Micro Laser Beam Scanner PROJECT

ESTEC contract n°4000103902/11/NL/CP

Executive Summary Phase 1

ESA STUDY CONTRACT REPORT - SPECIMEN			
ESA Contract No	SUBJECT MICRO LASER BEAM SCANNER		CONTRACTOR Sercalo Microtechnology ltd. EPFL CSEM ETHZ
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ABSTRACT:

Future space missions will make use of rovers. Rovers travelling on a planetary surface need optical sensors providing the 2D image and distance information, so called 3D vision systems or 3D imagers. There are active and passive 3D vision systems. While passive 3D vision systems are often stereo cameras (NASA's Mars Explorer). which can provide video rate range images over significant fields of view, but have limited range resolution over large measurement ranges and their performance is dependent on the environment illumination and target contrast.

In contrary, active 3D vision systems, for instance a laser beam scanning the scene, use time-of-flight techniques to determine the range and provide the third dimension and are also called imaging LIDARs. Superior 3D mapping performances are expected.

The scanning mechanism needs to be light, compact and extremely robust for planetary missions. Micro-system technology is an excellent solution to this challenging problem.

Objective of this contract is the development, manufacturing and testing of a prototype micro laser beam scanner for future planetary exploration 3D-vision systems. This scanner consists of a electrostatic driven MEMS mirror, is operated in analog mode not in resonant mode and can be switched between pointing and scanning operation. The performance verifications and tests will be performed in phase 2 in relevant environment. Two identical prototypes having successfully passed all tests will be delivered at the end of the activity. The requirements for this tests are driven by the application of rover navigation in future planetary exploration missions on Mars.

The work described in this report was done under ESA Contract. Responsibility for the contents resides in the author or organization that prepared it.

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Introduction

The objective of this activity is the development, manufacturing and testing of a prototype micro laser beam scanner for future planetary exploration 3D-vision systems. The performance verifications and tests shall be performed in relevant environment and will be done in Phase 2. Two identical prototypes (one spare), having successfully passed all tests shall be delivered at the end of the activity. The requirements for this activity are driven by the application of rover navigation in future planetary exploration missions on Mars. Statement of Work Issue: 1 Micro Laser Beam Scanner Date: 02.08.2010 ESA UNCLASSIFIED – Releasable to the Public Page 6/24

The function of the micro laser beam scanner is to scan the input laser beam in two angular directions and is composed at least of a scanning mirror mechanism, an optical fiber input connector, beam shaping optics and if necessary angular beam position sensor(s). The laser beam shall be fed to the scanner via an optical fibre. The development of the laser source is not part of this activity.

The navigation and hazards avoidance operations of a rover can be split in different operational modes. The requirements for the different modes depend on the objectives of the 3D vision system during the different navigation and hazard avoidance tasks. At *regional navigation mode* the 3D vision system can support the long term planning (identification of final travelling target) by acquiring large and still panoramic images of the rover surrounding terrain. The *mid range navigation mode* (from 4 up to 10 m) provides motionless images of the terrain in front of the rover and it is the primary means for the navigation planning. For immediate hazard avoidance or for detailed analysis of targets the *local navigation mode* (from rover up to 4m) is implemented. It is assumed that the 3D-vision system is mounted around 1.5 m above ground on a pan-tilt mechanism to cover the whole field of view under all operational modes. One functional micro laser beam scanner is therefore required to fulfil all navigational tasks. The following figure represents a drawing of the rover showing the vertical angular definitions for the different navigation modes. The field of regard which has to be covered by the scanner unit is 22° horizontally and 22° vertically, while the Pan-Tilt mechanism for larger field of regards, is not part of this project.

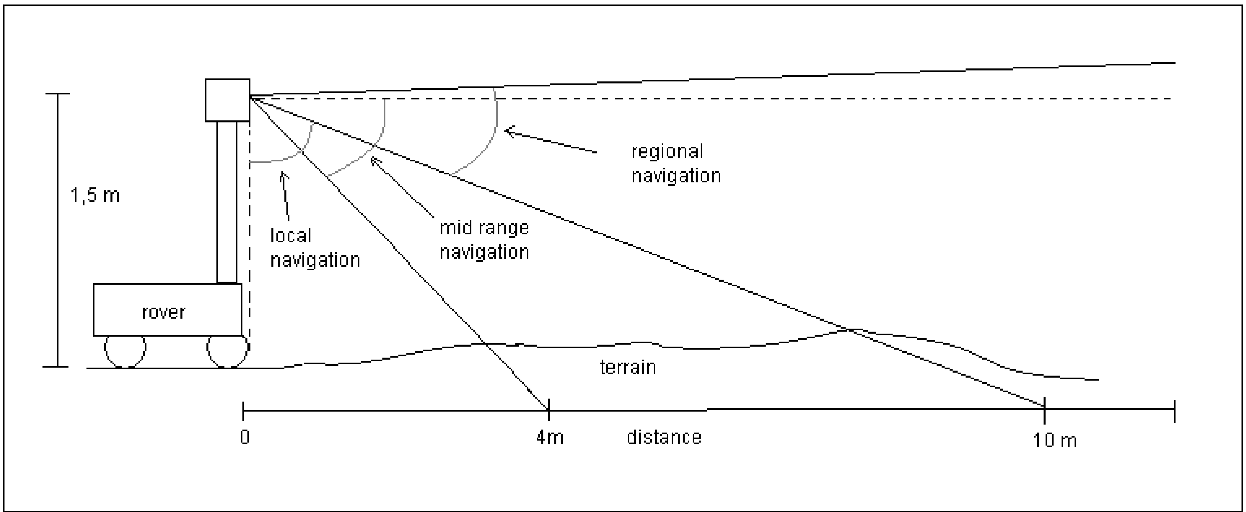


Figure 1: Mounting position and different navigation modes of the scanner unit

Scanner Layout and Function

With this scanner a field of regard of 22° horizontal and 22° vertical shall be scanned in 1 second with a coverage of 90% of the scene. The laser beam divergence should be better than 0.5°.

The scanner consists of the following main parts:

- MEMS Mirror
- Laser Collimator
- Mechanical Scanner Mount
- Driver Electronics

The main development under this activity is the MEMS scanning mirror. It is a electrostatic vertical comb drive actuated mirror. With this design, touching surfaces are avoided as well as snap in effects. In Ansys we could demonstrate that the stress level in the critical regions of the chip are fare below the critical value of 2GPa for all asked environmental test scenarios.

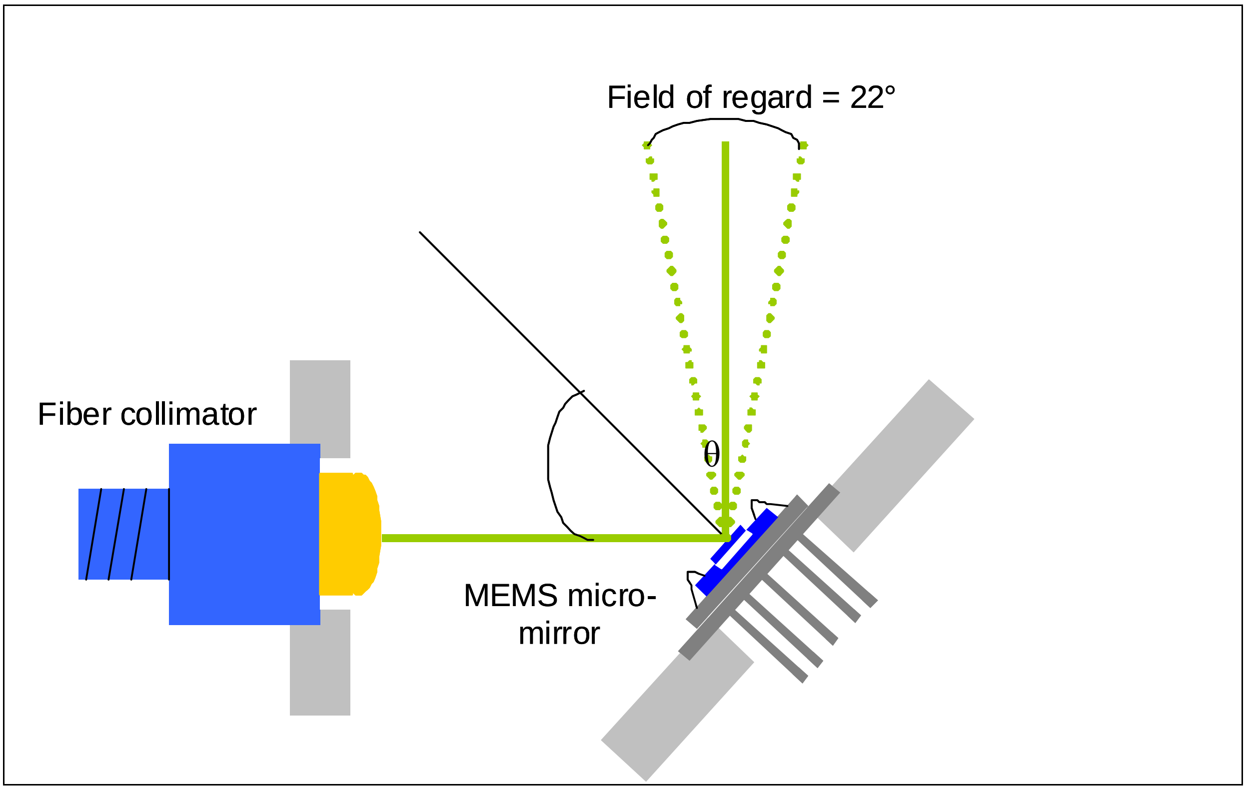


Figure 2: Schematic Layout of the scanner unit.

A prototype, depicted in Figure 3 was manufactured during phase 1 for performance verification and fabrication process development.

Figure 3: Hermetic packaged MEMS mirror

In order to collimate the fiber exiting laser beam, a commercial available fiber collimator with FC/PC connector will be used represented in Figure 4.

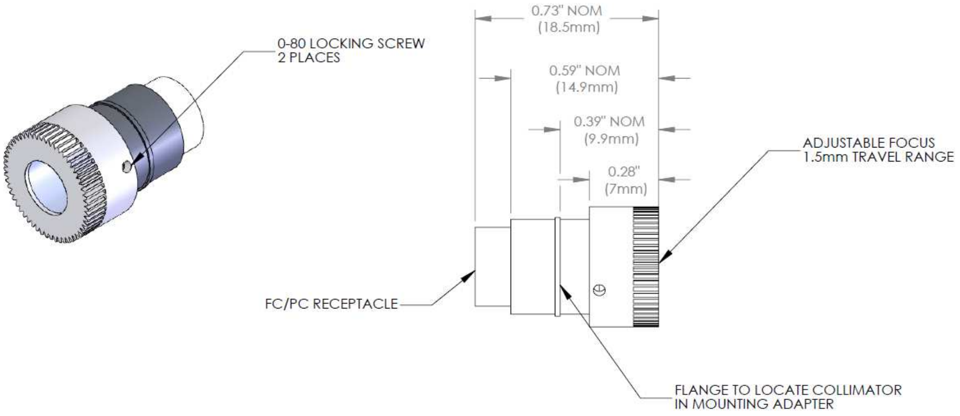


Figure 4: Used commercial available fiber collimator.

This collimator will be mounted together with the hermetic packaged MEMS on a mechanical mount.

For driving the mirror a max. DC Voltage of 100V is necessary. The electronics unit will generate out of the available voltages on the rover, the necessary high voltage in the Local Power Generator depicted in the schematics of Figure 5. Scanning commands from the rover are sent to the on board microprocessor which drives than the mirror according to the stored voltage-angle lookup table over the DAC´s and Voltage amplifiers. A second main function of the electronics board is the sensing of the end positions of the micro mirror. This enables a function check of the MEMS device as well as a sync of the driver signal and the deflection of the mirror. This feature is realized by sensing the capacity change in the comb drives during the actuation. This mirror will be analogue actuated and is also capable of static pointing for increasing the signal to noise ratio.

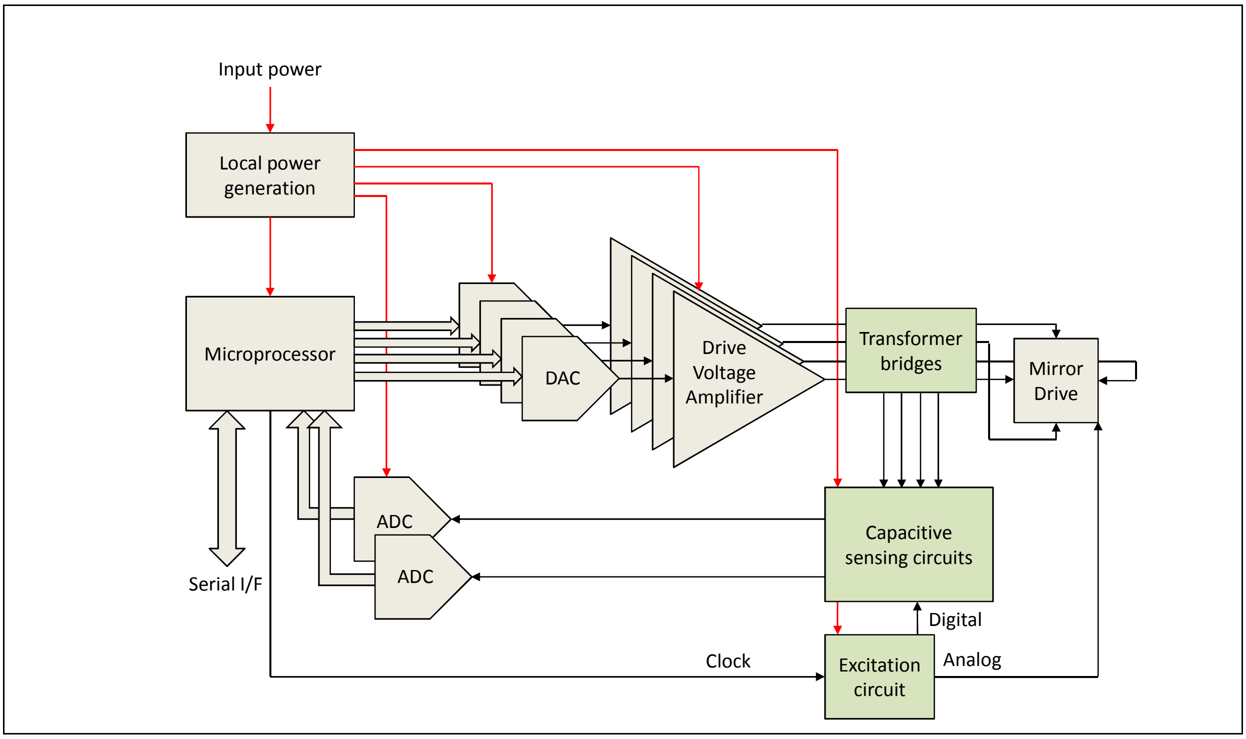


Figure 5: Schematic of the driver/sensing electronics.

A prototype board was fabricated during phase1 for performance and function verification.

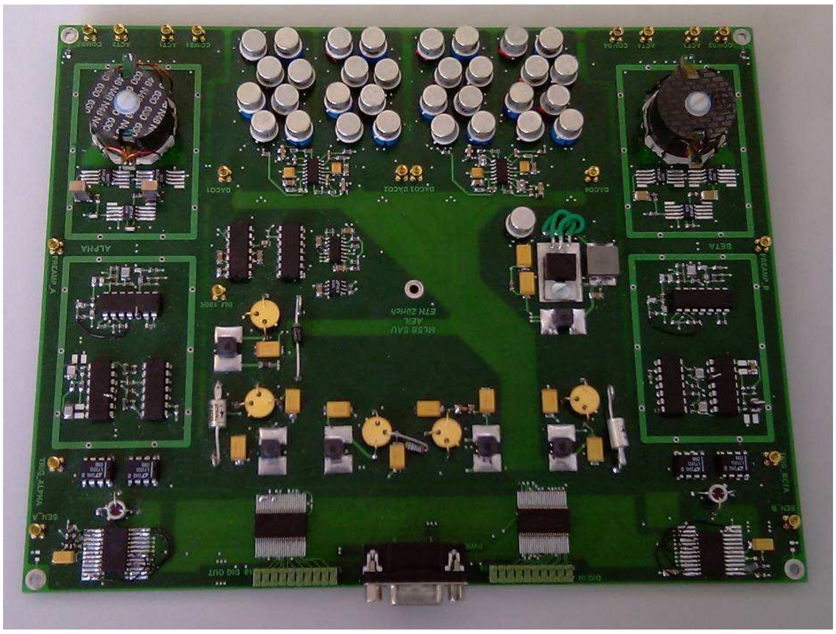
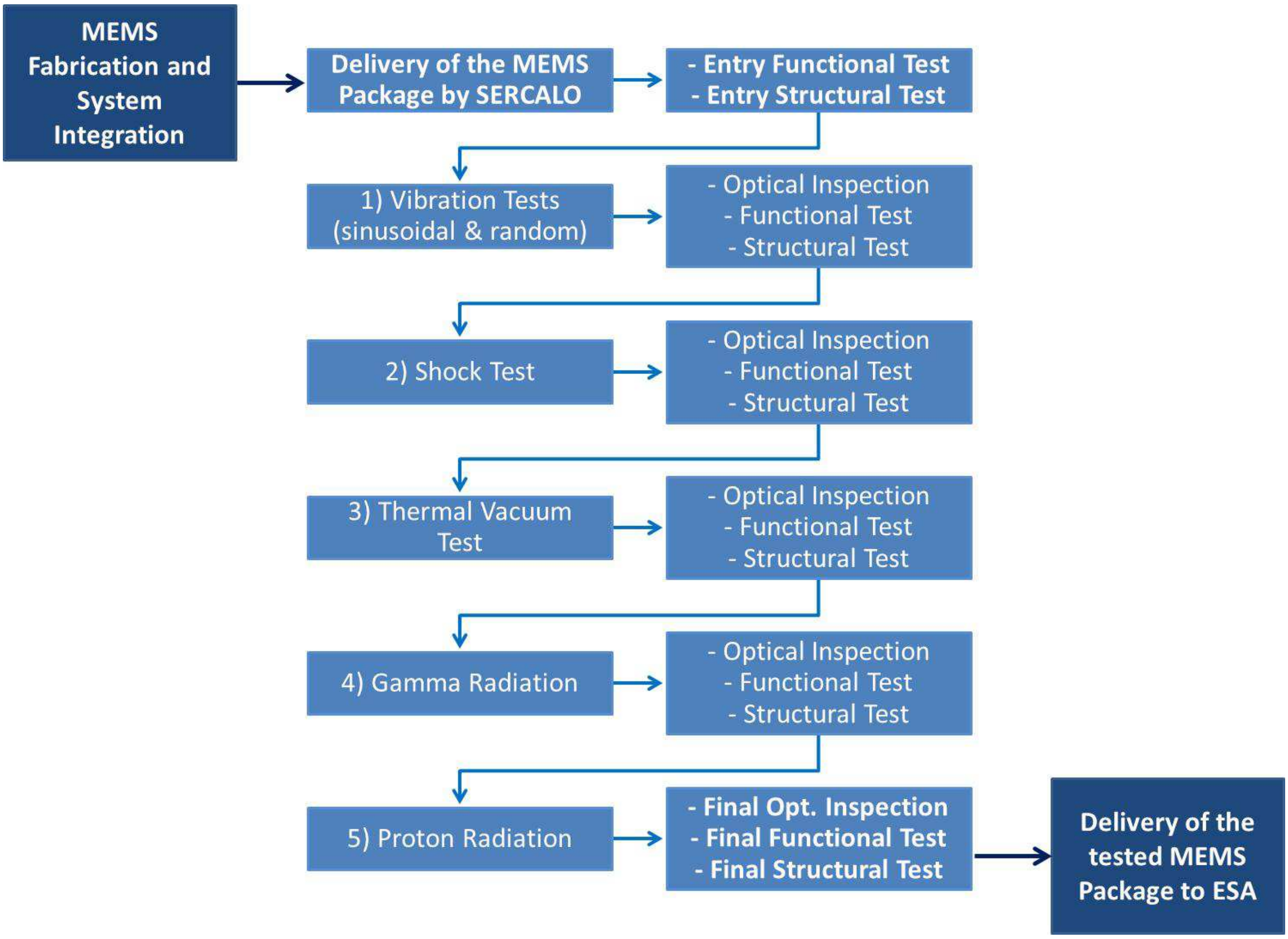


Figure 6: Verification electronics (FPGA is on external board)

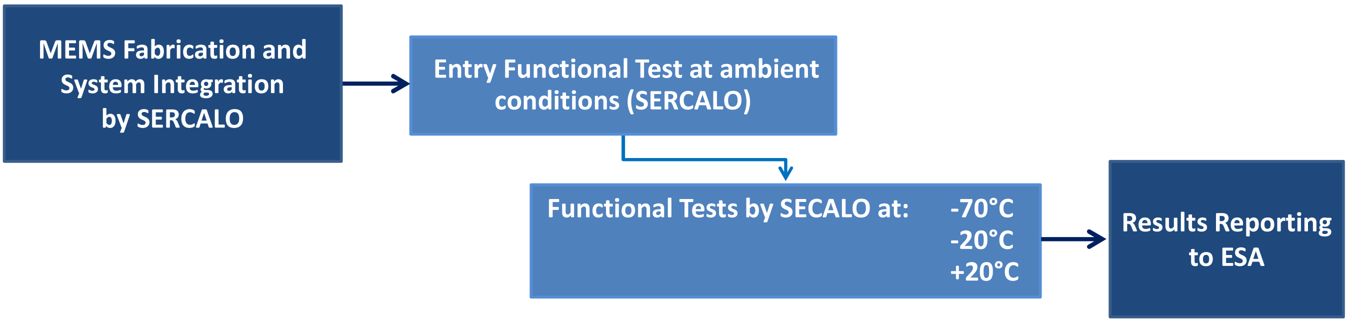
Performance and verification Tests

The design and fabrication phase of the micro laser beam scanner (MLBS) will be followed by a test phase showing the robustness of the MLBS against harsh environments as observed for space applications. Before performing the individual tests, functional testing and structural testing will be performed. Vibration, thermal vacuum and radiation tests will be carried out according to ESA's requirements. These environmental tests are followed by functional and structural testing. The device stability and aging behaviour will be discussed. During the final environmental tests, all tests have been to be performed in line. Our proposed sequence is represented in Scheme 1.



Scheme 1 : Test matrix for the final environmental tests on the MLBS.

In addition, functional testing at various and well defined temperatures have to be performed. After discussion and agreement by ESA, these functional tests will be done at normal pressure. Relevant functional tests of the scanner unit will be performed at temperatures of -70 ℃, -25 ℃ and 20 ℃ under ambient pressure. The tests will be performed by SERCALO:



Device sampling:
According to the qualification test philoshopy of ECSS-E-10-03A no fixed number of test specimen (Qualification Models) is required. The ESCC Basic Specification No. 22900 specifying the total dose steady-state irradiation test method a minimum number of 11 samples is required for radiation qualification testing.

Therefore it is planned to start the test campaign with a total number of 11 specimen of which one shall be designated an “untested control”. In case the number of devices available for the test campaign is below 11, a lower number of devices will be tested and the test plan shall be adapted accordingly.

Results of Phase 1

Phase 1 ends with the Critical Design review. Never the less prototypes were manufactured to demonstrate the technology readiness and the performance of the Micro Scanner.

We could show that we can fulfil the required specifications with a few exceptions. Please find the summary of our results during Phase 1 in the table below.

Requirement object	Required specification	Compliant AIR	Comment AIR	Compliant OIL	Comment OIL	Performance verification
Functional						
Func4 Laser Beam Divergence	0.5° horizontal 0.5° vertical	C	0.3° with suggested optics (aspheric)	C	0.3° with suggested optics (aspheric)	Measuring Spot Diamter
Func5 Laser Wavelength	1550nm	C	For DEMO Red Laser Light	C	For DEMO Red Laser Light	-
Func6 Mirror Dimension	>= 1mmx0.7mm	C	D=1mm	C	D=1mm	Design
Func7 Mass of MLBS	<=60g	C	< 60 g for both mechanical mount options	NC	<100g additional insulator and heater necessary	Measure
Func8 Volume SU	<=12 cm^3	C	<12 cm^3 for both mechanical mount options	NC	<43 cm^3 due insulator	Measure
Func9 Volume EU		C	Current estimations: 250 mm x 200 mm x 35 mm (not including 4 mounting feet)	C		Measure

Requirement object	Required specification	Compliant AIR	Comment AIR	Compliant OIL	Comment OIL	Performance verification
Performance						
Perf2 Field of Regard	22° horizontal 22° vertical	C	With 120V actuation Voltage	C	With 60V actuation Voltage	Measure
Perf3 Scene coverage	>90%	C	With a beam divergence of 0.3° 73Hz for fast axis and 1Hz for slow axis	C	With a beam divergence of 0.3° 73Hz for fast axis and 1Hz for slow axis	Combination of Spot diameter and scan point list
Perf4 Scan time ts for the whole FoR	$FoR/\alpha^2*10\mu s<ts<1s$	C	1 s	C	1s	Design and Lookup table
Perf5 Mirror scan speed variation	<5%	C	As discussed with ESA, this requirement is only applicable in the centre of the scan scene		Same as Air	Design
Perf6 Life-time	>2 years operational >4 years non operational	C	Hermetic TO5 Package	C	Hermetic TO5 Package	
Perf7 Mirror flatness	<λ/10	C	0.155µm over R=500µm mirror --> ROC>0.806m	C	0.155µm over R=500µm mirror --> ROC>0.806m	Wyko Measurement
Perf8 Maximum wavefront error of the scanner optics	<λ/3	C	< λ/4 (reported in TN3)	C	< λ/4 (reported in TN3)	Design

Perf9 Resonance frequency	>160 Hz	C	>300 Hz	C	>300 Hz	Measure
Perf10 Peak power consumption	<=5W	C		NC	<14W, because of additional heater power (8.5W)	Measure in Phase 2
Perf11 Average power consumption standby	<=1W	C	ADC and DAC in sleep mode, microprocessor in idle mode	C	ADC and DAC in sleep mode, microprocessor in idle mode, no heating	Measure in Phase 2
Perf12 Optical pointing stability	@ any angle within FoR, during 10seconds: ± 4mrad threshold ± 0.2mrad (goal)	C	Our mirror is not driven in resonance → static pointing possible. 12bit resolution of the electronics = 0.023mrad. No charging effects seen in pre tests--> no drift source.	C	Same like Air Version	Measure
Perf13 Angular position knowledge accuracy of the optical beam	±0.025°	C		C		Measure (Lookup table)
Perf14 Cross coupling between scan angle axis	Shall be <0.25° for entire FoR	C	Independent axes due to design of vertical comb drive	C	Same like Air Version	Line scan performed and reported in TN4

Requirement object	Required specification	Compliant AIR	Comment AIR	Compliant OIL	Comment OIL	Performance verification
Interface						
Intf1 Laser beam input	FC/APC or FC/PC	C	FC/PC	C	FC/PC	Design
Intf2 Power supply	3V, 5V, 15V, 28V	PC	Required voltages are +3.3V, +/-15V, +/-7.5V	PC	Required voltages are +3.3V, +/-15V, +/-7.5V, 28V	Design

Requirement object	Required specification	Compliant AIR	Comment AIR	Compliant OIL	Comment	Performance verification
Environmental						
Env1 Temp operational SU	-70°C to +20°C	C	Possible different Lookup tables necessary for different temperatures	C	Heater will keep MEMS at const. temp.. Only one Lookup table needed	Measure
Env2 Non operational Temp. SU	-130°C to +70°C	C		C	With Heater turned off, volume change compensation of oil, will be done by flexible tube	Measure of radius of curvature of mirror before and after -130°C treatment
Env3 Temp operational EU	-20°C to +40°C	C		C		
Env4 Non operational Temp. EU	-20°C to +70°C	C		C		
Env5 Pressure	1mbar to 1.2bar	C	Hermetic package	C	Hermetic package	