ESTEC VIRGO/LOI GSE and VDC SPECIFICATIONS

by

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Document change record

Issue	Rev.	Section	Page	Date	Changes
Draft 1	0	All	All	27-5-92	Document created
Ver. 1	1	Title	Front	9-5-95	Change title
	1	All	All	8-5-95	Reformatted
	1	2.2.1 2.2.2	5	8-5-95	Update telecommands according to ISID Issue 2.3
	1	2-3	7	9-5-95	Merge the 2 sections
	1	3.2	7	8-5-95	Remove obsolete telecommands
	1	3.4.1	9	8-5-95	Update or add formulae
	1	3.4.2	9	9-5-95	Update or add formulae
	1	3.6	10	9-5-95	Update all calibration curves
	1	3.7	12	9-5-95	Add formulae for corrections (after Purple Book 2.1)
	1	6-9	13	8-5-95	Delete obsolete sections
Ver. 1	2	4.1	10	21-8-95	Create new section 4 on Level-1 data
	2	3.4-3.7	10	21-8-95	Change 3.4-3.7 to 4.2-4.3
	2	4.1	10	21-8-95	Create 4.1 on Level-1 data file spec.
	2	4.2	10	21-8-95	Change title of old section 3.4
	2	4.2.3-4.2.4	10	21-8-95	Make old subsections 3.5-3.6 to a subsubsection
	2	4.2.4	12	21-8-95	Remove indexation of sections 3.6.1-3.6.2
	2	4.3	14	21-8-95	Change title of old section 3.7
	2	4.3	14	22-8-95	Include the limb darkening effect in the distance correction
	2	4.3.1	14	21-8-95	Change ppm/K to ppm/ºC

Issue	Rev.	Section	Page	Date	Changes
Ver. 1	2	4.3.1	14	22-8-95	Section 3.7.1-3.7.2 merged into one
	2	4.3.2	15	22-8-95	New section: limb darkening effect and distance correction
Ver. 1	3	4.1	10	18-9-95	Add 4 specific LOI keywords. Describe main file. Add 2 diameters to the main file. Describe aux. file.
	3	4.2	10	18-9-95	The data part of the main and auxilliary files are clearly indicated in bold
	3	4.2	11	18-9-95	Removed redundant formula (2). Renumber other formulas accordingly.
	3	4.2	12	18-9-95	Add a new section that describes how the EW and NS solar diameters, and the SPM corrections are obtained.
	3	4.3	15	18-9-95	Correct formula (9). The relativistic contribution does NOT depend on the absolute velocity *V*.
	3	4.3	15	18-9-95	Remove not needed formula (12). Renumber the other formula accordingly
	3	4.3	16	18-9-95	Change definition of Δr
	3	4.3	16	18-9-95	Update Table to take into account the limb darkening measured by Neckel and Labs, *Sol. Phys.*, 1995
Ver. 1	4	4.2.2	12	26-10-95	Add subtleties about the fast and the slow H/K data as an **important note**.
	4	4.2.2	13	26-10-95	Add the definition of the keyword POINT_NS and POINT_EW.s

Issue	Rev.	Section	Page	Date	Changes
	4	4.2.4	14	26-10-95	Correct equation (9). Averaging is done only for the SPM keywords
	4	4.2.4	14	26-10-95	Add an equation defining the mean solar diameter. Renumber equations accordingly.
	4	4.2.4	15	26-10-95	Add the name of the SPM keyword in the table.
	4	4.3.1	17	27-10-95	Change the name of the pixel variable toC_i instead of S_i.
Ver. 1	5	4.1	10	30-10-95	Correct typo, 4.2.4 instead of 4.3.2.
	5	4.2.2	12	30-10-95	POINT_NS and POINT_EW are given by a DAILY average.
Ver. 1	6	4.2.6	16	12-12-95	Slope a_1 of pixel calibration is positive
	6	4.2.6	17	12-12-95	Use of the correct calibration for T1-T4 (5-Volt calibration was used instead of the 2.5-V calibration)
	6	4.2.6	17	12-12-95	Error in the computation of the offset and the slope for T5-T10. Same as for the EGSE.
Ver. 1	7	4.2.4	14	21-05-96	Change 0.1515 in Eq (8) for 0.1344 (Calibrated for 1 AU)
	7	4.2.6	15	21-05-96	Updated all pixel offsets when LOI calibration ON and OFF
	7	4.3	17	21-05-96	Change sign of temperature correction for guiding pixels

Table of contents

1 General Outline of LOI GSE and VDC requirements

The LOI Data Acquisition System contains 12 scientific voltmeter channels and 16 housekeeping (H/K) channels. The 12 scientific channels are measured by LOI- internal analog-to- digital converter units. The conversion is based on the VFC principle. The resolution is 24 bits. The integration period is 59.4 seconds. The 16 H/K channels comprise 4 guiding pixel voltage, 4 temperature sensors (diodes integrated on detector), 2 piezo actuator voltage and 6 other temperature channels (AD590). The H/K channels are analog signals which are send to the VIRGO DAS and converted by VFCs.

2 Telecommands

2.1 Overview

LOI telecommands are used for the analog acquisition chain and for the guiding (automatic sun pointing). The analog acquisition chain is redundant and switchable. The automatic pointing can be disabled and the piezo actuators can be set to a fixed position by telecommand. The parameters of the automatic guiding servo loop can be modified to filter out different types of spacecraft vibration and pointing oscillations.

2.2 General outline

The telecommands should be displayed as a list of parameters (see below), which can be selected by mouse or arrow keys. They are toggled by a function key or mouse button. Numeric values shall be entered by the keyboard, after selection of the corresponding field. All numerical values shall be tested for validity (range etc.). After modification of a parameter or more, the operator has to confirm the command by clicking on a field labelled " TC confirm ". After that, no further modification is possible. The command can now be sent by clicking on a field labelled " TC send ", or aborted by clicking the " TC Abort " field A predefined warning message will alert the user, in case of a potentially hazardous operation, as soon as the option is selected from the parameter menu. The warning(s) will be repeated with an acoustic (beep) and optical (flashing) reminder, as soon as the TC confirm button is hit.

The exact screen layout should be the same as for the EGSE.

2.3 List of telecommands

Bit TC7 is used LOI- internally to address either the analog acquisition chain (AAC) or the guiding/ high voltage (GHV) section. All commands consist of one byte only.

2.3.1 Analog acquisition chain calibration

This parameter switches the analog acquisition channel into calibration mode. The VFCs are being switched over to a reference voltage. **Science data is lost !**

TC7	0
Value range	On, Off
Default range	Off
Coding Off On	TC2 0 1
Warnings	When switching from **Off** to **On** "Calibration mode...Science data will be lost"
Error	None

2.3.2 Latch-up detector threshold

This parameter switches the trip current of the LOI latch up detector.

TC0	0
Value range	High, Low
Default range	Low
Coding Normal Back-up	TC6 0 1
Warnings	When switching from **Low** to **High** "Latch up detection will be partially disabled"
Error	None

2.3.3 Z-Guiding and High Voltage commands

The guiding can be operated either in closed loop, or in an open loop mode, for either axis. In the latter case, a fixed voltage ranging from 0 to Full scale by step of a quarter of the full scale can be applied to the actuators. The tables of section 2.3.3 and 2.3.4 summarize the possibility. The 2 DC/DC converters can be switched on together with the first two TC of Table 2.3.3.

TC Bits								Address: TC Bit 7 and Bit 2 = 1
7	6	5	4	3	2	1	0	
1	X	X	X	X	1	0	1	28 V ON/OFF #1 and Guiding Z-axis, Toggle command
1	X	X	X	X	1	1	0	28 V ON/OFF #2 and Guiding Z-axis, Toggle command
1	X	0	0	0	1	0	0	Z-axis guiding and arming high-voltage TCs
1	X	1	1	0	1	0	0	Z-axis guiding and arming high-voltage TCs, redundant
1	X	0	0	1	1	0	0	Z-axis Fixed Full scale and arming high-voltage TCs
1	X	0	1	0	1	0	0	Z-axis Fixed Full 3/4 scale and arming high-voltage TCs
1	X	0	1	1	1	0	0	Z-axis Fixed Full 1/2 scale and arming high-voltage TCs
1	X	1	0	0	1	0	0	Z-axis Fixed Full 1/4 scale and arming high-voltage TCs
1	X	1	0	1	1	0	0	Z-axis Fixed min position and arming high-voltage TCs
1	X	1	1	1	1	0	0	Z-axis Fixed Full 1/2 scale and arming high-voltage TCs, redundant

2.3.4 Y-Guiding and High Voltage commands

TC Bits								Address: TC Bit 7 and Bit 2 = 0
7	6	5	4	3	2	1	0	
1	X	0	0	0	0	X	X	Y-axis guiding and arming high-voltage TCs
1	X	1	1	0	0	X	X	Y-axis guiding and arming high-voltage TCs, redundant
1	X	0	0	1	0	X	X	Y-axis Fixed Full scale and arming high-voltage TCs
1	X	0	1	0	0	X	X	Y-axis Fixed Full 3/4 scale and arming high-voltage TCs
1	X	0	1	1	0	X	X	Y-axis Fixed Full 1/2 scale and arming high-voltage TCs
1	X	1	0	0	0	X	X	Y-axis Fixed Full 1/4 scale and arming high-voltage TCs
1	X	1	0	1	0	X	X	Y-axis Fixed min position and arming high-voltage TCs
1	X	1	1	1	0	X	X	Y-axis Fixed Full 1/2 scale and arming high-voltage TCs, redundant

2.4 Telecommand verification

TBD

3 Telemetry

3.1 General Outline

Same as for the EGSE

3.2 Summary of science data channels

Science data consists of the 12 channels that contain the measurements from the inner detector pixels. They are digitized within the LOI unit and passed to the DAS in form of counts. They shall be represented either as :

- raw value (counts)
- voltage (after photocurrent- amplifier) "V"
- photocurrent "I_{ph}"

3.3 Summary of housekeeping/ status channels

Housekeeping channels provide temperature values and guiding information. They are passed to the DAS in form of voltages and digitized by VFCs located in the DAS.

These signals correspond to table 4.3.1 page 20 in the VIRGO ISID.

HK address	Mnemonic	Signal
0	PIX17	Temperature sensor diode on detector, pixel 17
1	PIX18	Temperature sensor diode on detector, pixel 18
2	PZAZ	Voltage on piezo actuator for z- axis
3	PZAY	Voltage on piezo actuator for y- axis
4	PIX13	Voltage on guiding pixel 13
5	PIX14	Voltage on guiding pixel 14
6	PIX15	Voltage on guiding pixel 15
7	PIX16	Voltage on guiding pixel 16
8	PIX19	Temperature sensor diode on detector, pixel 19
9	PIX20	Temperature sensor diode on detector, pixel 20
10	TOPT	Temperature optics
11	TAMP1	Temperature photocurrent amplifier 1
12	TAMP2	Temperature photocurrent amplifier 2
13	TVFC	Temperature voltage to frequency converter hybrid
14	TGUIF	Temperature guiding servo filter
15	TGUIP	Temperature guiding high voltage power supply DC/ DC

All status bits are active when at "1", e.g. the 28 V is switched on when bit is at "1".

Status Bit	Mnemonic	Function
0	28VON	28V switched on, DC/ DC running
4	LUDE	LOI latch up detector enabled

4 Level-1 data

4.1 Level-1 data file specification

The Level-1 data file will be a FITS file. In addition to the VIRGO common keywords, there will the LOI specific keywords; they are the following:

- PIX1COR: Pixel 1-4 surface correction for the SPM (after 4.2.4 corrections)
- PIX5COR: Pixel 5-8 surface correction for the SPM (after 4.2.4 corrections)
- PIX9COR: Pixel 9-12 surface correction for the SPM (after 4.2.4 corrections)
- PIX13COR: Pixel 13-16 surface correction for the SPM (after 4.2.4 corrections)

The main file will be organized as follows:

- 1st-12th columns: 12 scientific pixels (C_i, after 4.2.1 and 4.3.1 corrections)
- 13th column: quality flag word for the 12 pixels
- 14th-17th column: 4 guiding pixels (C_i, after 4.2.2 and 4.3.2 corrections)
- 18th column: quality flag word for the 4 guiding pixels
- 19th-20th columns: 2 diameters EW and NS (after 4.2.4 corrections)

All the columns but 13th and 18th are numeric values (E12.6). The columns 13th and 18th are ascii strings.

The auxiliary file (housekeeping data) will be organized as follows

- 1st-10th columns: 10 temperatures (after 4.2 corrections)
- 11th column: Y-axis high voltage (after 4.2 corrections)
- 12th column: Z-axis high voltage (after 4.2 corrections)
- 13th column: LOI status: 28 Volt ON/OFF
- 14th column: PDU status: LOI power on
- 15th column: DAS status: LOI latch-up detector enable
- 16th column: DAS latch-up flag

All the columns are numeric values; the last 4 status columns are I4, the others are E12.6.

4.2 Level-1: Conversion to physical units

This section describes how to obtain the level 1 data, and also the EGSE output for quick look evaluation.

4.2.1 Scientific channels

The 12 scientific channels are calibrated on ground. **They are part of the main file**. For quick look evaluation and the level 1 data, the signals will be given in terms of µA according to the following formula:

$$S_i = a_0 + a_1 . P_i \qquad (1)$$

where P_i is the ith scientific channels ($1<i<12$), the a_0, a_1 are the calibration coefficients which are in µA and in µA/count respectively. The calibration factor for the FS are given in section 4.2.5.

4.2.2 H/K channels

Important note: There are two kinds of H/K channels: the fast and the slow. The fast ones are updated every minute. The slow ones every 3 minutes. When both fast and slow H/K are present in one file, the slow H/K channels will be replicated for the time during which no data are available for these channels, as in the following example.

Time	Fast H/K	Slow H/K	Fast H/K	Slow H/K
t_o	T1(t_o)	T2	T3(t_o)	T4
t_o+1	T1(t_o+1)	T2	T3(t_o+1)	T4
t_o+2	T1(t_o+2)	T2	T3(t_o+2)	T4

The 4 guiding pixels are calibrated on ground. **They are part of the main file**. For quick look evaluation and the level 1 data, the signals will be given in terms of µA according to the formula (1) (See above). The calibration factor for the FS are given in section 4.2.5. The DASS provide the calibration to derive Volts from the count.

For quick look evaluation ONLY, the 4 guiding channels in the LOI housekeeping will be used to look at the pointing stability. The equatorial stability X_{eq} and the rotation axis stability X_{rot} will be computed according to the following formulae:

$$X_{eq} = b_1 . \frac{A-B}{A+B} \qquad \text{with } A=G_{14} \text{ and } B=G_{15} \qquad (2)$$

$X_{rot}=b_1 \cdot \frac{\text{C-D}}{\text{C+D}}$ with C=G_{13} and D=G_{16}. (3)

The b_1 is a calibration coefficient. (b_1 = 43.5 ")

For quick look evaluation and the level 1 data, the high voltage on the actuators (**they are part of the auxilliaty file**) will be given in terms of Volt according to the following formula:

$HV_{(Y\ or\ Z)}=Offset+Slope.V_{(Y\ or\ Z)}$ (4)

where $HV_{(Y\ or\ Z)}$ is the high voltage on the actuators, the calibration coefficients are in Volt and in Volt/Volt respectively. The calibration factor for the FS are given in section 4.6.2. The DASS provide the calibration to derive Volt from the count.

For quick look evaluation and the level 1 data, the temperature of the various components (**they are part of the auxilliaty file**) are given in terms of °C according to the following formula:

$T =Offset+Slope.V\ (HK)$ (5)

where T is the temperature in °C of the component, the calibration coefficients are in °C and in °C/Volt respectively. The calibration factor for the FS are given in section 4.2.5. The DASS provide the calibration to derive Volt from the count.

The values of VIRGO FITS keywords POINT_NS and POINT_EW are given by a daily avearge of θ_Z and θ_Y, respectively. The Z-axis offset θ_Z and the Y-axis axis offset θ_Y will be computed according to the following formulae:

$\theta_Z= a\ HV_Z + b\ HV_Y - c$ (6)

$\theta_Y= a'HV_Z + b'HV_Y - c$ (7)

a=0.0283 '/Volt, b=-0.002 '/Volt and c=3.42'

a'=0.0268 '/Volt, b'=-0.0005 '/Volt

where HV_y and HV_Z are given by equation (4).

4.2.3 Automatic parameter out- of- range monitoring

All temperatures are measured from -20 °C to +80 °C. There should be a warning whenever a temperature is outside the limits. Nominal operating temperature range is 0 °C to 40 °C.

All guiding pixel voltages are in the range from 0 to 2.5 V and can be directly used for housekeeping without re-scaling. If the guiding servo loop is active, all 4 values should be identical. Any coarse mismatch should result in a warning. Whenever the sun is seen by the instrument, and the guiding servo is active, the voltage on all pixels should be in the range of 0.5 V to 2.0 V, else a warning shall be generated.

The high voltage on the piezo actuators is scaled down to fit into the HK range of 0 to 3.5 V. Whenever the voltage is lower than 1 V or higher than 2.5 V the servo is at its limits of compensation for spacecraft guiding errors, so a warning should be generated.

4.2.4 Derived channels and keywords

Solar diameters

They are part of the main file. The equatorial and solar-axis solar diameters (in arcmin) can be obtained from the following formula:

$$D=31.9875 + 8.9773\,\Delta R - 7.0576\,\Delta R^{2} \qquad (8)$$

where ΔR is given by:

$$\Delta R = \frac{S_R}{S_c} - 0.1344 \qquad (9)$$

where S_R is the mean intensity on the EW or NS guiding pixels, and S_c is the mean intensity on the central pixels. They are given by:

$$S_{NS} = \frac{S_{13}+S_{16}}{2},$$

$$S_{EW} = \frac{S_{14}+S_{15}}{2},$$

$$S_c = \frac{S_9+S_{10}+S_{11}+S_{12}}{4} \qquad (10)$$

In formula (9), the value 0.1515 represents the mean ratio at L1.

The daily mean solar diameter ($\overline{D}$) to be used by the SPM keyword is given by:

$$\overline{D} = \frac{1}{1440}\sum_{i=1}^{1440} \frac{D_{NS}+D_{EW}}{2} \qquad (11)$$

SPM keywords

They are part of the main file. After having computed the mean solar diameter from an average of the NS and EW diameter, the SPM correction can be written as:

$$SPM(r)=o+\alpha\,\Delta\rho + \beta\,\Delta\rho^{2} \qquad (12)$$

where o is the offset, α is the slope, β is the curvature, and $\Delta\rho$ is the difference between the computed mean solar diameter and 31.9875' ($\Delta\rho = \overline{D} - 31.9875$). α and β are given in the following table.

Keyword	Offset (o)	Slope (α)	Curvature (β)
PIX1COR	1.0727	0.00169	-0.000516
PIX5COR	1.0737	0.00112	-0.000337
PIX9COR	1.0691	0.00008	-0.000006
PIX13COR	1.2962	-0.24736	0.175430

4.2.5 Quality criteria

For the scientific pixels, if one of the 12 pixels is below 3 μA the quality flag must be set to 'POOR' otherwise set it to 'GOOD'. For the guiding pixels, if one of the 4 pixels is below 0.5 μA the quality flag must be set to 'POOR' otherwise set it to 'GOOD'.

4.2.6 Calibration curves

All calibration curves are in principle linear, due to the characteristics of the temperature sensors (AD590 and diode voltage drop). There should be an option to add a third data point and thus compensate for non- linear effects, if necessary. Calibration curve has to be a second order polynomial in this case. Calibration points are given as "measured value / HK voltage" or " measured value / counts " (for science data, pixels 1- 12).

Science data calibration curves

Count values are based on an integration time of 59.4 s (VIRGO ISID, page 36, table 4.4.11). Scaling resistor on AD 652 VFC input is 5kOhm, both internal 10k resistors in parallel. Full scale is 2.5V on input. Resistor in feedback path of pre- amplifier (I_{photo} to voltage converter) R_f is determining the gain. Should be chosen to provide 2.5 V for full scale. Nominal operation will be at about 2/3 full scale. Photocurrent expected is about 25μA for 0.8mW/cm^2 input power. At that time we will provide a separate cal curve for every detector pixel, as mentioned above with 3 calibration points for each pixel.

Pixel	Offset (a_0 in μA)		Slope (a_1 in μA/cnt)
	Calibration ON	Calibration OFF	
1	-0.0350118	0.00575206	1.74850641e-06
2	-0.0396919	0.00475225	1.74725380e-06
3	-0.0370238	0.00912447	1.74707076e-06
4	-0.0398768	0.00190457	1.74780227e-06
5	-0.0402260	0.000638947	1.74726469e-06
6	-0.0449525	-0.000950035	1.74850109e-06
7	-0.0449315	0.000967897	1.74753397e-06
8	-0.0372301	0.00609152	1.75443265e-06
9	-0.0416478	0.00174825	1.74785079e-06
10	-0.0379758	0.00867406	1.74757447e-06
11	-0.0389594	0.00302329	1.74811353e-06
12	-0.0387467	0.00515085	1.74781395e-06

Housekeeping calibration curves

Guiding Pixel	Offset (a_0 in μA)		Slope (a_1 in μA/Volt)
	Calibration ON	Calibration OFF	
13	-0.0412026	0.00173682	13.3344
14	-0.0412874	-0.00232219	13.3442
15	-0.0404695	-0.000987642	13.3415
16	-0.0431335	-0.000184461	13.3452

High voltage on axis	Offset (in Volt)	Slope (in Volt/Volt)
Y	-145.0	352.6
Z	-144.7	353.3

Temperature sensor		Offset (in °C)	Slope (°C/Volt)
T1	(pix 17)	118.10	-50.754
T2	(pix 18)	117.85	-50.682
T3	(pix 19)	118.29	-50.857
T4	(pix 20)	112.09	-50.351
T5	(preamp)	-14.001	29.851
T6	(VFC)	-14.001	29.851
T7	(ADHK)	-14.001	29.851
T8	(VFC red.)	-14.001	29.851
T9	(HV-filt)	-14.001	29.851
T10	(HV-DC)	-49.001	29.851

4.3 Level-1 data: Known instrumental and orbital corrections

What follows is an extract from the VIRGO Purple Book.

4.3.1 LOI pixels

The current on the scientific and guiding pixels has to be corrected from 3 main effects:

- Correction of distance
- Correction of line-of-sight velocity
- Temperature effect on detector.

The first effect is mainly due to the limb darkening. The second effect is a relativistic contribution. The last effect is due the temperature sensitivity of the quantum efficiency of the silicon detector. The net correction can be written as:

$$C_i\,(1\,AU) = \frac{S_i}{f(r)}\,\frac{(1+T\,q_T\,)}{\cos\theta}\,\frac{1-\frac{v}{c}}{1+\frac{v}{c}} \qquad (13)$$

where C_i is the current on an LOI pixel i at 1 AU, $f(r)$ is the correction for the combined effect of the distance and the limb darkening (see section 4.3.2), T is the mean temperature, in °C, of the detector as measured by the 4 temperature diodes (T1, T2, T3, T4), q_T is the temperature dependence at 0 °C (q_T= -135.9 ppm/°C for the scientific pixel, q_T^G = -128.8 ppm/°C for the guiding pixels), v is the satellite velocity along the line of sight, c is the speed of light, θ is the off-axis angle between the line of sight and the optical axis of the LOI instrument; v is given by:

$$v = \frac{1}{r}\left(x\,\frac{\mathrm{d}x}{\mathrm{d}t} + y\,\frac{\mathrm{d}y}{\mathrm{d}t} + z\,\frac{\mathrm{d}z}{\mathrm{d}t}\right) \qquad (14)$$

where x, y and z are the heliocentric coordinates of the satellite; r (in UA) is given by:

$$r = \sqrt{x^2+y^2+z^2} \qquad (15)$$

r is the distance of the satellite to the center of the Sun. And finally, the angle θ in rad can be derived from the high voltage on the Y and Z axis of the LOI instrument using equations (7) and (8):

$$\theta = 0.000291\ \sqrt{\theta_Z^2+\theta_Y^2} \qquad (16)$$

v and r can be derived from the SOHO ancillary data.

4.3.2 Limb darkening effect and distance correction

For the LOI pixels this correction is written as:

$$f(r)=1.+a\ \Delta r + b\ \Delta r^{2} \qquad (17)$$

where a is the slope, b is the curvature, and Δr is the distance to the mean Sun-Earth orbit, in AU, counted positively away from the Sun ($\Delta r= r$-1.). This correction will be refined during the mission. The value for a and b are given in the following table.

Pixels	Slope (a)	Curvature (b)
1 to 4	-1.08050	-2.87140
5 to 8	-0.89908	-2.17970
9 to 12	-0.10910	-0.07862
13 to 16	-24.6500	100.3311

Nota: I must point out that the formula (14) of a previous document (version 1.1) was wrong. An equivalent formula to $f(r)$ should have been the following:

$$f(r)=\frac{r^2-R_g^2}{1-R_g^2} \qquad (18)$$

where R_g is the size of the guiding pixel at L1 (= 0.9473).

5 Telemetry / Telecommand trace files

All telemetry has to be recorded on a trace file. A log of all given commands shall be kept. An utility software package to access these data files would be very helpful, so the LOI team could write their own evaluation program on top of it.