CASSIS CALIBRATION PROGRAMME

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Instrument name:	Colour and Stereo Surface Imaging System (CaSSIS)
Origin Name:	Physikalisches Institut, Universität Bern
WBS code:	N/A
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DOCUMENT CHANGE RECORD

Issue	Revision	Date	Pages, Tables, Figures affected	Modification	Initials
0	1	06 May 2013	All	First Draft	RZ
0	2	25 Aug 2013	1	Changed title due to changed requirement in AD01	RZ
0	3	20 Sep 2013		Title changed	RZ
0	4	23 Jun 2014	2.12	List of calibration procedures	RZ
			5	Added calibration procedure template	RZ
0	5	22 Sep 2014	Section 4	Added calibration steps	NT
			Section 6	Added reference to Experiment Operations Plan	RZ
0	6	22 Sep 2014		Added Lisa Gambicorti in the authors table	LG
0	6	22 Sep 2014	Table 1	Inserted caption: summary of required measurements	LG
0	6	22 Sep 2014	Table 2	Deleted: Off-axis mirror collimator with ~2 m focal length using pinhole	LG
0	6	22 Sep 2014	Table 3	Inserted: Off-axis mirror collimator with ~1 m focal length using pinhole	LG
0	6	22 Sep 2014	Table 4	Deleted: Off-axis mirror collimator with 2 m focal length and 30 cm aperture using pinhole	LG
0	6	22 Sep 2014	Table 5	Inserted: Off-axis mirror collimator with 1 m focal length and 15 cm aperture using pinhole	LG
1	0	14 Nov 2014		Signatures for CDR	RZ
1	1	06 Jan 2015	Sec 5.1	Added understanding about characterisation of CaSSIS with optical cube.	RZ

Table of Contents

List of documents

Applicable documents		
AD01	EXM-PL-IRD-ESA-00003 Issue 2 Rev 0 TGO E-IRD (JCCB - Signed)	Experiment Interface Requirements Document

Reference documents		
RD01	DELETED	DELETED
RD02	EXM-CA-LIS-UBE-00001	List of Acronyms Iss 1, Rev 0
RD03	EXM-CA-PLN-UBE-00024	CaSSIS Experiment Operations Plan Iss 0, Rev 6

Scope of the Document

This document describes the CaSSIS calibration plan.

1 SUB-SYSTEM CALIBRATION

1.1 Filter

The individual filter strips which are to be placed on the detector within the focal plane assembly will be calibrated in transmission at one angle using a monochromator. This data will be stored as part of the determination of the instrument spectral bandwidth.

1.2 Telescope

1.2.1 Transmission

The telescope transmission will be tested by the supplier at one wavelength and compared to the expected values based upon measurements of the space-qualified silver coating to be used on test samples. The prediction is shown in the following figure and has been compared to the same configuration but with a particulate contamination of 3000 ppm.

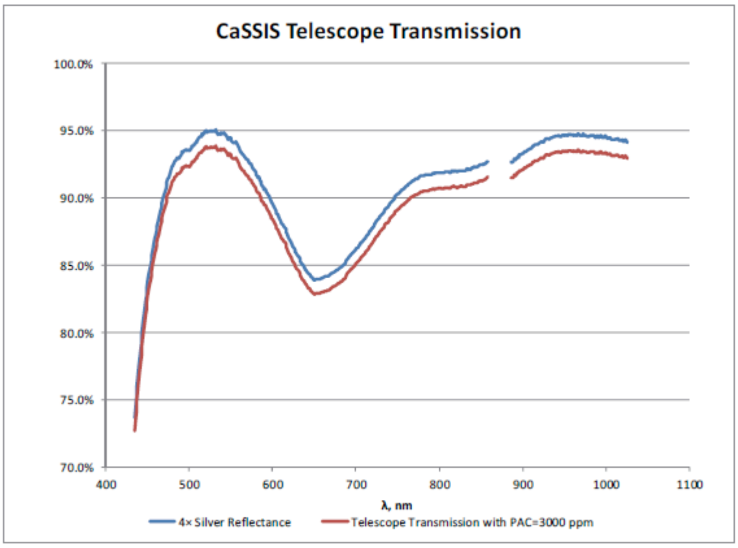


Figure 1 Predicted telescope transmission.

1.3 Detector

The detector sensitivity will be known through analysis (data sheets) only.

2 CALIBRATION FACILITIES

2.1 Calibration/Integration room (103)

Room 103 in the Exakte Wissenschaften building of the University of Bern has been converted into a class 100 (ISO 5) clean room including laminar flow system. The room will be verified and certified prior to installation of the flight hardware.

2.2 Gross Labor

The University of Bern Gross Labor contains a clean area which surrounds the thermal-vacuum chamber. This clean area will be used to house equipment to test CaSSIS when the instrument is undergoing thermal load. The clean area is used for CaSSIS itself during integration in the TV chamber and hence is required to maintain ISO 5 standard. This will be verified and certified prior to installation of the flight hardware.

3 BASIC CALIBRATION PROGRAMME

The instrument will undergo calibration and environmental testing in a combined programme. This is required to optimize the schedule and to limit the transport of the instrument within the UBE buildings.

3.1 Specific Calibration Procedures

The following procedures will be performed to calibrate the CaSSIS instrument

- Bias and darks at ambient
- bias and darks with temperature
- flat-field and linearity
- focal length and angular scale
- Geometric distortion
- PSF under thermal load
- relative spectral response
- relative spectral response under thermal load
- in-field straylight

For each procedure a separate document is created. An example is shown in Section 7

3.2 Flowcharts

3.2.1 Phase 1

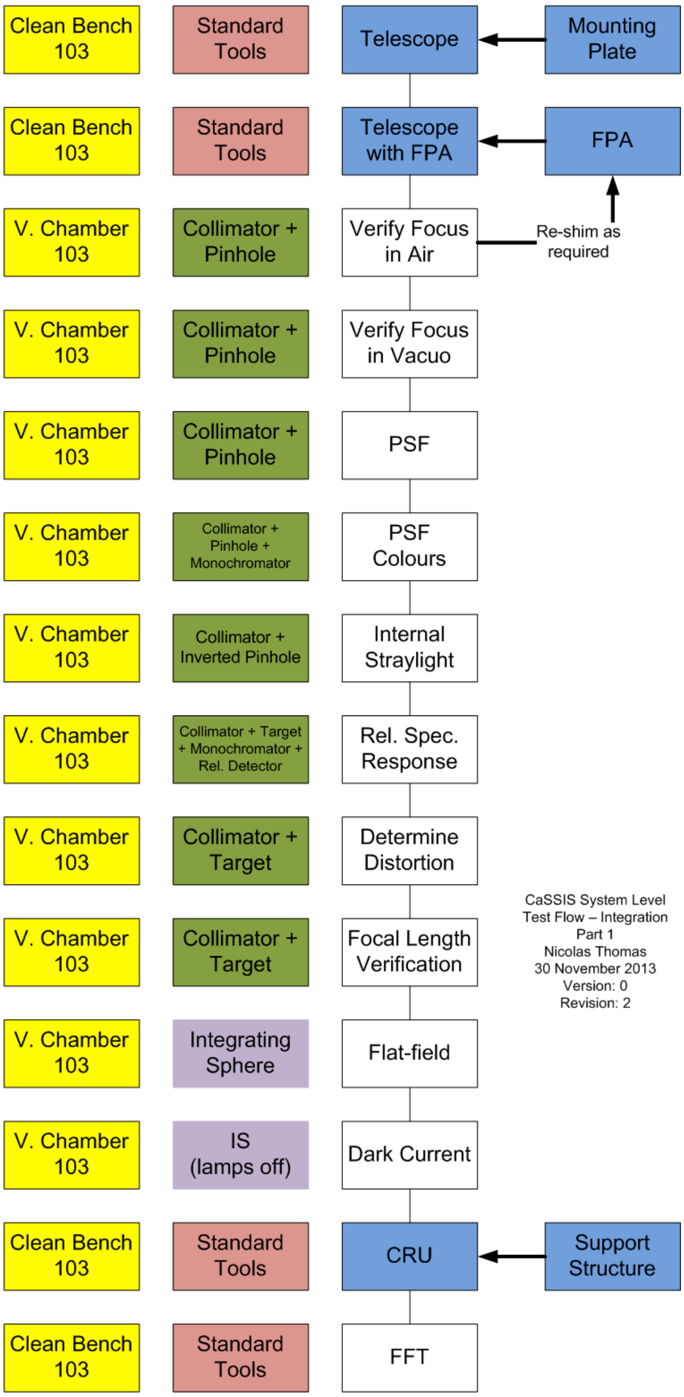


Figure 2 AIV flow for CaSSIS showing the integration, environmental test, and calibration steps. (Part 1).

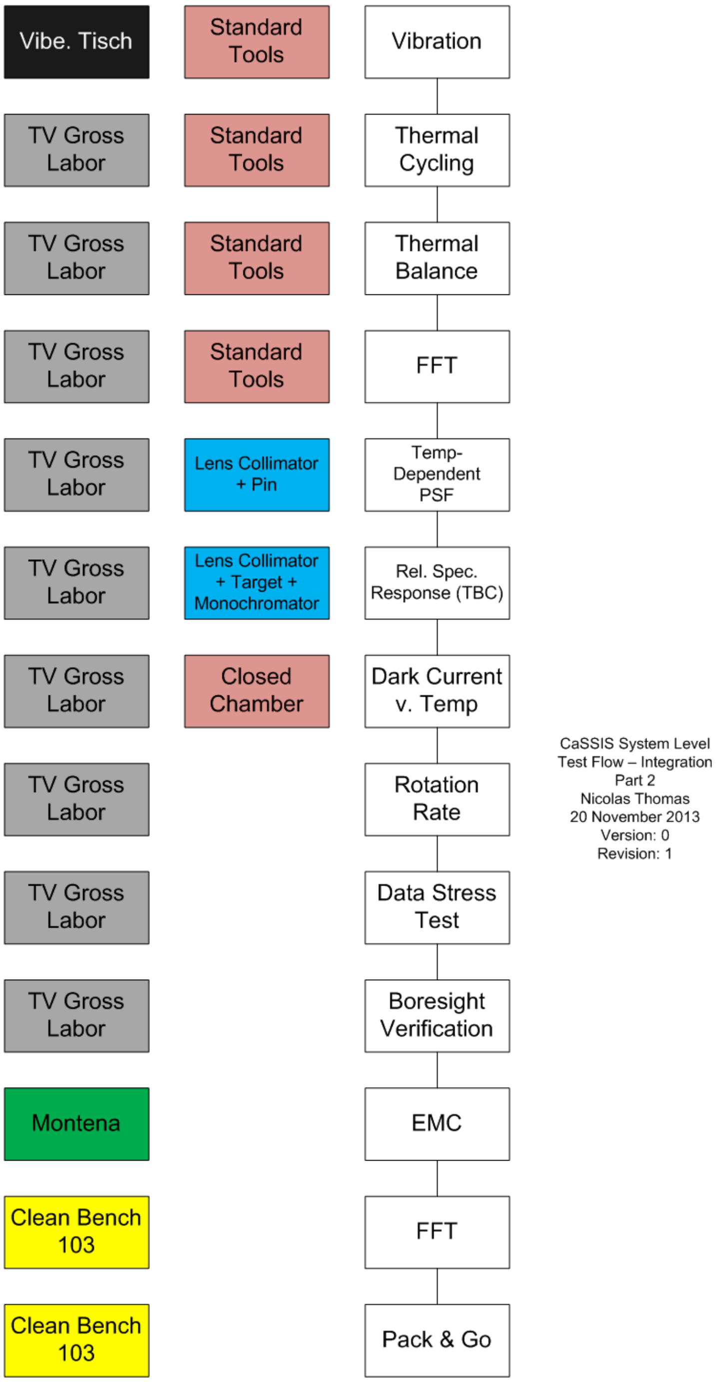
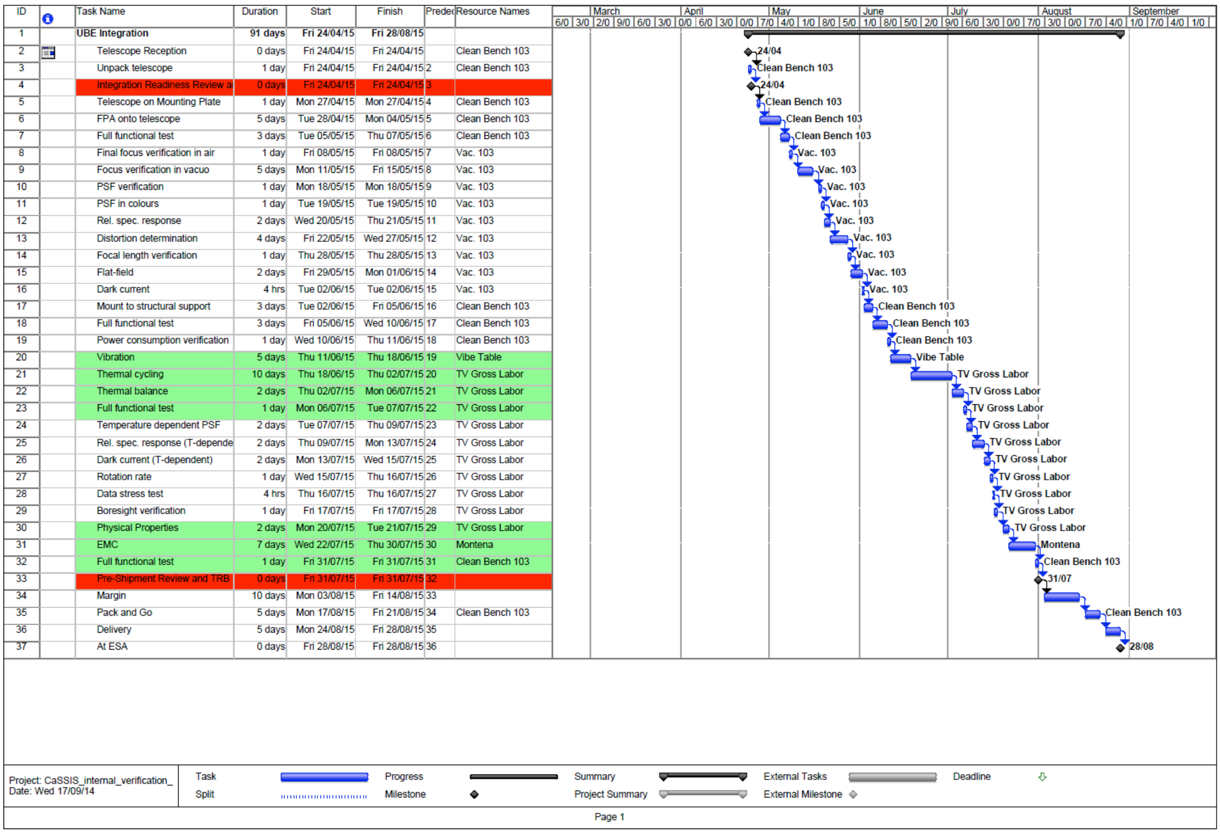


Figure 3 AIV flow for CaSSIS showing the integration, environmental test, and calibration steps. (Part 2).

3.3 Schedule

The schedule is indicated in the following figure.



ID		Task Name	Duration	Start	Finish	Predec	Resource Names
1		**UBE Integration**	**91 days**	**Fri 24/04/15**	**Fri 28/08/15**		
2		Telescope Reception	0 days	Fri 24/04/15	Fri 24/04/15		Clean Bench 103
3		Unpack telescope	1 day	Fri 24/04/15	Fri 24/04/15	2	Clean Bench 103
4		Integration Readiness Review a	0 days	Fri 24/04/15	Fri 24/04/15	3	
5		Telescope on Mounting Plate	1 day	Mon 27/04/15	Mon 27/04/15	4	Clean Bench 103
6		FPA onto telescope	5 days	Tue 28/04/15	Mon 04/05/15	5	Clean Bench 103
7		Full functional test	3 days	Tue 05/05/15	Thu 07/05/15	6	Clean Bench 103
8		Final focus verification in air	1 day	Fri 08/05/15	Fri 08/05/15	7	Vac. 103
9		Focus verification in vacuo	5 days	Mon 11/05/15	Fri 15/05/15	8	Vac. 103
10		PSF verification	1 day	Mon 18/05/15	Mon 18/05/15	9	Vac. 103
11		PSF in colours	1 day	Tue 19/05/15	Tue 19/05/15	10	Vac. 103
12		Rel. spec. response	2 days	Wed 20/05/15	Thu 21/05/15	11	Vac. 103
13		Distortion determination	4 days	Fri 22/05/15	Wed 27/05/15	12	Vac. 103
14		Focal length verification	1 day	Thu 28/05/15	Thu 28/05/15	13	Vac. 103
15		Flat-field	2 days	Fri 29/05/15	Mon 01/06/15	14	Vac. 103
16		Dark current	4 hrs	Tue 02/06/15	Tue 02/06/15	15	Vac. 103
17		Mount to structural support	3 days	Tue 02/06/15	Fri 05/06/15	16	Clean Bench 103
18		Full functional test	3 days	Fri 05/06/15	Wed 10/06/15	17	Clean Bench 103
19		Power consumption verification	1 day	Wed 10/06/15	Thu 11/06/15	18	Clean Bench 103
20		Vibration	5 days	Thu 11/06/15	Thu 18/06/15	19	Vibe Table
21		Thermal cycling	10 days	Thu 18/06/15	Thu 02/07/15	20	TV Gross Labor
22		Thermal balance	2 days	Thu 02/07/15	Mon 06/07/15	21	TV Gross Labor
23		Full functional test	1 day	Mon 06/07/15	Tue 07/07/15	22	TV Gross Labor
24		Temperature dependent PSF	2 days	Tue 07/07/15	Thu 09/07/15	23	TV Gross Labor
25		Rel. spec. response (T-depende	2 days	Thu 09/07/15	Mon 13/07/15	24	TV Gross Labor
26		Dark current (T-dependent)	2 days	Mon 13/07/15	Wed 15/07/15	25	TV Gross Labor
27		Rotation rate	1 day	Wed 15/07/15	Thu 16/07/15	26	TV Gross Labor
28		Data stress test	4 hrs	Thu 16/07/15	Thu 16/07/15	27	TV Gross Labor
29		Boresight verification	1 day	Fri 17/07/15	Fri 17/07/15	28	TV Gross Labor
30		Physical Properties	2 days	Mon 20/07/15	Tue 21/07/15	29	TV Gross Labor
31		EMC	7 days	Wed 22/07/15	Thu 30/07/15	30	Montena
32		Full functional test	1 day	Fri 31/07/15	Fri 31/07/15	31	Clean Bench 103
33		Pre-Shipment Review and TRB	0 days	Fri 31/07/15	Fri 31/07/15	32	
34		Margin	10 days	Mon 03/08/15	Fri 14/08/15	33	
35		Pack and Go	5 days	Mon 17/08/15	Fri 21/08/15	34	Clean Bench 103
36		Delivery	5 days	Mon 24/08/15	Fri 28/08/15	35	
37		At ESA	0 days	Fri 28/08/15	Fri 28/08/15	36	

Figure 4 Schedule for integration, enviromental testing and calibration of the CaSSIS PFM.

4 Calibration Programme Steps

4.1 Focus verification

Once the focal plane assembly has been installed, a focus verification will take place. This will occur initially in two steps.

The telescope with the FPA (but still not mounted on the CRU) will be installed in a vacuum chamber which will be mounted on an optical bench floating on nitrogen to minimize vibration. The telescope will be aligned so that the optical axis is parallel with the incoming beam from an off-axis parabola (OAP). The OAP shall have a focal length greater than the focal length of the telescope. A pinhole at the focus of the OAP shall be illuminated by a halogen lamp via a monochromator which will be directed at a piece of frosted glass to eliminate any focal mismatch between the monochromator and the collimator. The first measurement will be made in air at ambient. A three-axis translation stage at the focus of the OAP will be used to determine the position of the CaSSIS focal plane with respect to the telescope focal plane.

It is important to note that the CFRP structure contracts in vacuo and hence this will be pre-compensated (calculation by analysis) during the FPA integration. Hence, we do not expect the telescope/focal plane combination to be perfectly in focus at this time. However, through focus measurements should already indicate whether the focal plane has been correctly mounted according to analysis.

The vacuum chamber will then pumped to produce a vacuum in a second step. A through focus measurement will be acquired immediately after initial pump-down. For the next two days, the instrument will be monitored by repeated through focus measurements. This will confirm that, as the telescope dries out, the instrument will move towards a better focus.

4.2 Point spread function (PSF)

After completion of the focus check, a PSF calibration shall occur by using a pinhole target in the focal plane of the OAP. The telescope/FPA combination shall be at ambient and in vacuo.

Note that the final PSF of the system can only be checked in flight by standard star observations because of the need of the structure to dry out fully. This calibration should provide reference data against which flight data can be checked.

The PSF calibration will be repeated for all colours by shifting the pinhole using the 3-axis stage in such a way that all filters are exposed. Verification across the full field of view will also be performed if time allows. It is expected that the PSF will be broader in the RED and NIR filters.

4.3 Internal straylight

An internal straylight test will be carried out by using an inverted pinhole (dark disc corresponding to ~20 pixels in diameter surrounded by a translucent mask). The inverted pinhole will be illuminated by the halogen source. The telescope/FPA combination shall be used to produce images and the brightness inside the nominally dark disc imaged by the combination determined.

4.4 Relative spectral response

The monochromator will be used to scan through the entire wavelength range with a large pinhole at the collimator focus. A relative detector will be placed in the parallel beam of the collimator and the reading taken for each wavelength change. The telescope/FPA combination will be read-out at each wavelength setting using an appropriate exposure time. The signal on the detector will be integrated and compared to the output from the relative detector. The ratio will be taken and the total curve normalized to one at the maximum to obtain a relative spectral response in each channel. This will be compared to the predicted relative spectral response derived from the components (see e.g the following figure).

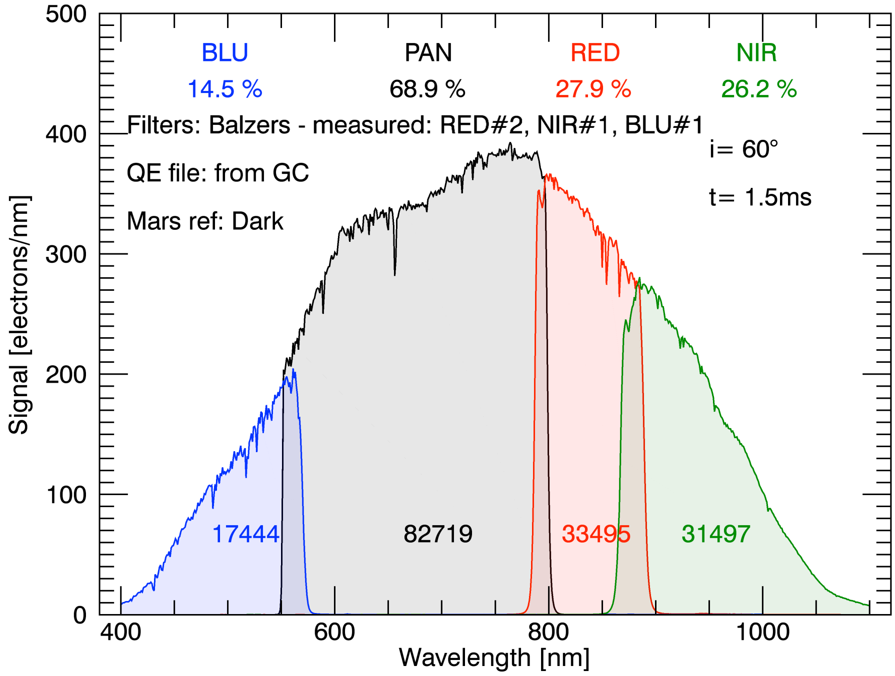


Figure 5 The relative spectral response expected in each channel will be derived from this absolute response calculation.

Ideally, the target at the collimator focus will be large enough to fill the field of view of the instrument. A relative detector with a known spectral response, covering the range 350 nm to 1100 nm needs to be used. The monochromator will be scanned from 350 nm to 1100 nm at 5 nm intervals. The relative detector will be read-out at each step to monitor the relative flux entering the instrument. Two images of the target will be obtained at each step.

A provisional version of the relative spectral response in shown in the following figure.

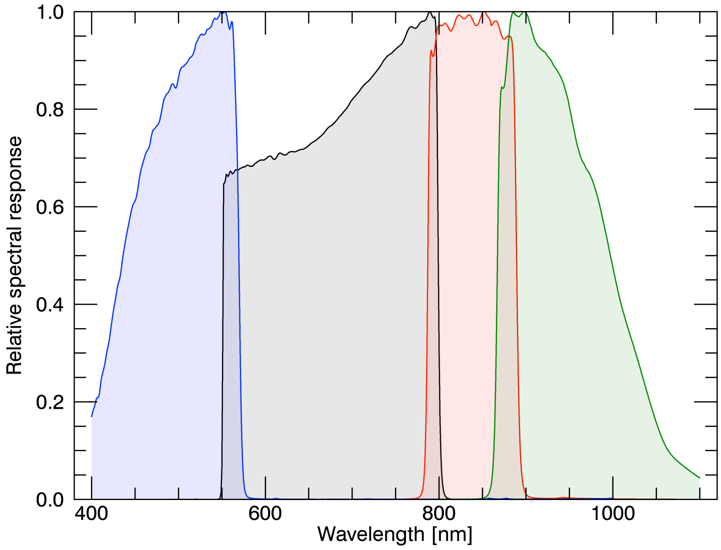


Figure 6 Relative spectral response expected for the instrument.

4.5 Geometric distortion

An optical target shall be placed in the focal plane of the collimator. The optical target will provide a grid to allow assessment of the geometric distortion over the field of view.

An alternative method placing a grid in the parallel beam of the collimator is also being discussed. Choice of method is still TBD.

4.6 Pixel scale/focal length

The motion of the collimator head will be combined with the collimator focal length to provide a measure of the pixel scale and thereby the focal length of the system. This will be verified in all four colours.

4.7 Flat-field and absolute response

An integrating sphere of approximately 1 metre diameter with an aperture diameter of 20 cm will be used to produce a flat-field. The integrating sphere will be temporarily placed between the collimator and the vacuum chamber housing the instrument. The sphere will be absolute calibrated over a wavelength range of 400 nm – 1100 nm in at least 8 steps.

At least 25 images of the flat-field source will be obtained in all colours.

Figure 7 CaSSIS integrating sphere

4.8 Dark current

With the integrating sphere lamps off, the dark current at ambient, in vacuo, will be measured using a range of exposure times.

4.9 Linearity

The integrating sphere will be used to test the linearity of the system. Exposure times from 0 ms to 1 s (TBC) will be used to establish the linearity to the incoming flux. The radiance from the integrating sphere will be changed and the test repeated to show the dependence upon illumination (TBC).

4.10 Transfer to Gross Labor

At this point, the instrument will be taken out of the vacuum chamber and mounted on to the CRU structure to provide a complete CRU. The CRU will then be transferred to the Gross Labor for thermal tests.

4.11 Gross Labor set-up

The instrument will be mounted inside the thermal-vacuum chamber of the Gross Labor. The instrument shall be mounted in a configuration such that at one rotation position, the instrument will look out through the suprasil window of the vacuum chamber towards a test set-up.

The test set-up shall comprise an optical bench on which a lens collimator shall be mounted. It should be noted that the the lens collimator will not fill the aperture of the instrument (a constraint necessary for schedule reasons). Targets shall be placed in the focus of the collimator. A frosted glass diffuser will be used. This will be illuminated by a monochromator.

4.12 Relative spectral response with temperature

The relative spectral response test (see above) will be repeated at 0 C and – 30 C using the partially filled aperture of the instrument. Although the set-up will be different, the measurement will be relative.

4.13 PSF with temperature

We expect some variation of the PSF with temperature. This will be verified at three wavelengths using a pinhole in the collimator as the instrument is temperature cycled.

4.14 Dark current with temperature

The dark current shall be measured as a function of temperature by blocking the light from the monochromator.

4.15 Data Stress Test

A data stress test shall be carried out to determine the data processing limits of the instrument. This shall include

- Maximum sub-exposure acquisition size
- Maximum number of sub-exposures in a sequence
- Compression/processing speed for defined sequences

4.16 Summary

The following table gives a summary of required measurements.

Table 6 summary of required measurements

Required Measuremt	Accuracy	Expected Value	Approach	Why
Effective focal length	0.1%	880 mm	Off-axis mirror collimator with ~1 m focal length using pinhole.	0.1% = 1 pixel scale error over 1000 pixel swath
Point spread function	5%	1.5 px FWHM	Off-axis mirror collimator with 1 m focal length and 15 cm aperture using pinhole	
Relative spectral response in all filters	3%	Filter dominated spectrum	Off-axis collimator. Wide pinhole combined with monochromator using a frosted glass mixer. Absolute detector used to determine monochromator output.	Need to see how red Mars is.
Absolute response	5%	>50% of input	Calibrated integrating sphere.	Need to know exact flux back from Mars at the 5% level.
Geometric distortion	0.02%	2%	Series of pinholes in the collimator focus at highly controlled distances apart.	Removal of mapping errors at the level of < 1 pixel.

5 Post-integration calibration at spacecraft level

5.1 Alignment

The orientation of CaSSIS with respect to the nadir panel post-integration needs to be established at spacecraft. It is understood by CaSSIS that the only ground operation expected from TAS to carry out during PFM integration is the measurement (characterisation) between the CaSSIS optical cube and the TGO main reference cube.

6 IN-FLIGHT CALIBRATION

In-flight calibration requirements and procedures can be found in the Experiment Operations Plan (EXM-CA-PLN-UBE-00024, RD03).

7 Appendix A: Calibration Procedure Example

Title:	**INSERT TITLE HERE**				
Initial conditions:	a. Instrument in vacuum chamber under vacuum (Room 103) b. Instrument is on and in standby c. Instrument is connected to an EGSE				
Start time:					
End time:					
Task	Description	Requirement tested	Values	Deviations	Completed
1					
2					
3					
4					
…					
…					
…					
N	Return to standby				
End of procedure					