increase: <average> [<peak> [<low>]]      (W)
   Data_rate_increase: <average> [<peak> [<low>]] (bits/sec)
   Update_when_ready: <MODE> <mode>
   Action_constraints: <constraint #1> <constraint #2> ...
   Run_actions: [PARALLEL|SEQUENTIAL]<action #1><action #2>
#
 ... (q actions)
```

The following Global Actions are defined for VeRa:

Global action labels	Description	Action parameters / constraints	update_when_ready /comments
COHERENCY_ON	Go to Two-way mode	Action_constraints: CHECK_USO	MS Coherency TWO_\ MS TCXO_state MUTE
COHERENCY_OFF	Go to One-way mode	Actions_constraints: CHECK_USO	MS Coherency ONE_\ MS TCXO_state ACTIVE\ MS SC_UPL _
SC_LINK	S/C Transponder D/L mode	Action_parameters: SCLINK	MSP SC_TRSP SCLINK
USO_UNMUTE	Unmute USO, mute TCXO		MS TCXO_state MUTE \ MS USO_state ACTIVE
USO_MUTE	Mute USO, unmute TCXO		MS TCXO_state ACTIVE \ MS USO_state MUTE
USO_UP	Bring the USO up: Heat for 20 min, then goto standby		Duration: 20 [minutes] Run_type: RELATIVE Run_actions: 00:00:00 uso_heat \ 00:20:00 uso_on
TM_ON	Switch telemetry modulation ON		MS TM_modulation ON
TM_OFF	Switch telemetry modulation OFF		MS TM_modulation OFF
IFMS_A_Configure	Configure IFMS A	Action_parameters: UL DL	MSP IFMS_A_UL UL \ MSP IFMS_A_DL DL
IFMS_B_Configure	Configure IFMS B	Action_parameters: UL DL	MSP IFMS_B_UL UL \ MSP IFMS_B_DL DL
IFMS_RS_Configure	Configure IFMS RS	Action_parameters: DL	MSP IFMS_RS_DL DL

TRACKMODE	Set tracking mode (Doppler/Range)	Action_parameters: TRKMOD	MSP TRACKMODE TRKMOD
SET_SAMPLING_OL	Set sampling rate for open-loop recording	Action_parameters: SAMPRATE_OL	MSP SAMPLING_OL\ SAMPRATE_OL
SET_SAMPLING_CL	Set sampling rate for closed-loop recording	Action_parameters: SAMPRATE_CL	MSP SAMPLING_CL\ SAMPRATE_CL

6.6.2.2 Global constraints

Mode constraints will be checked by the EPS whenever the experiment is set to this mode. It is also possible to allocate constraints to actions.
All actions are defined in the experiment template as follows:

```
Nr_of_constraints: <q>
#
   Constraint: <label> <description>
   Constraint_type: <TIME|GEOMETRIC|PARAMETRIC|CAPACITY>
   Severity: <FATAL|ERROR|WARNING|INFO>
   Condition: <EVENT|MODE|ACTION><IS|NOT> [<EXPERIMENT>]
   [<experiment>] <label #1> ...
```

The following global constraints are defined for VeRa:

Global constraints	Description	Constraint type	Severity	Condition
CHECK_TM_ON	Warn when telemetry is OFF	TIME	WARNING	MS NOT TM_modulation ON
CHECK_IFMS_A_ACTION	WATCH OUT! RSI IS TRYING TO MESS WITH IFMS A	TIME	WARNING	ACTION IS IFMS_A_Configure
CHECK_TCXO	TCXO is inactive	TIME	ERROR	MS NOT TCXO_state ACTIVE
CHECK_USO	USO is active	TIME	WARNING	MS IS USO_state

				ACTIVE

6.6.3 Experiment modes

An experiment mode is defined as a certain state of the experiment in which it can perform specific operations.

The build up of the mode template is as follows:

```
Nr_of_modes: <p>
#
    Mode: <label> <description>
    Mode_class:
    <OFF|INITIALISE|STANDBY|MEASUREMENT|CALIBRATION|MAINTENANCE>
    Module_states: <module #1> <module state #1> \
                <module #2> <module state #2> ...
    Nominal_power: <value (W)>
    Nominal_data_rate: <value> (bits/second)
    Equivalent_power: <average> [<peak>] [<low>]      (W)
    Equivalent_data_rate:<average>[<peak>][<low>](bits/second)
     Mode_transitions: <action #1> <action #2> ...
    Mode_actions: <action #1> <action #2> ...
    Mode_constraints : <constraint #1> <constraint #2>
#
...(p modes)
```

For VeRa the following modes are defined so far:

Instrument mode labels	Description
STDCONF	Standard configuration
ONEWAY_X	Standard ONES-X configuration
ONEWAY_S	Standard ONES-S configuration
ONEWAY_D	Standard ONED configuration
TWOWAY_X	Standard TWOS-X configuration
TWOWAY_S	Standard TWOS-S configuration
TWOWAY_DX	Standard TWOD-X configuration
TWOWAY_DS	Standard TWOD-S configuration

6.6.4 Experiment modules

The experiment subsystem can be described by the use of modules. Each module has different module states in which the experiment operates.

The modules are defined as follows:

```
Nr_of_modules: <m>
```

```
#
   Module: <label> <description>
   Module_level: <LEVEL1|LEVEL2|LEVEL3>
   Sub_modules: <module #1> <module #2> ...
   Nr_of_module_states: <n>
     Module_state: <label> <description>
      MS_power: <average> [<peak> [<low>]]      (W)
      MS_data_rate: <average> [<peak> [<low>]]   (bits/second)
      MS_constraints: <constraint #1> <constraint #2> ...
      ... (n module_states)
#
```

Experiment modules can have certain “Module_levels”. A “Level1 module” defines the highest level of module definition. Such a module can consist of several other modules with lower module levels. A “Level3 module” for example would describe a very basic module.

For VeRa the following modules are defined so far:

module label	description	module states		module level
		label	description/power	
Coherency	Up/downlink coherency definition	TWO_ ONE_	TWOx Configuration, i.e. coherency on ONEx Configuration, i.e. coherency off	1
SC_TRSP	S/C transponder downlink definition	S_x S_s D_xs	X-Band D/L (default) S-Band D/L Dual D/L	1
SC_UPL	S/C transponder uplink definition	x S _	X-Band U/L (default) S-Band U/L no uplink	1
S_BAND_TRANSM	S-Band Transmitter status	ON OFF	MS_power: 28 [Watts] MS_power: 0 [Watts]	1
USO_PWR	USO Power	ON OFF HEAT	MS_power: 5.5 [Watts] MS_power: 0 [Watts] MS_power: 9 [Watts]	1
USO_state	USO State	MUTE ACTIVE	MS_power: 5.5 [Watts] MS_power: 5.5	1

			[Watts]	
TCXO_state	TCXO_state	MUTE ACTIVE	mute active	1
TM_modulation	Telemetry modulation	ON OFF	TM on TM off	1
IFMS_A_UL	IFMS A Uplink	X S _	X-Band uplink S-Band uplink no request	1
IFMS_A_DL	IFMS A Downlink	X_CL S_CL	X-Band closed-loop S-Band closed-loop	1
IFMS_B_UL	IFMS B Uplink	X S _	X-Band uplink S-Band uplink no request	1
IFMS_B_DL	IFMS B Downlink	X_CL S_CL	X-Band closed-loop S-Band closed-loop	1
IFMS_RS_DL	IFMS RS Downlink	X_CL S_CL X_OLCL S_OLCL	X-Band closed-loop S-Band closed-loop X-Band open- & closed-loop S-Band open- & closed-loop	1
TRACKMODE	Tracking mode	DOPPLER DOP_RNG RANGE N_A STOP OL NOISE	Doppler only Simultaneous Doppler and Range Ranging only no request Stop recording Open loop Noise	1

6.6.5 Experiment actions

For VeRa the following actions are defined so far:
(see also global actions)

```
Action: ARFF908A  "DOT/GMC/SCX/AST/GWP Start"
        Action_level: LEVEL1
        Run_type: ABSOLUTE
        Run_actions: 00:00:00   S_BAND_ON                 \# 1h Warm up
                     00:57:00   IFMS_B_CONFIGURE (UL=X DL=X_CL)\#at G/S
                     00:58:00   IFMS_RS_CONFIGURE (DL=S_CL)    \#at G/S
                     00:59:00   SET_SAMPLING_CL (SAMPRATE_CL=1)\#at G/S
                     01:00:00   SC_LINK (SCLINK=D_xs)\
                     01:10:00   TRACKMODE (TRKMOD = DOP_RNG)\#start
                                                      #recording at G/S

Action: ARFF908B "DOT/GMC/SCX/AST/GWP END"
        Action_level: LEVEL1
        Run_type: ABSOLUTE
```

```
         Run_actions:   00:00:00   TRACKMODE (TRKMOD = STOP)\#stop
recording at G/S

 Action: ARFF904A "Occultation start"
         Action_level: LEVEL1
         Run_type: ABSOLUTE
         Run_actions: 00:00:00   S_BAND_ON                \# 1h Warm up
                      00:57:00   IFMS_B_CONFIGURE (UL=_ DL=X_CL)\#at G/S
                      00:58:00   IFMS_RS_CONFIGURE (DL=S_CL)    \#at G/S
                      00:59:00   SET_SAMPLING_CL (SAMPRATE_CL=10)\#at G/S
                      01:00:00   SC_LINK (SCLINK=D_xs)\
                      01:01:00   TM_OFF
                      01:02:00   USO_UNMUTE
                      01:03:00   COHERENCY_OFF
                      01:04:00   SC_UP (SCUL=_)\#at G/S
                      01:08:00   TRACKMODE (TRKMOD = DOP)\#start recording
                                                          #  at G/S

 Action: ARFF904B "Occultation end"
         Action_level: LEVEL1
         Run_type: ABSOLUTE
         Run_actions:   00:00:00   TRACKMODE (TRKMOD = STOP)\#stop
                                                             #recording a

 Action: OCX_START "Occultation only with X-Band start"
         Action_level: LEVEL1
         Run_type: ABSOLUTE
         Run_actions: 00:00:00   IFMS_B_CONFIGURE (UL=_ DL=X_CL)\#at G/S
                      00:01:00   IFMS_RS_CONFIGURE (DL=X_CL)    \#at G/S
                      00:02:00   SET_SAMPLING_CL (SAMPRATE_CL=10)\#at G/S
                      00:03:00   SC_LINK (SCLINK=S_x)\
                      00:04:00   TM_OFF
                      00:05:00   USO_UNMUTE
                      00:06:00   COHERENCY_OFF
                      00:07:00   SC_UP (SCUL=_)\#at G/S
                      00:11:00   TRACKMODE (TRKMOD = DOP)\#start recording
                                                          # at G/S

 Action: OCX_END "Occultation end"
         Action_level: LEVEL1
         Run_type: ABSOLUTE
         Run_actions: 00:00:00   TRACKMODE (TRKMOD = STOP)\#stop recording

 Action: ARFF907A "Solar conjunction start"
         Action_level: LEVEL1
         Run_type: ABSOLUTE
         Run_actions: 00:00:00   S_BAND_ON                \# 1h Warm up
                      00:52:00   IFMS_A_CONFIGURE (UL=S DL=S_CL)\#at G/S
                      00:53:00   IFMS_B_CONFIGURE (UL=S DL=S_CL)\#at G/S
                      00:54:00   IFMS_RS_CONFIGURE (DL=X_CL)    \#at G/S
                      00:55:00   SET_SAMPLING_CL (SAMPRATE_CL=1)\#at G/S
                      00:56:00   COHERENCY_OFF
                      00:57:00   SC_UP (SCUL=_)\#at G/S
                      00:58:00   SC_UP (SCUL=S)\#at G/S
                      00:59:00   COHERENCY_ON
                      01:00:00   SC_LINK (SCLINK=D_xs)\
                      01:05:00   TRACKMODE (TRKMOD = DOP_RNG)\#start
                                                        # recording at G/S

 Action: ARFF907B "Solar conjunction end"
```

```
         Action_level: LEVEL1
         Run_type: ABSOLUTE
         Run_actions:   00:00:00   TRACKMODE (TRKMOD = STOP)\#stop
recording a

Action: BRP_START "Bistatic radar calibration before actual measurement
with earth pointing"
         Action_level: LEVEL2
         Run_type: ABSOLUTE
         Run_actions: 00:00:00   S_BAND_ON            \# 1h Warm up
                      01:00:00   SC_LINK (SCLINK=D_xs)\
                      01:01:00   TM_OFF
                      01:02:00   USO_UNMUTE
                      01:03:00   COHERENCY_OFF
                      01:04:00   SC_UP (SCUL=_)\#at G/S
                      01:05:00   IFMS_B_CONFIGURE (UL=_ DL=X_CL)\#at G/S
                      01:06:00   IFMS_RS_CONFIGURE (DL=X_OL)    \#at G/S
                      01:07:00   SET_SAMPLING_CL (SAMPRATE_CL=10)\#at G/S
                      01:08:00   SET_SAMPLING_OL (SAMPRATE_OL=50000)\#at
                                                                 #G/S

 Action: BRP_MEASURE "Actual Bistatic radar measurement"
         Action_level: LEVEL2
         Run_type: ABSOLUTE
         Run_actions: 00:00:00   TRACKMODE (TRKMOD = OL)\#start recording
                                                        #at G/S
                      01:00:00   TRACKMODE (TRKMOD = STOP)\#stop recording
                                                          #at G/S

 Action: BRP_CAL "Bistatic radar calibration with earth pointing"
         Action_level: LEVEL2
         Run_type: ABSOLUTE
         Run_actions: 00:00:00   TRACKMODE (TRKMOD = OL)\#start recording
                                                        #at G/S
                      00:30:00   TRACKMODE (TRKMOD = STOP)\#stop recording
                                                          #at G/S

 Action: BRP_NOISE1 "Bistatic radar noise calibration before BRP"
         Action_level: LEVEL2
         Run_type: ABSOLUTE
         Run_actions: 00:00:00   TRACKMODE (TRKMOD = NOISE)\#start
                                                         #recording at G/S
                      03:00:00   TRACKMODE (TRKMOD = STOP)\#stop recording
                                                          #at G/S

 Action: BRP_NOISE2 "Bistatic radar noise calibration after BRP"
         Action_level: LEVEL2
         Run_type: ABSOLUTE
         Run_actions: 00:00:00   TRACKMODE (TRKMOD = NOISE)\#start
recording at G/S
                      01:00:00   TRACKMODE (TRKMOD = STOP)\#stop recording
                                                          #at G/S

 Action: ARFF906A "Bistatic radar procedure"
         Action_level: Level1
         Run_type: LEVEL1
         Run_type: ABSOLUTE
         Run_actions: 00:00:00 BRP_NOISE1 \# Start 3 hours of noise
                                    #calibration at
                                    #G/S no signal with s/c is required
```

```
01:56:00 BRP_START  \#prepare s/c and G/S for
                     #measurement
03:05:00 BRP_CAL    \#Calibration before measurement
                     #with S/C signal
                     #Allow for 30 minutes to slew to
                     #pointing
04:05:00 BRP_MAESURE\#1 hour measurement
                     #Allow for 30 minutes to slew
                     #back to earth pointing
05:35:00 BRP_CAL    \#Calibration after measurement
                     #with S/C signal
06:10:00 BRP_NOISE2 \# Start 1 hour of noise
                     #calibration
                    \# Actually this time has to be +
                     #2* OWLT
```

```
#
```

6.7 VeRa ITL

6.7.1 Introduction

The ITL files define

- the reference date of the activity
- start and stop of the activity in absolute time including the time needed for the execution of the IBATs
- start and stop of the IBATs in different options:
- relative to pericenter time
- relative to an event time
- in absolute time
- the pointing

6.7.2 VeRa ITL File Name Formats

TV_xxxxxxxx_yyyyyyyy_MOD_VSvPIw.ITL

Placeholder	description
TV	VeRa instrument acronym
xxxxxxxx	Phase: Case_4 Case_8 Case_10 Missing digits are filled by “_“
Yyyyyyyy	SAP type: TV_GRA TV_BSR TV_OCC TV_SCO Missing digits are filled by “_”
MOD	ITL mode
VSv	Integration number v by VSOC
Piw	Integration number w by PI

6.7.3 ITL syntax and statements

6.7.3.1 Initialising statements

Statement	Syntax	description
End_time	End_time: doy_hh:mm:ss	stop of activity doy = day of year hh = hour mm = minutes ss = seconds
ref_date	ref_date: dd-mm-yyyy	Ref_date is the absolute date of the start fo the activity described in this ITL dd = day of month mm = month of year yyyy = year
Start_time	Start_time: doy_hh:mm:ss	Start of activity doy = day of year hh = hour mm = minutes ss = seconds
Version	Version: xxxxx	Version number of this specific ITL file; xxxxx is an incremented number

6.7.3.2 Action statements

6.7.3.2.1 statements

Statement	Description Action is executed relative to the time of the event:
OCCE	Occultation egress
OCCS	Occultation ingress
PERICENTRE	Pericenter passage
VPER	Pericenter passage

6.7.3.2.2 Syntax

<statement> (count = x) <relative_time> VeRa <mode> <action>

	options	**description**
<statement>	As defined in 6.6.3.2.1	
(count = x)	x =	????????
<relative_time>	(-)hh:mm:ss	Time relative to an event as defined in <statement> in hh = hours mm = minutes ss = seconds
<mode>	ON OFF	????? ????? Where defined?
<action>	IBAT file name	for configuration or reconfiguration
	PTR file name	for custom pointing

	INERT_START(\\
	`SLEW_POLICY = IMMEDIATE \`
	`OBJECT = EARTH \`
	`OBJECT_TO_BE_POINTED = HGA\`
	)
		start of inertial HGA pointing with slew to Earth

	INERT_END	end of inertial pointing

6.7.4 VeRa ITL listings

6.7.4.1 Gravity

File name: “TV_CASE_10_TV_GRA___VS0PI0.itl”

```
#=================================================================#
# Filename: TV_CASE_10_TV_GRA___VS0PI0.itl
# Type:           Input Timeline file
#
# Description:    This is an ITL example for VeRa gravity obs
#
# Author:   Silvia Tellmann
#
# Verified by:    Nobody yet
#
# Date:           16 March 2005
#
# (c) IGM Cologne :-)
#
#-----------------------------------------------------------------#
#
# CVS version information:
# $Log: $
#
#=================================================================#

Version: 00001

Ref_date: 06-July-2006

Start_time:       187_23:51:00
End_time:         188_03:51:00

#-----------------------------------------------------------------#
# Description: 1 "Start Ground Station configuration for Occultation"
#-----------------------------------------------------------------#

# Option 1
# Relative to pericentre event
# PERICENTRE (COUNT = 60)     -02:00:00 VeRA ON TV_GRA_START  # Occ Start

# Option 2
# Relative to specific event
VPER (COUNT = 1)        -02:00:00 VeRA ON TV_GRA_START  # Occ Start

# Option 3
# Absolute time
# 187_23:51:00                        VeRA ON TV_GRA_START  # Occ Start

#-----------------------------------------------------------------#
# pointing for Observation
#-----------------------------------------------------------------#
VPER (COUNT = 36) -01:00:00   VeRA  INERT_START ( \
                                          SLEW_POLICY = IMMEDIATE \
                                     OBJECT = EARTH \
                                     OBJECT_TO_BE_POINTED = HGA)
```

```
VPER (COUNT = 36) 01:00:00    VeRA  INERT_END

#-----------------------------------------------------------------#
# Description: 2 "End Ground Station configuration for Occultation"
#-----------------------------------------------------------------#

# Option 1
# Relative to pericentre event
# PERICENTRE (COUNT = 60)    02:00:00 VeRA ON TV_GRA_END     # Occ End

# Option 2
# Relative to specific event
VPER (COUNT = 1)        02:00:00 VeRA ON TV_GRA_END     # Occ End

# Option 3
# Absolute time
# 188_03:51:00                   VeRA OFF TV_GRA_END    # Occ End
```

6.7.4.2 Gravity

File name: "TV_CASE_8__TV_OCC___VS0PI0.itl"

```
#=================================================================#
# Filename: TV_CASE_8__TV_OCC___VS0PI0.itl
# Type:           Input Timeline file
#
# Description:    This is an ITL example for VeRa Occultation
#
# Author:   Silvia Tellmann
#
# Verified by:    Nobody yet
#
# Date:           16 March 2005
#
# (c) IGM Cologne :-)
#
#-----------------------------------------------------------------#
#
# CVS version information:
# $Log: $
#
#=================================================================#

Version: 00001

Ref_date: 06-July-2006

Start_time:       187_23:27:00
End_time:         188_03:32:00

#-----------------------------------------------------------------#
# Description: 1 "Start Ground Station configuration for Occultation"
#-----------------------------------------------------------------#

# Option 1
# Relative to pericentre event
# PERICENTRE (COUNT = 60)     -02:24:00 VeRA ON TV_OCC_START  # Occ Start

# Option 2
# Relative to specific event
OCCS (COUNT = 1)        -02:00:00 VeRA ON TV_OCC_START  # Occ Start

# Option 3
# Absolute time
# 187_23:27:00                    VeRA ON TV_OCC_START  # Occ Start

#---------------------------------------------------------------#
# Description: 2 "End Ground Station configuration for Occultation"
#---------------------------------------------------------------#

# Option 1
# Relative to pericentre event
# PERICENTRE (COUNT = 60)     01:41:00 VeRA ON TV_OCC_END     # Occ End

# Option 2
# Relative to specific event
```

```
OCCE (COUNT = 1)        02:00:00 VeRA ON TV_OCC_END     # Occ End

# Option 3
# Absolute time
# 188_03:32:00                   VeRA OFF TV_OCC_END    # Occ End
```

7 Detailed Descriptions of Operational Procedures

7.1 Synoptic Table of the Operations

Time Period Nominal Mission	VeRa Experiment	Distance Earth-Venus [AU]	Surface Target	Station	Number of Passes
11.04.2006-23.04.2006	Earth Occultation Commissioning	0.9		NNO	2
22.05.2006	Bistatic Radar Commissioning	1.1	Akna Montes Lakshmi Pla-num	DSN/ NNO	2
15.06.2006-20.06.2006	Bistatic Radar 1	1.3	Maxwell Montes Slant Range:850km	DSN	3
07.07.2006-26.08.2006	Earth Occultation 1	1.5		NNO	25
04.08.2006-10.08.2006	Bistatic Radar 2	1.6	Ovda Regio	DSN	2
22.08.2006-28.08.2006	Bistatic Radar 3	1.6	Thetis Regio	DSN	2
26.08.2006-01.11.2006	Gravity 1	1.7	Atalanta Planitia, Coronae	NNO	4
30.09.2006-04.10.2006	Bistatic Radar 4	1.7	Ozza Mons	DSN	2
28.10.2006	Superior Solar Conjunction	1.7			
20.09.2006-06.12.2006	Solar Corona	1.7		DSN	30
12.11.2006-14.11.2006	Bistatic Radar 5	1.7	Theia Mons	DSN	1
18.11.2006-28.01.2007	Earth Occultation 2	1.6		NNO	15
17.03.2007-20.03.2007	Bistatic Radar 6	1.3	Theia Mons	DSN	2
22.04.2007-26.06.2007	Earth Occultation 3	0.8		NNO	36
23.06.2007-02.07.2008	Gravity 2	0.75	Atalanta Planitia, Coronae	NNO	10
16.06.2007-17.06.2007	Bistatic Radar 7	0.7	Ozza Mons	DSN	2
02.08.2007-03.08.2007	Bistatic Radar 8	0.3	Theia Mons	DSN	2
17.08.2007	Inferior Solar Conjunction	0.3			
13.08.2007-21.08.2007	Solar Wind	0.3		DSN	5
06.10.2007-11.10.2007	Bistatic Radar 9	0.5	Thetis Regio	DSN	2

Time Period Extended Mission	Experiment	Distance Earth-Venus [AU]			
09.11.2007-15.11.2007	Bistatic Radar 10	0.8	Maat Mons/ Ozza Mons	DSN	3
21.12.2007-25.12.2007	Bistatic Radar 11	1.1	Theia Mons/ Dali Chasma	DSN	3
31.12.2007-10.03.2008	Earth Occultation 4	1.3		NNO	
26.12.2007-01.03.2008	Gravity 3	1.3	Atalanta Planitia, Coronae		
09.06.2008	Superior Solar Conjunction	1.7			
02.05.2008-15.07.2008	Solar Corona	1.7		DSN	30
02.06.2008-28.07.2008	Earth Occultation 5	1.7			
06.09.2008-27.10.2008	Gravity 4	1.4	Atalanta Planitia, Coronae		
25.10.2008-27.12.2008	Earth Occultation 6	1.0			
Source: ESA Orbit File :	**ORVF_FDLVMA_DA_______ _______00001.VEX**		**06.04.2005 B.H./J.S.**		

7.2 Occultations: Neutral and Ionized Atmosphere

7.2.1 Description

Occultation observations will provide a measure of the vertical structure of the atmosphere and ionosphere of Venus. Density, temperature and pressure profiles will be derived from the Doppler recordings during the occultation ingress and egress phase.

7.2.2 Measurement Technique

Before the spacecraft is entering occultation as seen from the Earth, the radio ray slices through the layers of the ionosphere and neutral atmosphere. The TT&C system is operating in the one-way mode. Changes in the received radio frequency to an accuracy of 10^{-13} correspond to a detection of a change in the angle of refraction of radio rays in occultation experiments in the order of 10^{-8} radians.
The effective vertical resolution through use of the Abel transform is determined by the first Fresnel zone radius $(\lambda D)^{1/2}$ which translates to 300 m for X-band and 600 m for S-band radio waves, respectively, (*D* is the distance of the spacecraft to the closest approach of the ray path to the planet). This resolution is far superior than what can be achieved by other sounding instruments which are limited to typically one atmospheric scale height (order of kilometers).

7.2.3 Operations

7.2.3.1 Configuration

Operations will be conducted using a coherent simultaneous dual-frequency one-way tracking link prior to occultation entry. When leaving occultation the spacecraft is also configured as ONED. A dual-frequency downlink is mandatory for the separation of ionospheric and interplanetary plasma effects from the classical Doppler shift. Open loop tracking is requested to analyze high temporal variations.

Table 7.2-1: Configurations for atmospheric and ionospheric sounding

S/C configuration	ONED-USO entry phase		
	ONED-USO exit phase		
Ground segment configuration		up	down
	IFMS A		X-CL
	IFMS B		X-CL
	IFMS RS Closed-loop Open-loop Open-loop		 S-CL X-OL S-OL
Telemetry modulation	OFF		
VeRa nominal operational procedures	OCI-OFF		
In case of single downlink (X-band)	OCX-OFF		

7.2.3.2 HGA1 Pointing

All radio science experiments must use HGA1 as active S/C antenna (dual frequency requirement). In order to compensate for the ray bending effects in an occultation experiment, the S/C (together with the rigidly mounted HGA1) has to perform specific attitude maneuvers which differ from orbit to orbit. (For examples see [3]). The maneuvers will be predetermined by the VeRa team. There is no constraint wrt the rotation angle of the S/C around the boresight axis of the HGA1.
The pointing accuracy of the S/C (J2000 geocentric reference frame) has to be ≤ 0.2° (absolute) while performing the manoeuvers.

7.2.3.3 Operations Timeline (Sequence-of-events SOE)

For this kind of observation, the radio signals of Venus Express will be analysed for calibration purposes before the spacecraft enters the occultation of the planet as seen from the Earth and after leaving the occultation. The HGA1 is pointed toward the Earth before the attitude manoeuver and the spacecraft operates in the one-way mode when entering occultation and in the one-way mode when leaving occultation.
Timing accuracy (absolute) for the conduction of attitude maneuvers has to be < 1 second UTC.

Detailed timelines and sequence of events are given in section 6.2 .

7.2.3.4 Number of occultations

The number of occultations occurring in the prime mission time is shown in Figure 7.1-1 below. The number of occultation passes to be covered by the ground stations is still tbd.

ESA ground station NNO:

Table 7.2-2: Occultation seasons as a function of mission time

ground station New Norcia NNO					
Occultation season			Orbit numbers	Number of orbits	number of requested orbits
Acronym	start	stop			
OCC-1	07.07.2006	26.08.2006	81 – 131	50	25
OCC-2	18.11.2005	28.01.2005	215 - 286	72	15
OCC-3	22.04.2005	27.06.2005	370 - 435	66	36
OCC-4	Tbd	Tbd			
OCC-5	Tbd	Tbd			
OCC-6	Tbd	Tbd			

7.2.3.5 Duration of occultations

Fig. 7.1-1 shows the duration of the occultation as a function of mission time [1]. (See also VEX-ESC-RP-5500 I1, Consolidated Mission Report)

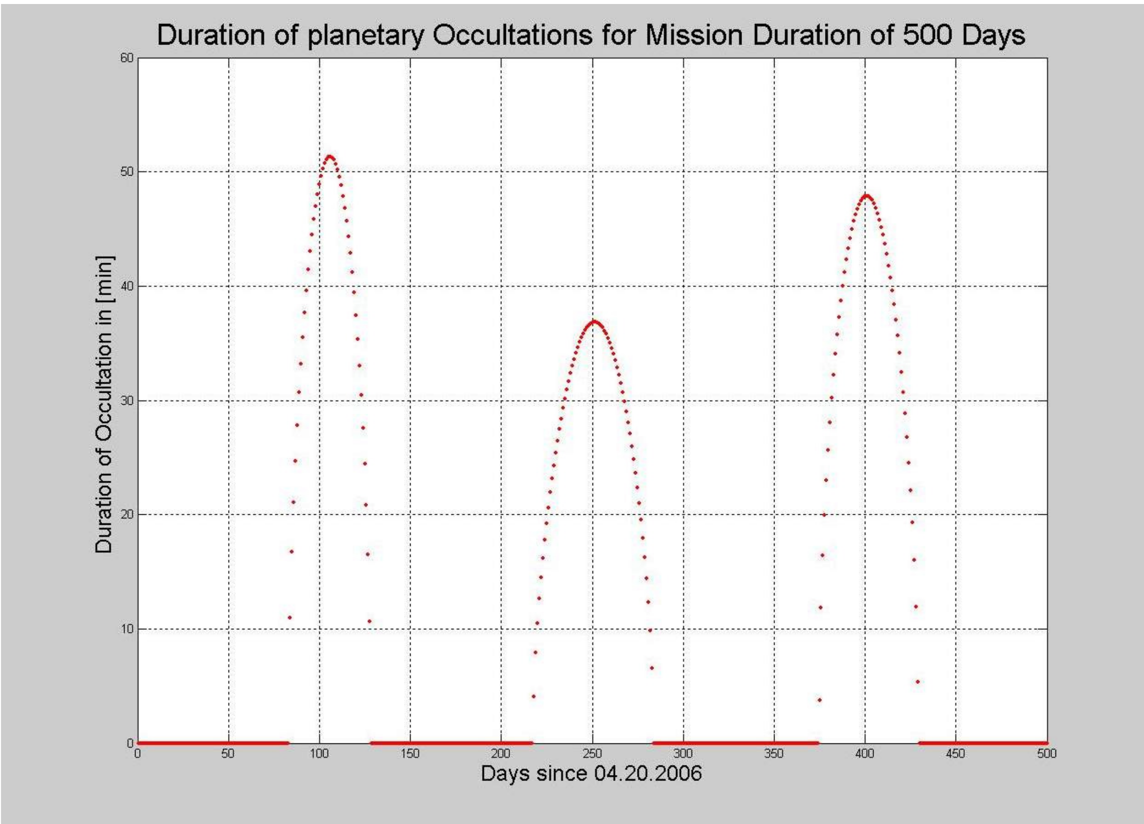


Fig. 7.1-1 Duration of occultations in prime mission time

7.2.3.6 Occultation entry and exit

Figure 7.1-2 show the location of True Anomaly of VEX S/C during the planetary occultations [1].

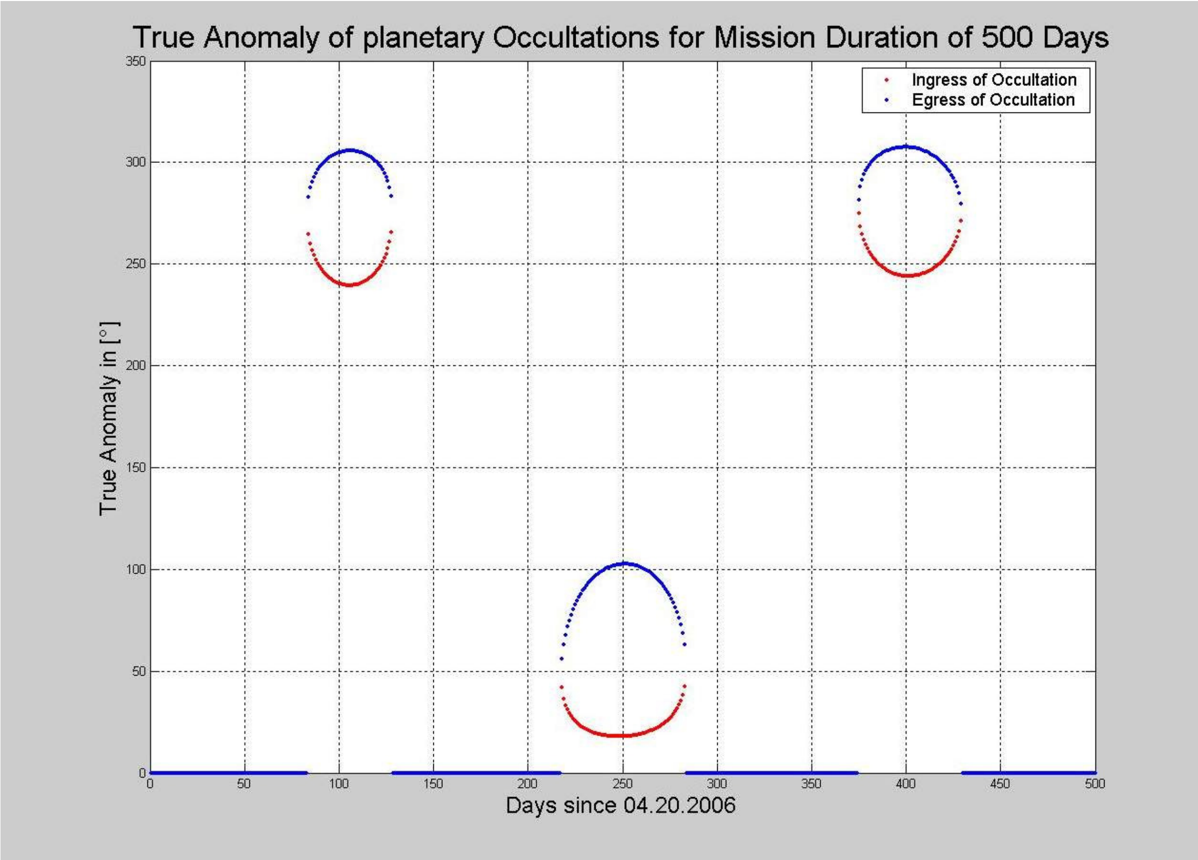


Figure 7.2-1: Occultation entries with respect to pericenter (degrees)

7.2.3.7 Constraints

According to the Venus Express orbit analysis, Earth occultations will occur in distinct seasons. The occultation entry and exits will cover planetary latitudes in both hemispheres. In case of thruster activities, a logging of relevant thrust parameters has to be performed.

7.2.4 Data

7.2.4.1 Mission Products

NNO Ground Station:

Table 7.2-3: IFMS Data products

Receiver	Frequency band	Data products
IFMS A (closed-loop)	X	DOP1 DOP2 AGC1 AGC2 MET
IFMS B (closed-loop)	X	DOP1 DOP2 AGC1 AGC2
IFMS RS Closed-loop	S	DOP1 DOP2 AGC1 AGC2
open-loop	X & S	Voltage samples

Deep Space Network:

Table 7.2-4: DSN Data products

Receiver	Frequency band	Data products	Data file type
closed-loop	X	Doppler	ODF
	S	Doppler	
open-loop	X	Voltage samples	RSR
	S	Voltage samples	

7.2.4.2 Accuracy

The accuracy of the derived atmospheric values is governed by the stability of the frequency reference source. A stability of 10^{-15} at one second integration time is required at the ground station to achieve the goals.

7.2.4.3 Sample Rate

Table 7.2-5: Occultations: sample rate

Closed-loop	10 samples / second
Open-loop	100,000 samples/second (IFMS) 50,000 Hz bandwidth

7.2.4.4 Data Volume

Table 7.2.4-16: Occultations: Data volume

	Data Volume
Closed-loop IFMS	See section 3.4.3.7
Open-loop IFMS	See section 3.4.3.7

7.2.4.5 Availability

TBD

7.2.5 Detailed description of occultation seasons

```
#******************************************************************************
#***   List of orbits with possibilities for RS-Occultation-Observations    ***
#******************************************************************************
#OUTPUT DATA: ORB             - orbit number at occultation entry
#             DATE entry [SC] - date and time of occultation entry in S/C time frame
#             DATE entry [UT] - date and time of occultation entry in UT
#             DurPER [min]    - duration between occultation entry and pericentre pass [min]
#             DurOCC [min]    - duration of occultation [MM:SS]
#             LONent          - geograph. longitude of ray impact point at occultation entry (˚)
#             LATent          - geograph. latitude of ray impact point at occultation exit (˚)
#             LONexi          - geograph. longitude of ray impact point at occultation entry (˚)
#             LATexi          - geograph. latitude of ray impact point at occultation exit (˚)
#             ELEent          - sun elevation at ray impact point at occultation entry (˚)
#                               (90˚ zenith, 0˚ horizon)
#             ELEexi          - sun elevation at ray impact point at occultation exit (˚)
#                               (90˚ zenith, 0˚ horizon)
#             AZIent          - sun azimuth at ray impact point at occultation entry (˚)
#                               (0˚ N - midnight, 90˚ E - sunrise, 180˚ S - noon, 270˚ W - sunset)
#             AZIexi          - sun azimuth at ray impact point at occultation exit (˚)
#                               (0˚ N - midnight, 90˚ E - sunrise, 180˚ S - noon, 270˚ W - sunset)
```

7.2.5.1 Occultation season 1

#ORB	DATE entry [SC]	DATE entry [UT]	DurPER	DurOCC	LONent	LATent	LONexi	LATexi	ELEent	AZIent	ELEexi	AZIexi
81	2006/07/07 01:27:29	2006/07/07 01:39:14	-35.83	4.50	286.03	30.76	285.91	43.81	36.69	114.49	30.39	122.04
82	2006/07/08 01:23:01	2006/07/08 01:34:48	-40.60	12.16	288.80	18.11	288.49	53.21	40.69	104.78	24.81	125.70
83	2006/07/09 01:20:06	2006/07/09 01:31:57	-43.78	16.70	291.53	10.02	291.12	58.07	41.93	97.74	21.66	126.98
84	2006/07/10 01:17:42	2006/07/10 01:29:35	-46.48	20.32	294.24	3.29	293.77	61.61	42.13	91.70	19.29	127.65
85	2006/07/11 01:15:34	2006/07/11 01:27:29	-48.90	23.42	296.94	-2.71	296.42	64.44	41.66	86.41	17.34	128.00
86	2006/07/12 01:13:37	2006/07/12 01:25:36	-51.12	26.18	299.64	-8.24	299.09	66.82	40.74	81.75	15.67	128.19
87	2006/07/13 01:11:51	2006/07/13 01:23:52	-53.19	28.68	302.34	-13.43	301.77	68.90	39.47	77.67	14.20	128.25
88	2006/07/14 01:10:13	2006/07/14 01:22:16	-55.11	30.97	305.03	-18.36	304.46	70.73	37.94	74.09	12.89	128.23
89	2006/07/15 01:08:42	2006/07/15 01:20:48	-56.91	33.07	307.72	-23.09	307.16	72.39	36.21	70.97	11.70	128.16
90	2006/07/16 01:07:18	2006/07/16 01:19:26	-58.60	35.01	310.41	-27.65	309.86	73.90	34.33	68.27	10.62	128.05
91	2006/07/17 01:06:00	2006/07/17 01:18:11	-60.18	36.81	313.09	-32.08	312.58	75.30	32.34	65.93	9.61	127.90
92	2006/07/18 01:04:49	2006/07/18 01:17:03	-61.65	38.46	315.77	-36.40	315.31	76.60	30.26	63.92	8.67	127.74
93	2006/07/19 01:03:44	2006/07/19 01:16:00	-63.02	39.99	318.45	-40.62	318.05	77.83	28.13	62.20	7.80	127.56
94	2006/07/20 01:02:45	2006/07/20 01:15:04	-64.29	41.39	321.13	-44.76	320.81	78.98	25.95	60.74	6.97	127.37
95	2006/07/21 01:01:53	2006/07/21 01:14:14	-65.45	42.66	323.80	-48.83	323.59	80.08	23.74	59.51	6.19	127.18
96	2006/07/22 01:01:06	2006/07/22 01:13:30	-66.51	43.81	326.46	-52.84	326.39	81.13	21.51	58.50	5.45	127.00
97	2006/07/23 01:00:26	2006/07/23 01:12:52	-67.48	44.85	329.12	-56.79	329.22	82.14	19.28	57.68	4.74	126.83
98	2006/07/24 00:59:51	2006/07/24 01:12:20	-68.33	45.77	331.77	-60.70	332.09	83.12	17.05	57.03	4.06	126.70
99	2006/07/25 00:59:23	2006/07/25 01:11:54	-69.09	46.57	334.41	-64.58	335.02	84.07	14.83	56.56	3.40	126.60
100	2006/07/26 00:59:01	2006/07/26 01:11:34	-69.75	47.26	337.03	-68.42	338.04	84.99	12.62	56.25	2.78	126.58
101	2006/07/27 00:58:45	2006/07/27 01:11:21	-70.30	47.83	339.62	-72.23	341.19	85.90	10.42	56.11	2.17	126.69
102	2006/07/28 00:58:36	2006/07/28 01:11:13	-70.75	48.28	342.15	-76.03	344.59	86.79	8.26	56.15	1.58	127.04
103	2006/07/29 00:58:32	2006/07/29 01:11:12	-71.10	48.63	344.57	-79.80	348.52	87.66	6.12	56.43	1.00	127.90
104	2006/07/30 00:58:35	2006/07/30 01:11:17	-71.34	48.86	346.66	-83.57	353.88	88.53	4.01	57.14	0.44	130.19
105	2006/07/31 00:58:43	2006/07/31 01:11:28	-71.49	48.97	347.10	-87.32	6.60	89.38	1.93	59.62	-0.10	139.83
106	2006/08/01 00:58:58	2006/08/01 01:11:45	-71.53	48.97	183.06	-88.90	138.12	89.67	-0.11	226.70	-0.64	268.25
107	2006/08/02 00:59:19	2006/08/02 01:12:08	-71.46	48.86	178.47	-85.15	165.69	88.85	-2.10	234.43	-1.17	292.73
108	2006/08/03 00:59:47	2006/08/03 01:12:37	-71.30	48.64	180.22	-81.39	172.34	87.98	-4.06	235.91	-1.69	296.27
109	2006/08/04 01:00:20	2006/08/04 01:13:13	-71.03	48.30	182.55	-77.62	176.64	87.10	-5.96	236.93	-2.20	297.45
110	2006/08/05 01:01:00	2006/08/05 01:13:54	-70.66	47.85	185.04	-73.83	180.21	86.21	-7.81	237.89	-2.71	297.90
111	2006/08/06 01:01:45	2006/08/06 01:14:42	-70.19	47.29	187.61	-70.02	183.47	85.31	-9.60	238.88	-3.21	298.02
#ORB	DATE entry [SC]	DATE entry [UT]	DurPER	DurOCC	LONent	LATent	LONexi	LATexi	ELEent	AZIent	ELEexi	AZIexi

#--

112	2006/08/07 01:02:37	2006/08/07 01:15:36	-69.61	46.61	190.21	-66.19	186.56	84.38	-11.33	239.93	-3.71	297.97
113	2006/08/08 01:03:35	2006/08/08 01:16:36	-68.94	45.82	192.84	-62.32	189.56	83.43	-13.00	241.07	-4.22	297.81
114	2006/08/09 01:04:39	2006/08/09 01:17:42	-68.17	44.91	195.48	-58.42	192.49	82.45	-14.59	242.30	-4.72	297.58
115	2006/08/10 01:05:49	2006/08/10 01:18:53	-67.29	43.89	198.13	-54.48	195.39	81.44	-16.11	243.63	-5.23	297.30
116	2006/08/11 01:07:05	2006/08/11 01:20:11	-66.32	42.76	200.79	-50.49	198.25	80.39	-17.54	245.06	-5.74	296.98
117	2006/08/12 01:08:27	2006/08/12 01:21:35	-65.25	41.51	203.45	-46.44	201.10	79.30	-18.89	246.60	-6.26	296.63
118	2006/08/13 01:09:55	2006/08/13 01:23:05	-64.08	40.14	206.12	-42.32	203.94	78.15	-20.14	248.25	-6.78	296.24
119	2006/08/14 01:11:29	2006/08/14 01:24:41	-62.80	38.65	208.78	-38.13	206.76	76.93	-21.29	250.00	-7.32	295.83
120	2006/08/15 01:13:09	2006/08/15 01:26:23	-61.43	37.03	211.45	-33.84	209.57	75.65	-22.32	251.87	-7.88	295.39
121	2006/08/16 01:14:55	2006/08/16 01:28:11	-59.96	35.28	214.13	-29.45	212.38	74.27	-23.24	253.85	-8.46	294.91
122	2006/08/17 01:16:47	2006/08/17 01:30:05	-58.38	33.39	216.80	-24.93	215.19	72.78	-24.02	255.95	-9.06	294.41
123	2006/08/18 01:18:46	2006/08/18 01:32:06	-56.69	31.34	219.47	-20.26	217.99	71.16	-24.65	258.16	-9.69	293.87
124	2006/08/19 01:20:53	2006/08/19 01:34:14	-54.89	29.13	222.14	-15.40	220.80	69.38	-25.13	260.48	-10.37	293.28
125	2006/08/20 01:23:06	2006/08/20 01:36:29	-52.96	26.73	224.81	-10.31	223.60	67.39	-25.44	262.93	-11.09	292.63
126	2006/08/21 01:25:29	2006/08/21 01:38:53	-50.89	24.09	227.48	-4.91	226.40	65.12	-25.54	265.52	-11.90	291.91
127	2006/08/22 01:28:02	2006/08/22 01:41:28	-48.63	21.15	230.14	0.90	229.21	62.46	-25.42	268.26	-12.80	291.07
128	2006/08/23 01:36:40	2006/08/23 01:50:07	-46.12	17.75	232.80	7.41	232.04	59.18	-25.00	271.24	-13.86	290.06
129	2006/08/24 01:45:39	2006/08/24 01:59:09	-43.24	13.65	235.46	14.93	234.88	54.88	-24.17	274.53	-15.19	288.75
130	2006/08/25 01:51:56	2006/08/25 02:05:27	-41.03	13.18	238.15	17.84	237.51	57.29	-23.53	275.63	-14.20	288.91
131	2006/08/26 01:57:31	2006/08/26 02:11:03	-37.42	7.64	240.76	27.75	240.39	50.77	-21.78	279.47	-16.13	287.01

7.2.5.2 Occultation season 2

#ORB	DATE entry [SC]	DATE entry [UT]	DurPER	DurOCC	LONent	LATent	LONexi	LATexi	ELEent	AZIent	ELEexi	AZIexi
215	2006/11/18 05:11:56	2006/11/18 05:26:06	-7.48	5.31	289.22	57.37	289.95	35.78	-4.30	82.34	-6.23	84.88
216	2006/11/19 05:13:02	2006/11/19 05:27:12	-8.34	8.22	291.68	61.43	292.84	28.27	-3.98	81.47	-6.99	85.57
217	2006/11/20 05:14:27	2006/11/20 05:28:36	-8.86	10.47	294.17	64.12	295.68	22.22	-3.77	80.73	-7.61	86.18
218	2006/11/21 05:16:01	2006/11/21 05:30:10	-9.25	12.42	296.67	66.18	298.52	16.88	-3.60	80.03	-8.16	86.76
219	2006/11/22 05:17:40	2006/11/22 05:31:48	-9.54	14.17	299.17	67.87	301.34	11.98	-3.46	79.36	-8.65	87.35
220	2006/11/23 05:19:23	2006/11/23 05:33:30	-9.78	15.79	301.66	69.32	304.16	7.39	-3.33	78.70	-9.09	87.95
221	2006/11/24 05:21:08	2006/11/24 05:35:15	-9.98	17.31	304.15	70.60	306.98	3.05	-3.20	78.05	-9.48	88.56
222	2006/11/25 05:22:55	2006/11/25 05:37:01	-10.14	18.75	306.63	71.75	309.79	-1.10	-3.09	77.39	-9.83	89.19
223	2006/11/26 05:24:43	2006/11/26 05:38:49	-10.29	20.12	309.09	72.79	312.61	-5.09	-2.97	76.73	-10.14	89.84
224	2006/11/27 05:26:33	2006/11/27 05:40:38	-10.41	21.42	311.55	73.75	315.43	-8.95	-2.86	76.06	-10.40	90.50
225	2006/11/28 05:28:23	2006/11/28 05:42:27	-10.51	22.67	313.98	74.64	318.25	-12.69	-2.74	75.37	-10.61	91.18
226	2006/11/29 05:30:15	2006/11/29 05:44:18	-10.60	23.86	316.40	75.48	321.07	-16.33	-2.63	74.68	-10.78	91.87
227	2006/11/30 05:32:07	2006/11/30 05:46:09	-10.68	25.00	318.80	76.27	323.90	-19.88	-2.51	73.96	-10.91	92.57
228	2006/12/01 05:33:59	2006/12/01 05:48:01	-10.75	26.09	321.17	77.02	326.73	-23.35	-2.39	73.23	-10.99	93.27
229	2006/12/02 05:35:52	2006/12/02 05:49:53	-10.81	27.14	323.51	77.74	329.57	-26.75	-2.27	72.47	-11.02	93.98
230	2006/12/03 05:37:45	2006/12/03 05:51:46	-10.86	28.14	325.83	78.43	332.41	-30.09	-2.15	71.68	-11.00	94.69
231	2006/12/04 05:39:39	2006/12/04 05:53:39	-10.90	29.09	328.11	79.10	335.26	-33.37	-2.03	70.86	-10.94	95.40
232	2006/12/05 05:41:33	2006/12/05 05:55:32	-10.94	29.99	330.34	79.74	338.12	-36.60	-1.90	70.00	-10.83	96.10
233	2006/12/06 05:43:28	2006/12/06 05:57:25	-10.97	30.85	332.53	80.36	340.99	-39.78	-1.77	69.09	-10.68	96.79
234	2006/12/07 05:45:22	2006/12/07 05:59:19	-10.99	31.66	334.66	80.97	343.87	-42.92	-1.64	68.13	-10.47	97.46
235	2006/12/08 05:47:17	2006/12/08 06:01:13	-11.01	32.42	336.72	81.56	346.76	-46.02	-1.50	67.10	-10.22	98.12
236	2006/12/09 05:49:12	2006/12/09 06:03:07	-11.03	33.14	338.69	82.14	349.67	-49.09	-1.36	65.99	-9.92	98.75
237	2006/12/10 05:51:08	2006/12/10 06:05:02	-11.04	33.81	340.57	82.71	352.60	-52.13	-1.21	64.78	-9.58	99.34
238	2006/12/11 05:53:03	2006/12/11 06:06:56	-11.05	34.43	342.32	83.27	355.56	-55.14	-1.07	63.45	-9.18	99.90
239	2006/12/12 05:54:59	2006/12/12 06:08:51	-11.05	35.01	343.91	83.82	358.55	-58.12	-0.91	61.96	-8.75	100.41
240	2006/12/13 05:56:54	2006/12/13 06:10:45	-11.05	35.54	345.30	84.36	1.59	-61.08	-0.76	60.27	-8.26	100.86
241	2006/12/14 05:58:50	2006/12/14 06:12:40	-11.05	36.02	346.44	84.89	4.68	-64.02	-0.60	58.33	-7.73	101.23
242	2006/12/15 06:00:46	2006/12/15 06:14:35	-11.04	36.45	347.22	85.41	7.85	-66.94	-0.43	56.05	-7.16	101.49
243	2006/12/16 06:02:42	2006/12/16 06:16:30	-11.03	36.83	347.54	85.92	11.14	-69.84	-0.26	53.29	-6.54	101.62
244	2006/12/17 06:04:38	2006/12/17 06:18:25	-11.01	37.16	347.19	86.43	14.59	-72.73	-0.09	49.88	-5.88	101.55
245	2006/12/18 06:06:35	2006/12/18 06:20:21	-11.00	37.44	345.88	86.91	18.31	-75.60	0.09	45.50	-5.17	101.19
246	2006/12/19 06:08:31	2006/12/19 06:22:16	-10.98	37.68	343.12	87.38	22.50	-78.46	0.27	39.67	-4.43	100.32

#ORB DATE entry [SC] DATE entry [UT] DurPER DurOCC LONent LATent LONexi LATexi ELEent AZIent ELEexi AZIexi

247	2006/12/20 06:10:27	2006/12/20 06:24:11	-10.95	37.86	338.10	87.81	27.62	-81.31	0.46	31.58	-3.65	98.50
248	2006/12/21 06:12:24	2006/12/21 06:26:07	-10.92	37.99	329.59	88.19	34.98	-84.11	0.66	20.02	-2.82	94.39
249	2006/12/22 06:14:21	2006/12/22 06:28:02	-10.90	38.08	316.22	88.46	50.37	-86.82	0.85	3.59	-1.96	82.22
250	2006/12/23 06:16:17	2006/12/23 06:29:58	-10.86	38.11	298.23	88.57	117.17	-88.57	1.06	342.55	-1.07	18.60
251	2006/12/24 06:18:14	2006/12/24 06:31:53	-10.83	38.09	279.80	88.49	182.88	-86.78	1.27	321.05	-0.14	316.02
252	2006/12/25 06:20:11	2006/12/25 06:33:49	-10.79	38.02	265.56	88.22	198.07	-84.08	1.49	303.77	0.83	303.93
253	2006/12/26 06:19:05	2006/12/26 06:32:41	-11.81	38.00	263.78	88.10	205.22	-81.41	1.58	298.93	1.77	299.82
254	2006/12/27 06:16:58	2006/12/27 06:30:34	-11.77	37.84	257.95	87.80	210.35	-78.62	1.77	290.05	2.78	297.68
255	2006/12/28 06:14:52	2006/12/28 06:28:27	-11.72	37.63	254.24	87.45	214.55	-75.80	1.96	283.31	3.82	296.43
256	2006/12/29 06:15:01	2006/12/29 06:28:34	-11.68	37.37	252.07	87.07	218.28	-72.97	2.15	278.08	4.88	295.59
257	2006/12/30 06:15:10	2006/12/30 06:28:42	-11.63	37.06	250.97	86.67	221.74	-70.12	2.35	273.95	5.97	294.97
258	2006/12/31 06:15:19	2006/12/31 06:28:50	-11.58	36.71	250.66	86.25	225.03	-67.26	2.56	270.59	7.08	294.47
259	2007/01/01 06:15:29	2007/01/01 06:28:58	-11.52	36.31	250.92	85.82	228.20	-64.37	2.77	267.81	8.21	294.02
260	2007/01/02 06:15:38	2007/01/02 06:29:05	-11.46	35.86	251.60	85.37	231.29	-61.47	2.99	265.46	9.36	293.59
261	2007/01/03 06:15:47	2007/01/03 06:29:13	-11.41	35.36	252.60	84.91	234.33	-58.55	3.22	263.43	10.53	293.15
262	2007/01/04 06:15:56	2007/01/04 06:29:21	-11.34	34.82	253.86	84.44	237.32	-55.60	3.45	261.66	11.71	292.68
263	2007/01/05 06:16:06	2007/01/05 06:29:29	-11.28	34.23	255.32	83.96	240.27	-52.63	3.70	260.09	12.90	292.18
264	2007/01/06 06:16:16	2007/01/06 06:29:38	-11.21	33.59	256.94	83.46	243.20	-49.62	3.95	258.68	14.09	291.62
265	2007/01/07 06:16:25	2007/01/07 06:29:46	-11.14	32.90	258.69	82.95	246.11	-46.59	4.20	257.40	15.29	291.01
266	2007/01/08 06:16:35	2007/01/08 06:29:54	-11.06	32.17	260.54	82.42	249.00	-43.52	4.47	256.24	16.49	290.32
267	2007/01/09 06:16:45	2007/01/09 06:30:03	-10.98	31.39	262.48	81.87	251.88	-40.41	4.75	255.17	17.68	289.56
268	2007/01/10 06:16:56	2007/01/10 06:30:12	-10.90	30.56	264.50	81.31	254.74	-37.27	5.04	254.17	18.87	288.72
269	2007/01/11 06:17:06	2007/01/11 06:30:21	-10.81	29.69	266.58	80.73	257.60	-34.07	5.35	253.25	20.03	287.78
270	2007/01/12 06:17:17	2007/01/12 06:30:30	-10.71	28.77	268.72	80.13	260.44	-30.83	5.66	252.38	21.18	286.75
271	2007/01/13 06:17:28	2007/01/13 06:30:40	-10.61	27.81	270.90	79.50	263.28	-27.52	6.00	251.57	22.29	285.60
272	2007/01/14 06:17:40	2007/01/14 06:30:50	-10.51	26.80	273.12	78.85	266.11	-24.16	6.34	250.80	23.37	284.35
273	2007/01/15 06:17:52	2007/01/15 06:31:00	-10.39	25.74	275.38	78.16	268.94	-20.73	6.71	250.07	24.40	282.97
274	2007/01/16 06:18:04	2007/01/16 06:31:11	-10.27	24.63	277.67	77.43	271.76	-17.23	7.10	249.38	25.37	281.46
275	2007/01/17 06:18:17	2007/01/17 06:31:22	-10.13	23.47	279.99	76.67	274.58	-13.64	7.51	248.73	26.27	279.82
276	2007/01/18 06:18:31	2007/01/18 06:31:34	-9.99	22.26	282.32	75.85	277.39	-9.95	7.95	248.12	27.09	278.04
277	2007/01/19 06:18:45	2007/01/19 06:31:47	-9.83	20.99	284.68	74.98	280.21	-6.16	8.42	247.53	27.81	276.10
278	2007/01/20 06:19:01	2007/01/20 06:32:01	-9.65	19.67	287.06	74.03	283.02	-2.24	8.93	246.99	28.41	274.02
279	2007/01/21 06:19:17	2007/01/21 06:32:16	-9.45	18.28	289.45	73.00	285.82	1.82	9.49	246.48	28.87	271.78
280	2007/01/22 06:19:35	2007/01/22 06:32:32	-9.23	16.82	291.86	71.86	288.63	6.06	10.10	246.01	29.16	269.39
281	2007/01/23 06:19:55	2007/01/23 06:32:50	-8.98	15.27	294.28	70.58	291.44	10.50	10.79	245.58	29.26	266.83

#ORB	DATE entry [SC]	DATE entry [UT]	DurPER	DurOCC	LONent	LATent	LONexi	LATexi	ELEent	AZIent	ELEexi	AZIexi
282	2007/01/24 06:20:18	2007/01/24 06:33:11	-8.68	13.61	296.70	69.12	294.25	15.20	11.57	245.22	29.12	264.10

283	2007/01/25 06:20:44	2007/01/25 06:33:35	-8.32	11.81	299.13	67.38	297.07	20.25	12.48	244.93	28.70	261.21
284	2007/01/26 06:21:16	2007/01/26 06:34:05	-7.87	9.81	301.56	65.23	299.90	25.80	13.59	244.76	27.90	258.11
285	2007/01/27 06:21:58	2007/01/27 06:34:46	-7.24	7.43	303.98	62.35	302.75	32.19	15.05	244.79	26.56	254.76
286	2007/01/28 06:23:07	2007/01/28 06:35:53	-6.16	4.14	306.33	57.55	305.67	40.59	17.36	245.38	24.15	250.81

7.2.5.3 Occultation season 3

#ORB	DATE entry [SC]	DATE entry [UT]	DurPER	DurOCC	LONent	LATent	LONexi	LATexi	ELEent	AZIent	ELEexi	AZIexi
370	2007/04/22 06:04:45	2007/04/22 06:13:44	-30.96	8.19	352.46	27.79	354.96	54.25	-53.61	50.98	-32.83	36.42
371	2007/04/23 06:02:07	2007/04/23 06:11:02	-33.69	12.32	354.61	19.63	358.48	59.20	-58.98	59.99	-28.70	35.15
372	2007/04/24 05:59:59	2007/04/24 06:08:50	-35.92	15.46	356.89	13.13	1.88	62.54	-62.48	69.71	-25.88	34.50
373	2007/04/25 05:58:06	2007/04/25 06:06:54	-37.89	18.12	359.21	7.43	5.26	65.13	-64.71	80.31	-23.69	34.11
374	2007/04/26 05:56:23	2007/04/26 06:05:08	-39.69	20.48	1.57	2.23	8.62	67.25	-65.83	91.43	-21.87	33.89
375	2007/04/27 05:54:48	2007/04/27 06:03:29	-41.37	22.63	3.94	-2.61	12.00	69.07	-65.97	102.42	-20.32	33.78
376	2007/04/28 05:53:18	2007/04/28 06:01:56	-42.94	24.61	6.31	-7.19	15.39	70.65	-65.28	112.63	-18.95	33.77
377	2007/04/29 05:51:55	2007/04/29 06:00:28	-44.42	26.44	8.69	-11.56	18.81	72.06	-63.92	121.64	-17.73	33.84
378	2007/04/30 05:50:36	2007/04/30 05:59:06	-45.82	28.16	11.06	-15.76	22.27	73.33	-62.05	129.33	-16.61	33.99
379	2007/05/01 05:49:21	2007/05/01 05:57:48	-47.15	29.77	13.43	-19.81	25.77	74.49	-59.82	135.78	-15.59	34.20
380	2007/05/02 05:48:11	2007/05/02 05:56:34	-48.40	31.27	15.79	-23.75	29.32	75.55	-57.34	141.17	-14.64	34.50
381	2007/05/03 05:47:05	2007/05/03 05:55:24	-49.58	32.69	18.13	-27.57	32.94	76.54	-54.67	145.69	-13.75	34.87
382	2007/05/04 05:46:04	2007/05/04 05:54:19	-50.70	34.02	20.46	-31.31	36.62	77.46	-51.89	149.51	-12.92	35.34
383	2007/05/05 05:45:06	2007/05/05 05:53:17	-51.74	35.27	22.77	-34.96	40.39	78.32	-49.02	152.78	-12.12	35.90
384	2007/05/06 05:44:12	2007/05/06 05:52:19	-52.72	36.43	25.05	-38.55	44.25	79.14	-46.09	155.61	-11.37	36.57
385	2007/05/07 05:43:22	2007/05/07 05:51:26	-53.64	37.52	27.31	-42.06	48.23	79.90	-43.12	158.10	-10.64	37.36
386	2007/05/08 05:42:35	2007/05/08 05:50:36	-54.49	38.53	29.53	-45.52	52.35	80.63	-40.13	160.32	-9.94	38.30
387	2007/05/09 05:41:53	2007/05/09 05:49:49	-55.28	39.47	31.71	-48.92	56.64	81.32	-37.12	162.35	-9.27	39.42
388	2007/05/10 05:41:14	2007/05/10 05:49:07	-56.00	40.33	33.83	-52.28	61.12	81.98	-34.11	164.22	-8.62	40.73
389	2007/05/11 05:40:40	2007/05/11 05:48:28	-56.66	41.13	35.88	-55.59	65.84	82.61	-31.09	165.99	-7.98	42.30
390	2007/05/12 05:40:09	2007/05/12 05:47:54	-57.25	41.84	37.85	-58.86	70.85	83.21	-28.07	167.71	-7.36	44.15
391	2007/05/13 05:39:42	2007/05/13 05:47:23	-57.78	42.49	39.69	-62.09	76.22	83.78	-25.05	169.43	-6.75	46.38
392	2007/05/14 05:39:18	2007/05/14 05:46:55	-58.25	43.07	41.37	-65.29	82.03	84.32	-22.04	171.21	-6.14	49.05
393	2007/05/15 05:38:59	2007/05/15 05:46:32	-58.65	43.57	42.81	-68.45	88.40	84.83	-19.02	173.14	-5.55	52.27
394	2007/05/16 05:38:43	2007/05/16 05:46:12	-58.99	44.01	43.91	-71.58	95.45	85.31	-16.02	175.34	-4.97	56.19
395	2007/05/17 05:38:31	2007/05/17 05:45:56	-59.27	44.38	44.45	-74.67	103.35	85.74	-13.01	178.02	-4.39	60.95
396	2007/05/18 05:38:22	2007/05/18 05:45:44	-59.48	44.68	44.04	-77.71	112.28	86.13	-10.01	181.61	-3.81	66.75
397	2007/05/19 05:38:17	2007/05/19 05:45:35	-59.64	44.91	41.79	-80.68	122.38	86.46	-7.02	186.98	-3.23	73.72
398	2007/05/20 05:38:16	2007/05/20 05:45:30	-59.73	45.08	35.33	-83.51	133.74	86.71	-4.02	196.53	-2.66	81.95
399	2007/05/21 05:38:19	2007/05/21 05:45:29	-59.76	45.18	16.93	-85.95	146.22	86.88	-1.03	217.97	-2.09	91.31
400	2007/05/22 05:38:25	2007/05/22 05:45:31	-59.73	45.21	330.95	-86.93	159.43	86.95	1.95	266.98	-1.51	101.39
401	2007/05/23 05:38:35	2007/05/23 05:45:37	-59.64	45.18	292.35	-85.41	172.72	86.91	4.94	308.56	-0.93	111.57

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402	2007/05/24 05:38:48	2007/05/24 05:45:46	-59.50	45.08	278.46	-82.85	185.44	86.77	7.92	325.42	-0.35	121.17
403	2007/05/25 05:39:05	2007/05/25 05:45:59	-59.29	44.92	273.49	-80.03	197.10	86.54	10.91	333.34	0.24	129.70
404	2007/05/26 05:39:25	2007/05/26 05:46:15	-59.03	44.70	271.83	-77.12	207.50	86.23	13.89	337.94	0.84	136.99
405	2007/05/27 05:39:48	2007/05/27 05:46:34	-58.71	44.42	271.70	-74.17	216.68	85.86	16.88	341.00	1.44	143.06
406	2007/05/28 05:40:15	2007/05/28 05:46:57	-58.34	44.07	272.38	-71.21	224.78	85.44	19.87	343.24	2.05	148.05
407	2007/05/29 05:40:45	2007/05/29 05:47:23	-57.91	43.66	273.53	-68.23	231.98	84.98	22.87	345.01	2.68	152.13
408	2007/05/30 05:41:18	2007/05/30 05:47:52	-57.43	43.20	274.99	-65.24	238.43	84.48	25.87	346.47	3.32	155.47
409	2007/05/31 05:41:55	2007/05/31 05:48:24	-56.90	42.67	276.66	-62.24	244.29	83.96	28.87	347.74	3.97	158.22
410	2007/06/01 05:42:34	2007/06/01 05:49:00	-56.31	42.08	278.47	-59.24	249.66	83.40	31.88	348.87	4.64	160.48
411	2007/06/02 05:43:17	2007/06/02 05:49:38	-55.68	41.44	280.38	-56.22	254.64	82.82	34.91	349.92	5.32	162.35
412	2007/06/03 05:44:02	2007/06/03 05:50:20	-54.99	40.74	282.38	-53.19	259.30	82.20	37.94	350.93	6.03	163.90
413	2007/06/04 05:44:51	2007/06/04 05:51:04	-54.26	39.98	284.43	-50.15	263.69	81.56	40.98	351.91	6.75	165.18
414	2007/06/05 05:45:42	2007/06/05 05:51:51	-53.48	39.17	286.53	-47.09	267.86	80.89	44.04	352.90	7.51	166.24
415	2007/06/06 05:46:36	2007/06/06 05:52:41	-52.65	38.30	288.66	-44.01	271.85	80.19	47.11	353.92	8.28	167.11
416	2007/06/07 05:47:33	2007/06/07 05:53:34	-51.78	37.37	290.82	-40.90	275.67	79.46	50.20	355.00	9.09	167.82
417	2007/06/08 05:48:32	2007/06/08 05:54:30	-50.86	36.38	293.00	-37.78	279.36	78.69	53.31	356.17	9.94	168.39
418	2007/06/09 05:49:35	2007/06/09 05:55:28	-49.90	35.34	295.20	-34.62	282.92	77.88	56.43	357.49	10.82	168.84
419	2007/06/10 05:50:39	2007/06/10 05:56:29	-48.89	34.24	297.41	-31.43	286.39	77.02	59.58	359.00	11.74	169.18
420	2007/06/11 05:51:47	2007/06/11 05:57:32	-47.84	33.08	299.64	-28.20	289.76	76.11	62.74	0.79	12.72	169.42
421	2007/06/12 05:52:57	2007/06/12 05:58:38	-46.75	31.85	301.87	-24.92	293.04	75.15	65.92	3.00	13.74	169.58
422	2007/06/13 05:54:10	2007/06/13 05:59:47	-45.61	30.57	304.11	-21.59	296.25	74.12	69.11	5.84	14.83	169.65
423	2007/06/14 05:55:26	2007/06/14 06:00:59	-44.42	29.21	306.35	-18.20	299.40	73.02	72.30	9.68	15.99	169.65
424	2007/06/15 05:56:45	2007/06/15 06:02:14	-43.19	27.78	308.60	-14.73	302.48	71.84	75.44	15.19	17.22	169.57
425	2007/06/16 05:58:06	2007/06/16 06:03:31	-41.91	26.27	310.85	-11.17	305.50	70.55	78.46	23.75	18.56	169.42
426	2007/06/17 05:59:31	2007/06/17 06:04:52	-40.57	24.67	313.10	-7.51	308.47	69.15	81.13	38.15	20.00	169.19
427	2007/06/18 06:00:59	2007/06/18 06:06:16	-39.18	22.97	315.34	-3.72	311.39	67.60	82.89	62.65	21.58	168.89
428	2007/06/19 06:02:32	2007/06/19 06:07:45	-37.72	21.14	317.59	0.23	314.25	65.87	82.82	94.79	23.33	168.51
429	2007/06/20 06:04:09	2007/06/20 06:09:18	-36.18	19.17	319.84	4.40	317.08	63.92	80.73	120.22	25.30	168.04
430	2007/06/21 06:08:35	2007/06/21 06:13:40	-34.52	16.98	322.08	8.89	319.87	61.64	77.32	135.47	27.56	167.45
431	2007/06/22 06:13:09	2007/06/22 06:18:10	-32.73	14.51	324.32	13.78	322.61	58.93	73.07	144.59	30.24	166.72
432	2007/06/23 06:15:07	2007/06/23 06:20:04	-31.54	15.38	326.65	14.21	324.77	62.98	72.35	143.15	26.27	166.16
433	2007/06/24 06:15:39	2007/06/24 06:20:32	-29.73	12.87	328.87	19.26	327.49	60.14	67.77	148.71	29.05	165.38
434	2007/06/25 06:16:28	2007/06/25 06:21:17	-27.64	9.79	331.09	25.19	330.18	56.40	62.25	153.00	32.68	164.33
435	2007/06/26 06:18:00	2007/06/26 06:22:45	-24.84	5.29	333.27	33.42	332.85	50.34	54.52	156.99	38.50	162.59

7.2.5.4 Occultation season 4

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#ORB	DATE entry [SC]	DATE entry [UT]	DurPER	DurOCC	LONent	LATent	LONexi	LATexi	ELEent	AZIent	ELEexi	AZIexi
623	2007/12/31 01:27:34	2007/12/31 01:37:05	-3.49	5.68	175.84	62.27	174.77	39.12	21.84	148.31	40.19	138.72
624	2008/01/01 01:27:48	2008/01/01 01:37:23	-4.28	8.32	178.81	65.72	177.27	32.11	18.91	148.84	44.95	133.55
625	2008/01/02 01:28:18	2008/01/02 01:37:55	-4.81	10.44	181.73	68.07	179.83	26.29	16.90	149.04	48.44	128.23
626	2008/01/03 01:28:55	2008/01/03 01:38:35	-5.22	12.29	184.62	69.89	182.42	21.08	15.35	149.08	51.11	122.62
627	2008/01/04 01:29:36	2008/01/04 01:39:20	-5.56	13.99	187.49	71.39	185.02	16.26	14.07	149.05	53.11	116.72
628	2008/01/05 01:30:21	2008/01/05 01:40:08	-5.84	15.57	190.35	72.67	187.64	11.73	12.98	148.96	54.52	110.59
629	2008/01/06 01:31:07	2008/01/06 01:40:57	-6.09	17.06	193.21	73.79	190.27	7.42	12.03	148.83	55.39	104.36
630	2008/01/07 01:31:55	2008/01/07 01:41:49	-6.30	18.48	196.05	74.80	192.91	3.29	11.19	148.67	55.76	98.18
631	2008/01/08 01:32:45	2008/01/08 01:42:41	-6.50	19.84	198.89	75.70	195.55	-0.69	10.44	148.50	55.66	92.19
632	2008/01/09 01:33:36	2008/01/09 01:43:35	-6.68	21.14	201.73	76.54	198.19	-4.55	9.75	148.31	55.16	86.52
633	2008/01/10 01:34:27	2008/01/10 01:44:30	-6.84	22.39	204.56	77.31	200.85	-8.30	9.12	148.10	54.31	81.27
634	2008/01/11 01:35:20	2008/01/11 01:45:25	-6.99	23.59	207.40	78.02	203.50	-11.95	8.54	147.89	53.16	76.47
635	2008/01/12 01:36:13	2008/01/12 01:46:21	-7.13	24.75	210.23	78.70	206.16	-15.52	8.00	147.66	51.76	72.16
636	2008/01/13 01:37:06	2008/01/13 01:47:18	-7.26	25.86	213.05	79.33	208.82	-19.02	7.49	147.44	50.16	68.32
637	2008/01/14 01:38:00	2008/01/14 01:48:15	-7.38	26.93	215.88	79.94	211.49	-22.45	7.02	147.20	48.39	64.92
638	2008/01/15 01:38:55	2008/01/15 01:49:13	-7.50	27.96	218.71	80.51	214.15	-25.82	6.57	146.97	46.50	61.93
639	2008/01/16 01:39:50	2008/01/16 01:50:10	-7.60	28.94	221.54	81.06	216.82	-29.13	6.15	146.73	44.50	59.31
640	2008/01/17 01:40:45	2008/01/17 01:51:09	-7.71	29.88	224.37	81.59	219.49	-32.40	5.75	146.49	42.42	57.02
641	2008/01/18 01:41:41	2008/01/18 01:52:07	-7.80	30.78	227.21	82.10	222.17	-35.62	5.37	146.25	40.28	55.02
642	2008/01/19 01:42:36	2008/01/19 01:53:06	-7.89	31.64	230.05	82.60	224.84	-38.80	5.01	146.02	38.09	53.28
643	2008/01/20 01:43:33	2008/01/20 01:54:05	-7.98	32.45	232.89	83.08	227.51	-41.95	4.66	145.79	35.87	51.76
644	2008/01/21 01:44:29	2008/01/21 01:55:05	-8.06	33.22	235.75	83.55	230.19	-45.06	4.33	145.56	33.62	50.46
645	2008/01/22 01:45:26	2008/01/22 01:56:04	-8.14	33.94	238.61	84.00	232.86	-48.14	4.01	145.35	31.36	49.34
646	2008/01/23 01:46:23	2008/01/23 01:57:04	-8.21	34.62	241.49	84.45	235.53	-51.19	3.70	145.15	29.08	48.38
647	2008/01/24 01:47:20	2008/01/24 01:58:04	-8.28	35.26	244.39	84.89	238.21	-54.22	3.40	144.97	26.80	47.58
648	2008/01/25 01:48:18	2008/01/25 01:59:05	-8.34	35.84	247.31	85.32	240.88	-57.23	3.11	144.81	24.52	46.91
649	2008/01/26 01:49:15	2008/01/26 02:00:05	-8.41	36.39	250.27	85.74	243.54	-60.22	2.82	144.68	22.24	46.37
650	2008/01/27 01:50:13	2008/01/27 02:01:06	-8.47	36.88	253.27	86.16	246.20	-63.19	2.55	144.60	19.97	45.95
651	2008/01/28 01:51:11	2008/01/28 02:02:07	-8.52	37.33	256.33	86.58	248.86	-66.15	2.28	144.58	17.70	45.65
652	2008/01/29 01:52:09	2008/01/29 02:03:08	-8.57	37.73	259.48	86.99	251.50	-69.09	2.02	144.65	15.45	45.45
653	2008/01/30 01:53:08	2008/01/30 02:04:09	-8.62	38.08	262.76	87.40	254.12	-72.03	1.77	144.85	13.20	45.37
654	2008/01/31 01:54:06	2008/01/31 02:05:10	-8.67	38.38	266.25	87.81	256.71	-74.95	1.51	145.25	10.98	45.41
655	2008/02/01 01:55:05	2008/02/01 02:06:12	-8.72	38.63	270.09	88.22	259.25	-77.87	1.27	146.00	8.77	45.59
656	2008/02/02 01:56:04	2008/02/02 02:07:14	-8.76	38.83	274.59	88.62	261.67	-80.78	1.02	147.42	6.57	45.96
657	2008/02/03 01:57:03	2008/02/03 02:08:16	-8.79	38.98	280.59	89.02	263.85	-83.69	0.78	150.34	4.40	46.66
658	2008/02/04 01:58:03	2008/02/04 02:09:18	-8.83	39.08	291.20	89.42	265.09	-86.60	0.54	157.86	2.25	48.37
659	2008/02/05 01:59:02	2008/02/05 02:10:20	-8.86	39.13	329.51	89.77	249.90	-89.48	0.31	193.09	0.12	66.60
660	2008/02/06 02:00:02	2008/02/06 02:11:22	-8.89	39.13	63.58	89.66	98.16	-87.57	0.07	284.07	-1.98	221.46

661	2008/02/07 02:01:02	2008/02/07 02:12:25	-8.92	39.08	85.06	89.27	98.44	-84.66	-0.16	302.47	-4.06	224.37
662	2008/02/08 02:02:02	2008/02/08 02:13:28	-8.94	38.98	93.31	88.86	100.45	-81.74	-0.39	307.63	-6.10	225.65
663	2008/02/09 02:03:02	2008/02/09 02:14:30	-8.96	38.82	98.60	88.44	102.82	-78.81	-0.62	309.83	-8.12	226.63
664	2008/02/10 02:04:03	2008/02/10 02:15:33	-8.98	38.61	102.79	88.00	105.34	-75.87	-0.86	310.94	-10.10	227.55
665	2008/02/11 02:05:03	2008/02/11 02:16:37	-8.99	38.35	106.45	87.56	107.93	-72.92	-1.09	311.51	-12.05	228.49
666	2008/02/12 02:06:04	2008/02/12 02:17:40	-9.00	38.04	109.82	87.12	110.56	-69.96	-1.33	311.79	-13.95	229.47
667	2008/02/13 02:07:05	2008/02/13 02:18:44	-9.01	37.67	113.01	86.66	113.21	-66.98	-1.57	311.89	-15.82	230.53
668	2008/02/14 02:08:06	2008/02/14 02:19:47	-9.01	37.25	116.08	86.19	115.89	-63.98	-1.81	311.88	-17.64	231.66
669	2008/02/15 02:09:07	2008/02/15 02:20:51	-9.01	36.78	119.07	85.71	118.57	-60.96	-2.05	311.77	-19.41	232.88
670	2008/02/16 02:10:09	2008/02/16 02:21:55	-9.01	36.26	122.00	85.22	121.26	-57.91	-2.30	311.61	-21.12	234.19
671	2008/02/17 02:11:11	2008/02/17 02:22:59	-9.00	35.68	124.88	84.72	123.96	-54.84	-2.55	311.40	-22.77	235.61
672	2008/02/18 02:12:13	2008/02/18 02:24:04	-8.99	35.06	127.73	84.20	126.66	-51.75	-2.80	311.15	-24.36	237.13
673	2008/02/19 02:13:15	2008/02/19 02:25:09	-8.97	34.37	130.55	83.66	129.37	-48.61	-3.07	310.88	-25.88	238.75
674	2008/02/20 02:14:17	2008/02/20 02:26:14	-8.95	33.64	133.35	83.11	132.08	-45.45	-3.34	310.57	-27.32	240.50
675	2008/02/21 02:15:20	2008/02/21 02:27:19	-8.92	32.85	136.13	82.54	134.80	-42.24	-3.62	310.25	-28.67	242.36
676	2008/02/22 02:16:23	2008/02/22 02:28:24	-8.88	32.01	138.89	81.94	137.52	-38.99	-3.90	309.91	-29.94	244.35
677	2008/02/23 02:17:27	2008/02/23 02:29:30	-8.84	31.12	141.64	81.32	140.24	-35.69	-4.20	309.56	-31.10	246.46
678	2008/02/24 02:18:30	2008/02/24 02:30:36	-8.79	30.17	144.38	80.67	142.96	-32.34	-4.51	309.19	-32.15	248.69
679	2008/02/25 02:19:35	2008/02/25 02:31:43	-8.74	29.16	147.10	79.98	145.69	-28.92	-4.83	308.80	-33.07	251.05
680	2008/02/26 02:20:39	2008/02/26 02:32:50	-8.67	28.10	149.82	79.26	148.42	-25.44	-5.17	308.40	-33.87	253.52
681	2008/02/27 02:21:45	2008/02/27 02:33:58	-8.60	26.98	152.53	78.50	151.15	-21.89	-5.53	307.99	-34.52	256.11
682	2008/02/28 02:22:51	2008/02/28 02:35:06	-8.51	25.81	155.24	77.69	153.88	-18.26	-5.91	307.57	-35.02	258.81
683	2008/02/29 02:23:57	2008/02/29 02:36:15	-8.41	24.57	157.94	76.82	156.61	-14.52	-6.31	307.12	-35.35	261.60
684	2008/03/01 02:25:05	2008/03/01 02:37:25	-8.29	23.26	160.63	75.88	159.35	-10.69	-6.75	306.67	-35.50	264.48
685	2008/03/02 02:26:14	2008/03/02 02:38:36	-8.15	21.89	163.31	74.87	162.09	-6.72	-7.22	306.19	-35.46	267.43
686	2008/03/03 02:27:24	2008/03/03 02:39:48	-7.99	20.44	165.99	73.75	164.83	-2.61	-7.73	305.69	-35.20	270.44
687	2008/03/04 02:28:35	2008/03/04 02:41:02	-7.80	18.90	168.67	72.52	167.57	1.67	-8.30	305.17	-34.73	273.50
688	2008/03/05 02:29:49	2008/03/05 02:42:18	-7.57	17.26	171.33	71.13	170.32	6.16	-8.94	304.61	-34.00	276.58
689	2008/03/06 02:31:06	2008/03/06 02:43:37	-7.30	15.49	174.00	69.53	173.07	10.93	-9.68	304.00	-33.00	279.68
690	2008/03/07 02:32:27	2008/03/07 02:45:00	-6.95	13.56	176.65	67.64	175.83	16.05	-10.56	303.33	-31.69	282.81
691	2008/03/08 02:33:54	2008/03/08 02:46:29	-6.49	11.39	179.29	65.32	178.59	21.68	-11.63	302.54	-29.98	285.97
692	2008/03/09 02:35:32	2008/03/09 02:48:10	-5.86	8.83	181.92	62.24	181.37	28.16	-13.06	301.56	-27.75	289.25
693	2008/03/10 02:37:37	2008/03/10 02:50:17	-4.77	5.36	184.52	57.38	184.18	36.51	-15.30	300.08	-24.50	292.94

7.2.5.5 Occultation season 5

#ORB	DATE entry [SC]	DATE entry [UT]	DurPER	DurOCC	LONent	LATent	LONexi	LATexi	ELEent	AZIent	ELEexi	AZIexi
777	2008/06/02 03:28:21	2008/06/02 03:42:46	-34.60	7.56	232.32	29.06	232.93	54.26	2.31	91.78	1.68	93.08
778	2008/06/03 03:26:22	2008/06/03 03:40:48	-37.51	11.88	234.90	20.30	235.92	59.62	2.06	91.30	1.27	93.17
779	2008/06/04 03:24:58	2008/06/04 03:39:23	-39.86	15.10	237.51	13.44	238.87	63.14	1.73	91.01	0.95	93.16
780	2008/06/05 03:23:49	2008/06/05 03:38:15	-41.95	17.81	240.14	7.47	241.83	65.83	1.37	90.83	0.68	93.11
781	2008/06/06 03:22:51	2008/06/06 03:37:17	-43.86	20.22	242.78	2.03	244.79	68.03	0.99	90.75	0.45	93.04
782	2008/06/07 03:22:01	2008/06/07 03:36:27	-45.64	22.40	245.41	-3.04	247.77	69.90	0.61	90.76	0.25	92.98
783	2008/06/08 03:21:17	2008/06/08 03:35:43	-47.31	24.41	248.05	-7.83	250.76	71.53	0.24	90.83	0.07	92.91
784	2008/06/09 03:20:38	2008/06/09 03:35:04	-48.89	26.27	250.68	-12.39	253.77	72.98	-0.12	90.98	-0.10	92.86
785	2008/06/10 03:20:05	2008/06/10 03:34:31	-50.39	28.02	253.32	-16.79	256.81	74.29	-0.45	91.18	-0.24	92.82
786	2008/06/11 03:19:37	2008/06/11 03:34:03	-51.81	29.65	255.95	-21.04	259.87	75.48	-0.77	91.44	-0.37	92.81
787	2008/06/12 03:19:13	2008/06/12 03:33:39	-53.15	31.18	258.57	-25.16	262.96	76.59	-1.05	91.74	-0.49	92.82
788	2008/06/13 03:18:54	2008/06/13 03:33:19	-54.41	32.61	261.19	-29.18	266.09	77.61	-1.30	92.10	-0.60	92.87
789	2008/06/14 03:18:39	2008/06/14 03:33:04	-55.61	33.95	263.80	-33.11	269.27	78.58	-1.52	92.50	-0.69	92.96
790	2008/06/15 03:18:28	2008/06/15 03:32:54	-56.73	35.20	266.40	-36.96	272.50	79.48	-1.70	92.94	-0.78	93.09
791	2008/06/16 03:18:22	2008/06/16 03:32:47	-57.78	36.37	268.99	-40.74	275.80	80.34	-1.84	93.42	-0.85	93.29
792	2008/06/17 03:18:20	2008/06/17 03:32:45	-58.75	37.46	271.56	-44.46	279.17	81.16	-1.93	93.94	-0.92	93.57
793	2008/06/18 03:18:23	2008/06/18 03:32:47	-59.66	38.46	274.12	-48.13	282.64	81.95	-1.99	94.49	-0.97	93.95
794	2008/06/19 03:18:29	2008/06/19 03:32:54	-60.49	39.38	276.65	-51.75	286.24	82.70	-2.00	95.08	-1.02	94.44
795	2008/06/20 03:18:41	2008/06/20 03:33:05	-61.25	40.21	279.16	-55.32	290.01	83.43	-1.96	95.71	-1.06	95.10
796	2008/06/21 03:18:56	2008/06/21 03:33:20	-61.94	40.97	281.62	-58.86	293.98	84.13	-1.88	96.39	-1.09	95.97
797	2008/06/22 03:19:17	2008/06/22 03:33:40	-62.56	41.64	284.04	-62.37	298.25	84.81	-1.75	97.12	-1.11	97.13
798	2008/06/23 03:19:41	2008/06/23 03:34:04	-63.10	42.24	286.37	-65.85	302.92	85.47	-1.57	97.92	-1.12	98.70
799	2008/06/24 03:20:10	2008/06/24 03:34:33	-63.56	42.75	288.59	-69.31	308.19	86.11	-1.34	98.84	-1.12	100.86
800	2008/06/25 03:20:44	2008/06/25 03:35:06	-63.95	43.18	290.63	-72.74	314.38	86.73	-1.07	99.92	-1.12	103.94
801	2008/06/26 03:21:22	2008/06/26 03:35:44	-64.27	43.54	292.36	-76.15	322.07	87.32	-0.76	101.31	-1.11	108.51
802	2008/06/27 03:22:05	2008/06/27 03:36:26	-64.52	43.81	293.47	-79.55	332.35	87.88	-0.39	103.30	-1.08	115.69
803	2008/06/28 03:22:52	2008/06/28 03:37:13	-64.68	44.00	293.08	-82.92	347.45	88.37	0.01	106.76	-1.05	127.67
804	2008/06/29 03:23:43	2008/06/29 03:38:04	-64.78	44.11	287.25	-86.22	10.96	88.73	0.46	115.64	-1.02	148.07
805	2008/06/30 03:24:40	2008/06/30 03:38:59	-64.80	44.14	227.86	-88.81	43.11	88.83	0.95	178.05	-0.97	177.11
806	2008/07/01 03:25:40	2008/07/01 03:39:59	-64.74	44.09	150.75	-86.61	72.65	88.61	1.49	258.15	-0.91	203.53
807	2008/07/02 03:26:46	2008/07/02 03:41:04	-64.61	43.97	143.37	-83.32	92.47	88.19	2.06	268.48	-0.84	220.24
808	2008/07/03 03:27:55	2008/07/03 03:42:13	-64.40	43.76	142.66	-79.96	105.36	87.67	2.67	272.11	-0.76	230.02
809	2008/07/04 03:29:09	2008/07/04 03:43:27	-64.12	43.47	143.65	-76.58	114.46	87.10	3.31	273.99	-0.68	236.01
810	2008/07/05 03:30:28	2008/07/05 03:44:44	-63.77	43.10	145.32	-73.17	121.49	86.50	3.99	275.14	-0.58	239.92

811	2008/07/06	03:31:51	2008/07/06	03:46:07	-63.34	42.66	147.33	-69.75	127.28	85.87	4.69	275.91	-0.47	242.61
812	2008/07/07	03:33:19	2008/07/07	03:47:33	-62.85	42.13	149.53	-66.31	132.31	85.23	5.43	276.43	-0.35	244.52
813	2008/07/08	03:34:50	2008/07/08	03:49:04	-62.27	41.53	151.85	-62.84	136.82	84.57	6.18	276.77	-0.21	245.93
814	2008/07/09	03:36:26	2008/07/09	03:50:39	-61.63	40.84	154.26	-59.35	140.98	83.88	6.96	276.98	-0.07	246.98
815	2008/07/10	03:38:07	2008/07/10	03:52:19	-60.92	40.08	156.71	-55.83	144.89	83.18	7.76	277.06	0.10	247.78
816	2008/07/11	03:39:51	2008/07/11	03:54:03	-60.13	39.24	159.21	-52.28	148.60	82.45	8.56	277.04	0.27	248.39
817	2008/07/12	03:41:40	2008/07/12	03:55:51	-59.27	38.33	161.73	-48.68	152.17	81.70	9.38	276.91	0.47	248.85
818	2008/07/13	03:43:33	2008/07/13	03:57:43	-58.35	37.33	164.28	-45.04	155.63	80.92	10.20	276.69	0.68	249.21
819	2008/07/14	03:45:30	2008/07/14	03:59:39	-57.36	36.25	166.85	-41.36	159.00	80.10	11.02	276.36	0.91	249.49
820	2008/07/15	03:47:32	2008/07/15	04:01:39	-56.29	35.09	169.43	-37.61	162.29	79.24	11.83	275.94	1.16	249.69
821	2008/07/16	03:49:37	2008/07/16	04:03:43	-55.16	33.85	172.02	-33.80	165.53	78.34	12.63	275.42	1.43	249.84
822	2008/07/17	03:51:47	2008/07/17	04:05:52	-53.96	32.53	174.62	-29.92	168.72	77.38	13.41	274.79	1.73	249.96
823	2008/07/18	03:54:00	2008/07/18	04:08:04	-52.69	31.12	177.22	-25.95	171.87	76.36	14.16	274.05	2.06	250.03
824	2008/07/19	03:56:18	2008/07/19	04:10:20	-51.35	29.62	179.84	-21.88	174.99	75.27	14.87	273.20	2.42	250.09
825	2008/07/20	03:58:40	2008/07/20	04:12:41	-49.94	28.02	182.45	-17.70	178.08	74.09	15.52	272.23	2.82	250.13
826	2008/07/21	04:01:06	2008/07/21	04:15:06	-48.46	26.32	185.07	-13.38	181.14	72.81	16.12	271.13	3.27	250.16
827	2008/07/22	04:03:37	2008/07/22	04:17:36	-46.89	24.50	187.69	-8.90	184.19	71.39	16.63	269.91	3.76	250.18
828	2008/07/23	04:06:13	2008/07/23	04:20:11	-45.24	22.56	190.31	-4.22	187.21	69.80	17.05	268.55	4.32	250.22
829	2008/07/24	04:08:55	2008/07/24	04:22:52	-43.50	20.45	192.93	0.72	190.23	68.00	17.35	267.03	4.96	250.28
830	2008/07/25	04:11:44	2008/07/25	04:25:40	-41.63	18.14	195.55	6.00	193.24	65.90	17.48	265.34	5.71	250.38
831	2008/07/26	04:14:43	2008/07/26	04:28:37	-39.61	15.56	198.15	11.76	196.24	63.36	17.41	263.46	6.60	250.56
832	2008/07/27	04:17:54	2008/07/27	04:31:47	-37.36	12.56	200.74	18.27	199.26	60.12	17.05	261.31	7.72	250.87
833	2008/07/28	04:21:32	2008/07/28	04:35:23	-34.68	8.71	203.29	26.24	202.30	55.47	16.18	258.74	9.26	251.48

7.2.5.6 Occultation season 6

#ORB	DATE entry [SC]	DATE entry [UT]	DurPER	DurOCC	LONent	LATent	LONexi	LATexi	ELEent	AZIent	ELEexi	AZIexi
922	2008/10/25 06:19:15	2008/10/25 06:29:38	0.16	8.19	261.46	53.94	263.61	25.03	-27.07	38.69	-45.65	57.12
923	2008/10/26 06:19:09	2008/10/26 06:29:29	-0.84	11.63	263.52	58.31	266.65	17.56	-23.92	36.35	-49.33	64.17
924	2008/10/27 06:19:24	2008/10/27 06:29:41	-1.49	14.34	265.65	61.40	269.62	11.43	-21.64	34.61	-51.77	70.94
925	2008/10/28 06:19:49	2008/10/28 06:30:03	-1.97	16.68	267.79	63.85	272.55	6.00	-19.82	33.12	-53.38	77.66
926	2008/10/29 06:20:21	2008/10/29 06:30:31	-2.34	18.78	269.94	65.90	275.45	1.02	-18.28	31.78	-54.32	84.31
927	2008/10/30 06:20:57	2008/10/30 06:31:04	-2.63	20.70	272.07	67.67	278.35	-3.63	-16.93	30.52	-54.70	90.79
928	2008/10/31 06:21:36	2008/10/31 06:31:40	-2.87	22.48	274.19	69.23	281.24	-8.04	-15.73	29.31	-54.59	96.99
929	2008/11/01 06:22:18	2008/11/01 06:32:19	-3.07	24.15	276.29	70.64	284.13	-12.25	-14.63	28.12	-54.06	102.81
930	2008/11/02 06:23:01	2008/11/02 06:32:59	-3.24	25.72	278.35	71.93	287.02	-16.29	-13.62	26.94	-53.16	108.19
931	2008/11/03 06:23:46	2008/11/03 06:33:41	-3.38	27.19	280.38	73.11	289.92	-20.21	-12.69	25.75	-51.95	113.09
932	2008/11/04 06:24:33	2008/11/04 06:34:24	-3.49	28.58	282.36	74.21	292.82	-24.00	-11.81	24.54	-50.48	117.49
933	2008/11/05 06:25:20	2008/11/05 06:35:09	-3.59	29.89	284.30	75.24	295.72	-27.70	-10.97	23.30	-48.80	121.43
934	2008/11/06 06:26:08	2008/11/06 06:35:54	-3.67	31.13	286.17	76.21	298.64	-31.31	-10.18	22.01	-46.95	124.92
935	2008/11/07 06:26:58	2008/11/07 06:36:40	-3.74	32.30	287.98	77.13	301.57	-34.84	-9.42	20.67	-44.96	128.01
936	2008/11/08 06:27:47	2008/11/08 06:37:26	-3.80	33.39	289.70	78.00	304.52	-38.30	-8.70	19.26	-42.84	130.72
937	2008/11/09 06:28:38	2008/11/09 06:38:14	-3.84	34.42	291.33	78.83	307.49	-41.71	-7.99	17.77	-40.64	133.10
938	2008/11/10 06:29:29	2008/11/10 06:39:01	-3.88	35.38	292.85	79.63	310.48	-45.06	-7.31	16.17	-38.35	135.17
939	2008/11/11 06:30:21	2008/11/11 06:39:50	-3.90	36.28	294.23	80.40	313.51	-48.36	-6.65	14.44	-36.00	136.96
940	2008/11/12 06:31:13	2008/11/12 06:40:39	-3.92	37.11	295.45	81.13	316.58	-51.61	-6.00	12.56	-33.59	138.49
941	2008/11/13 06:32:05	2008/11/13 06:41:28	-3.93	37.87	296.46	81.84	319.70	-54.83	-5.37	10.48	-31.14	139.78
942	2008/11/14 06:32:58	2008/11/14 06:42:17	-3.94	38.57	297.23	82.52	322.88	-58.01	-4.76	8.15	-28.65	140.83
943	2008/11/15 06:33:51	2008/11/15 06:43:07	-3.93	39.21	297.68	83.18	326.16	-61.16	-4.15	5.52	-26.12	141.64
944	2008/11/16 06:34:45	2008/11/16 06:43:57	-3.92	39.78	297.74	83.82	329.55	-64.28	-3.55	2.50	-23.57	142.20
945	2008/11/17 06:35:38	2008/11/17 06:44:48	-3.91	40.28	297.30	84.42	333.12	-67.36	-2.96	358.97	-20.99	142.46
946	2008/11/18 06:36:33	2008/11/18 06:45:39	-3.89	40.72	296.19	85.00	336.94	-70.43	-2.37	354.79	-18.39	142.37
947	2008/11/19 06:37:27	2008/11/19 06:46:30	-3.86	41.09	294.21	85.55	341.14	-73.46	-1.79	349.75	-15.76	141.79
948	2008/11/20 06:38:22	2008/11/20 06:47:21	-3.83	41.41	291.10	86.05	345.98	-76.47	-1.22	343.56	-13.12	140.48
949	2008/11/21 06:39:17	2008/11/21 06:48:13	-3.80	41.65	286.51	86.49	351.99	-79.43	-0.65	335.91	-10.46	137.92
950	2008/11/22 06:40:12	2008/11/22 06:49:05	-3.76	41.83	280.11	86.87	0.48	-82.32	-0.08	326.45	-7.78	132.80
951	2008/11/23 06:41:07	2008/11/23 06:49:57	-3.71	41.95	271.72	87.14	15.51	-85.04	0.49	315.00	-5.08	121.07
952	2008/11/24 06:42:03	2008/11/24 06:50:49	-3.67	42.01	261.62	87.30	52.18	-87.08	1.06	301.84	-2.37	87.63
953	2008/11/25 06:42:59	2008/11/25 06:51:41	-3.61	42.00	250.80	87.31	112.85	-86.74	1.63	287.97	0.37	30.13
954	2008/11/26 06:43:55	2008/11/26 06:52:34	-3.56	41.93	240.60	87.17	142.05	-84.44	2.20	274.72	3.12	4.04
955	2008/11/27 06:44:51	2008/11/27 06:53:27	-3.49	41.79	232.06	86.91	154.84	-81.68	2.77	263.12	5.88	354.29

956	2008/11/28 06:45:48	2008/11/28 06:54:20	-3.43	41.59	225.50	86.56	162.54	-78.78	3.35	253.52	8.67	349.58
957	2008/11/29 06:46:45	2008/11/29 06:55:14	-3.36	41.33	220.78	86.13	168.19	-75.83	3.93	245.75	11.48	346.86
958	2008/11/30 06:47:42	2008/11/30 06:56:07	-3.28	41.00	217.56	85.65	172.83	-72.85	4.52	239.48	14.30	345.10
959	2008/12/01 06:48:39	2008/12/01 06:57:01	-3.20	40.62	215.49	85.12	176.91	-69.85	5.11	234.37	17.15	343.83
960	2008/12/02 06:49:37	2008/12/02 06:57:55	-3.12	40.17	214.31	84.57	180.63	-66.83	5.71	230.15	20.01	342.86
961	2008/12/03 06:50:34	2008/12/03 06:58:50	-3.03	39.66	213.80	84.00	184.12	-63.79	6.32	226.60	22.90	342.05
962	2008/12/04 06:51:33	2008/12/04 06:59:45	-2.94	39.09	213.81	83.40	187.45	-60.72	6.94	223.56	25.81	341.33
963	2008/12/05 06:52:31	2008/12/05 07:00:40	-2.84	38.46	214.21	82.78	190.66	-57.64	7.57	220.93	28.75	340.65
964	2008/12/06 06:53:30	2008/12/06 07:01:35	-2.73	37.78	214.94	82.14	193.79	-54.53	8.21	218.62	31.71	339.97
965	2008/12/07 06:54:29	2008/12/07 07:02:30	-2.62	37.03	215.91	81.48	196.85	-51.40	8.87	216.55	34.70	339.26
966	2008/12/08 06:55:28	2008/12/08 07:03:26	-2.50	36.22	217.08	80.79	199.85	-48.23	9.55	214.70	37.72	338.50
967	2008/12/09 06:56:28	2008/12/09 07:04:23	-2.38	35.36	218.43	80.09	202.82	-45.04	10.24	213.01	40.76	337.65
968	2008/12/10 06:57:29	2008/12/10 07:05:20	-2.25	34.44	219.90	79.36	205.74	-41.81	10.96	211.45	43.83	336.68
969	2008/12/11 06:58:29	2008/12/11 07:06:17	-2.11	33.46	221.49	78.61	208.64	-38.54	11.70	210.02	46.93	335.56
970	2008/12/12 06:59:31	2008/12/12 07:07:15	-1.96	32.42	223.18	77.82	211.51	-35.22	12.46	208.68	50.05	334.23
971	2008/12/13 07:00:32	2008/12/13 07:08:13	-1.80	31.32	224.95	77.01	214.36	-31.86	13.26	207.43	53.19	332.64
972	2008/12/14 07:01:35	2008/12/14 07:09:12	-1.63	30.17	226.79	76.15	217.19	-28.44	14.10	206.25	56.36	330.69
973	2008/12/15 07:02:38	2008/12/15 07:10:11	-1.45	28.96	228.68	75.25	220.00	-24.96	14.98	205.13	59.53	328.25
974	2008/12/16 07:03:42	2008/12/16 07:11:12	-1.25	27.68	230.63	74.30	222.80	-21.40	15.90	204.07	62.69	325.15
975	2008/12/17 07:04:47	2008/12/17 07:12:13	-1.04	26.35	232.63	73.30	225.58	-17.77	16.89	203.05	65.82	321.10
976	2008/12/18 07:05:53	2008/12/18 07:13:16	-0.81	24.94	234.66	72.22	228.35	-14.04	17.94	202.09	68.85	315.67
977	2008/12/19 07:07:01	2008/12/19 07:14:20	-0.56	23.47	236.73	71.06	231.12	-10.21	19.07	201.16	71.69	308.21
978	2008/12/20 07:08:10	2008/12/20 07:15:25	-0.29	21.91	238.83	69.81	233.87	-6.25	20.29	200.28	74.17	297.80
979	2008/12/21 07:09:20	2008/12/21 07:16:32	0.02	20.27	240.95	68.42	236.61	-2.13	21.64	199.43	75.97	283.54
980	2008/12/22 07:10:34	2008/12/22 07:17:42	0.38	18.52	243.10	66.89	239.35	2.18	23.15	198.63	76.67	265.66
981	2008/12/23 07:11:51	2008/12/23 07:18:55	0.78	16.65	245.26	65.14	242.08	6.73	24.86	197.87	75.89	246.83
982	2008/12/24 07:13:12	2008/12/24 07:20:13	1.27	14.60	247.44	63.10	244.81	11.60	26.85	197.17	73.59	230.57
983	2008/12/25 07:14:40	2008/12/25 07:21:38	1.86	12.31	249.63	60.64	247.53	16.95	29.26	196.53	69.94	218.22
984	2008/12/26 07:16:20	2008/12/26 07:23:14	2.65	9.62	251.81	57.44	250.27	23.07	32.40	196.02	64.94	209.18
985	2008/12/27 07:18:27	2008/12/27 07:25:17	3.89	6.03	253.96	52.58	253.06	30.89	37.15	195.81	57.93	202.30

7.3 Gravity

7.3.1 Description

The highly eccentric orbit of Venus Express about the planet is not suited well for a global investigation of the gravity field. The investigation proposed here will focus on specific target areas for the determination of local gravity anomalies.

7.3.2 Measurement Technique

Gravity information can be obtained at all times when the spacecraft is using the two-way dual-frequency radio link and the spacecraft is close enough to the surface that gravity accelerations significantly affects the spacecraft velocity (pericenter passes). The Earth pointing of the HGA is required to maintain a continuous radio link. The coherent and simultaneous dual-frequency downlink allows the extraction of the dispersive effects on the downlink due to the interplanetary medium and the earth ionosphere, in particular if the uplink is operated at S-band. Doppler tracking data will be acquired at a rate of one sample per 1 seconds and ranging data will be collected at a rate of one point per 10 minutes.
Velocity contributions induced by attitude control movements of the spacecraft which result in a HGA motion relative to the line-of-sight to Earth may reach several mm/s. Therefore, thruster activities, attitude control commands and antenna steering commands have to be recorded in order to reconstruct the attitude motion for later correction of derived LOS gravity accelerations.

7.3.3 Operations

7.3.3.1 Configuration

Operations will be conducted using a coherent simultaneous dual-frequency two-way tracking link (TWOD). Coherency of the transponded signal is mandatory for Doppler data acquisition. Dual-frequency operations are mandatory for an a posteriori calibration of ionospheric and interplanetary plasma effects and removal from the Doppler data. Two-way tracking is required to make use of the high-precision ground station frequency reference.

Table 7.3-1: Configurations for the determination of local gravity anomalies

S/C configuration	TWOD		
Ground segment configuration		up	down
	IFMS A	X	X-CL
	IFMS B		X-CL
	IFMS RS		S-CL
Telemetry modulation	OFF		
VeRa operational procedure	GRA		

7.3.3.2 HGA Pointing

The HGA-1 is pointed toward the Earth.

7.3.3.3 Operations Timeline

Timeline and sequence of events is given in section 6.2 .

7.3.3.4 Number of observations

ground station New Norcia NNO or DSN					
Gravity season			Orbit numbers	Number of orbits	number of requested orbits
Acronym	start	stop			
GRA-1	06.09.2006	31.10.2006		55	4
GRA-2	23.06.2007	02.07.2007		10	10
GRA-3	tbd				

7.3.3.5 Constraints

Gravity mapping can be performed during pericenter passes only. HGA-1 Earth pointing is required.

Spacecraft orbit correction maneuvers must not be performed within the operation period. Furthermore, spacecraft attitude thruster activities should be avoided or kept at a minimum. In case of thruster activities, a logging of relevant thrust parameters has to be performed.

7.3.4 Data

7.3.4.1 Mission Products

New Norcia ground station:

Table 7.3-2: Gravity data products

Receiver	Frequency band	Data products
IFMS A (closed-loop)	X	DOP1 DOP2 AGC1 AGC2 MET
IFMS B (closed-loop)	X	DOP1 DOP2 AGC1 AGC2
IFMS RS Closed-loop	S	DOP1 DOP2 AGC1 AGC2
open-loop	X & S	Voltage samples I + Q channels

Deep Space Network:

Table 7.3-3: DSN Data products

Receiver	Frequency band	Data products	Data file type
closed-loop	X	Doppler ranging	ODF
	S	Doppler ranging	
open-loop	-	-	-
	-	-	

7.3.4.2 Accuracy

The accuracy of the X/X- and X/S-Doppler data should be better than 0.3 mm/s (1σ) at 1 second integration time.

7.3.4.3 Sample Rate

Table 7.3-4: Gravity sample rate

Closed-loop	1 samples / second
Open-loop	-
Auxiliary data	See section 7.1.6.1

7.3.4.4 Data Volume

Table 7.3-5: Gravity data volume

	Data Volume
Closed-loop IFMS DSN	 615 kByte per frequency 520 kByte per frequency
Open-loop IFMS DSN	 N/A N/A

7.3.4.5 Availability

TBD

7.4 Surface (Bistatic Radar)

7.4.1 Description

The scientific objectives of this investigation are the determination of the dielectric properties and roughness of pre-selected Venusian surface areas from scattering and polarisation studies of bistatic radar echoes reflected from the nucleus surface and received on Earth.
The circularly polarized one-way downlink carrier signal from the S/C, impinging on the surface at the angle of incidence γ, is transformed into a linearly polarized signal when specularly reflected from the comet's surface at the Brewster angle $\gamma = \gamma_B$. The dielectric constant (surface permittivity) ε of the planetary surface can be inferred from determinations of the Brewster angle γ_B according to the relation $\varepsilon = \tan^2 \gamma_B$.
The total power contained in the bistatic radar echoes will be recorded for an estimate of the radio albedo of the Venusian surface. The broadening of the echo frequency spectrum is related to the roughness of the surface on scales of the radio wavelength.

7.4.2 Measurement Technique

The measurement is devided in a number of subactivities:

1. BNOISE; the ground station antenna is pointed toward the zenith, receiving the cold sky and the background noise of the sky and the equipment is determined. A spacecraft signal is not necessary at this stage.
2. BCAL; the antenna is now turned and pointed toward the spacecraft in order to receive thedirect radio signal transmitted from the spacecraft. A noise calibration with the direct signal is performed
3. BSLEW; The spacecraft is now slewed to point the HGA-1 toward the Venusian surface
4. BSR-INERT or BSR-SPEC or BSR-SPOT are the custom pointings of BSR. The dual-frequency one-way signal is transmitted and reflected from the planetary surface to be recived on ground. The signals are received in four channels at X-band and S-band and at two polarisations each (RCP and LCP).
5. BSLEW; after the observation, the spacecraft is slewed again toward direct HGA-1 Earth pointing.
6. BCAL; see (2)
7. BNOISE; see (1)

A 70-m DSN ground station is required.

7.4.3 Operations

7.4.3.1 Configuration

The S/C will transmit a one-way dual-frequency downlink (ONED) driven by the USO.

Table 7.4-1: Configurations for the determination of the surface properties

S/C configuration	ONED		
Ground segment configuration		up	down
	IFMS A		X-CL
	IFMS B		X-CL
	IFMS RS		S-OL RCP S-OL LCP
	DSN RSR Chn 1		X-OL LCP
	DSN RSR Chn 2		X-OL RCP
	DSN RSR Chn 3		S-OL LCP
	DSN RSR Chn 4		S-OL RCP
Telemetry modulation	OFF		
VeRa operational procedure	BSR		

7.4.3.2 HGA Pointing

Bistatic radar observations require a predefined S/C slew manoeuver to obtain specular reflection of the HGA-1 signals at the Venusian surface.

7.4.3.3 Operations Timeline

Before depointing, switch to one-way X-band and S-Band downlink and record frequency receiver offset caused by regular transponder oscillator output frequency shift for about 30 minutes. Then depoint HGA to the surface and record the the reception of the relected radio signals. After the observation of tbd length, slew the spacecraft back to HGA Earth pointing and record again the direct radio signals for about 30 minutes.
Sequence-of-events are given in section 6.2 .

7.4.3.4 Number of observations

ground station New Norcia NNO				
Occultation season			**Target area**	**number of requested orbits**
Acronym	**start**	**stop**		
BSR-1	15.06.2006	20.06.2006	Maxwell Montes	3
BSR-2	04.08.2006	10.08.2006	Ovda Regio	2
BSR-3	22.08.2006	28.08.2006	Thetis Regio	2
BSR-4	30.09.2006	04.10.2006	Ozza Mons	2
BSR-5	12.11.2006	14.11.2006	Theia Mons	1
BSR-6	17.03.2007	20.03.2007	Theia Mons	1
BSR-7	17.06.2007		Ozza Mons	3
BSR-8	02.08.2007		Theia Mons	3
BSR-9	06.10.2007	11.10.2007	Thetis Regio	3
BSR-10	13.11.2007	15.11.2007	Ozza Mons	2
BSR-11	21.12.2007	24.12.2007	Theia Mons	2

7.4.3.5 Constraints

The HGA manoeuver starts by pointing with HGA1 towards Earth. Then the manoeuver starts to achieve a specular reflection of the beam which penetrates the atmosphere at the Venusian surface. The depointing of the antenna shall follow a preprogrammed AOCS manoeuver sequence. Continuous HK and telemetry reception is not feasible. The S/C shall be automatically controlled that the HGA remains pointed toward the Venusian surface. No telemetry modulation shall be activated.

A 70-m antenna is required for the polarization channel assignments at the DSN ground stations. In case of a limitation of ground crew shifts, the DSS 43 in Australia is requested (same visibility window as NNO).

7.4.4 Data

7.4.4.1 Mission Products

NNO Ground Station:

Table 7.4-2: Bistatic radar: data products

Receiver	Frequency band	Data products
IFMS A (closed-loop)	X-CL	DOP1 DOP2 AGC1 AGC2 MET
IFMS B (closed-loop)	X-CL	DOP1 DOP2 AGC1 AGC2 MET
IFMS RS (open-loop)	X-OL RCP X-OL LCP	voltage samples (I + Q channels)

Deep Space Network:
Note: The 70m DSN 43 ground station (Australia) is requested for this procedure

Table 7.4-3: DSN bistatic radar data products

Receiver	Frequency band	Data products	Data file type
closed-loop	-	-	-
	-	-	
open-loop	X	LCP voltage samples	RSR
	X	RCP voltage samples	
	S	LCP voltage samples	
	S	RCP voltage samples	

7.4.4.2 Accuracy

The required resolution in the frequency spectrum is Δf = 5 Hz.
The required accuracy for the polarisation angle is 0.1° (TBD).

7.4.4.3 Sample Rate

Table 7.4-4: Bistatic radar: sample rate

Closed-loop	-
Open-loop	50,000 samples/second
Auxiliary data	See section 7.1.6.1

7.4.4.4 Data Volume

Table 7.4-5: Bistatic radar: data volume

	Data Volume
Closed-loop IFMS DSN	 N/A N/A
Open-loop IFMS DSN	 2.2 Gbyte (1hour) 2.2 GByte (1 hour)
Auxiliary data	TBD
Ground station meteo	Already contained in IFMS figure

7.4.4.5 Availability

TBD

7.4.5 BSR Target List

GENERAL RESTRICTIONS FOR BSR REQUESTS:

```
 - Nominal Length of BSR Request before and after Specular Condition [min]:  30.00
 - Minimum time before/after Specular Condition in case of visibility loss [min]:  10.00
 - Minimum angle above tangential plane at Specular Condition [deg]:  10.00
 - Minimum angle between sun direction and -x axis (ESOC restriction) [deg]:  90.00


 NOMENCLATURE:
 - ONr:                     Number of Orbit with Specular Condition
 - Begin Exp (SC time):     Date and Time of Begin of Experiment in S/C time frame
 - End Exp:                 Time of End of Experiment in S/C time frame
 - SpecCond:                Time of Specular Condition in S/C time frame
 - Vi:                        Cut of nominal request time due to loss of visibility (1: YES / 0:
NO)
 - Target Area:             Name of pre-defined BSR Target Area
 - TarLon:                  Longitude of Specular Point in degrees [-180; 180]
 - TarLat:                  Latitude of Specular Point in degrees [-90; 90]
 - INC:                     Angle of Incidence at Specular Condition in [deg]
 - RAN:                     Range from Spacecraft to Specular Point in [km]
 - SPT:                     Approx. illumination of Specular Point in x-band in [km]
 - SLW:                     Slewing Angle of Spacecraft from Earth direction in [deg]
 - VSP:                     Velocity of Specular Point on surface in [km/s]
 -  SMX:                          Angle between Sun and minus X direction (cooling plate) [deg]
```

ONr	Begin Exp (SC time)		End Exp	SpecCond	Vi	Target Area	TarLon	TarLat	INC	RAN	SPT	SLW	VSP	SMX
10	27-Apr-2006	00:48:00	01:48:00	01:18:00	0	unnamed_3	-92.78	24.61	79.87	4092	40.92	69.39	6.57	124.37
11	28-Apr-2006	01:03:00	02:03:00	01:33:00	0	unnamed_5	-92.38	14.17	77.03	4906	49.06	69.21	5.80	131.72
12	29-Apr-2006	01:14:56	02:14:56	01:44:56	0	unnamed_5	-90.42	13.90	76.36	4874	48.74	70.31	5.73	133.46
13	30-Apr-2006	01:15:00	02:15:00	01:45:00	0	unnamed_5	-87.62	18.60	76.85	4402	44.02	71.85	5.91	132.11
15	02-May-2006	01:15:00	02:15:00	01:45:00	0	RheaMons	-82.12	29.65	78.13	3440	34.40	75.39	7.00	128.22
16	03-May-2006	01:15:00	02:15:00	01:45:00	0	RheaMons	-79.37	33.11	78.65	3086	30.86	76.91	7.24	126.97
17	04-May-2006	01:15:00	02:15:00	01:45:00	0	RheaMons	-77.28	34.06	78.32	2974	29.74	78.04	7.28	127.58
18	05-May-2006	01:15:00	02:15:00	01:45:00	0	RheaMons	-75.20	35.01	77.99	2865	28.65	79.15	7.31	128.15
19	06-May-2006	01:15:00	02:15:00	01:45:00	0	RheaMons	-73.13	35.98	77.68	2757	27.57	80.24	7.35	128.67
21	08-May-2006	01:24:00	02:24:00	01:54:00	0	unnamed_11	-73.67	8.17	69.35	4923	49.23	80.04	4.60	151.60
22	09-May-2006	01:24:00	02:24:00	01:54:00	0	unnamed_11	-71.57	8.83	68.87	4805	48.05	81.19	4.60	152.71
23	10-May-2006	01:27:00	02:27:00	01:57:00	0	unnamed_11	-71.23	2.57	66.40	5507	55.07	82.17	4.18	159.33
23	10-May-2006	01:39:00	02:39:00	02:09:00	0	unnamed_2	-77.99	-15.43	60.97	8777	87.77	82.37	2.18	163.21
24	11-May-2006	01:27:00	02:27:00	01:57:00	0	unnamed_11	-69.12	3.15	65.89	5389	53.89	83.32	4.22	160.63
24	11-May-2006	01:42:00	02:42:00	02:12:00	0	unnamed_2	-77.39	-17.93	59.52	9461	94.61	83.55	1.94	161.98
25	12-May-2006	01:27:00	02:27:00	01:57:00	0	unnamed_11	-67.02	3.74	65.37	5272	52.72	84.47	4.23	161.89
25	12-May-2006	01:42:00	02:42:00	02:12:00	0	unnamed_2	-75.24	-17.50	59.00	9349	93.49	84.59	1.95	162.72
26	13-May-2006	01:27:00	02:27:00	01:57:00	0	unnamed_11	-64.92	4.32	64.86	5156	51.56	85.62	4.16	163.10
26	13-May-2006	01:45:00	02:45:00	02:15:00	0	unnamed_2	-74.56	-19.66	57.69	10030	100.30	85.71	1.72	160.46
27	14-May-2006	01:27:00	02:27:00	01:57:00	0	unnamed_10	-62.83	4.89	64.34	5041	50.41	86.77	4.11	164.24
27	14-May-2006	01:45:00	02:45:00	02:15:00	0	unnamed_2	-72.41	-19.25	57.16	9920	99.20	86.74	1.72	160.79
28	15-May-2006	01:27:00	02:27:00	01:57:00	0	unnamed_10	-60.74	5.47	63.82	4927	49.27	87.92	4.12	165.30
28	15-May-2006	01:48:00	02:48:00	02:18:00	0	unnamed_2	-71.63	-21.12	55.96	10595	105.95	87.80	1.53	158.00
29	16-May-2006	01:30:00	02:30:00	02:00:00	0	unnamed_10	-60.38	-0.02	61.49	5634	56.34	88.99	3.70	171.97
29	16-May-2006	01:48:58	02:48:58	02:18:58	0	unnamed_2	-69.90	-21.42	55.25	10739	107.39	88.81	669.59	157.06
30	17-May-2006	01:30:00	02:30:00	02:00:00	0	unnamed_10	-58.29	0.49	60.94	5521	55.21	90.14	3.73	173.29
31	18-May-2006	01:30:00	02:30:00	02:00:00	0	unnamed_10	-56.21	1.00	60.38	5408	54.08	91.30	3.77	174.45
32	19-May-2006	01:30:00	02:30:00	02:00:00	0	unnamed_10	-54.13	1.51	59.82	5297	52.97	92.45	3.59	175.32
33	20-May-2006	01:39:00	02:39:00	02:09:00	0	unnamed_12	-56.80	-11.20	55.45	7654	76.54	93.30	2.32	167.84
34	21-May-2006	01:39:00	02:39:00	02:09:00	0	unnamed_12	-54.70	-10.81	54.87	7545	75.45	94.43	2.27	167.24
35	22-May-2006	01:41:17	02:41:17	02:11:17	0	unnamed_12	-53.70	-12.86	53.64	8057	80.57	95.43	933.58	163.36
52	08-Jun-2006	00:51:00	01:51:00	01:21:00	0	nova_4	-133.84	18.63	73.40	7312	73.12	65.88	3.23	92.71
54	10-Jun-2006	00:45:00	01:45:00	01:15:00	0	plains_are_1	-128.37	8.04	72.62	9231	92.31	62.37	2.52	91.01
55	11-Jun-2006	00:45:00	01:45:00	01:15:00	0	plains_are_1	-126.29	7.79	73.19	9350	93.50	61.18	2.53	92.54
55	11-Jun-2006	01:27:00	02:27:00	01:57:00	0	GulaMons	-6.43	22.27	50.19	2343	23.43	116.40	6.03	141.78
ONr	Begin Exp (SC time)		End Exp	SpecCond	Vi	Target Area	TarLon	TarLat	INC	RAN	SPT	SLW	VSP	SMX

56	12-Jun-2006 00:48:00	01:48:00	01:18:00	0	plains_are_1	-124.91	12.30	74.62	8639	86.39	60.43	2.82	96.07
56	12-Jun-2006 01:27:00	02:27:00	01:57:00	0	GulaMons	-4.52	23.01	49.79	2268	22.68	117.23	6.07	140.17
57	13-Jun-2006 00:48:00	01:48:00	01:18:00	0	plains_are_1	-122.82	12.07	75.17	8760	87.60	59.23	2.83	97.55
57	13-Jun-2006 01:03:00	02:03:00	01:33:00	0	SekmetMons	-123.14	47.70	79.64	4317	43.17	68.49	5.31	111.41
57	13-Jun-2006 01:27:00	02:27:00	01:57:00	0	GulaMons	-2.61	23.76	49.42	2195	21.95	118.02	6.12	138.57
58	14-Jun-2006 01:27:00	02:27:00	01:57:00	0	GulaMons	-0.71	24.52	49.06	2124	21.24	118.78	6.18	136.98
59	15-Jun-2006 01:18:00	02:18:00	01:48:00	0	MaxwellMontes	-1.95	65.55	70.97	873	8.73	101.61	8.81	126.93
59	15-Jun-2006 01:27:00	02:27:00	01:57:00	0	GulaMons	1.19	25.30	48.72	2054	20.54	119.50	6.23	135.40
60	16-Jun-2006 01:18:00	02:18:00	01:48:00	0	MaxwellMontes	-0.85	66.65	71.36	865	8.65	101.25	8.72	126.70
60	16-Jun-2006 01:29:56	02:29:56	01:59:56	0	GulaMons	1.91	16.80	44.07	2627	26.27	122.96	5.60	133.36
61	17-Jun-2006 01:18:00	02:18:00	01:48:00	0	MaxwellMontes	0.15	67.74	71.78	861	8.61	100.85	8.61	126.52
62	18-Jun-2006 01:18:00	02:18:00	01:48:00	0	MaxwellMontes	1.06	68.80	72.22	861	8.61	100.39	8.55	126.40
63	19-Jun-2006 01:18:00	02:18:00	01:48:00	0	MaxwellMontes	1.86	69.84	72.67	864	8.64	99.88	8.48	126.33
65	21-Jun-2006 01:33:00	02:33:00	02:03:00	0	nova_5	10.22	11.73	38.05	2967	29.67	129.66	4.61	122.68
66	22-Jun-2006 01:33:00	02:33:00	02:03:00	0	nova_5	12.13	12.29	37.47	2890	28.90	130.63	4.65	120.86
67	23-Jun-2006 01:33:00	02:33:00	02:03:00	0	nova_5	14.02	12.86	36.91	2815	28.15	131.58	4.54	119.04
68	24-Jun-2006 01:33:50	02:33:50	02:03:50	0	nova_5	15.61	11.36	35.48	2939	29.39	133.09	1414.63	116.57
69	25-Jun-2006 01:35:06	02:35:06	02:05:06	0	nova_5	17.05	8.97	33.74	3172	31.72	134.80	4.26	113.74
70	26-Jun-2006 01:34:15	02:34:15	02:04:15	0	nova_5	19.24	11.47	33.91	2889	28.89	135.28	1860.68	112.56
77	03-Jul-2006 01:42:00	02:42:00	02:12:00	0	young_nova_1	30.13	-0.20	24.53	4316	43.16	145.29	2.98	94.08
78	04-Jul-2006 01:42:00	02:42:00	02:12:00	0	young_nova_1	32.03	0.16	23.75	4237	42.37	146.50	3.03	92.11
79	05-Jul-2006 01:36:00	02:36:00	02:06:00	0	Pavlova	35.48	12.27	27.07	2663	26.63	144.74	4.82	94.44
80	06-Jul-2006 01:36:00	02:36:00	02:06:00	0	Pavlova	37.32	12.85	26.59	2595	25.95	145.51	4.86	92.64
81	07-Jul-2006 01:32:00	02:30:00	02:00:00	1	TepevMons	40.43	33.04	39.80	1360	13.60	133.21	7.22	102.57
82	08-Jul-2006 01:35:12	02:30:00	02:00:00	1	TepevMons	42.18	34.01	40.09	1315	13.15	133.07	7.28	101.75
85	11-Jul-2006 01:39:01	02:33:00	02:03:00	1	TepevMons	46.99	25.31	31.62	1678	16.78	141.68	6.73	90.36
150	14-Sep-2006 02:06:00	03:06:00	02:36:00	0	TheiaMons	-79.09	21.26	79.21	7452	74.52	56.29	3.89	172.96
151	15-Sep-2006 02:09:00	03:09:00	02:39:00	0	TheiaMons	-76.86	23.33	78.93	7092	70.92	57.88	3.93	171.85
152	16-Sep-2006 02:10:40	03:10:40	02:40:40	0	TheiaMons	-74.80	22.33	78.22	7122	71.22	58.89	3.88	170.55
153	17-Sep-2006 01:44:25	02:44:25	02:14:25	0	unnamed_2	-79.90	-14.95	69.84	14495	144.95	59.23	162.93	152.89
153	17-Sep-2006 02:00:00	03:00:00	02:30:00	0	unnamed_1	-75.55	0.22	73.57	10566	105.66	58.16	2.20	162.00
153	17-Sep-2006 02:18:00	03:18:00	02:48:00	0	RheaMons	-72.50	35.68	79.45	5471	54.71	63.22	4.69	169.52
154	18-Sep-2006 01:45:00	02:45:00	02:15:00	0	unnamed_2	-78.19	-15.65	68.94	14767	147.67	60.56	1.23	150.66
154	18-Sep-2006 02:00:00	03:00:00	02:30:00	0	unnamed_1	-74.02	-2.17	72.37	11022	110.22	59.43	2.02	159.05
155	19-Sep-2006 01:45:00	02:45:00	02:15:00	0	unnamed_2	-76.62	-16.66	67.94	15176	151.76	61.94	1.15	148.20

ONr	Begin Exp (SC time)	End Exp	SpecCond	Vi	Target Area	TarLon	TarLat	INC	RAN	SPT	SLW	VSP	SMX
155	19-Sep-2006 02:03:00	03:03:00	02:33:00	0	unnamed_1	-71.68	-0.88	71.99	10689	106.89	60.64	2.06	158.00

156	20-Sep-2006	01:45:00	02:45:00	02:15:00	0	unnamed_2	-75.04	-17.57	66.97	15580	155.80	63.31	1.07	145.79
156	20-Sep-2006	02:03:00	03:03:00	02:33:00	0	unnamed_1	-70.16	-3.10	70.79	11143	111.43	61.93	1.89	155.09
157	21-Sep-2006	01:45:00	02:45:00	02:15:00	0	unnamed_2	-73.44	-18.38	66.02	15981	159.81	64.66	1.00	143.45
157	21-Sep-2006	02:06:00	03:06:00	02:36:00	0	unnamed_1	-67.81	-1.88	70.40	10812	108.12	63.14	1.94	154.02
158	22-Sep-2006	01:45:00	02:45:00	02:15:00	0	unnamed_2	-71.82	-19.12	65.09	16378	163.78	65.99	0.11	141.15
158	22-Sep-2006	02:03:25	03:03:25	02:33:25	0	unnamed_1	-67.00	-6.46	68.58	11928	119.28	64.56	1.70	149.67
158	22-Sep-2006	02:12:00	03:12:00	02:42:00	0	unnamed_11	-64.67	3.08	70.87	9680	96.80	64.38	2.27	154.84
159	23-Sep-2006	02:06:00	03:06:00	02:36:00	0	unnamed_6	-64.77	-5.77	68.06	11710	117.10	65.76	1.64	148.33
160	24-Sep-2006	02:09:00	03:09:00	02:39:00	0	unnamed_6	-62.43	-4.69	67.64	11385	113.85	66.95	1.67	147.21
161	25-Sep-2006	02:03:00	03:03:00	02:33:00	0	unnamed_12	-62.49	-11.16	65.24	13333	133.33	68.61	1.27	141.47
161	25-Sep-2006	03:06:00	04:06:00	03:36:00	0	SapasMons	-176.77	10.75	50.53	3573	35.73	111.13	4.34	90.07
162	26-Sep-2006	02:06:00	03:06:00	02:36:00	0	unnamed_12	-60.15	-10.25	64.79	13020	130.20	69.76	1.30	140.29
162	26-Sep-2006	03:06:00	04:06:00	03:36:00	0	unnamed_7	-175.82	15.80	53.20	3119	31.19	109.29	5.47	96.29
163	27-Sep-2006	02:09:00	03:09:00	02:39:00	0	unnamed_12	-57.82	-9.34	64.33	12705	127.05	70.93	1.32	139.10
163	27-Sep-2006	03:06:00	04:06:00	03:36:00	0	unnamed_7	-174.84	21.64	56.26	2686	26.86	107.25	5.86	103.39
164	28-Sep-2006	02:09:00	03:09:00	02:39:00	0	unnamed_12	-56.26	-10.59	63.29	13136	131.36	72.25	1.23	136.54
164	28-Sep-2006	03:09:00	04:09:00	03:39:00	0	unnamed_7	-172.46	18.49	55.76	2965	29.65	106.62	5.65	102.34
165	29-Sep-2006	02:09:00	03:09:00	02:39:00	0	unnamed_12	-54.68	-11.73	62.27	13563	135.63	73.56	1.14	134.05
165	29-Sep-2006	03:09:00	04:09:00	03:39:00	0	unnamed_7	-171.45	24.75	58.94	2541	25.41	104.58	6.05	109.72
166	30-Sep-2006	02:06:26	03:06:26	02:36:26	0	unnamed_12	-53.70	-14.21	60.88	14600	146.00	75.00	1.03	130.66
166	30-Sep-2006	03:12:00	04:12:00	03:42:00	0	unnamed_7	-169.08	21.39	58.35	2817	28.17	103.99	5.84	108.45
167	01-Oct-2006	03:15:00	04:15:00	03:45:00	0	unnamed_4	-166.66	18.26	57.91	3104	31.04	103.24	5.47	107.57
168	02-Oct-2006	03:15:43	04:15:43	03:45:43	0	unnamed_4	-165.34	22.10	60.06	2843	28.43	101.69	684.45	112.56
169	03-Oct-2006	03:18:00	04:18:00	03:48:00	0	unnamed_4	-163.26	21.14	60.42	2956	29.56	100.68	5.65	113.51
170	04-Oct-2006	03:19:40	04:19:40	03:49:40	0	unnamed_4	-161.47	22.10	61.48	2926	29.26	99.47	684.58	116.03
171	05-Oct-2006	03:24:00	04:24:00	03:54:00	0	uplifted_area	-158.36	15.14	59.77	3552	35.52	98.85	5.24	112.33
172	06-Oct-2006	03:24:13	04:24:13	03:54:13	0	uplifted_area	-157.30	20.26	62.26	3155	31.55	97.37	5.53	118.04
173	07-Oct-2006	03:36:27	04:36:27	04:06:27	0	unnamed_8	-150.00	-2.55	55.62	5917	59.17	96.91	346.29	103.76
174	08-Oct-2006	03:39:00	04:39:00	04:09:00	0	unnamed_8	-147.72	-3.48	56.11	6124	61.24	95.66	3.06	105.07
175	09-Oct-2006	03:39:00	04:39:00	04:09:00	0	unnamed_8	-146.75	-0.34	57.81	5637	56.37	94.40	3.35	108.95
176	10-Oct-2006	03:42:00	04:42:00	04:12:00	0	unnamed_8	-144.23	-2.10	58.04	5969	59.69	93.16	3.27	109.71
177	11-Oct-2006	03:39:00	04:39:00	04:09:00	0	nova_1	-144.90	7.35	61.70	4673	46.73	91.85	4.29	117.78
178	12-Oct-2006	03:39:00	04:39:00	04:09:00	0	nova_1	-143.98	12.07	63.90	4199	41.99	90.58	4.70	122.77
179	13-Oct-2006	03:36:00	04:36:00	04:06:00	0	Boleyn	-144.48	27.17	69.23	2977	29.77	89.38	6.40	134.68
ONr	Begin Exp (SC time)		End Exp	SpecCond	Vi	Target Area	TarLon	TarLat	INC	RAN	SPT	SLW	VSP	SMX
180	14-Oct-2006	03:39:00	04:39:00	04:09:00	0	Boleyn	-142.03	23.69	68.84	3279	32.79	88.25	6.21	133.97
181	15-Oct-2006	03:39:20	04:39:20	04:09:20	0	Boleyn	-140.75	29.50	71.17	2920	29.20	87.27	781.96	139.30
182	16-Oct-2006	03:42:00	04:42:00	04:12:00	0	Boleyn	-138.46	27.05	71.09	3140	31.40	86.11	6.39	139.30

183	17-Oct-2006 03:43:19	04:43:19	04:13:19	0	Boleyn	-136.73	29.50	72.39	3024	30.24	85.14	781.36	142.32
184	18-Oct-2006 03:45:57	04:45:57	04:15:57	0	nova_3	-134.45	27.20	72.37	3239	32.39	83.93	753.44	142.47
185	19-Oct-2006 03:48:00	04:48:00	04:18:00	0	nova_3	-132.40	27.00	72.93	3309	33.09	82.81	6.27	143.89
186	20-Oct-2006 03:21:00	04:21:00	03:51:00	0	GulaMons	-4.64	24.59	57.91	4396	43.96	98.14	3.67	118.95
186	20-Oct-2006 03:51:00	04:51:00	04:21:00	0	nova_4	-129.92	23.57	72.66	3627	36.27	81.46	5.96	143.48
187	21-Oct-2006 03:21:00	04:21:00	03:51:00	0	GulaMons	-3.03	20.31	55.75	4871	48.71	99.64	3.35	114.28
187	21-Oct-2006 03:57:00	04:57:00	04:27:00	0	plains_are_1	-125.84	11.72	70.14	4755	47.55	79.61	4.87	138.32
188	22-Oct-2006 03:24:00	04:24:00	03:54:00	0	GulaMons	-0.84	22.39	55.80	4557	45.57	100.57	3.46	114.05
188	22-Oct-2006 04:00:00	05:00:00	04:30:00	0	plains_are_1	-123.26	9.15	70.12	5091	50.91	78.27	4.74	138.55
189	23-Oct-2006 03:27:00	04:27:00	03:57:00	0	GulaMons	1.33	24.62	55.93	4247	42.47	101.42	3.67	114.01
189	23-Oct-2006 04:02:24	05:02:24	04:32:24	0	plains_are_1	-121.00	8.13	70.54	5268	52.68	77.00	4.68	139.69
190	24-Oct-2006 03:27:00	04:27:00	03:57:00	0	GulaMons	2.92	20.35	53.68	4719	47.19	103.06	3.34	109.13
190	24-Oct-2006 03:54:00	04:54:00	04:24:00	0	SekmetMons	-123.35	42.85	79.24	2581	25.81	79.54	7.81	158.52
191	25-Oct-2006 03:42:47	04:42:47	04:12:47	0	MaxwellMontes	-2.00	65.14	71.97	1600	16.00	94.94	8.28	145.58
192	26-Oct-2006 03:45:00	04:45:00	04:15:00	0	MaxwellMontes	-0.92	66.29	72.27	1548	15.48	94.99	8.27	146.04
194	28-Oct-2006 03:30:00	04:30:00	04:00:00	0	nova_5	9.68	11.85	47.78	5848	58.48	108.76	2.49	95.77
194	28-Oct-2006 03:48:00	04:48:00	04:18:00	0	MaxwellMontes	6.24	62.02	69.75	1654	16.54	97.06	8.13	140.68
195	29-Oct-2006 03:33:00	04:33:00	04:03:00	0	nova_5	11.88	13.38	47.56	5533	55.33	109.79	2.53	95.03
195	29-Oct-2006 03:51:00	04:51:00	04:21:00	0	MaxwellMontes	4.88	66.70	71.84	1494	14.94	95.87	8.41	144.76
196	30-Oct-2006 03:33:00	04:33:00	04:03:00	0	nova_5	13.38	10.49	45.81	6018	60.18	111.35	2.26	91.11
197	31-Oct-2006 03:36:00	04:36:00	04:06:00	0	nova_5	15.58	11.93	45.54	5704	57.04	112.39	2.38	90.28
205	08-Nov-2006 04:48:02	05:48:02	05:18:02	0	unnamed_2	-79.90	-18.67	74.21	10021	100.21	58.10	307.50	151.82
206	09-Nov-2006 04:51:00	05:51:00	05:21:00	0	unnamed_2	-77.19	-20.28	74.42	10335	103.35	57.14	2.66	152.50
207	10-Nov-2006 04:51:00	05:51:00	05:21:00	0	unnamed_2	-76.30	-17.88	75.92	9892	98.92	55.48	2.96	155.93
208	11-Nov-2006 04:54:00	05:54:00	05:24:00	0	unnamed_2	-73.55	-19.66	76.10	10216	102.16	54.53	2.87	156.53
286	28-Jan-2007 05:21:00	06:21:00	05:51:00	0	SapasMons	-175.30	8.59	30.93	5594	55.94	134.22	2.04	91.49
287	29-Jan-2007 05:21:00	06:21:00	05:51:00	0	SapasMons	-173.37	8.46	31.68	5645	56.45	133.04	2.04	93.37
288	30-Jan-2007 05:12:00	06:12:00	05:42:00	0	MaatMons	-169.87	-0.44	30.13	8090	80.90	132.58	1.29	91.84
289	31-Jan-2007 05:12:00	06:12:00	05:42:00	0	MaatMons	-167.90	-0.53	30.89	8143	81.43	131.33	1.29	93.71
290	01-Feb-2007 05:15:00	06:15:00	05:45:00	0	MaatMons	-166.44	1.83	32.14	7400	74.00	130.13	1.48	96.46
290	01-Feb-2007 06:15:00	07:15:00	06:45:00	0	unnamed_12	-54.91	-12.78	79.74	9229	92.29	50.54	3.60	127.70
291	02-Feb-2007 05:15:00	06:15:00	05:45:00	0	MaatMons	-164.48	1.73	32.90	7454	74.54	128.89	1.48	98.34
ONr	Begin Exp (SC time)	End Exp	SpecCond	Vi	Target Area	TarLon	TarLat	INC	RAN	SPT	SLW	VSP	SMX
292	03-Feb-2007 05:12:00	06:12:00	05:42:00	0	MaatMons	-161.99	-0.83	33.15	8306	83.06	127.59	1.29	99.28
293	04-Feb-2007 05:18:00	06:18:00	05:48:00	0	OzzaMons	-161.13	4.37	35.15	6763	67.63	126.27	1.71	103.24
294	05-Feb-2007 05:18:00	06:18:00	05:48:00	0	OzzaMons	-159.17	4.27	35.90	6819	68.19	125.04	1.71	105.11
295	06-Feb-2007 05:18:00	06:18:00	05:48:00	0	OzzaMons	-157.21	4.16	36.65	6876	68.76	123.81	1.71	106.99
296	07-Feb-2007 05:20:09	06:20:09	05:50:09	0	OzzaMons	-155.70	6.39	38.09	6355	63.55	122.37	123.99	109.85

ONr	Begin Exp (SC time)	End Exp	SpecCond	Vi	Target Area	TarLon	TarLat	INC	RAN	SPT	SLW	VSP	SMX
298	09-Feb-2007 04:58:57	05:58:57	05:28:57	0	unnamed_9	-147.90	-9.10	36.48	12003	120.03	119.07	0.82	107.06
298	09-Feb-2007 05:09:00	06:09:00	05:39:00	0	unnamed_8	-149.55	-3.58	37.22	9436	94.36	119.97	1.14	109.41
299	10-Feb-2007 05:03:00	06:03:00	05:33:00	0	unnamed_9	-146.52	-7.23	37.39	11042	110.42	118.26	0.92	109.65
300	11-Feb-2007 04:54:00	05:54:00	05:24:00	0	edge_of_plateau_1	-143.12	-11.43	37.66	13334	133.34	116.20	0.72	109.51
301	12-Feb-2007 04:57:00	05:57:00	05:27:00	0	edge_of_plateau_1	-141.53	-10.32	38.44	12659	126.59	115.31	0.77	111.77
302	13-Feb-2007 05:03:00	06:03:00	05:33:00	0	edge_of_plateau_1	-140.48	-7.58	39.49	11219	112.19	114.62	0.93	114.87
303	14-Feb-2007 05:06:00	06:06:00	05:36:00	0	edge_of_plateau_1	-139.00	-6.02	40.47	10514	105.14	113.62	1.04	117.45
304	15-Feb-2007 05:06:00	06:06:00	05:36:00	0	edge_of_plateau_1	-136.99	-6.14	41.18	10575	105.75	112.40	1.04	119.21
305	16-Feb-2007 05:06:00	06:06:00	05:36:00	0	edge_of_plateau_1	-134.98	-6.26	41.88	10637	106.37	111.17	1.04	120.96
306	17-Feb-2007 05:09:42	06:09:42	05:39:42	0	edge_of_plateau_1	-133.70	-4.00	43.07	9741	97.41	110.12	76.19	123.97
306	17-Feb-2007 05:21:00	06:21:00	05:51:00	0	plains_are_2	-136.23	6.24	45.76	6735	67.35	110.06	1.98	128.77
307	18-Feb-2007 05:27:00	06:27:00	05:57:00	0	nova_2	-135.73	14.66	49.32	5187	51.87	108.04	2.78	133.66
308	19-Feb-2007 05:30:00	06:30:00	06:00:00	0	nova_4	-134.46	20.14	52.07	4458	44.58	106.13	3.32	136.83
309	20-Feb-2007 05:23:51	06:23:51	05:53:51	0	plains_are_1	-131.00	9.56	49.08	6161	61.61	106.15	2.31	135.64
309	20-Feb-2007 05:30:00	06:30:00	06:00:00	0	nova_4	-132.50	19.99	52.73	4519	45.19	105.02	3.31	138.47
310	21-Feb-2007 05:24:00	06:24:00	05:54:00	0	plains_are_1	-129.06	9.65	49.85	6187	61.87	104.93	2.32	137.51
310	21-Feb-2007 06:03:00	07:03:00	06:33:00	0	GulaMons	-6.28	19.89	74.58	4255	42.55	75.70	5.88	110.85
311	22-Feb-2007 05:24:00	06:24:00	05:54:00	0	plains_are_1	-127.07	9.53	50.56	6254	62.54	103.72	2.32	139.29
311	22-Feb-2007 06:03:00	07:03:00	06:33:00	0	GulaMons	-4.22	20.05	74.00	4177	41.77	76.87	5.88	109.39
312	23-Feb-2007 05:24:00	06:24:00	05:54:00	0	plains_are_1	-125.09	9.41	51.26	6321	63.21	102.51	2.32	141.08
312	23-Feb-2007 06:03:00	07:03:00	06:33:00	0	GulaMons	-2.17	20.21	73.41	4101	41.01	78.03	5.88	107.94
313	24-Feb-2007 05:24:00	06:24:00	05:54:00	0	plains_are_1	-123.10	9.29	51.96	6390	63.90	101.30	2.32	142.85
313	24-Feb-2007 06:03:00	07:03:00	06:33:00	0	GulaMons	-0.13	20.38	72.83	4025	40.25	79.19	5.88	106.49
314	25-Feb-2007 05:24:00	06:24:00	05:54:00	0	plains_are_1	-121.11	9.17	52.66	6459	64.59	100.09	2.48	144.62
314	25-Feb-2007 05:39:00	06:39:00	06:09:00	0	SekmetMons	-123.07	44.19	65.27	2588	25.88	96.49	6.20	143.29
314	25-Feb-2007 06:03:00	07:03:00	06:33:00	0	GulaMons	1.92	20.56	72.25	3950	39.50	80.34	5.88	105.04
315	26-Feb-2007 05:39:00	06:39:00	06:09:00	0	SekmetMons	-121.10	43.93	65.66	2641	26.41	95.71	6.17	144.02
316	27-Feb-2007 05:39:00	06:39:00	06:09:00	0	SekmetMons	-119.12	43.66	66.06	2694	26.94	94.92	6.15	144.71
317	28-Feb-2007 05:39:00	06:39:00	06:09:00	0	SekmetMons	-117.14	43.41	66.47	2749	27.49	94.11	6.12	145.37
318	01-Mar-2007 05:39:00	06:39:00	06:09:00	0	SekmetMons	-115.16	43.16	66.88	2805	28.05	93.29	6.09	146.00
319	02-Mar-2007 06:06:00	07:06:00	06:36:00	0	nova_5	10.56	12.92	66.78	4378	43.78	85.87	4.85	91.54
325	08-Mar-2007 05:33:00	06:33:00	06:03:00	0	unnamed_3	-101.14	24.38	64.91	4810	48.10	86.79	3.90	158.83
326	09-Mar-2007 05:33:00	06:33:00	06:03:00	0	unnamed_3	-99.11	24.25	65.51	4884	48.84	85.67	3.90	159.50
327	10-Mar-2007 05:30:00	06:30:00	06:00:00	0	unnamed_5	-96.50	17.65	64.30	5780	57.80	84.38	3.31	163.74
328	11-Mar-2007 05:30:00	06:30:00	06:00:00	0	unnamed_5	-94.47	17.54	64.92	5858	58.58	83.21	3.31	164.51
329	12-Mar-2007 05:30:00	06:30:00	06:00:00	0	unnamed_5	-92.44	17.43	65.55	5936	59.36	82.04	3.32	165.12
330	13-Mar-2007 05:30:00	06:30:00	06:00:00	0	unnamed_5	-90.40	17.32	66.17	6015	60.15	80.86	3.33	165.57

ONr	Begin Exp (SC time)	End Exp	SpecCond	Vi	Target Area	TarLon	TarLat	INC	RAN	SPT	SLW	VSP	SMX
331	14-Mar-2007 04:51:00	05:51:00	05:21:00	0	unnamed_2	-78.64	-18.49	57.05	16043	160.43	80.62	0.10	154.48
331	14-Mar-2007 05:30:00	06:30:00	06:00:00	0	unnamed_5	-88.36	17.22	66.79	6095	60.95	79.68	3.34	165.83
332	15-Mar-2007 04:51:00	05:51:00	05:21:00	0	unnamed_2	-76.54	-18.78	57.64	16114	161.14	79.51	0.10	155.51
333	16-Mar-2007 04:54:00	05:54:00	05:24:00	0	unnamed_2	-75.11	-17.74	58.62	15493	154.93	78.25	0.86	158.05
334	17-Mar-2007 04:57:00	05:57:00	05:27:00	0	unnamed_2	-73.72	-16.58	59.65	14863	148.63	76.95	0.94	160.69
334	17-Mar-2007 05:33:00	06:33:00	06:03:00	0	TheiaMons	-82.77	23.39	70.20	5504	55.04	76.61	3.90	160.27
335	18-Mar-2007 04:57:00	05:57:00	05:27:00	0	unnamed_2	-71.63	-16.87	60.25	14938	149.38	75.83	0.95	161.53
335	18-Mar-2007 05:15:00	06:15:00	05:45:00	0	unnamed_1	-76.26	-4.18	63.86	10474	104.74	74.75	1.68	175.46
335	18-Mar-2007 05:33:00	06:33:00	06:03:00	0	TheiaMons	-80.71	23.29	70.77	5586	55.86	75.47	3.90	159.78
336	19-Mar-2007 04:58:28	05:58:28	05:28:28	0	unnamed_2	-69.90	-16.40	61.07	14667	146.67	74.60	62.13	163.16
336	19-Mar-2007 05:18:00	06:18:00	05:48:00	0	unnamed_1	-75.04	-1.25	65.34	9769	97.69	73.42	1.90	179.28
336	19-Mar-2007 05:33:00	06:33:00	06:03:00	0	TheiaMons	-78.65	23.20	71.35	5668	56.68	74.32	3.91	159.18
337	20-Mar-2007 05:18:00	06:18:00	05:48:00	0	unnamed_1	-72.99	-1.44	65.97	9853	98.53	72.22	1.91	177.97
337	20-Mar-2007 05:33:00	06:33:00	06:03:00	0	TheiaMons	-76.59	23.11	71.92	5751	57.51	73.17	3.92	158.48
338	21-Mar-2007 05:18:00	06:18:00	05:48:00	0	unnamed_1	-70.94	-1.63	66.61	9937	99.37	71.01	1.93	176.34
338	21-Mar-2007 05:36:00	06:36:00	06:06:00	0	RheaMons	-74.75	30.66	74.09	4988	49.88	73.02	4.70	152.37
339	22-Mar-2007 05:18:00	06:18:00	05:48:00	0	unnamed_1	-68.89	-1.83	67.24	10022	100.22	69.81	1.94	174.68
339	22-Mar-2007 05:36:00	06:36:00	06:06:00	0	RheaMons	-72.67	30.58	74.62	5070	50.70	71.92	4.70	151.63
340	23-Mar-2007 05:06:00	06:06:00	05:36:00	0	unnamed_12	-63.52	-12.91	64.87	13160	131.60	69.46	1.29	169.21
340	23-Mar-2007 05:18:35	06:18:35	05:48:35	0	unnamed_1	-67.00	-1.36	68.04	9955	99.55	68.59	127.43	172.76
341	24-Mar-2007 05:09:00	06:09:00	05:39:00	0	unnamed_12	-62.27	-10.93	66.13	12499	124.99	68.05	1.42	170.35
342	25-Mar-2007 05:09:00	06:09:00	05:39:00	0	unnamed_12	-60.20	-11.22	66.74	12582	125.82	66.89	1.44	169.45
343	26-Mar-2007 05:12:00	06:12:00	05:42:00	0	unnamed_12	-58.98	-8.93	68.07	11912	119.12	65.46	1.60	168.98
344	27-Mar-2007 05:12:00	06:12:00	05:42:00	0	unnamed_12	-56.91	-9.22	68.68	11998	119.98	64.29	1.62	167.58
345	28-Mar-2007 05:12:00	06:12:00	05:42:00	0	unnamed_12	-54.84	-9.52	69.28	12083	120.83	63.13	1.63	166.12
346	29-Mar-2007 05:24:00	06:24:00	05:54:00	0	unnamed_10	-56.12	4.85	73.51	9039	90.39	61.32	2.63	159.10
347	30-Mar-2007 05:24:00	06:24:00	05:54:00	0	unnamed_10	-54.05	4.67	74.11	9131	91.31	60.12	2.70	157.52
407	29-May-2007 06:51:00	07:51:00	07:21:00	0	DaliChasma	172.31	-19.32	17.00	11360	113.60	151.89	0.71	91.58
408	30-May-2007 06:51:00	07:51:00	07:21:00	0	DaliChasma	174.22	-19.26	17.12	11328	113.28	151.70	0.72	93.15
412	03-Jun-2007 06:58:20	07:58:20	07:28:20	0	fractured_area	-177.80	-21.57	20.07	13028	130.28	146.18	33.24	98.57
413	04-Jun-2007 06:54:00	07:54:00	07:24:00	0	fractured_area	-176.09	-20.07	18.99	11929	119.29	148.38	0.67	100.61
414	05-Jun-2007 06:24:50	07:21:00	06:51:00	1	SapasMons	-176.79	7.58	14.70	3309	33.09	160.11	3.73	109.32
414	05-Jun-2007 06:54:00	07:54:00	07:24:00	0	fractured_area	-174.18	-20.01	19.21	11900	119.00	148.03	0.67	102.14
415	06-Jun-2007 06:24:52	07:15:00	06:45:00	1	unnamed_7	-175.72	23.01	28.08	1991	19.91	145.08	5.69	109.95
415	06-Jun-2007 06:54:00	07:54:00	07:24:00	0	fractured_area	-172.27	-19.94	19.44	11871	118.71	147.66	0.68	103.67
416	07-Jun-2007 06:24:53	07:15:00	06:45:00	1	unnamed_7	-174.03	23.48	28.77	1969	19.69	144.29	5.72	111.42
416	07-Jun-2007 06:54:00	07:54:00	07:24:00	0	fractured_area	-170.38	-19.88	19.68	11842	118.42	147.27	0.68	105.19

417	08-Jun-2007 06:24:53	07:15:00	06:45:00	1	unnamed_7	-172.35	23.97	29.47	1946	19.46	143.49	5.75	112.82
417	08-Jun-2007 06:54:00	07:54:00	07:24:00	0	fractured_area	-168.48	-19.82	19.93	11814	118.14	146.86	0.69	106.72
418	09-Jun-2007 06:24:53	07:15:00	06:45:00	1	unnamed_7	-170.67	24.45	30.17	1925	19.25	142.68	5.77	114.15
419	10-Jun-2007 06:24:52	07:15:00	06:45:00	1	unnamed_7	-168.99	24.95	30.89	1903	19.03	141.87	5.80	115.42
420	11-Jun-2007 06:24:50	07:18:00	06:48:00	1	unnamed_4	-166.92	16.53	24.15	2471	24.71	148.90	5.03	119.84
421	12-Jun-2007 06:24:47	07:18:00	06:48:00	1	unnamed_4	-165.23	16.94	24.87	2447	24.47	148.04	5.05	121.43
422	13-Jun-2007 06:24:42	07:16:21	06:46:21	1	unnamed_4	-163.79	22.10	29.38	2092	20.92	143.19	324.29	121.03
423	14-Jun-2007 06:24:37	07:16:31	06:46:31	1	unnamed_4	-162.09	22.10	29.71	2100	21.00	142.76	324.01	122.50
424	15-Jun-2007 06:24:29	07:18:00	06:48:00	1	uplifted_area	-160.19	18.23	27.03	2375	23.75	145.44	5.08	125.89
425	16-Jun-2007 06:24:20	07:18:00	06:48:00	1	uplifted_area	-158.51	18.67	27.76	2351	23.51	144.58	5.11	127.24
426	17-Jun-2007 06:24:14	07:24:14	06:54:14	0	OzzaMons	-155.70	5.14	19.86	3758	37.58	152.56	3.13	132.67
429	20-Jun-2007 06:30:00	07:30:00	07:00:00	0	unnamed_8	-149.48	-2.53	19.54	5159	51.59	151.48	2.37	137.00
430	21-Jun-2007 06:33:00	07:33:00	07:03:00	0	unnamed_8	-147.69	-2.68	20.10	5212	52.12	150.60	2.37	138.83
431	22-Jun-2007 06:36:00	07:36:00	07:06:00	0	unnamed_8	-145.91	-2.83	20.66	5264	52.64	149.74	2.34	140.65
432	23-Jun-2007 06:30:28	07:29:08	06:59:08	1	nova_1	-145.90	8.17	24.65	3248	32.48	146.80	217.79	143.82
433	24-Jun-2007 06:28:29	07:27:00	06:57:00	1	nova_1	-144.43	10.18	26.13	3031	30.31	145.22	4.17	144.78
434	25-Jun-2007 06:26:14	07:21:00	06:51:00	1	Boleyn	-143.94	23.14	34.55	1968	19.68	137.17	6.15	135.51
435	26-Jun-2007 06:23:16	07:18:00	06:48:00	1	Boleyn	-142.69	29.44	39.43	1631	16.31	132.51	6.57	128.98
436	27-Jun-2007 06:18:00	07:18:00	06:48:00	0	Boleyn	-140.76	25.20	36.65	1865	18.65	134.95	6.28	134.76
437	28-Jun-2007 06:15:36	07:15:36	06:45:36	0	Boleyn	-139.38	29.50	40.02	1646	16.46	131.74	393.48	129.89
438	29-Jun-2007 06:15:00	07:15:00	06:45:00	0	Boleyn	-137.59	27.35	38.77	1765	17.65	132.77	6.41	133.17
438	29-Jun-2007 06:29:47	07:29:47	06:59:47	0	edge_of_plateau_1	-133.70	-3.75	24.50	5376	53.76	143.99	2.20	153.30
439	30-Jun-2007 06:13:13	07:13:13	06:43:13	0	Boleyn	-136.08	29.50	40.56	1664	16.64	131.03	392.29	130.65
440	01-Jul-2007 06:12:40	07:12:40	06:42:40	0	nova_3	-134.28	27.20	39.22	1793	17.93	132.11	373.49	134.17
441	02-Jul-2007 06:12:00	07:12:00	06:42:00	0	nova_3	-132.50	25.39	38.29	1905	19.05	132.82	6.09	137.07
442	03-Jul-2007 06:12:00	07:12:00	06:42:00	0	nova_4	-130.52	21.56	36.16	2160	21.60	134.56	5.63	142.96
ONr	Begin Exp (SC time)	End Exp	SpecCond	Vi	Target Area	TarLon	TarLat	INC	RAN	SPT	SLW	VSP	SMX
443	04-Jul-2007 06:12:00	07:12:00	06:42:00	0	nova_4	-128.52	18.09	34.45	2429	24.29	135.86	5.36	148.42
444	05-Jul-2007 06:15:00	07:15:00	06:45:00	0	plains_are_1	-125.59	8.19	30.12	3443	34.43	139.05	4.00	162.28
445	06-Jul-2007 06:13:23	07:13:23	06:43:23	0	plains_are_1	-124.06	9.09	30.85	3349	33.49	138.26	3.87	162.23
446	07-Jul-2007 06:11:32	07:11:32	06:41:32	0	plains_are_1	-122.61	10.51	31.78	3199	31.99	137.35	208.24	161.06
447	08-Jul-2007 06:00:00	07:00:00	06:30:00	0	SekmetMons	-123.57	44.91	53.03	1134	11.34	119.31	8.36	107.49
447	08-Jul-2007 06:10:13	07:10:13	06:40:13	0	plains_are_1	-121.00	10.85	32.26	3178	31.78	136.76	3.97	161.10
448	09-Jul-2007 06:00:00	07:00:00	06:30:00	0	SekmetMons	-121.88	39.55	49.31	1313	13.13	122.49	8.09	115.18
449	10-Jul-2007 05:57:00	06:57:00	06:27:00	0	SekmetMons	-120.33	47.78	55.22	1066	10.66	117.29	8.45	102.42
450	11-Jul-2007 05:57:00	06:57:00	06:27:00	0	SekmetMons	-118.73	42.25	51.36	1233	12.33	120.60	8.20	110.23
452	13-Jul-2007 05:54:00	06:54:00	06:24:00	0	SekmetMons	-115.57	45.01	53.38	1158	11.58	118.77	8.30	105.02
461	22-Jul-2007 05:45:00	06:45:00	06:15:00	0	unnamed_3	-100.52	26.00	41.83	2056	20.56	127.92	5.90	129.99

ONr	Begin Exp	(SC time)	End Exp	SpecCond	Vi	Target Area	TarLon	TarLat	INC	RAN	SPT	SLW	VSP	SMX
462	23-Jul-2007	05:42:00	06:42:00	06:12:00	0	unnamed_3	-98.57	22.11	39.87	2331	23.31	129.34	5.63	135.47
463	24-Jul-2007	05:36:00	06:36:00	06:06:00	0	unnamed_3	-97.63	27.67	42.64	1964	19.64	127.29	6.01	125.69
464	25-Jul-2007	05:33:00	06:33:00	06:03:00	0	unnamed_3	-95.71	23.64	40.53	2233	22.33	128.86	5.71	131.29
465	26-Jul-2007	05:27:29	06:27:29	05:57:29	0	unnamed_3	-94.63	27.69	42.49	1971	19.71	127.44	207.53	123.99
466	27-Jul-2007	05:24:00	06:24:00	05:54:00	0	unnamed_3	-92.90	25.19	41.11	2135	21.35	128.50	5.75	127.07
467	28-Jul-2007	05:19:13	06:19:13	05:49:13	0	unnamed_3	-91.59	26.88	41.83	2028	20.28	128.03	349.21	123.52
467	28-Jul-2007	06:04:40	07:04:40	06:34:40	0	unnamed_2	-79.90	-20.11	35.35	13863	138.63	119.83	36.31	138.41
468	29-Jul-2007	05:17:48	06:17:48	05:47:48	0	unnamed_5	-89.14	18.54	37.85	2661	26.61	130.83	5.03	135.17
468	29-Jul-2007	06:00:00	07:00:00	06:30:00	0	unnamed_2	-78.51	-19.88	35.38	13770	137.70	119.84	0.64	138.01
469	30-Jul-2007	05:13:39	06:13:39	05:43:39	0	unnamed_5	-87.64	18.27	37.59	2689	26.89	131.07	4.92	134.48
469	30-Jul-2007	05:54:00	06:54:00	06:24:00	0	unnamed_2	-77.35	-19.20	35.26	13350	133.50	120.29	0.67	138.19
470	31-Jul-2007	05:48:00	06:48:00	06:18:00	0	unnamed_2	-76.22	-18.50	35.11	12924	129.24	120.79	0.70	138.30
471	01-Aug-2007	05:42:00	06:42:00	06:12:00	0	unnamed_2	-75.11	-17.77	34.93	12494	124.94	121.35	0.74	138.35
472	02-Aug-2007	04:59:04	05:59:04	05:29:04	0	TheiaMons	-83.98	23.33	39.13	2280	22.80	130.44	190.90	124.16
472	02-Aug-2007	05:36:00	06:36:00	06:06:00	0	unnamed_2	-74.03	-17.00	34.73	12059	120.59	121.96	0.78	138.34
473	03-Aug-2007	04:55:06	05:55:06	05:25:06	0	TheiaMons	-82.46	22.45	38.47	2347	23.47	131.04	5.36	124.42
473	03-Aug-2007	05:11:46	06:11:46	05:41:46	0	unnamed_1	-77.00	-5.14	32.59	6732	67.32	130.22	100.09	146.43
473	03-Aug-2007	05:33:00	06:33:00	06:03:00	0	unnamed_2	-72.44	-17.37	34.85	12382	123.82	121.55	0.75	136.90
474	04-Aug-2007	04:48:00	05:48:00	05:18:00	0	RheaMons	-81.98	31.61	42.69	1753	17.53	128.11	6.70	109.97
474	04-Aug-2007	05:06:00	06:06:00	05:36:00	0	unnamed_1	-76.03	-3.64	32.39	6320	63.20	131.04	1.97	145.29
474	04-Aug-2007	05:27:00	06:27:00	05:57:00	0	unnamed_2	-71.39	-16.59	34.61	11945	119.45	122.24	0.79	136.78
475	05-Aug-2007	04:42:12	05:42:12	05:12:12	0	RheaMons	-80.97	37.40	45.64	1471	14.71	125.91	422.74	100.22
475	05-Aug-2007	05:00:00	06:00:00	05:30:00	0	unnamed_1	-75.16	-1.77	32.19	5840	58.40	132.00	2.18	143.88
475	05-Aug-2007	05:21:00	06:21:00	05:51:00	0	unnamed_2	-70.36	-15.79	34.34	11503	115.03	123.00	0.83	136.58
476	06-Aug-2007	04:39:00	05:39:00	05:09:00	0	RheaMons	-79.32	33.26	42.94	1662	16.62	128.20	6.78	105.71
476	06-Aug-2007	04:57:00	05:57:00	05:27:00	0	unnamed_1	-73.44	-3.03	32.03	6191	61.91	131.76	2.01	142.50
476	06-Aug-2007	05:12:09	06:12:09	05:42:09	0	unnamed_2	-69.90	-13.62	33.67	10311	103.11	124.98	0.92	137.53
477	07-Aug-2007	04:36:00	05:36:00	05:06:00	0	RheaMons	-77.57	28.75	40.19	1908	19.08	130.49	6.47	111.50
477	07-Aug-2007	04:47:03	05:47:03	05:17:03	0	unnamed_11	-73.80	3.89	32.01	4625	46.25	134.18	156.21	139.25
478	08-Aug-2007	04:30:00	05:30:00	05:00:00	0	RheaMons	-76.69	34.92	43.17	1573	15.73	128.33	6.87	101.47
478	08-Aug-2007	04:42:00	05:42:00	05:12:00	0	unnamed_11	-72.70	5.08	31.84	4414	44.14	134.78	3.04	137.21
479	09-Aug-2007	04:27:00	05:27:00	04:57:00	0	RheaMons	-74.97	30.26	40.23	1811	18.11	130.83	6.56	107.47
479	09-Aug-2007	04:39:00	05:39:00	05:09:00	0	unnamed_11	-70.96	3.27	31.36	4756	47.56	134.88	2.77	136.82
480	10-Aug-2007	04:21:00	05:21:00	04:51:00	0	RheaMons	-74.07	36.60	43.39	1487	14.87	128.46	6.95	97.26
480	10-Aug-2007	04:33:00	05:33:00	05:03:00	0	unnamed_11	-70.18	5.85	31.28	4286	42.86	135.81	3.08	134.05
480	10-Aug-2007	04:50:11	05:50:11	05:20:11	0	unnamed_6	-65.70	-10.63	32.38	9005	90.05	128.15	65.95	134.82
481	11-Aug-2007	04:30:00	05:30:00	05:00:00	0	unnamed_11	-68.46	3.99	30.75	4627	46.27	135.97	2.84	133.76

481	11-Aug-2007 04:42:00	05:42:00	05:12:00	0	unnamed_6	-65.28	-8.03	31.59	7937	79.37	130.43	1.36	134.73
482	12-Aug-2007 04:24:00	05:24:00	04:54:00	0	unnamed_11	-67.69	6.62	30.63	4158	41.58	136.95	3.10	130.92
483	13-Aug-2007 04:21:00	05:21:00	04:51:00	0	unnamed_11	-65.98	4.69	30.06	4497	44.97	137.17	2.92	130.72
484	14-Aug-2007 04:15:00	05:15:00	04:45:00	0	unnamed_11	-65.21	7.37	29.93	4031	40.31	138.17	3.07	127.82
485	15-Aug-2007 04:11:05	05:11:05	04:41:05	0	unnamed_11	-63.80	6.79	29.44	4123	41.23	138.69	2.98	126.88
486	16-Aug-2007 04:09:00	05:09:00	04:39:00	0	unnamed_10	-61.86	3.56	28.82	4711	47.11	138.60	2.69	127.27
487	17-Aug-2007 04:06:00	05:06:00	04:36:00	0	unnamed_10	-60.21	1.90	28.43	5057	50.57	138.64	2.49	126.57
488	18-Aug-2007 04:00:00	05:00:00	04:30:00	0	unnamed_10	-59.41	4.18	28.01	4583	45.83	139.95	2.66	124.33
489	19-Aug-2007 03:57:00	04:57:00	04:27:00	0	unnamed_10	-57.77	2.46	27.62	4928	49.28	140.01	2.51	123.69
490	20-Aug-2007 03:51:00	04:51:00	04:21:00	0	unnamed_10	-56.95	4.78	27.19	4456	44.56	141.31	2.61	121.38
491	21-Aug-2007 03:48:00	04:48:00	04:18:00	0	unnamed_10	-55.31	3.01	26.80	4801	48.01	141.37	2.46	120.79
492	22-Aug-2007 03:42:43	04:42:43	04:12:43	0	unnamed_10	-54.28	4.34	26.37	4527	45.27	142.37	130.13	118.89
537	06-Oct-2007 00:24:00	01:24:00	00:54:00	0	ThetisRegio	123.72	-8.24	79.94	12793	127.93	43.39	2.26	94.46
538	07-Oct-2007 00:24:00	01:24:00	00:54:00	0	ThetisRegio	125.74	-7.65	79.66	12632	126.32	44.13	2.27	95.87
539	08-Oct-2007 00:24:00	01:24:00	00:54:00	0	ThetisRegio	127.77	-7.07	79.38	12469	124.69	44.89	2.28	97.27
540	09-Oct-2007 00:21:00	01:21:00	00:51:00	0	ThetisRegio	128.73	-10.23	78.32	13066	130.66	45.87	2.07	99.98
541	10-Oct-2007 00:21:00	01:21:00	00:51:00	0	ThetisRegio	130.77	-9.66	78.02	12905	129.05	46.65	2.06	101.40
542	11-Oct-2007 00:18:42	01:18:42	00:48:42	0	ThetisRegio	132.00	-11.71	77.13	13320	133.20	47.64	1.98	103.74
561	30-Oct-2007 00:00:00	01:00:00	00:30:00	0	DaliChasma	165.76	-17.53	65.84	14824	148.24	66.02	1.12	135.70
562	30-Oct-2007 23:57:00	00:57:00	00:27:00	0	DaliChasma	167.03	-18.84	64.88	15375	153.75	67.21	1.03	137.19
563	31-Oct-2007 23:54:00	00:54:00	00:24:00	0	DaliChasma	168.34	-20.01	63.96	15919	159.19	68.39	0.96	138.52
564	01-Nov-2007 23:54:00	00:54:00	00:24:00	0	DaliChasma	170.46	-19.61	63.50	15767	157.67	69.33	0.96	139.92

ONr	Begin Exp (SC time)	End Exp	SpecCond	Vi	Target Area	TarLon	TarLat	INC	RAN	SPT	SLW	VSP	SMX
565	02-Nov-2007 23:51:00	00:51:00	00:21:00	0	DaliChasma	171.81	-20.67	62.61	16306	163.06	70.50	0.11	141.04
565	03-Nov-2007 00:30:00	01:30:00	01:00:00	0	unnamed_7	-177.07	19.34	72.40	6349	63.49	70.39	3.69	126.81
566	03-Nov-2007 23:51:00	00:51:00	00:21:00	0	DaliChasma	173.94	-20.28	62.14	16156	161.56	71.45	0.11	142.38
566	04-Nov-2007 00:24:00	01:24:00	00:54:00	0	SapasMons	-176.56	8.76	69.64	7847	78.47	70.40	2.81	134.65
567	05-Nov-2007 00:24:00	01:24:00	00:54:00	0	SapasMons	-174.49	9.39	69.24	7674	76.74	71.47	2.75	135.92
568	06-Nov-2007 00:24:00	01:24:00	00:54:00	0	SapasMons	-172.41	10.03	68.84	7502	75.02	72.54	2.78	137.16
569	07-Nov-2007 00:24:00	01:24:00	00:54:00	0	SapasMons	-170.34	10.67	68.44	7330	73.30	73.62	2.82	138.37
570	07-Nov-2007 23:51:00	00:51:00	00:21:00	0	fractured_area	-177.55	-18.78	60.23	15554	155.54	75.34	0.92	147.63
570	08-Nov-2007 00:18:00	01:18:00	00:48:00	0	MaatMons	-170.01	2.37	65.88	8794	87.94	74.35	2.26	144.91
571	08-Nov-2007 23:51:00	00:51:00	00:21:00	0	fractured_area	-175.43	-18.41	59.74	15404	154.04	76.33	0.90	148.89
571	09-Nov-2007 00:18:00	01:18:00	00:48:00	0	MaatMons	-167.92	2.91	65.43	8625	86.25	75.42	2.20	146.35
572	09-Nov-2007 23:48:00	00:48:00	00:18:00	0	fractured_area	-174.03	-19.42	58.85	15949	159.49	77.47	0.11	149.41
572	10-Nov-2007 00:15:00	01:15:00	00:45:00	0	MaatMons	-166.73	-0.25	64.04	9259	92.59	76.47	1.96	149.65
573	10-Nov-2007 23:48:00	00:48:00	00:18:00	0	fractured_area	-171.91	-19.07	58.36	15801	158.01	78.47	0.11	150.56
573	11-Nov-2007 00:15:00	01:15:00	00:45:00	0	MaatMons	-164.64	0.25	63.57	9092	90.92	77.55	1.98	151.16

ONr	Begin Exp (SC time)	End Exp	SpecCond	Vi	Target Area	TarLon	TarLat	INC	RAN	SPT	SLW	VSP	SMX
574	11-Nov-2007 23:45:00	00:45:00	00:15:00	0	fractured_area	-170.48	-20.00	57.50	16341	163.41	79.60	0.11	150.77
574	12-Nov-2007 00:15:00	01:15:00	00:45:00	0	MaatMons	-162.55	0.74	63.10	8926	89.26	78.63	2.00	152.66
575	12-Nov-2007 23:45:00	00:45:00	00:15:00	0	fractured_area	-168.35	-19.66	57.00	16195	161.95	80.60	0.11	151.76
575	13-Nov-2007 00:12:00	01:12:00	00:42:00	0	MaatMons	-161.35	-2.09	61.74	9556	95.56	79.73	1.82	155.62
576	14-Nov-2007 00:15:00	01:15:00	00:45:00	0	OzzaMons	-158.38	1.74	62.14	8594	85.94	80.81	2.06	155.65
577	15-Nov-2007 00:15:00	01:15:00	00:45:00	0	OzzaMons	-156.30	2.25	61.66	8428	84.28	81.91	2.07	157.12
581	19-Nov-2007 00:12:00	01:12:00	00:42:00	0	unnamed_8	-148.84	0.71	58.75	8575	85.75	86.33	1.90	165.00
582	20-Nov-2007 00:09:00	01:09:00	00:39:00	0	unnamed_8	-147.60	-1.99	57.38	9208	92.08	87.47	1.70	167.64
583	21-Nov-2007 00:03:00	01:03:00	00:33:00	0	unnamed_9	-147.14	-6.83	55.44	10612	106.12	88.65	1.36	167.93
584	22-Nov-2007 00:06:00	01:06:00	00:36:00	0	unnamed_9	-144.26	-3.95	55.56	9676	96.76	89.74	1.54	170.57
585	23-Nov-2007 00:03:00	01:03:00	00:33:00	0	unnamed_9	-142.97	-6.07	54.35	10298	102.98	90.88	1.38	170.26
586	23-Nov-2007 23:54:06	00:54:06	00:24:06	0	edge_of_plateau_1	-143.08	-11.70	52.25	12397	123.97	92.04	32.45	164.02
587	25-Nov-2007 00:00:00	01:00:00	00:30:00	0	edge_of_plateau_1	-139.57	-7.59	52.64	10758	107.58	93.14	1.26	169.16
588	26-Nov-2007 00:00:00	01:00:00	00:30:00	0	edge_of_plateau_1	-137.49	-7.23	52.08	10604	106.04	94.27	1.27	169.37
588	26-Nov-2007 00:21:00	01:21:00	00:51:00	0	nova_4	-131.94	18.63	59.56	5042	50.42	93.65	3.44	157.45
589	27-Nov-2007 00:00:00	01:00:00	00:30:00	0	edge_of_plateau_1	-135.41	-6.87	51.51	10449	104.49	95.40	1.28	169.32
589	27-Nov-2007 00:16:34	01:16:34	00:46:34	0	plains_are_1	-131.00	11.19	56.62	6069	60.69	95.03	86.89	167.12
590	27-Nov-2007 23:57:00	00:57:00	00:27:00	0	edge_of_plateau_1	-134.05	-8.60	50.42	11063	110.63	96.53	1.16	166.14
590	28-Nov-2007 00:15:00	01:15:00	00:45:00	0	plains_are_1	-129.36	9.37	55.41	6330	63.30	96.21	2.50	170.08
591	29-Nov-2007 00:15:00	01:15:00	00:45:00	0	plains_are_1	-127.30	9.98	54.94	6174	61.74	97.29	2.55	169.76
592	30-Nov-2007 00:15:00	01:15:00	00:45:00	0	plains_are_1	-125.25	10.60	54.48	6018	60.18	98.36	2.60	169.18
593	01-Dec-2007 00:15:00	01:15:00	00:45:00	0	plains_are_1	-123.19	11.23	54.02	5864	58.64	99.43	2.65	168.36
593	01-Dec-2007 00:27:00	01:27:00	00:57:00	0	SekmetMons	-121.70	40.16	64.28	2853	28.53	96.30	6.04	136.95
594	02-Dec-2007 00:12:00	01:12:00	00:42:00	0	plains_are_1	-121.94	7.35	52.12	6509	65.09	100.79	2.37	171.31
594	02-Dec-2007 00:27:00	01:27:00	00:57:00	0	SekmetMons	-119.88	41.56	64.36	2732	27.32	96.84	6.13	135.91
596	04-Dec-2007 00:21:00	01:21:00	00:51:00	0	SekmetMons	-115.03	44.01	65.24	2346	23.46	97.91	6.56	134.16
604	12-Dec-2007 00:18:00	01:18:00	00:48:00	0	unnamed_3	-99.79	25.87	52.92	3377	33.77	108.65	4.26	149.23
605	13-Dec-2007 00:18:00	01:18:00	00:48:00	0	unnamed_3	-98.09	23.28	51.13	3589	35.89	110.27	4.11	150.04
606	14-Dec-2007 00:15:39	01:15:39	00:45:39	0	unnamed_5	-97.00	15.88	47.27	4407	44.07	113.03	103.95	152.02
607	15-Dec-2007 00:18:00	01:18:00	00:48:00	0	unnamed_5	-94.75	18.64	47.75	4024	40.24	113.46	3.50	149.76
608	16-Dec-2007 00:18:00	01:18:00	00:48:00	0	unnamed_5	-93.09	16.56	46.17	4246	42.46	115.02	3.38	148.79
609	17-Dec-2007 00:21:00	01:21:00	00:51:00	0	unnamed_5	-90.70	20.85	47.40	3707	37.07	114.92	3.67	146.25
610	18-Dec-2007 00:21:00	01:21:00	00:51:00	0	unnamed_5	-89.04	18.62	45.70	3925	39.25	116.59	3.50	145.30
611	19-Dec-2007 00:22:35	01:22:35	00:52:35	0	unnamed_5	-87.00	19.91	45.61	3746	37.46	117.23	3.74	143.53
613	21-Dec-2007 00:27:00	01:27:00	00:57:00	0	TheiaMons	-82.71	25.83	47.26	3103	31.03	117.13	4.23	139.31
614	22-Dec-2007 00:27:00	01:27:00	00:57:00	0	TheiaMons	-81.02	23.26	45.27	3311	33.11	119.06	4.08	138.41
615	23-Dec-2007 00:27:00	01:27:00	00:57:00	0	TheiaMons	-79.35	20.87	43.37	3523	35.23	120.94	3.93	137.08

ONr	Begin Exp (SC time)	End Exp	SpecCond	Vi	Target Area	TarLon	TarLat	INC	RAN	SPT	SLW	VSP	SMX
616	24-Dec-2007 00:30:00	01:30:00	01:00:00	0	TheiaMons	-77.07	25.87	45.39	3020	30.20	119.87	4.24	135.07
616	24-Dec-2007 01:18:00	02:18:00	01:48:00	0	DaliChasma	169.81	-18.61	75.80	10431	104.31	54.62	2.72	91.23
617	25-Dec-2007 00:30:00	01:30:00	01:00:00	0	TheiaMons	-75.38	23.30	43.33	3226	32.26	121.91	4.08	133.76
617	25-Dec-2007 01:18:00	02:18:00	01:48:00	0	DaliChasma	171.34	-17.56	76.83	10237	102.37	53.23	2.84	93.53
618	26-Dec-2007 00:14:52	01:14:52	00:44:52	0	unnamed_1	-77.00	-0.94	32.57	7387	73.87	129.48	47.91	125.67
618	26-Dec-2007 00:33:00	01:33:00	01:03:00	0	RheaMons	-73.17	28.71	45.79	2741	27.41	120.34	5.03	131.85
618	26-Dec-2007 01:21:00	02:21:00	01:51:00	0	DaliChasma	174.55	-20.71	76.55	10808	108.08	52.63	2.70	93.78
619	26-Dec-2007 23:48:00	00:48:00	00:18:00	0	unnamed_2	-79.21	-15.40	30.90	14403	144.03	127.20	0.10	114.75
619	27-Dec-2007 00:15:00	01:15:00	00:45:00	0	unnamed_1	-75.23	-1.66	31.66	7583	75.83	130.69	1.42	123.37
619	27-Dec-2007 01:19:06	02:19:06	01:49:06	0	DaliChasma	175.00	-16.89	78.44	10133	101.33	50.71	3.01	97.42
620	27-Dec-2007 23:51:00	00:51:00	00:21:00	0	unnamed_2	-76.96	-14.69	30.22	13897	138.97	128.60	0.10	113.60
620	28-Dec-2007 00:15:00	01:15:00	00:45:00	0	unnamed_1	-73.48	-2.45	30.74	7817	78.17	131.88	1.35	121.03
621	28-Dec-2007 23:51:00	00:51:00	00:21:00	0	unnamed_2	-75.05	-14.95	29.65	14105	141.05	129.48	0.10	111.79
621	29-Dec-2007 00:15:00	01:15:00	00:45:00	0	unnamed_1	-71.71	-3.20	29.86	8051	80.51	133.04	1.29	118.72
622	29-Dec-2007 23:51:00	00:51:00	00:21:00	0	unnamed_2	-73.14	-15.20	29.10	14313	143.13	130.34	0.10	109.99
622	30-Dec-2007 00:18:00	01:18:00	00:48:00	0	unnamed_1	-69.42	-1.57	29.40	7488	74.88	134.31	1.41	117.63
622	30-Dec-2007 01:24:00	02:24:00	01:54:00	0	fractured_area	-177.64	-21.04	79.33	10805	108.05	47.84	2.81	100.78
623	30-Dec-2007 23:54:00	00:54:00	00:24:00	0	unnamed_2	-70.90	-14.50	28.39	13808	138.08	131.77	0.10	108.77
623	31-Dec-2007 00:18:00	01:18:00	00:48:00	0	unnamed_1	-67.66	-2.35	28.49	7724	77.24	135.50	1.34	115.31
624	01-Jan-2008 00:27:00	01:27:00	00:57:00	0	unnamed_11	-64.28	5.65	29.85	5565	55.65	135.86	2.03	116.90
625	02-Jan-2008 00:15:00	01:15:00	00:45:00	0	unnamed_6	-64.56	-5.83	26.59	8983	89.83	137.48	1.07	109.81
626	03-Jan-2008 00:15:00	01:15:00	00:45:00	0	unnamed_6	-62.75	-6.41	25.83	9216	92.16	138.53	1.03	107.67
627	04-Jan-2008 00:09:00	01:09:00	00:39:00	0	unnamed_12	-61.67	-10.04	25.27	10988	109.88	138.38	0.79	104.17
628	05-Jan-2008 00:12:00	01:12:00	00:42:00	0	unnamed_12	-59.46	-9.05	24.49	10452	104.52	139.94	0.84	102.81
629	06-Jan-2008 00:12:00	01:12:00	00:42:00	0	unnamed_12	-57.60	-9.49	23.86	10680	106.80	140.86	0.81	100.83
630	07-Jan-2008 00:12:00	01:12:00	00:42:00	0	unnamed_12	-55.73	-9.91	23.25	10908	109.08	141.75	0.78	98.88
630	07-Jan-2008 00:29:14	01:29:14	00:59:14	0	unnamed_10	-53.50	1.62	23.87	6400	64.00	143.85	1.66	103.35

TABLE 2. Characteristics of Low-Emissivity Features

Name or Description	Location		Maximum Radius	Critical Radius*	Area with $e < 0.7$,	Minimum Emissivity	Location of Minimum		Radius at Minimum
	Latitude deg	Longitude deg	km	km	10^3 km^2		Latitude deg	Longitude deg	deg
Highlands									
Ovda Regio	3.0 S	90.0 E	6059.7	6054.7	3113.1	0.26	5.8 S	96.3 E	6055.4
Thetis Regio	8.0 S	127.0 E	6059.5	6054.8	1489.0	0.35	4.7 S	127.7 E	6055.3
Maxwell Montes	65.0 N	3.0 E	6062.7	6056.4	403.7	0.36	64.3 N	7.8 E	6058.7
Volcanoes									
Ozza Mons	3.8 N	199.3 E	6058.5	6054.9	400.4	0.34	4.1 N	198.4 E	6056.5
Theia Mons	23.6 N	280.2 E	6057.0	6055.0	278.4	0.38	23.8 N	278.7 E	6055.8
Rhea Mons	32.4 N	282.6 E	6058.5	6055.6	66.8	0.52	30.0 N	281.7 E	6055.5
Sapas Mons	8.9 N	188.0 E	6055.6	6053.7	57.3	0.46	9.1 N	188.5 E	6054.2
(unnamed)	2.0 S	288.0 E	6055.0	6054.6	28.4	0.57	2.0 S	287.0 E	6053.4
(unnamed)	17.9 S	285.1 E	6056.5	6054.0	25.0	0.54	17.9 S	285.8 E	6054.9
Maat Mons	0.9 N	194.6 E	6060.2	—	19.8	0.53	0.5 S	193.6 E	6055.8
(unnamed)	24.2 N	263.8 E	6056.1	6054.9	9.4	0.60	24.5 N	263.8 E	6055.5
(unnamed)	17.1 N	194.2 E	6058.6	—	8.9	0.61	16.3 N	193.9 E	6054.8
(unnamed)	18.9 N	268.0 E	6055.6	6051.6	8.7	0.59	19.3 N	268.2 E	6051.8
Tepev Mons	29.6 N	45.0 E	6056.7	6055.1	7.3	0.51	29.6 N	44.9 E	6056.2
Sekmet Mons	44.3 N	240.4 E	6053.9	6053.2	5.3	0.58	44.1 N	240.6 E	6053.5
Gula Mons	21.8 N	358.5 E	6055.6	6054.6	4.8	0.57	21.8 N	358.6 E	6055.4
(unnamed)	6.2 S	299.3 E	6054.5	6054.1	4.4	0.55	6.0 S	299.3 E	6053.6
(unnamed)	20.1 N	187.6 E	6056.2	6055.7	2.6	0.59	20.1 N	187.9 E	6056.0
(unnamed)	1.7 S	215.0 E	6054.8	6054.6	2.1	0.64	1.7 S	215.0 E	6054.4
(unnamed)	5.6 S	217.1 E	6055.5	6055.2	1.4	0.59	5.7 S	217.2 E	6055.2
(unnamed)	2.6 N	301.5 E	6053.8	6053.6	1.1	0.62	2.4 N	301.5 E	6053.7
(unnamed)	5.3 N	291.2 E	6053.2	—	1.0	0.68	5.3 N	291.1 E	6052.4
(unnamed)	9.7 S	301.3 E	6054.5	—	0.11	0.69	9.8 S	301.2 E	6054.2
Ridges									
Hestia Rupes	2.3 N	73.3 E	6055.6	6054.8	57.6	0.48	2.5 N	73.7 E	6055.4
Dali Chasma	20.0 S	170.0 E	6059.5	6056.1	10.9	0.57	17.2 S	170.0 E	6056.1
Novae and Related Features									
Pavlova	14.2 N	39.8 E	6054.3	6053.3	18.9	0.47	12.7 N	39.6 E	6053.6
(young nova)	0.7 N	34.4 E	6054.8	6053.0	11.7	0.43	0.6 N	34.6 E	6054.4
(nova)	9.0 N	219.1 E	6057.3	6054.3	5.7	0.63	9.0 N	219.1 E	6054.4
(nova)	15.3 N	221.2 E	6056.3	6054.6	5.1	0.50	15.4 N	221.1 E	6055.2
(edge of plateau)	6.7 S	221.3 E	6056.0	6054.9	5.0	0.53	6.1 S	221.1 E	6055.1
(young nova)	2.6 N	45.5 E	6053.8	6053.3	4.1	0.51	2.6 N	45.5 E	6053.4
(nova)	22.2 N	223.7 E	6055.7	6055.2	4.1	0.55	21.5 N	224.2 E	6055.3
(edge of plateau)	11.3 N	219.4 E	6054.7	—	3.7	0.61	10.9 N	219.4 E	6054.1
(nova)	19.4 N	227.4 E	6056.0	6054.8	3.6	0.62	19.7 N	227.3 E	6055.0
(nova)	11.1 N	14.3 E	6053.8	6053.5	1.9	0.63	11.0 N	14.4 E	6053.6
Impact Features									
Boleyn	24.5 N	220.0 E	—	—	1.6	0.61	24.5 N	220.0 E	6051.5
Stanton	23.2 S	199.3 E	—	—	1.5	0.66	23.3 S	199.2 E	6051.0
Stuart	30.8 S	20.2 E	—	—	0.4	0.69	30.7 S	20.2 E	6051.0
Mead	12.5 N	57.5 E	—	—	< 0.1	0.70	13.1 N	57.6 E	6051.0
Miscellaneous Areas									
(plains area)	10.0 N	234.0 E	6055.4	—	98.8	0.64	9.1 N	229.4 E	6052.1
(plains area)	4.0 N	219.5 E	6052.7	—	2.1	0.65	4.5 N	220.2 E	6051.7
(fractured area)	20.0 S	187.2 E	6054.6	—	0.8	0.67	20.1 S	187.2 E	6054.1
(uplifted area)	16.4 N	197.7 E	6056.2	6056.0	0.7	0.65	16.4 N	197.8 E	6055.5

*Critical radius corresponds to the altitude above which the emissivity falls below 0.7

7.5 Solar Corona

7.5.1 Description

The scientific objectives are the determination of the total electron content of the solar corona, the solar wind speed, the turbulence spectrum, and the identification of coronal mass ejections.

7.5.2 Measurement Technique

The total electron content and its temporal changes, the solar wind speed, and the turbulence spectrum can be derived from measurements of dual-frequency differential group time delay (ranging) and the differential Doppler shift.

7.5.3 Operations

7.5.3.1 Configuration

Table 7.5-1: Configurations for the observation of the solar corona

S/C configuration	TWOD		
Ground segment configuration		up	down
	IFMS A	S	S-CL, S-rang. [1]
	IFMS B		S-CL, X-rang. [1]
	IFMS RS		X-CL X-OL RCP S-OL RCP
Telemetry modulation	OFF		
VeRa operational procedure	SCP		
	SCP		

[1] Dual frequency ranging presently not available at NNO. Ranging shall be activated in intervals of 15 min.

7.5.3.2 Operations Timeline

A daily tracking pass at NNO and at one DSN ground station (either Madrid or Goldstone) is requested for the time of solar conjunction when the spacecraft is within 10° elongation about the solar disk in the plane of sky. These measurements can be performed when the spacecraft is tracked for telemetry return.
Detailed timelines and sequence of events are included in section 8.

7.5.3.3 Solar Conjunction Duration

Table 7.5-2: solar conjunctions as a function of mission time

Solar conjunction			Conjunction Date	Solar offset	Number of tracking passes
Acronym	**start**	**stop**			
SCS-1	20.09.2006	06.12.2006	24.10.2006		76
SCS-2	13.08.2007	21.08.2007	17.08.2007		5
SCS-3	29.04.2008	17.07.2008			
SCS-4	21.03.2009	03.04.2009			

Figure 7.5-1: superior solar conjunction in tbd (upper panel). Spacecraft position in the plane of sky for each day at 00:00 UT.

7.5.3.4 Constraints

Outside of 12 solar radii (see Figure 7.5-1) the tracking of a 34-m ground station is sufficient (NNO and DSN). Inside of 12 solar radii two tracking passes of 70-m DSN ground stations are requested.

7.5.4 Data

7.5.4.1 Mission Products

Perth Ground Station:

Table 7.5-3: IFMS solar conjunction mission products

Receiver	Frequency band	Data products
IFMS A (closed-loop)	X	Doppler1 ranging meteo
IFMS B (closed-loop)	X	Doppler2
IFMS RS (open-loop)	S	Doppler Ranging Voltage samples

Deep Space Network:

Note: If the apparent S/C position is inside 12 solar radii, a 70-m ground station is requested.

Table 7.5-4: DSN solar conjunction mission products

Receiver	Frequency band	Data products	Data file type
closed-loop	X	Doppler Ranging	ATDF
	S	Doppler Ranging	
open-loop	X	LCP voltage samples	RSR
	X	RCP voltage samples	
	S	LCP voltage samples	
	S	RCP voltage samples	

7.5.4.2 Accuracy

To achieve an accuracy in electron content of 0.005 hexem (5×10^{-13} el/m^2), an accuracy in phase of < 0.02 rad or <1° is required, or a frequency variation of < 2 mHz over the integration period of 1 second.
Ranging or group delay accuracy is required to be better than 5 ns.

7.5.4.3 Sample Rate

Table 7.5-5: sample rate

Closed-loop	1 sample / second S & X-band Doppler 15 minutes ranging at begin and end of track (Perth) ranging sample rate 10 min at DSN
Open-loop	5000 samples per second
Auxiliary data	TBD

7.5.4.4 Data Volume

Table 7.5-6: Data volume

	Data Volume perr pass
Closed-loop IFMS DSN	 5403 kByte per frequency 6800 kByte per frequency
Open-loop IFMS DSN	 TBD 195,000 kByte
Auxiliary data	TBD
Ground station meteo	Already contained in IFMS figure

7.5.4.5 Availability

TBD

7.6 Tracking Verification Test

7.6.1 Description

A Tracking Verification Tests (TVT) shall be performed after launch during the Commissioning Phase and at Venus arrival. The purpose of the TVT is the determination and verification of the link quality, Doppler and range accuracy, data recording and retrieval test in the ground station, etc.

7.6.2 Objective

The Tracking Verification Test is an end-to-end test to ensure the proper functioning of the ground station and the S/C TT&C system with regard to radio science operations.
A Tracking Verification Tests (TVT) shall be performed after launch during the Commissioning Phase and at Venus arrival. The purpose of the TVT is the determination and verification of the link quality, Doppler and range accuracy, data recording and retrieval test in the ground station, etc.

7.6.3 Operations

On the S/C side, the ONES, ONED, TWOS and TWOD links will be tested in various configurations. On the ground station side, S and X-Band uplinks, Open-loop and and closed-Loop data processing will be tested in various configurations with processing alternating between IFMS A, B and RS to insure a full end-to-end test.
In order to estimate the effect of telemetry modulation of the carrier on Doppler precision steps with “telemetry modulation ON” should be carried out such that Doppler tracking is performed at 262 and 8.2 kHz subcarrier frequency. Four radio links will be tested: ONES, ONED, TWOS, TWOD

Table 7.6-1: Configurations for the tracking verification test

S/C configuration	TWOS, TWOD		
Ground segment configuration		up	down
	IFMS A	X	X-CL
	IFMS B		X-CL
	IFMS RS		S-CL X-OL RCP S-OL RCP
Telemetry modulation	OFF		
VeRa operational procedure	TVT step 1		

S/C configuration	TWOS, TWOD		
Ground segment configuration		Up	down
	IFMS A		X-CL
	IFMS B	X	X-CL
	IFMS RS		S-CL X-OL RCP S-OL RCP
Telemetry modulation	OFF		
VeRa operational procedure	TVT step 2		

S/C configuration	OM[illegible]D		
Ground segment configuration		up	down
	IFMS A		X-CL
	IFMS B		X-CL
	IFMS RS		S-CL X-OL RCP S-OL RCP
Telemetry modulation	OFF		
VeRa operational procedure	TVT step [illegible]		

S/C configuration	ONED		
Ground segment configuration		up	down
	IFMS A	X	X-CL
	IFMS B		
	IFMS RS		X-CL X-OL RCP X-OL LCP
Telemetry modulation	OFF		
VeRa operational procedure	TVT step 4		

S/C configuration	TWOS, TWOD		
Ground segment configuration		Up	down
	IFMS A	S	S-CL
	IFMS B	[illegible]	S-CL
	IFMS C	[illegible]	X-CL X-OL RCP S-OL RCP
Telemetry modulation	OFF		
VeRa operational procedure	TVT step 6		
	SC[illegible]		

7.6.3.1 Operations Timeline

Tracking verification tests are to be performed regularly during commissioning phase, and prior to Venus arrival. The tracking verification tests constitute of a number of tracking passes, each 6 [illegible] hours long. The total tracking verification test may last as long as TBD days.
Detailed timelines are listed in section 8.

7.6.3.2 Constraints

No S/C orbit corrections are to be scheduled within the tracking verification phase.
Thruster activities shall be logged.
NNO, DSN 34-m and 70-m ground stations are requested.

7.6.4 Data TVT

7.6.4.1 Data Products

NNO Ground Station:

Table 7.6-2: IFMS TVT mission products

Receiver	**Frequency band**	**Data products**
IFMS A (closed-loop)		
IFMS B (closed-loop)		
IFMS RS (closed-loop) IFMS RS (open-loop)		

Receiver	**Frequency band**	**Data products**
IFMS A (closed-loop)		
IFMS B (closed-loop)		
IFMS RS (closed-loop) IFMS RS (open-loop)		

Receiver	**Frequency band**	**Data products**
IFMS A (closed-loop)		
IFMS B (closed-loop)	-	
IFMS RS (closed-loop) IFMS RS (open-loop)	-	-

Receiver	**Frequency band**	**Data products**
IFMS A (closed-loop)		
IFMS B (closed-loop)		
IFMS RS (closed-loop) IFMS RS (open-loop)		

Deep Space Network:

Table 7.6-3: DSN TVT mission products

Receiver	Frequency band	Data products	Data file type
closed-loop	X	Doppler	ATDF
	-	-	
open-loop	X	LCP voltage samples	ODR
	X	RCP voltage samples	
	-	-	
	-	-	

Receiver	Frequency band	Data products	Data file type
closed-loop	X	Doppler Ranging	ATDF
	-	-	
open-loop	-	-	-
	-	-	
	-	-	
	-	-	

Receiver	Frequency band	Data products	Data file type
closed-loop	X	Doppler	ATDF
	S	Doppler	
open-loop	X	LCP voltage samples	ODR
	X	RCP voltage samples	
	S	LCP voltage samples	
	S	RCP voltage samples	

Receiver	Frequency band	Data products	Data file type
closed-loop	X	Doppler Ranging	ATDF
	S	Doppler Ranging	
open-loop	X	LCP voltage samples	ODR
	X	RCP voltage samples	
	S	LCP voltage samples	
	S	RCP voltage samples	

7.6.4.2 Sample Rate

Table 7.6-4: Sample rate configurations for the various TVT steps

Closed-loop	1 sample / second Doppler
Open-loop	50,000 samples / second
Auxiliary data	TBD
Ground station meteo	1 sample / minute

Closed-loop	10 samples / second Doppler
Open-loop	5,000 samples / second
Auxiliary data	TBD
Ground station meteo	1 sample / minute

Closed-loop	1 sample / second Doppler 15 min ranging (simultaneous w/ Doppler)
Open-loop	
Auxiliary data	TBD
Ground station meteo	1 sample / minute

Closed-loop	1 sample / second Doppler 15 min ranging (simultaneous w/ Doppler)
Open-loop	5,000 samples / second
Auxiliary data	TBD
Ground station meteo	1 sample / minute

7.6.4.3 Data Volume through the various TVT steps

Table 7.6-5: Default data volume 1 sec sampling closed-loop only

	Data Volume per hour
Closed-loop IFMS DSN	 1016 kByte per frequency / hour 1036 kByte per frequency / hour
Open-loop IFMS DSN	 -
Auxiliary data	TBD
Ground station meteo	Already contained in IFMS figure

Table 7.6-6: TVT data volume OL 50000 samples/second

	Data Volume per hour
Closed-loop IFMS DSN	 8,000 kByte per frequency / hour 1,036 kByte per frequency / hour
Open-loop IFMS DSN	 TBD 7,500,000 kByte / hour
Auxiliary data	TBD
Ground station meteo	Already contained in IFMS figure

Table 7.6-7: TVT data OL 5000 samples/second

	Data Volume per hour
Closed-loop IFMS DSN	 N/A N/A
Open-loop IFMS DSN	 TBD 750,000 kBytes / hour
Auxiliary data	TBD
Ground station meteo	Already contained in IFMS figure

7.6.4.4 Accuracy

Accuracy will be determined.

7.6.4.5 Availability

TBD

see Commissioning Plan
VEX-VERA-IGM-PL-3008

7.7 USO Database

7.7.1 VeRa USO TM Table

The table below summarizes the USO telemetry data and the nominal value of each channel, for the warm-up case and for the steady-state case.

TM conversion Table:

TM Name	TM Raw Unit	TM Conversion	TM Unit
DC Current	V	Raw Value/5	A
DC/DC Voltage	V	Raw Value *3	V
Output Power A	V	<2.5V muted >2.5V enabled	V
Output Power B	V	<2.5V muted >2.5V enabled	V
Oven Temp A	V	<2.4 V to cold 2.4V … 2.7V nominal >2.7V to hot	V
Oven Temp B	V	<2.4 V to cold 2.4V … 2.7V nominal >2.7V to hot	V
Lock State A (note 1)	V	0.0V … 2.5V unlock 2.5V … 5.0V lock	V
Lock State B (Note 1)	V	0.0V … 2.5V unlock 2.5V … 5.0V lock	V
USO TRP		Yellowspring YSI-44907	°C

Note 1): Addition of two signals: LockState + (10V-Utune)/4

Nominal values during warm-up:

TM Name	TM Raw min.	TM Raw max.	TM value min	TM value max
DC Current	0.8 V	1.7 V	0.16 A	0.34 A
DC/DC Voltage	3.32 V	3.33 V	9.96 V	9.99 V
Output Power A	1.7 V	2.2 V	1.7 V	2.2 V
Output Power B	1.7 V	2.2 V	1.7 V	2.2 V
Oven Temp A	0 V	2.7 V	0 V	2.7 V
Oven Temp B	0 V	2.7 V	0 V	2.7 V
Lock State A	0.5 V	0.7 V	0.5 V	0.7 V
Lock State B	0.5 V	0.7 V	0.5 V	0.7 V
USO TRP			-30 °C	+50 °C

Nominal Values at steady state:

TM Name	TM Raw min.	TM Raw max.	TM value min	TM value max
DC Current	0.8 V	1.1 V	0.16 A	0.22 A
DC/DC Voltage	3.32 V	3.33 V	9.96 V	9.99 V
Output Power A	4.0 V	4.3 V	4.0 V	4.3 V
Output Power B	3.6 V	3.9 V	3.6 V	3.9 V
Oven Temp A	2.4 V	2.7 V	2.4 V	2.7 V
Oven Temp B	2.4 V	2.7 V	2.4 V	2.7 V
Lock State A	3.7 V	4.3 V	3.7 V	4.3 V
Lock State B	3.7 V	4.3 V	3.7 V	4.3 V
USO TRP			-20 °C	+50 °C

The data are valid under vacuum condition at BOL.
All values shall be constant under stable environment conditions; they only change versus environment temperature.
The Lock-State (e.g. Utune) will drift versus lifetime. When extrapolated, the value at EOL shall not exceed the range between 3.0V and 4.7V. This shall be reported to the PI on a regular base.

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9 Appendix

9.1 Venus Express Link Budget S-Band (HGA 1)

General Parameters

General Parameters :			
Distance Groundstation to Satellite	AU		1,7
Distance Groundstation to Satellite	m		2,54316E+11
Transmitter Frequency Uplink	Hz		2.120.000.000
Bitrate Uplink	Bit/s		16
Bitrate Uplink	dBHz		12,041
Bit Errorrate Uplink			1,000E-12
Required Eb/No Uplink	dB		16
Required S/N Uplink	dB		10
Path Loss Uplink	dB		-267,076
Transmitter Frequency Downlink	Hz		2.300.000.000
Bitrate Downlink	Bit/s		200000
Bitrate Downlink	dBHz		53,010
Bit Errorrate Downlink			1,000E-05
Required Eb/No Downlink	dB		9,6
Required S/N Downlink	dB		12
Required Subcarrier S/N Downlink	dB		12
Required S/No Downlink (Ranging)	dBHz		-10
Path Loss Downlink	dB		-267,784
Coding Gain (Convolutional Coding)	dB		4,500
Ranging Waveform	sin / sqr		sin
Ranging Effective Bandwidth	Hz		3,000E+06
Ranging Effective Bandwidth	dBHz		64,771
Ranging Tone Frequency			1,00E+06
Availability	%		95
Rain Attenuation uplink (fixed) *	dB		0,000
Rain Attenuation downlink (fixed) *	dB		0,000
Rain Attenuation (calculated)	dB		0,000
Ionospheric Loss	dB		0,000
Atmospheric Loss uplink	dB		-0,200
Atmospheric Loss downlink	dB		-0,200
Boltzmann-Constant	dBm/(K*Hz)		-198,600
* do not use both settings at a time (Rain Attenuation Coefficient / Rain Attenuation fixed)			

Groundstation Data

Groundstation Data :			
Antenna Diameter	m		34,000
Elevation Angle	deg		90,000
Height above Sea Level	km		0,500
Latitude of Groundstation	deg		36,000
Rain Attenuation Coefficient *	dB/km		0,000
Antenna Efficiency Uplink			0,500
Ground Station Antenna Gain Uplink	dBi		54,546
3 dB Angle Uplink	deg		0,291
Antenna Efficiency Downlink			0,570
Ground Station Antenna Gain Downlink	dBi		55,823
3 dB Angle Downlink	deg		0,269
Transmitter Power [W]	W		20000,000
Transmitter Power [dBm]	dBm		73,010
System Noise Temp. (clear sky)	K		55,000
Noise increase (due rain)	K		0,000
System Noise Temperature	K		55,000
System Noise Temperature	dBK		17,404
Carrier Loop Bandwidth	Hz		3,000
Carrier Loop Bandwidth	dBHz		4,771
Subcarrier Loop Bandwidth	Hz		10,000
Subcarrier Loop Bandwidth	dBHz		10,000
Ranging Modulation Index rad pk (R)	rad		1,400
Ranging Modulation Index rad pk (R/TC)	rad		0,400
Ranging Modulation Type Coefficient			1,000
TC Modulation Index rad pk (TC)	rad		1,400
TC Modulation Index rad pk (R/TC)	rad		0,700
Subcarrier Modulation Index rad pk (R/TC) S/C	rad		1,400
Antenna Pointing Loss	dB		-0,100
Antenna Circuit Loss	dB		0,000
Diversity Combiner Loss	dB		-0,300
Carrier Circuit Loss	dB		-1,100
Subcarrier Circuit Loss	dB		0,000
G/T	dBi/K		38,420
Noise Power Density	dBm/Hz		-181,196
* do not use both settings at a time (Rain Attenuation Coefficient / Rain Attenuation fixed)			

Groundstation: NNO

Spacecraft Data

Spacecraft Data :			
Satellite Antenna Gain Uplink	dBi		25,500
3dB Angle in H Plane Uplink	deg		8,255
3dB Angle in E Plane Uplink	deg		8,255
Satellite Antenna Gain Downlink	dBi		25,751
3dB Angle in H Plane Downlink	deg		7,609
3dB Angle in E Plane Downlink	deg		7,609
Transmitter Power	W		5,000
Transmitter Power	dBm		36,990
System Noise Temp. incl. Sky Noise	K		230,000
System Noise Temp. incl. Sky Noise	dBK		23,617
Carrier Loop Bandwidth	Hz		400,000
Carrier Loop Bandwidth	dBHz		26,021
Subcarrier Loop Bandwidth	Hz		30,000
Subcarrier Loop Bandwidth	dBHz		14,771
TM Waveform	sin / sqr		sin
TM Modulation Index rad pk (TM)	rad		1,400
TM Modulation Index rad pk (R / TM)	rad		0,700
Ranging Mod. Index (R/TM)	rad		0,500
Ranging Mod. Index (R)	rad		1,400
Subcarrier Waveform	sin / sqr		sqr
Subcarrier Modulation Index rad pk	rad		1,571
Antenna Pointing Loss	dB		0,000
On-Board Losses	dB		-1,000
Degradation	dB		-0,500
Carrier Circuit Loss	dB		-1,100
G/T	dBi/K		1,883
Noise Power Density	dBm/Hz		-174,983

Uplink Budget MPTS Ranging

Uplink Budget MPTS Ranging :			
Transmitter Frequency Uplink	***Hz***		**2.120.000.000**
Transmitter Power	dBm		73,010
Antenna Circuit Loss	dB		0,000
Groundstation Antenna Gain Uplink	dBi		54,546
Groundstation Pointing Loss	dB		-0,100
EIRP	**dBm**		**127,457**
Rain Attenuation	dB		0,000
Atmospheric Loss	dB		-0,200
Ionospheric Loss	dB		0,000
Path Loss Uplink	dB		-267,076
Satellite Pointing Loss	dB		0,000
Satellite Antenna Gain Uplink	dBi		25,500
On Board Losses	dB		-1,000
Total Received Power	**dBm**		**-115,319**
Noise Power Density	dBm/Hz		-174,983
Available S/No	**dBHz**		**59,664**
Carrier Locking			
Ranging Modulation Index rad pk	rad		1,400
Ranging Modulation Loss	dB		-4,931
Carrier Circuit Loss	dB		-1,100
Available Carrier Power	**dBm**		**-121,349**
Noise Power Density	dBm/Hz		-174,983
Carrier Loop Bandwidth	dBHz		26,021
Noise Power in Loop Bandwidth	**dBm**		**-148,962**
Carrier S/N	dB		27,613
Required S/N	dB		10,000
Margin Carrier Loop	**dB**		**17,613**
Ranging Channel			
Ranging Modulation Index rad pk	rad		1,400
Ranging Modulation Loss	dB		-2,311
Degradation	dB		-0,500
Available Signal Power	**dBm**		**-118,129**
Noise Power Density	dBm/Hz		-174,983
Ranging Effective Bandwidth	dBHz		64,771
Noise Power in Bandwidth	**dBm**		**-110,212**
Available S/N Ranging (Sat. Level)	**dB**		**-7,918**

Downlink Budget MPTS Ranging with Telemetry on Subcarrier

Downlink MPTS Ranging with TM :			
Transmitter Frequency Downlink	***Hz***		**2.300.000.000**
Transmitter Power	dBm		36,990
On-Board Loss	dB		-1,000
Satellite Antenna Gain Downlink	dBi		25,751
Satellite Pointing Loss	dB		0,000
EIRP	**dBm**		**61,740**
Path Loss Downlink	dB		-267,784
Ionospheric Loss	dB		0,000
Atmospheric Loss	dB		-0,200
Rain Attenuation	dB		0,000
Groundstation Pointing Loss	dB		-0,100
Groundstation Antenna Gain Downlink	dBi		55,823
Diversity Combiner Loss	dB		-0,300
Antenna Circuit Loss	dB		0,000
Total Received Power	**dBm**		**-150,820**
Noise Power Density	dBm/Hz		-181,196
Available S/No	**dBHz**		**30,376**
Frequency Shift Loss	dB		-0,708
Carrier Locking			
TM Modulation Index rad pk	rad		0,700
TM Modulation Loss	dB		-1,099
Ranging Modulation Index nominal pk	rad		0,500
Ranging Modulation Index rad pk	rad		0,174
Ranging Modulation Loss	dB		-0,066
Noise Modulation Index rad rms	rad		0,332
Noise Modulation Loss	dB		-0,477
Sum of Modulation Losses	**dB**		**-1,641**
Carrier Circuit Loss	dB		-1,100
Available Carrier Power	**dBm**		**-153,562**
Noise Power Density	dBm/Hz		-181,196
Carrier Loop Bandwidth	dBHz		4,771
Noise Power in Loop Bandwidth	**dBm**		**-176,425**
Carrier S/No	**dBm/Hz**		**27,635**
Carrier S/N	**dB**		**22,864**

+3 dB			25,864
Sigma Phi	rad		5,091E-02
Sigma Phi	**deg**		**2,92**
Sigma v (delta t =1s)	**m/s**		**7,47E-04**
Required S/N	dB		12,000
Margin Carrier Loop	**dB**		**10,864**

Available S/No (SC Level)	**dBHz**		**53,633**
Available S/No (GS Level)	**dBHz**		**27,635**
S/No overall	**dBHz**		**27,624**

Ranging Channel			
TM Modulation Index rad pk	rad		0,700
TM Modulation Loss	dB		-1,099
Ranging Modulation Index nominal pk	rad		0,500
Ranging Modulation Index rad pk	rad		0,174
Ranging Modulation Loss	dB		-18,248
Noise Modulation Index rad rms	rad		0,332
Noise Modulation Loss	dB		-0,477
Sum of Modulation Losses	**dB**		**-19,824**
Degradation	dB		-0,500
Available Signal Power	**dBm**		**-171,144**
Noise Power Density	dBm/Hz		-181,196
Ranging Effective Bandwidth	dBHz		64,771
Noise Power in Bandwidth	**dBm**		**-116,425**
Available S/No	dBHz		10,053
Sigma r (T=10s)	**m**		**1,864E+00**
Required S/No	dBHz		-10,000
Margin Ranging	**dB**		**20,053**

Downlink Budget Telemetry on Subcarrier without Ranging

Downlink TM without Ranging :			
Transmitter Frequency Downlink	*Hz*		**2.300.000.000**
Transmitter Power	dBm		36,990
On-Board Loss	dB		-1,000
Satellite Antenna Gain Downlink	dBi		25,751
Satellite Pointing Loss	dB		0,000
EIRP coherent Mode	**dBm**		**61,740**
Path Loss Downlink	dB		-267,784
Ionospheric Loss	dB		0,000
Atmospheric Loss	dB		-0,200
Rain Attenuation	dB		0,000
Groundstation Pointing Loss	dB		-0,100
Groundstation Antenna Gain Downlink	dBi		55,823
Diversity Combiner Loss	dB		-0,300
Antenna Circuit Loss	dB		0,000
Total Received Power	**dBm**		**-150,820**
Noise Power Density	dBm/Hz		-181,196
Available S/No	**dBHz**		**30,376**
Frequency Shift Loss	dB		-0,708
Carrier Locking			
TM Modulation Index rad pk	rad		1,400
TM Modulation Loss	dB		-4,931
Noise Modulation Index rad rms	rad		
Noise Modulation Loss	dB		
Sum of Modulation Losses	**dB**		**-4,931**
Carrier Circuit Loss	dB		-1,100
Available Carrier Power	**dBm**		**-156,851**
Noise Power Density	dBm/Hz		-181,196
Carrier Loop Bandwidth	dBHz		4,771
Noise Power in Loop Bandwidth	**dBm**		**-176,425**
Carrier S/No	**dBHz**		**24,346**
Carrier S/N	**dB**		**19,575**
+3 dB			22,575
Sigma Phi (sqrt phase noise variance)	rad		7,43E-02
Sigma Phi (sqrt phase noise variance)	**deg**		**4,260**
Sigma v (delta t =1s)	**m/s**		**1,09E-03**
Required S/N	dB		12,000
Margin Carrier Loop	**dB**		**7,575**
Overview			
Available S/No (SC Level)	**dBHz**		**57,353**
Available S/No (GS Level)	**dBHz**		**24,346**
S/No overall	**dBHz**		**24,344**
Telemetry			
TM Modulation Index rad pk	rad		1,400
TM Modulation Loss	dB		-2,311
Sum of Modulation Losses	**dB**		**-2,311**
Degradation	dB		-0,500
Available Signal Power	**dBm**		**-153,631**
Noise Power Density	dBm/Hz		-181,196
Bitrate	dBHz		53,010
Noise Power in Bitrate	**dBm**		**-128,186**
Available Eb/No	dB		-25,445
Required Eb/No	dB		9,600
Margin Data (Concat(1/2))	**dB**		**-35,045**
Required Eb/No conv. Coding	dB		4,300
Margin Data (convolutional coding)	**dB**		**-29,745**

Downlink Budget Ranging

Downlink with Ranging:			
Transmitter Frequency Downlink	***Hz***		**2.300.000.000**
Transmitter Power	dBm		36,990
On-Board Loss	dB		-1,000
Satellite Antenna Gain Downlink	dBi		25,751
Satellite Pointing Loss	dB		0,000
EIRP	**dBm**		**61,740**
Path Loss Downlink	dB		-267,784
Ionospheric Loss	dB		0,000
Atmospheric Loss	dB		-0,200
Rain Attenuation	dB		0,000
Groundstation Pointing Loss	dB		-0,100
Groundstation Antenna Gain Downlink	dBi		55,823
Diversity Combiner Loss	dB		-0,300
Antenna Circuit Loss	dB		0,000
Total Received Power	**dBm**		**-150,820**
Noise Power Density	dBm/Hz		-181,196
Available S/No	**dBHz**		**30,376**
Frequency Shift Loss	dB		-0,708
Carrier			
Ranging Modulation Index nominal pk	rad		1,400
Ranging Modulation Loss	dB		-4,931
Carrier Circuit Loss	dB		-1,100
Noise Modulation Index rad rms	rad		
Noise Modulation Loss	dB		
Carrier Power	**dBm**		**-156,851**
C/No	**dB/ Hz**		**24,346**
Carrier Loop Bandwidth	dB Hz		4,771
Carrier C/N			**19,575**
+3 dB			22,575
Sigma Phi	rad		0,074
Sigma Phi	**deg**		**4,26**
Sigma v (delta t =1s)	**m/s**		**1,09E-03**
Ranging Channel			
Ranging Modulation Index nominal pk	rad		1,400
Ranging Modulation Index rad pk	rad		0,486
Ranging Modulation Loss	dB		-9,530
Noise Modulation Index rad rms	rad		0,928
Noise Modulation Loss	dB		-3,743
Sum of Modulation Losses	**dB**		**-13,272**
Carrier Circuit Loss	dB		-1,100
Available Signal Power	**dBm**		**-165,192**
Noise Power Density	dBm/Hz		-181,196
S/No	**dB/Hz**		**16,004**
Sigma r (T=10s)	**m**		**9,39E-01**

Ranging Effective Bandwidth	dBHz		64,771
Noise Power in Ranging Bandwidth	**dBm**		**-116,425**
Available S/N Rang.(Ground Level)	**dB**		**-48,767**
Required S/No Rang.(Ground Level)	dB		-10,000
Margin Ranging	**dB**		**26,004**

Ranging Channel Signal Power at S/C-Level/N	dB		-8,626
N/Ranging Channel Signal Power at S/C-Level (1/k)			7,287
Ranging Modulation Index nominal pk	rad		1,400
Ranging Modulation Loss			-2,311
k/(k+1)	dB		-9,184
Carrier Circuit Loss	dB		-1,100
Available Ranging Tone Power	**dBm**		-163,415
Ranging Tone Power/No	dB		17,782
Required S/No Rang.(Ground Level)	dB		-10,000
Margin Ranging	**dB**		**27,782**

9.2 Venus Express Link Budget X-Band (HGA 1)

General Parameters

General Parameters :			
Distance Groundstation to Satellite	AU		1,7
Distance Groundstation to Satellite	m		2,54316E+11
Transmitter Frequency Uplink	Hz		7.300.000.000
Bitrate Uplink	Bit/s		16
Bitrate Uplink	dBHz		12,041
Bit Errorrate Uplink			1,000E-12
Required Eb/No Uplink	dB		16
Required S/N Uplink	dB		10
Path Loss Uplink	dB		-277,815
Transmitter Frequency Downlink	Hz		8.400.000.000
Bitrate Downlink	Bit/s		200000
Bitrate Downlink	dBHz		53,010
Bit Errorrate Downlink			1,000E-05
Required Eb/No Downlink	dB		9,6
Required S/N Downlink	dB		12
Required Subcarrier S/N Downlink	dB		12
Required S/No Downlink (Ranging)	dBHz		-10
Path Loss Downlink	dB		-279,035
Coding Gain (Convolutional Coding)	dB		4,500
Ranging Waveform	sin / sqr		sin
Ranging Effective Bandwidth	Hz		3,000E+06
Ranging Effective Bandwidth	dBHz		64,771
Ranging Tone Frequency			1,00E+06
Availability	%		95
Rain Attenuation uplink (fixed) *	dB		0,000
Rain Attenuation downlink (fixed) *	dB		0,000
Rain Attenuation (calculated)	dB		0,000
Ionospheric Loss	dB		0,000
Atmospheric Loss uplink	dB		-0,200
Atmospheric Loss downlink	dB		-0,200
Boltzmann-Constant	dBm/(K*Hz)		-198,600
* do not use both settings at a time (Rain Attenuation Coefficient / Rain Attenuation fixed)			

Groundstation Data (NNO)

Groundstation Data :			
Antenna Diameter	m		34,000
Elevation Angle	deg		90,000
Height above Sea Level	km		0,500
Latitude of Groundstation	deg		36,000
Rain Attenuation Coefficient *	dB/km		0,000
Antenna Efficiency Uplink			0,510
Ground Station Antenna Gain Uplink	dBi		65,372
3 dB Angle Uplink	deg		0,085
Antenna Efficiency Downlink			0,740
Ground Station Antenna Gain Downlink	dBi		68,208
3 dB Angle Downlink	deg		0,074
Transmitter Power [W]	W		20000,000
Transmitter Power [dBm]	dBm		73,010
System Noise Temp. (clear sky)	K		83,500
Noise increase (due rain)	K		0,000
System Noise Temperature	K		83,500
System Noise Temperature	dBK		19,217
Carrier Loop Bandwidth	Hz		30,000
Carrier Loop Bandwidth	dBHz		14,771
Subcarrier Loop Bandwidth	Hz		10,000
Subcarrier Loop Bandwidth	dBHz		10,000
Ranging Modulation Index rad pk (R)	rad		1,200
Ranging Modulation Index rad pk (R/TC)	rad		0,700
Ranging Modulation Type Coefficient			1,000
TC Modulation Index rad pk (TC)	rad		1,200
TC Modulation Index rad pk (R/TC)	rad		0,700
Subcarrier Modulation Index rad pk (R/TC) S/C	rad		1,900
Antenna Pointing Loss	dB		-0,100
Antenna Circuit Loss	dB		0,000
Diversity Combiner Loss	dB		-0,300
Carrier Circuit Loss	dB		-1,100
Subcarrier Circuit Loss	dB		0,000
G/T	dBi/K		48,991
Noise Power Density	dBm/Hz		-179,383
* do not use both settings at a time (Rain Attenuation Coefficient / Rain Attenuation fixed)			

Spacecraft Data

Spacecraft Data :			
Satellite Antenna Gain Uplink	dBi		36,240
3dB Angle in H Plane Uplink	deg		2,397
3dB Angle in E Plane Uplink	deg		2,397
Satellite Antenna Gain Downlink	dBi		37,002
3dB Angle in H Plane Downlink	deg		2,083
3dB Angle in E Plane Downlink	deg		2,083
Transmitter Power	W		65,000
Transmitter Power	dBm		48,129
System Noise Temp. incl. Sky Noise	K		300,000
System Noise Temp. incl. Sky Noise	dBK		24,771
Carrier Loop Bandwidth	Hz		400,000
Carrier Loop Bandwidth	dBHz		26,021
Subcarrier Loop Bandwidth	Hz		30,000
Subcarrier Loop Bandwidth	dBHz		14,771
TM Waveform	sin / sqr		sin
TM Modulation Index rad pk (TM)	rad		1,400
TM Modulation Index rad pk (R / TM)	rad		0,700
Ranging Mod. Index (R/TM)	rad		0,700
Ranging Mod. Index (R)	rad		1,400
Subcarrier Waveform	sin / sqr		sqr
Subcarrier Modulation Index rad pk	rad		1,571
Antenna Pointing Loss	dB		0,000
On-Board Losses	dB		-1,000
Degradation	dB		-0,500
Carrier Circuit Loss	dB		-1,100
G/T	dBi/K		11,469
Noise Power Density	dBm/Hz		-173,829

Uplink Budget MPTS Ranging

Uplink Budget MPTS Ranging :			
Transmitter Frequency Uplink	***Hz***		**7.300.000.000**
Transmitter Power	dBm		73,010
Antenna Circuit Loss	dB		0,000
Groundstation Antenna Gain Uplink	dBi		65,372
Groundstation Pointing Loss	dB		-0,100
EIRP	**dBm**		**138,282**
Rain Attenuation	dB		0,000
Atmospheric Loss	dB		-0,200
Ionospheric Loss	dB		0,000
Path Loss Uplink	dB		-277,815
Satellite Pointing Loss	dB		0,000
Satellite Antenna Gain Uplink	dBi		36,240
On Board Losses	dB		-1,000
Total Received Power	**dBm**		**-104,493**
Noise Power Density	dBm/Hz		-173,829
Available S/No	**dBHz**		**69,336**
Carrier Locking			
Ranging Modulation Index rad pk	rad		1,200
Ranging Modulation Loss	dB		-3,464
Carrier Circuit Loss	dB		-1,100
Available Carrier Power	**dBm**		**-109,057**
Noise Power Density	dBm/Hz		-173,829
Carrier Loop Bandwidth	dBHz		26,021
Noise Power in Loop Bandwidth	**dBm**		**-147,808**
Carrier S/N	dB		38,751
Required S/N	dB		10,000
Margin Carrier Loop	**dB**		**28,751**
Ranging Channel			
Ranging Modulation Index rad pk	rad		1,200
Ranging Modulation Loss	dB		-3,040
Degradation	dB		-0,500
Available Signal Power	**dBm**		**-108,033**
Noise Power Density	dBm/Hz		-173,829
Ranging Effective Bandwidth	dBHz		64,771
Noise Power in Bandwidth	**dBm**		**-109,058**
Available S/N Ranging (Sat. Level)	**dB**		**1,024**

Downlink Budget MPTS Ranging with Telemetry on Subcarrier

Downlink MPTS Ranging with TM :			
Transmitter Frequency Downlink	***Hz***		**8.400.000.000**
Transmitter Power	dBm		48,129
On-Board Loss	dB		-1,000
Satellite Antenna Gain Downlink	dBi		37,002
Satellite Pointing Loss	dB		0,000
EIRP	**dBm**		**84,131**
Path Loss Downlink	dB		-279,035
Ionospheric Loss	dB		0,000
Atmospheric Loss	dB		-0,200
Rain Attenuation	dB		0,000
Groundstation Pointing Loss	dB		-0,100
Groundstation Antenna Gain Downlink	dBi		68,208
Diversity Combiner Loss	dB		-0,300
Antenna Circuit Loss	dB		0,000
Total Received Power	**dBm**		**-127,296**
Noise Power Density	dBm/Hz		-179,383
Available S/No	**dBHz**		**52,087**
Frequency Shift Loss	dB		-1,219
Carrier Locking			
TM Modulation Index rad pk	rad		0,700
TM Modulation Loss	dB		-1,099
Ranging Modulation Index nominal pk	rad		0,700
Ranging Modulation Index rad pk	rad		0,489
Ranging Modulation Loss	dB		-0,528
Noise Modulation Index rad rms	rad		0,354
Noise Modulation Loss	dB		-0,544
Sum of Modulation Losses	**dB**		**-2,171**
Carrier Circuit Loss	dB		-1,100
Available Carrier Power	**dBm**		**-130,567**
Noise Power Density	dBm/Hz		-179,383
Carrier Loop Bandwidth	dBHz		14,771
Noise Power in Loop Bandwidth	**dBm**		**-164,612**
Carrier S/No	**dBm/Hz**		**48,817**
Carrier S/N	**dB**		**34,045**

+3 dB			37,045
Sigma Phi	rad		1,405E-02
Sigma Phi	**deg**		**0,81**
Sigma v (delta t =1s)	**m/s**		**5,65E-05**
Required S/N	dB		12,000
Margin Carrier Loop	**dB**		**22,045**

Available S/No (SC Level)	**dBHz**		**64,772**
Available S/No (GS Level)	**dBHz**		**48,817**
S/No overall	**dBHz**		**48,708**

Ranging Channel			
TM Modulation Index rad pk	rad		0,700
TM Modulation Loss	dB		-1,099
Ranging Modulation Index nominal pk	rad		0,700
Ranging Modulation Index rad pk	rad		0,489
Ranging Modulation Loss	dB		-9,478
Noise Modulation Index rad rms	rad		0,354
Noise Modulation Loss	dB		-0,544
Sum of Modulation Losses	**dB**		**-11,121**
Degradation	dB		-0,500
Available Signal Power	**dBm**		**-138,917**
Noise Power Density	dBm/Hz		-179,383
Ranging Effective Bandwidth	dBHz		64,771
Noise Power in Bandwidth	**dBm**		**-114,612**
Available S/No	dBHz		40,466
Sigma r (T=10s)	**m**		**5,619E-02**
Required S/No	dBHz		-10,000
Margin Ranging	**dB**		**50,466**

Downlink Budget Telemetry on Subcarrier without Ranging

Downlink TM without Ranging :			
Transmitter Frequency Downlink	***Hz***		**8.400.000.000**
Transmitter Power	dBm		48,129
On-Board Loss	dB		-1,000
Satellite Antenna Gain Downlink	dBi		37,002
Satellite Pointing Loss	dB		0,000
EIRP coherent Mode	**dBm**		**84,131**
Path Loss Downlink	dB		-279,035
Ionospheric Loss	dB		0,000
Atmospheric Loss	dB		-0,200
Rain Attenuation	dB		0,000
Groundstation Pointing Loss	dB		-0,100
Groundstation Antenna Gain Downlink	dBi		68,208
Diversity Combiner Loss	dB		-0,300
Antenna Circuit Loss	dB		0,000
Total Received Power	**dBm**		**-127,296**
Noise Power Density	dBm/Hz		-179,383
Available S/No	**dBHz**		**52,087**
Frequency Shift Loss	dB		-1,219
Carrier Locking			
TM Modulation Index rad pk	rad		1,400
TM Modulation Loss	dB		-4,931
Noise Modulation Index rad rms	rad		
Noise Modulation Loss	dB		
Sum of Modulation Losses	**dB**		**-4,931**
Carrier Circuit Loss	dB		-1,100
Available Carrier Power	**dBm**		**-133,327**
Noise Power Density	dBm/Hz		-179,383
Carrier Loop Bandwidth	dBHz		14,771
Noise Power in Loop Bandwidth	**dBm**		**-164,612**
Carrier S/No	**dBHz**		**46,057**
Carrier S/N	**dB**		**31,285**
+3 dB			34,285
Sigma Phi (sqrt phase noise variance)	rad		1,93E-02
Sigma Phi (sqrt phase noise varianc	**deg**		**1,106**
Sigma v (delta t =1s)	**m/s**		**7,76E-05**
Required S/N	dB		12,000
Margin Carrier Loop	**dB**		**19,285**
Overview			
Available S/No (SC Level)	**dBHz**		**66,296**
Available S/No (GS Level)	**dBHz**		**46,057**
S/No overall	**dBHz**		**46,016**
Telemetry			
TM Modulation Index rad pk	rad		1,400
TM Modulation Loss	dB		-2,311
Sum of Modulation Losses	**dB**		**-2,311**
Degradation	dB		-0,500
Available Signal Power	**dBm**		**-130,107**
Noise Power Density	dBm/Hz		-179,383
Bitrate	dBHz		53,010
Noise Power in Bitrate	**dBm**		**-126,373**
Available Eb/No	dB		-3,734
Required Eb/No	dB		9,600
Margin Data (Concat(1/2))	**dB**		**-13,334**
Required Eb/No conv. Coding	dB		4,300
Margin Data (convolutional coding)	**dB**		**-8,034**

Downlink Budget Ranging

Downlink with Ranging:			
Transmitter Frequency Downlink	***Hz***		**8.400.000.000**
Transmitter Power	dBm		48,129
On-Board Loss	dB		-1,000
Satellite Antenna Gain Downlink	dBi		37,002
Satellite Pointing Loss	dB		0,000
EIRP	**dBm**		**84,131**
Path Loss Downlink	dB		-279,035
Ionospheric Loss	dB		0,000
Atmospheric Loss	dB		-0,200
Rain Attenuation	dB		0,000
Groundstation Pointing Loss	dB		-0,100
Groundstation Antenna Gain Downlink	dBi		68,208
Diversity Combiner Loss	dB		-0,300
Antenna Circuit Loss	dB		0,000
Total Received Power	**dBm**		**-127,296**
Noise Power Density	dBm/Hz		-179,383
Available S/No	**dBHz**		**52,087**
Frequency Shift Loss	dB		-1,219
Carrier			
Ranging Modulation Index nominal pk	rad		1,400
Ranging Modulation Loss	dB		-4,931
Carrier Circuit Loss	dB		-1,100
Noise Modulation Index rad rms	rad		
Noise Modulation Loss	dB		
Carrier Power	**dBm**		**-133,327**
C/No	**dB/ Hz**		**46,057**
Carrier Loop Bandwidth	dB Hz		14,771
Carrier C/N			**31,285**
+3 dB			34,285
Sigma Phi	rad		0,019
Sigma Phi	**deg**		**1,11**
Sigma v (delta t =1s)	**m/s**		**7,76E-05**
Ranging Channel			
Ranging Modulation Index nominal pk	rad		1,400
Ranging Modulation Index rad pk	rad		0,979
Ranging Modulation Loss	dB		-4,258
Noise Modulation Index rad rms	rad		0,708
Noise Modulation Loss	dB		-2,176
Sum of Modulation Losses	**dB**		**-6,434**
Carrier Circuit Loss	dB		-1,100
Available Signal Power	**dBm**		**-134,830**
Noise Power Density	dBm/Hz		-179,383
S/No	**dB/Hz**		**44,553**
Sigma r (T=10s)	**m**		**3,51E-02**
Ranging Effective Bandwidth	dBHz		64,771
Noise Power in Ranging Bandwidth	**dBm**		**-114,612**
Available S/N Rang.(Ground Level)	**dB**		**-20,218**
Required S/No Rang.(Ground Level)	dB		-10,000
Margin Ranging	**dB**		**54,553**

Ranging Channel Signal Power at S/C-Level/N	dB		-0,195
N/Ranging Channel Signal Power at S/C-Level (1/k)			1,046
Ranging Modulation Index nominal pk	rad		1,400
Ranging Modulation Loss			-2,311
k/(k+1)	dB		-3,109
Carrier Circuit Loss	dB		-1,100
Available Ranging Tone Power	**dBm**		-133,815
Ranging Tone Power/No	dB		45,568
Required S/No Rang.(Ground Level)	dB		-10,000
Margin Ranging	**dB**		**55,568**