

# Acceptance Tests of the INTEGRAL Optical Monitoring Camera Sub-Systems

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## ABSTRACT

The Optical Monitoring Camera (OMC) is a part of the scientific payload being developed for the ESA INTEGRAL mission, scheduled to be launched in 2001. The OMC is an imager that will monitor star variations in the V-band in a  $5 \times 5^\circ$  field of view. This paper describes the acceptance tests for 3 sub-systems of OMC: the optical system, the baffle and the cover system.

The optical system is based on a 6-lens objective mounted in a Titanium alloy barrel. It has been manufactured by Delft Sensor System (DSS-OIP). The optical performances are verified (spectral range, PSF, MTF) and compared to predictions. The mechanical and thermal behaviours in space environment are then tested in CSL premises. Specific set-ups to measure the wavefront error at 633 nm and the PSF in the V-band have been developed to detect any degradation resulting from environmental constraints.

The baffle consists in a 600 mm length Aluminium alloy cylinder surrounding the optical system and including internal vanes. The mechanical stiffness is verified at instrument level.

The cover system basically consists of a door mechanism and a forebaffle. The door is closed during integration and launch to prevent the optics from contamination. The mechanism will be operated only once in flight but shall be intensively tested on ground. Specific environmental tests, such as vibration and thermal tests are performed to verify the correct functioning of the mechanism in extreme conditions.

The test results are discussed in terms of performances in severe conditions.

**Keywords:** environmental test, space optical instrument, optical testing

## 1. INTRODUCTION

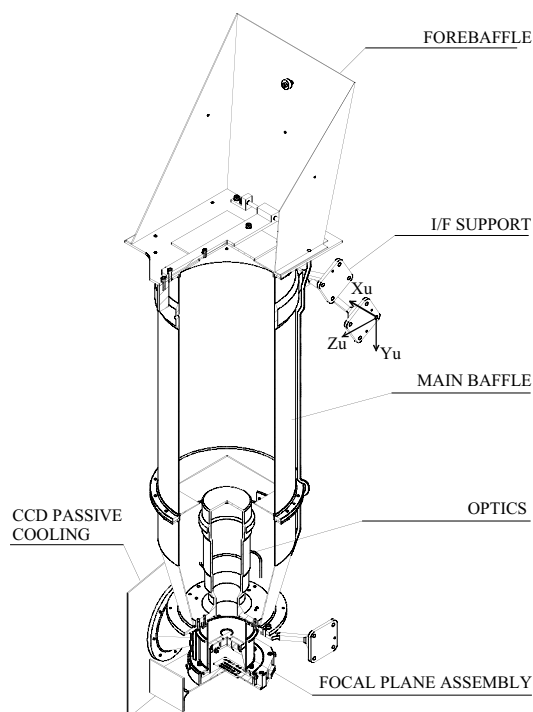


Figure 1: The OMC instrument.

The Optical Monitoring Camera (OMC) is a part of the INTEGRAL payload, an ESA scientific mission (INTERNATIONAL Gamma-Ray Astrophysics Laboratory) dedicated to the fine spectroscopy and fine imaging of celestial gamma-ray sources. It covers the energy range of 15 keV to 10 MeV with concurrent monitoring in the X-ray (3-35 keV) and optical (V-band) energy range. The satellite is scheduled to be launched in September 2001 with a PROTON although all environmental specifications have also to be fulfilled for the ARIANE 5 alternative option.

The Optical Monitoring Camera (OMC) is being built by an European consortium of Spanish (INTA/LAEFF), Belgian (CSL), Irish (UCD/DIAS) and British (MSSL) institutes. The OMC instrument consists of a CCD camera unit connected to a single electronic unit. It is a 20 kg class instrument mounted on the top of the INTEGRAL payload module. The camera unit is based on a large format CCD (2048x1024 pixels) working in frame transfer mode (1024x1024 pixel image area) that avoids the use of a mechanical shutter. The CCD is cooled by means of a passive radiator down to operational temperatures lower than  $-80^\circ\text{C}$  for noise reduction purposes. An optical baffle affords the necessary reduction of scattered sunlight required for faint source detection up to  $m_v = 19.7$ . A one-shot deployable cover is used to protect the optics and the baffle interior from contamination during ground testing and early days in orbit. Figure 1 shows a schematic view of the OMC.

Aperture size :	50 mm diameter
Field of View (FOV) :	5 x 5 arcdeg square
Pixel size :	13 x 13 $\mu\text{m}$
	17.6 x 17.6 arcsec
Spectral range :	V-band centred at 550 nm
Sensitivity :	19.7 visual magnitude

The main optical requirements of the instrument are listed in table 1. The FOV is defined by the payload pointing mode. It is a compromise between the source confusion and the FOV of other instruments on the payload, particularly the X monitoring instruments. The V-band selection is achieved with a specific filter included in the optical system. The very high sensitivity will be reached with adequate diaphragms and dedicated baffles.

**Table 1: OMC specifications.**

## 2. DEVELOPMENT PHILOSOPHY

### 2.1. CSL sub-systems

CSL is responsible for the design, fabrication and sub-system level verification of three elements: the main baffle, the optical system and the cover system that are described in §§3, 4 and 5 respectively. CSL elements are then integrated into the Camera Unit under INTA responsibility. Other main sub-systems are the focal plane assembly, the radiators, the thermal and electrical elements (MLI, harnesses...).

### 2.2. Model philosophy

The qualification and acceptance campaign of the OMC is based on four models: the Structural and Thermal Model (STM), the Engineering Model (EM), the Qualification Model (QM) and the Flight Model (FM). The qualification is performed on the STM, EM and QM. Nevertheless, the QM will be used as Flight Spare Model (SFM), so it is required that no qualification levels are applied on the QM sub-elements.

For the OMC sub-elements, CSL has to deliver to INTA STM's of the baffle, the cover and the optical systems, a Development Model (DM) of the cover system fully operational, that will be integrated on the STM spacecraft for tests, an EM of the cover system, QM's of the baffle, the cover and the optical systems and finally FM's of all of them.

Before the acceptance campaign on QM sub-elements described in this paper, qualification tests were already performed on the STM (vibration of the optical system) and on the DM (thermal vacuum, vibration and functional tests of the cover system). Table 2 describes the tests performed at sub-system level at CSL.

	STM	DM	EM	QM/SFM	FM
Optical system	Vib (Q)	Vib (Q)		Funct, Vib, TV (A)	Funct, Vib, TV (A)
Cover system		Vib, TV, Lifetime (Q)		Funct, Vib, TV (A)	Funct, Vib, TV (A)
Main Baffle					Straylight

Funct: functional test

TV: thermal vacuum test

Vib: Vibration test

Q: qualification level

A: acceptance level

**Table 2: Qualification and acceptance summary.**

## 3. OPTICAL SYSTEM DESCRIPTION

### 3.1. Requirements

The optical design is driven by two main parameters: high optical performances and specific environmental conditions. These parameters are summarised in table 3. The optical performances must be met within the operational conditions range while the non-operational environment defines the extreme conditions that shall be withstood without damage. The nominal operational temperature and the very wide temperature ranges result from the thermal design of the instrument. Moreover, the thermal requirements at the interfaces dictate the lens barrel material: titanium alloy.

Encircled energy:	> 70% in a pixel (13x13 $\mu\text{m}$ )
Modulation Transfer Function (MTF):	> 70% at Nyquist Frequency (38.5 c/mm)
Backfocus:	$\approx$ 50 mm
Transmission (@550 nm):	> 70% at the beginning of life > 60% at the end of life

Lens barrel material:	Titanium alloy (Ti-6Al-4V)
Backfocus (part of Focal Plane assembly) material:	INVAR material
Radiation dose:	42 krad over 5 years in case of Ariane V launcher
Nominal conditions :	0°C (in vacuum)
Thermal range (operational conditions):	-20°C to +20°C
Thermal range (non-operational conditions):	-80°C to +45°C
Vibrations (non-operational conditions):	Random: 27 g <sub>RMS</sub> in the range 20 – 2000 Hz

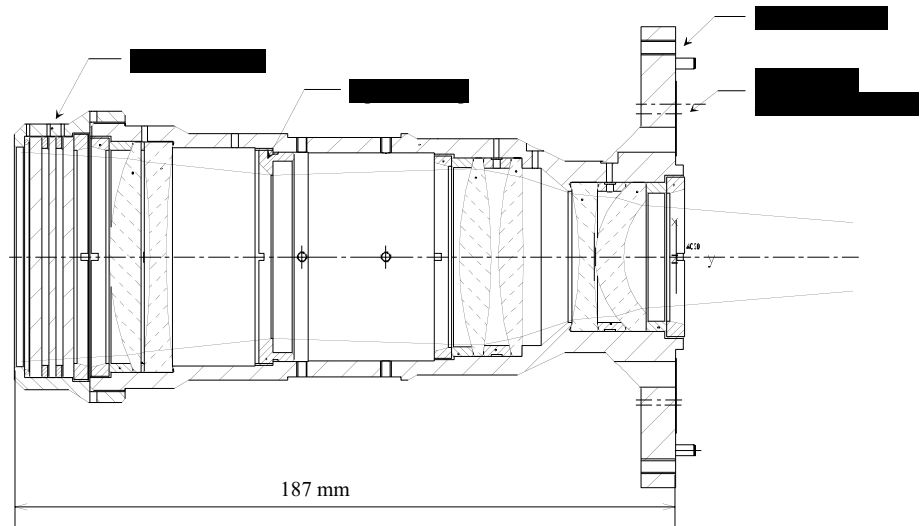
**Table 3: Optical requirements and environmental conditions.**

### 3.2. Optical and mechanical description

Optical design was described in a previous paper [1]. It consists of six radiation-hard lenses (F/3) housed in a titanium barrel (figure 2).

The filter assembly holds two colored filters (Schott BG39 and GG495) defining the useful spectral range. An additional BK7G18 glass plate protects the filters from radiation. The filters and the protective plates are maintained with a retainer and an O-ring.

The titanium material is treated with black chromium.



**Figure 2: Cut-view of the optical system.**

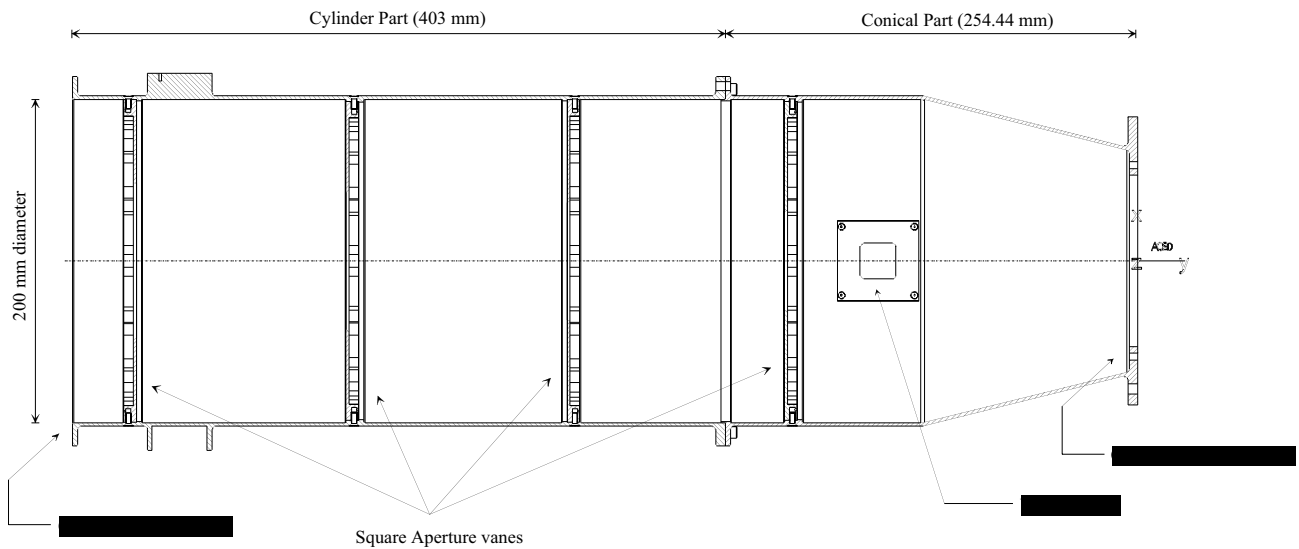
## 4. MAIN BAFFLE DESCRIPTION

### 4.1. Requirements

The main baffle was designed to achieve the high rejection factor required for observation of stars up to visual magnitude of 19.7. The design is described in [2] where its straylight properties were investigated. The main baffle consists of a cylinder and a cone, both made of aluminium and with a mean thickness of 2 mm. On these tubes are added interfaces for the optical system, for the cover system, for the alignment cube, for the mounting legs, for the lifting tool, for the MLI grounding and for the electrical connectors. Inside this tube, 4 square aperture vanes are inserted for straylight purpose. A venting hole is also included in the design to allow depressurization without parasitic light. The entire baffle is black anodised to improve the rejection efficiency.

### 4.2. Manufacturing and testing

The main baffle mechanical design was placed under INTA's responsibility because it is the main structural piece of the OMC instrument, which holds all other sub-systems. Baffling vanes and venting device were defined by CSL. It is planned to perform a straylight rejection test in order to correlate the straylight analysis reported in reference [3]. Because of schedule constraint, this test is delayed until availability of the FM unit.



**Figure 3: Cut view of the OMC main baffle.**

## 5. COVER SYSTEM DESCRIPTION

### 5.1. Requirements

The goal of the cover system is to prevent particles from entering the main baffle. It must be kept closed during integration and launch and opened only once in orbit.

The cover system also includes a forebaffle that protects the cover mechanism and the aperture of the main baffle from direct sunlight. The position of the sun with respect to the instrument is defined in the specifications (minimum 50 arcdeg from the optical axis).

### 5.2. Description

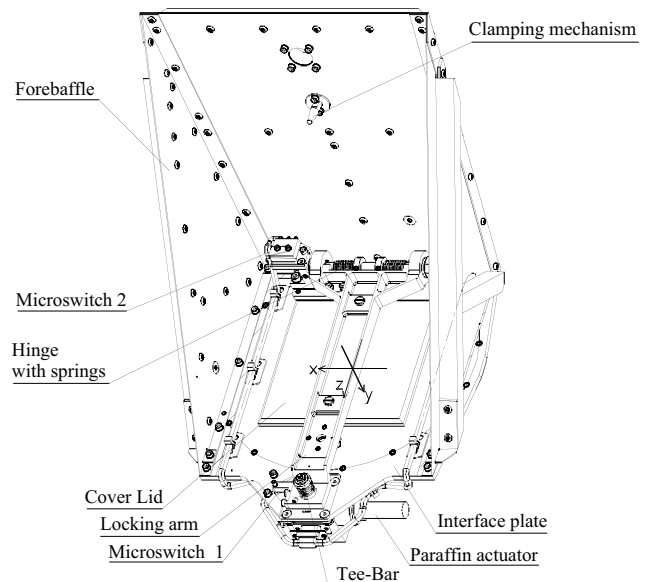
The cover mechanism and the forebaffle are mounted on an interface plate that is also the interface with the main baffle and the first vane of the baffling system. The forebaffle consists in 3 aluminum walls, (1 mm thick), stiffened with U-section aluminum beams.

The mechanism is based on a paraffin actuator provided by Starsys Research Corporation. An internal mechanism maintains a T-shaped bar. This T-bar is mounted on a locking arm that maintains a cover lid on the aperture in the interface plate. The lid is spring-mounted to the arm to provide for intimate contact with the interface plate.

Two torsion springs, mounted around a stainless steel shaft, provide the opening torque. Once the T-bar is released by the paraffin actuator, the springs open the door and maintain it opened. A starlock washer is used as a redundancy to maintain the door in open position. A starlock washer is a washer that can slide in one direction on a rod but not in the other. It is mounted on the locking arm and will be slipped on a clamping rod at the end of the opening.

Two microswitches are included in the design to verify the status of the door. One is located near the paraffin actuator (#1) to check the closed position, the other one (#2) is located near the hinge to check the open position.

The connection of the paraffin actuator and the microswitches to the OMC electronic unit is performed through a 9 socket sub-D connector located under the interface plate.



**Figure 4: Cover system description.**

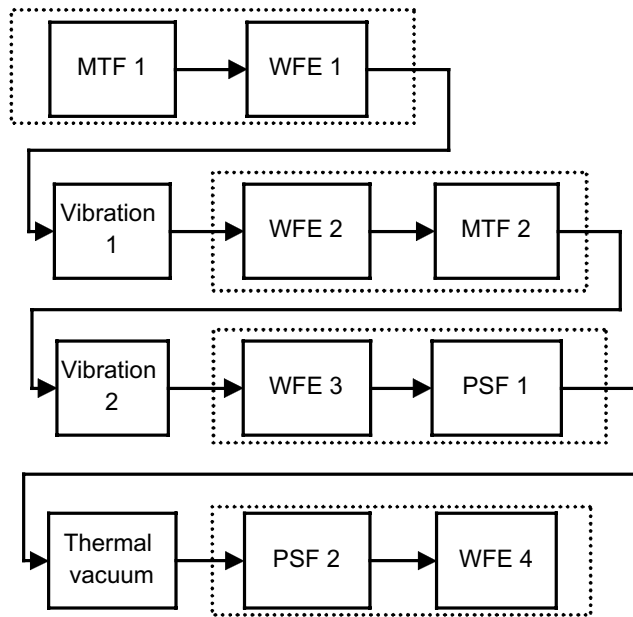
## 6. OPTICAL SYSTEM TESTS

### 6.1. Optical System Test Plan

The goal of the tests on the optical system is to measure the optical performances and verify the degradation due to the high environmental constrains. The test plan was articulated on three main tests: optical tests to verify the optical performances of the optics (i.e. MTF 1 and WFE 1 in Figure 5), vibration tests and thermal vacuum test to verify the optical system behavior to respectively vibration conditions and thermal conditions. This verification plan is sketched in figure 5.

Between each environmental test, the optical system is checked to identify possible damage or misalignments. This check consists in visual inspections, WaveFront Error (WFE) measurements, Modulation Transfer Function (MTF) measurements and Point Spread Function (PSF) measurements. Due to planning constraints, the PSF measurement was performed only after the vibration test and the thermal vacuum test and the MTF measurement only before and after the vibration test.

A second vibration test was performed after that the optical check following the first vibration test showed a degradation of the optical performances (see § 0).



**Figure 5: Acceptance test plan for the optical system (dashed lines represents optical check).**

### 6.2. Vibration tests description

The goal of the vibration test is to verify that the optical performances will not degrade after exposure to launch loads. The levels applied are the acceptance levels defined in tables 4 and 5 along 2 axes (axial and lateral).

Frequency (Hz)	Level
5 - 21	± 7.33 mm
21 - 60	± 13.33 g
60 - 100	± 4 g

Sweep rate: 4 octaves/minute  
1 sweep up

**Table 4: Sine vibration test levels.**

Axis	Frequency (Hz)	Level	Rms Acceleration
Lateral X	20 - 100	+6 dB/octave	18.402 g <sub>rms</sub>
	100 - 2000	0.178 g /Hz	
Axial Y	20 - 100	+6 dB/octave	15.937 g <sub>rms</sub>
	100 - 2000	0.133 g /Hz	

Duration of test: 1 minutes each axis

**Table 5: Random vibration test levels.**

### 6.3. Vibration tests results

From a mechanical point of view, the first vibration test was successful, no visible damage was observed. The eigenfrequencies were close to the ones observed on the STM (620 Hz lateral and 2200 Hz in axial direction), the difference being explained by the slight difference in mass between the two models.

Nevertheless optical verifications showed a degradation both in WFE and MTF (see optical tests). The origin of the problem was investigated. A MTF deterioration due to lenses movement is not possible since the maximum displacement allowable modify too slightly the degradation. A second vibration test was performed to verify that this modification is stable and could be caused by stress release. The result is that the WFE still changed but this time, the quality was improved.

Analysis and optical tests on dummy models lead us to incriminate the stresses caused by the retaining rings. When tightening the rings, the lenses are deformed, this is visible on the WFE. During vibration, micro displacement causes stresses modification and thus optical performances modifications.

It was decided that the optical system is accepted in this configuration since the optical performances remain within specifications and also because the alternative designs investigated imply too large modifications and important costs/risks at this stage of the development.

### 6.4. Thermal vacuum test description

The goal of the thermal vacuum test is to verify that the optical system will survive thermal cycling.

The optical system was mounted on a regulated conductive interface and mounted in the FOCAL 1.5 vacuum chamber at CSL. Radiative thermal panels were surrounding the specimen. All panels were regulated in serial with one nitrogen gas line.

One constraint for this test was that the gradient between the first and last lenses must be lower than 10 degrees. Four cycles were performed. The first one begins with high non-operational temperature (+50°C), after a two-hours stabilization the temperature was decreased to high operational temperature (+25°C). The system was then exposed to low non-operational temperature (-45°C) during 2 hours and to low operational temperature (-25°C). After 2 hours stabilization, the optical system goes through the 3 following cycles between high and low operational temperatures.

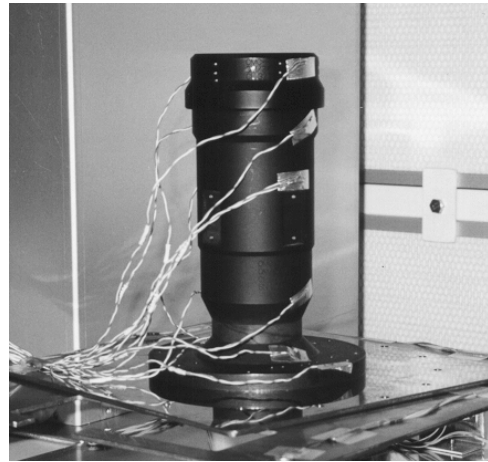


Figure 6: optical system instrumented with thermocouples.

### 6.5. Thermal vacuum test results

Due to the maximum allowable gradient (10°C) the gradient between the conductive panel and the 5 radiative panels had to be as small as possible. As all thermal panels were regulated with only one nitrogen gas line extremely low rates for the temperature slopes were necessary (0.015°/sec) at the expense of the test duration. All thermal cycles were performed nominally (see figure 7). The maximum gradient observed was about 8°C. The cleanliness requirements were also fulfilled.

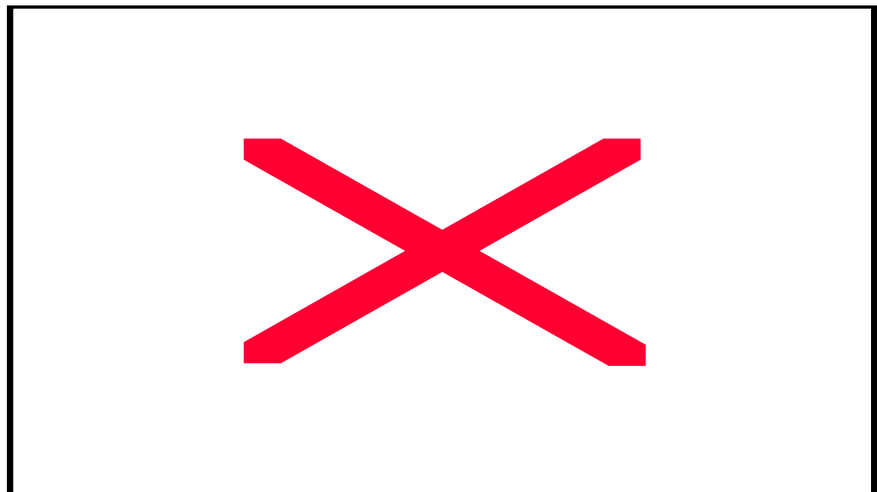


Figure 7: Thermal cycle results.

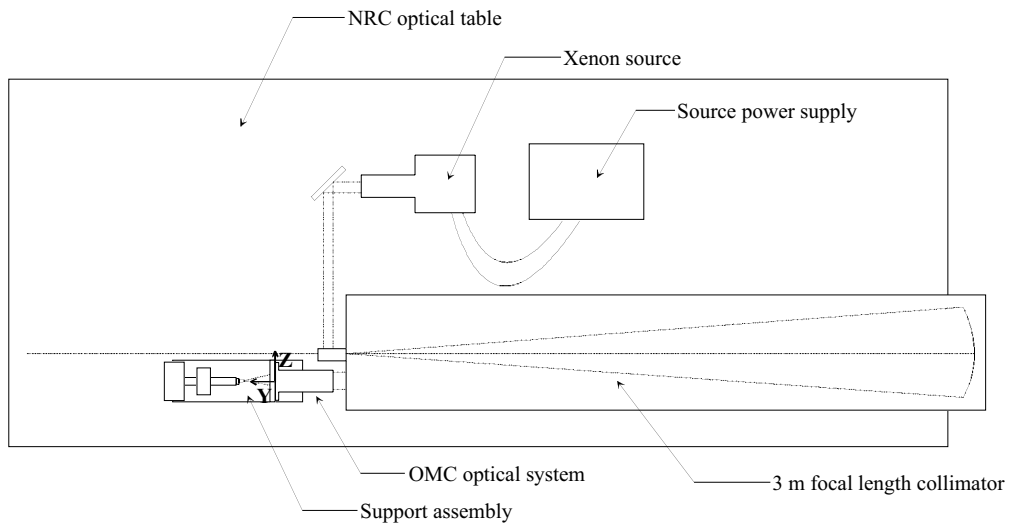
**6.6. Optical tests description**

The optical tests are based on three measurements: a WFE measurement, MTF measurements and PSF measurements. All tests are performed at 20°C assuming no major modification at the nominal temperature (0°C).

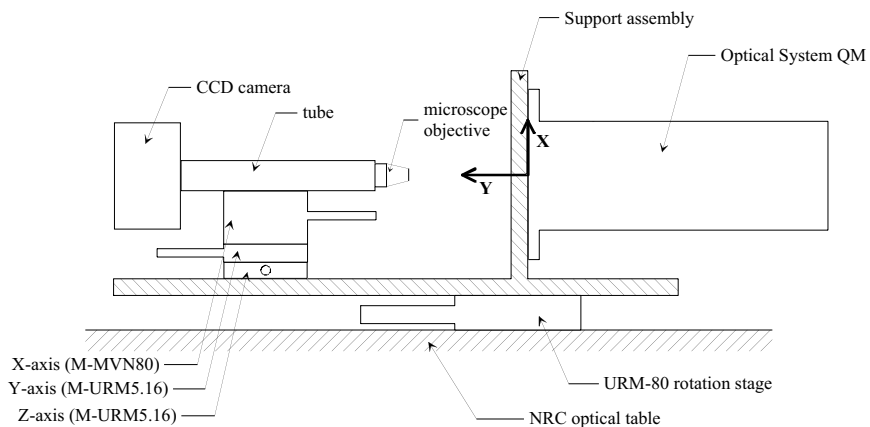
The WFE measurement consists in an on-axis wavefront error measurement at 633 nm of the optical system in a vertical position to limit gravity effects. The WFE measurement is used as a check for possible misalignment during the environmental tests.

The MTF measurement is performed on an ODETTA optical test bench in Delft Sensor Systems facility (Oudenaarde, Belgium).

The PSF measurement consists of acquiring on a CCD camera the PSF of the optical system illuminated by a three meter focal length Newtonian collimator. To compute the encircled energy on the PSF, it is magnified by a x40 microscope objective. A rotation stage allows modifying the field of view on the optical system and three axis translation stages, below the microscope objective assembly, allow focussing this one. Figures 8 and 9 describes the set-up. The optical test bench is located on an optical table protected from straylight by black curtains. A laminar flow, besides the optical system, allows keeping the required cleanliness.



**Figure 8: PSF measurement set-up (not scale).**



**Figure 9: Detailed set-up of the support assembly (not scale).**

**6.7. Optical tests results**

The optical performances were measured during the MTF test (i.e. MTF 1). Table 8 summarizes the MTF results. The optical checks are summarized in the tables 6 and 7.

As mentioned in § 6.3, a variation of the WFE and the MTF was noticed after the vibration test 1, due to lenses deformations under stress. The requirements (i.e. MTF > 70 % at 38.5 c/mm) are always fulfilled and a lens mounting modification is not needed. The PSF measurement results are summarized in figure 10. Small variations were noticed before and after the thermal vacuum test but main of these comes from degradation induced by the microscope objective lens. These degradations vary with the considered field of view since the F/3 light beam coming from the optical system focal plane defines a sub-aperture smaller than the microscope objective aperture. When the microscope objective axis is aligned with the optical system, the sub-aperture is located in the paraxial area of the microscope objective and the degradation is minimized. Otherwise, for another field of view, the microscope objective adds its own aberrations to the PSF. Therefore only the minimum values have to be considered. These minimum values are better than theoretical values and are not modified by the thermal vacuum test.

	Field of view	MTF at 38.5 c/mm
Horizontal direction	(0°, 0°)	78
	(0°, 1°)	73
	(0°, 2°)	79
	(0°, 2.5°)	78
	(0°, -1°)	76
	(0°, -2°)	75
	(0°, -2.5°)	75
Rotated clockwise by 45°	(0°, 0°)	76
	(0°, 1°)	73
	(0°, 2°)	74
	(0°, 2.5°)	76
Rotated counter clockwise by 45°	(0°, 0°)	80
	(0°, 1°)	78
	(0°, 2°)	78
	(0°, 2.5°)	79
Rotated clockwise by 90°	(0°, 0°)	77
	(0°, 1°)	78
	(0°, 2°)	74
	(0°, 2.5°)	75
	(0°, -1°)	77
	(0°, -2°)	76
	(0°, -2.5°)	74

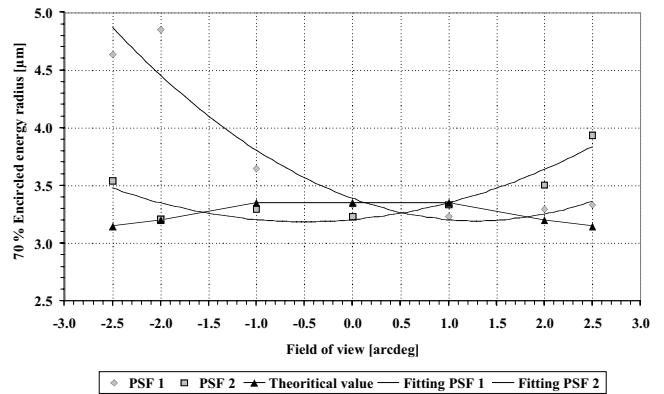
**Table 8: MTF measurement at the Nyquist frequency (38.5 c/mm).**

		MTF at 38.5 c/mm	
Reference	MTF 1	78 %	
Post vibration 1 test	MTF 2	74 %	

**Table 7: MTF check results.**

		WFE RMS [wave]	WFE P-V [wave]
Reference	WFE 1	0.078	0.797
Post vibration 1 test	WFE 2	0.162	0.917
Post vibration 2 test	WFE 3	0.115	0.774
Post thermal test	WFE 4	0.124	0.854

**Table 6: WFE measurement results.**



**Figure 10: 70 % encircled energy radius in the field of view of the optical system.**

**6.8. Optical test conclusions**

The optical tests have demonstrated that the optical system QM fulfills the optical specifications. Although the optical performances vary little with the environmental constraints, the optical performances remain within the specifications. A maximum variation of 4 % of the MTF can be expected.

The PSF measurements are limited by the microscope objective aberrations but reliable values, at the minimum of degradations, are better than theoretical values.



## 7. COVER SYSTEM TESTS

### 7.1. Cover System Test Plan

A test plan was defined for the cover system acceptance. After the initial functional test, vibration tests will be performed according to the specifications. Then a functional test is performed again and followed by the thermal vacuum test. A final functional test is performed after the tests, before packaging.

### 7.2. Functional tests description

The goal of the functional tests is to verify that the cover will open within the required time (less than 300 seconds) after the different environmental condition exposures and during thermal vacuum test at high and low operational temperatures. The two circuits (nominal and redundant) will be verified. In order not to damage the less protected redundant circuit, only current measurement will be performed on this last part.

For functional tests, the cover system will be mounted on a specific support that allows the connection of the cover to the EGSE through the interface connector.

Before opening, the current is measured in the redundant lines. By applying 28 V to the redundant circuit, the measured current is reported. After this, the cover is opened using nominal line. The opening time as well as the microswitches status is reported. A visual inspection is performed and an activation report is filled in.

At the beginning of the campaign, it was decided that all the opening will not lead to a clamping of the arm. For this, the arm was manually stopped during opening. It allow a direct closure of the door without activating the paraffin actuator one more time.

### 7.3. Results of the functional tests

The opening times and the currents are reported in table 9. Are also included the activation performed during thermal vacuum test. All the activations were successful. It can be concluded that the functional acceptance test is successful.

Description	Measured current (mA)	Time to release (sec)	Temperature (°C)
Test after assembly	353	80	Room Temperature
Nominal opening at reception	354	72	RT
Redundant opening at reception	354	70	RT
Nominal opening after vibration	353	90	RT
Redundant current measurement after vibration	354	-	RT
Nominal opening during TV	350	54	40 (vacuum)
Redundant current measurement during TV	352	-	40 (vacuum)
Nominal opening during TV	354	180	-45 (vacuum)
Redundant current measurement during TV	355	-	-45 (vacuum)
Nominal opening during TV	352	180	-45 (vacuum)
Redundant current measurement during TV	356	-	-45 (vacuum)
Nominal opening after TV	352	90	RT
Redundant current measurement after TV	355	-	RT

**Table 9: Functional tests results.**

### 7.4. Vibration test description

The goal of the vibration is to apply to the cover system the vibration loads that the instrument will be exposed to during launch. The levels applied are the acceptance level which margin of safety are lower that the ones applied for qualification test.

The cover system was shaken along its three reference axes with the levels described in the tables 10 and 11.

Frequency (Hz)	Level
5- 21	± 7.33 mm
21 - 60	± 13.33 g
60 - 100	± 4 g

Sweep rate: 4 octaves/minute  
1 sweep up

**Table 10: Sine vibration test levels.**

Axis	Frequency (Hz)	Level	Rms Acceleration
Lateral Z	20 - 100	+6 dB/octave	13.14 g <sub>rms</sub>
	100 - 2000	0.089 g /Hz	
Lateral X	20 - 100	+6 dB/octave	21.518 g <sub>rms</sub>
	100 - 334	0.178 g /Hz	
	334 - 440	+12 dB/octave	
	440 - 650	0.533 g /Hz	
	650 - 856	-12 dB/octave	
856 - 2000	0.178 g /Hz		
Axial Y	20 - 100	+6 dB/octave	16.09g <sub>rms</sub>
	100 - 2000	0.133 g /Hz	

Duration of test: 1 minutes each axis

**Table 11: Random vibration test levels.**

### 7.5. Vibration tests results

The system was shaken in CSL premises in class 1000 conditions. The required levels were respected without notching and the main structure survived to the test. The eigenfrequencies observed were more or less identical to the ones observed during STM-DM campaign except for the locking arm which design was modified for QM and for the paraffin actuator interface which is in close contact with the locking arm (see Table 12).

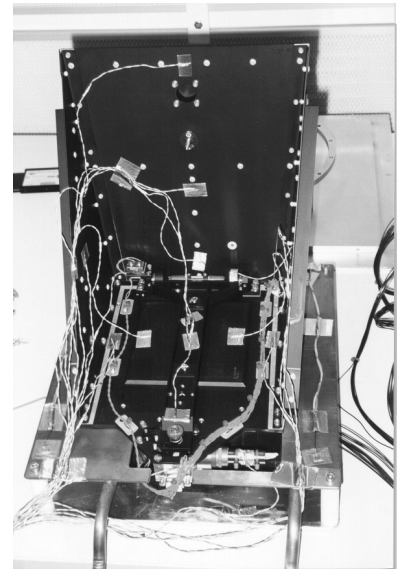
Axis	Location	Eigenfrequencies	
		DM	QM
X	Forebaffle	285 Hz	285 Hz
	Locking arm	600 Hz	400 Hz
	Actuator I/F	850 Hz	790 Hz
Y	Forebaffle	Not recorded	1700 Hz
	Locking arm	620 Hz	450 Hz
	Actuator I/F	550 Hz	450 Hz
Z	Forebaffle	230 Hz	230 Hz
	Locking arm	1000 Hz	1000 Hz
	Actuator I/F	550 Hz	400 Hz

**Table 12: Cover system eigenfrequencies**

Nevertheless, two discrepancies were observed. One screw of the internal connector was found loosened after vibration test. This has no impact on the connection since the second one was still in correct position. In fact, this screw was not glued and it was decided to glue it before going on with the test plan. This screw will be glued also on the FM. The second discrepancy was more important: the microswitch 1 (that verifies the closed position) was no longer activated. This was due to a bad positioning of the lever screw. No sufficient margin were taken and slight displacement of the locking arm lead to the fact that the pressure was released on the microswitch. By correcting this problem, it was also pointed out that the microswitches mounting was wrong and that it decrease the operating range of the microswitch lever. This will be corrected for the FM. Nevertheless, the vibration test was considered successful and no additional test will be performed on the QM.

### 7.6. Thermal vacuum test description

The goal of the thermal vacuum test is to verify that the cover system could operate at low and high operational temperature under vacuum and that it can survive to non-operational temperatures and cycling. The setup was identical to the one of the optical system. Once again, only one line was allowable on the facility. As a result, the test was longer than predicted. Four cycles were performed. The first one begins with high operational temperature (+40°C) (equivalent to high non-operational temperature in this case), after a two-hours stabilization, the door was opened. The vacuum chamber was then brought back to air to allow the manual resetting of the mechanism. The system was then exposed to low non-operational temperature (-95°C) during 2 hours and to low operational temperature (-45°C). After 2 hours stabilization, a functional test was performed again. After a new opening of the vacuum chamber for resetting, the cover system goes through the 3 following cycles between high and low operational temperatures and after the last stabilization at -45°C, a functional test was performed again.



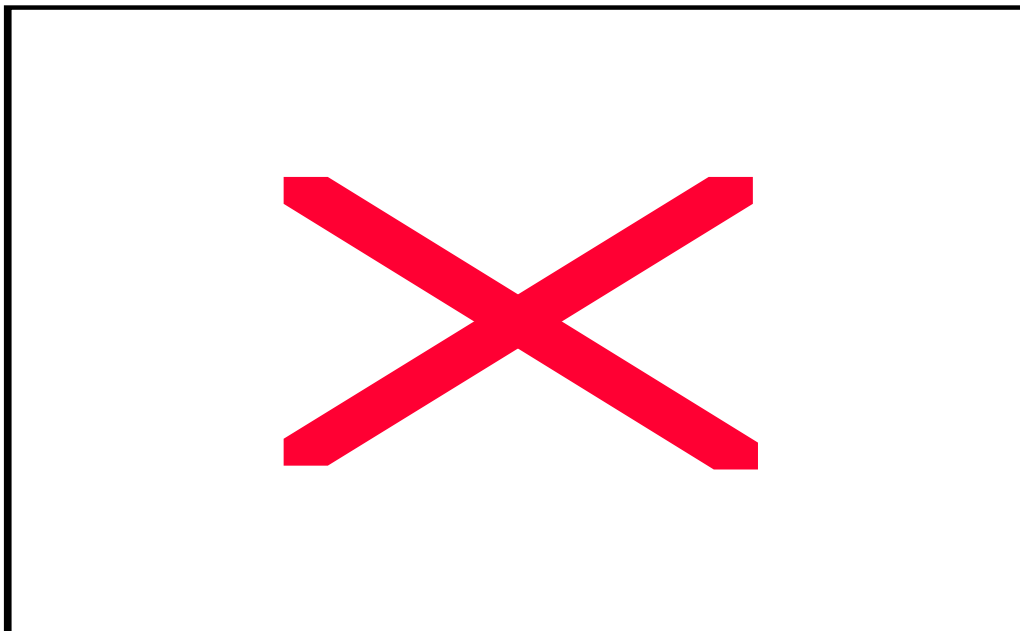
**Figure 11: Cover system instrumented with thermocouples.**

### 7.7. Thermal vacuum test results

The thermal vacuum test was performed without problem from a thermal and vacuum point of view. All the functional tests were successful (as described in table 9). Figure 12 summarized the thermal behavior of the cover system. The temperature setpoint and the temperature at 3 points of the cover system are indicated (interface plate, forebaffle and paraffin cell) as well as the pressure in the vacuum chamber.

It can be noted that the thermocouple located on the paraffin cell recorded all the activation of the paraffin actuator. Points 1, 3 and 5 are the openings. In the hot case, the temperature raised to 60°C while in cold case, the temperature was only 30°C on the cell. The points 2 and 4 correspond to the resetting of the cover that is always performed at ambient pressure.

The only discrepancy concerns the particulate cleanliness that was measured beyond specification. The value given by PFO witness is 75 ppm obscuration during the test period (22.5 ppm/24hrs) that is worse than the expected class 1000 (12 ppm/24hrs). This was probably due to the air movement during pressure recovery. The cover system was cleaned after the test. The molecular contamination was well within the specifications (lower than  $0.2 \cdot 10^{-7} \text{ g/cm}^2$ ).



**Figure 12: Thermal cycling result.**

### 7.8. Conclusion of the cover system acceptance tests

As a general conclusion, the cover system QM acceptance campaign was successful. The specimen shows its ability to operate after vibrations, under extreme temperature conditions and after thermal cycling. These tests also point out some discrepancies that will be solved for the FM unit.

The FM will be manufactured identically and will take advantage of the experience of its predecessor. The QM will be packed and sent to INTA to be integrated into the camera unit and will go through the unit tests at qualification level.

## 8. CONCLUSIONS

As a general conclusion, the acceptance of all OMC QM sub-systems was considered successful. The QM campaign has highlighted a few discrepancies that will be corrected for the FM units.

This test campaign will be very important in the preparation of the FM test campaign, the procedures will be adapted taking into account the observations and remarks of the QM tests. They concerns mainly the schedule preparation, we have now a good idea of the duration of the different phases and the cleanliness control, a better follow-up of the contamination. All GSE used for the QM will be used again for the FM along with proven procedures.

## 9. ACKNOWLEDGMENT

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## 10. REFERENCES

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## 11. APPENDIX

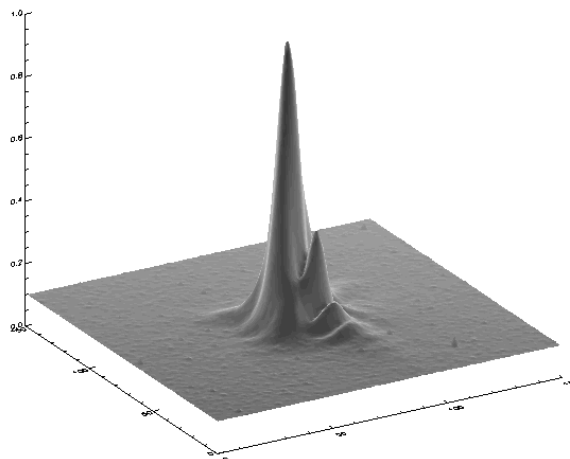


Figure 13: Example of PSF of the optical system