



MAORY LGS WFS MAIT Plan

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1. INTRODUCTION

1.1 Scope

This document describes the Manufacturing, Assembly, Integration and Test plan of the sub-system LGSWFS of the Multi-conjugate Adaptive Optics RelaY (MAORY) which is one of the first light instruments of the European Extremely Large Telescope (ELT).

The MAORY instrument is designed and developed by a European consortium composed by INAF (Istituto Nazionale di AstroFisica, Italy), CNRS/INSU (Centre National de la Recherche Scientifique/ Institut National des Sciences de l'Univers, France), NUIG (National University of Ireland Galway, Ireland) and ESO (European Southern Observatory, Europe).

The AIT of the overall instrument will take place at INAF-Bologna (Italy), and this document covers:

- Organizational and management aspects related to the sub-system LGSWFS AIT
- Basic logistic aspects of the AIT at sub-system level
- The sub-system LGSWFS MAIT procedure
- Packing, shipping procedure and unpacking in the Bologna integration hall

The MAIT is described at sub-system level, the verification of the sub-system functionalities has been agreed with the system group and has the purpose to verify all the sub-system requirements.

1.2 Definitions, Acronyms and Abbreviations

AD	Applicable Document
ADP	Acceptance Data Package
AO	Adaptive Optics
AIT	Assembly Integration Test
AIV	Assembly Integration Verification
BoM	Bill of Materials
CBS	Cost Breakdown Structure
CMP	Configuration Management Plan
Col	Co-Investigator
CV	Curriculum Vitae
CNRS	Centre National de la Recherche Scientifique
ELT	European Extremely Large Telescope
EFC	Executive Funding Committee



ESO	European Southern Observatory
DM	Deformable Mirror
DRD	Document Requirements Definition
FDR	Final Design Review
FoV	Field of View
FTE	Full Time Equivalent
GTO	Guaranteed Time Observing allocation
HW	Hardware
ICDR	Instrument Critical Design Review
IECR	Instrument End of Commissioning Review
INAF	Istituto Nazionale di AstroFisica
INS	Instrumentation Software
INSU	Institut National des Sciences de l'Univers
IORR	Instrument Operations Readiness Review
IPAG	Institut de Planétologie et d'Astrophysique de Grenoble
IPDR	Instrument Preliminary Design Review
ISQR	Instrument System Qualification Review
ISRR	Instrument System Requirements Review
KO	Kick Off
LGS	Laser Guide Stars
LOR	Low Order and Reference
MAD	Multi conjugate Adaptive optics Demonstrator
MAIT	Manufacturing Assembly Integration and Test
MLA	Micro Lens Array
MAORY	Multi Conjugate Adaptive Optics Relay for ELT
MCAO	Multi Conjugate Adaptive Optics
MICADO	Multi-AO Imaging Camera for Deep Observations
MoU	Memorandum of Understanding
MRB	Material Review Board
MSQR	MAORY System Qualification Review
MTA	Milestone Trend Analysis
N/A	Not Applicable
NCR	Non Conformity Report



NGS	Natural Guide Star
NUIG	School of Physics at the National University of Ireland Galway
OAA	Osservatorio Astrofisico di Arcetri
OAAB	Osservatorio Astronomico d' Abruzzo
OAB	Osservatorio Astronomico di Brera
OACN	Osservatorio Astronomico di Capodimonte
OAPD	Osservatorio Astronomico di Padova
OAS	Osservatorio di Astrofisica e Scienza dello Spazio di Bologna
PA	Product Assurance
PAC	Preliminary Acceptance Review in Chile
PAE	Preliminary Acceptance Europe
PAP	Product Assurance Plan
PDM	Product Data Management
PDR	Preliminary Design Review
PI	Principal Investigator
PM	Project Manager
PMP	Project Management Plan
PSF	Point Spread Function
PT	Product Tree
QE	Quantum Efficiency
RAMS	Reliability, Availability, Maintainability and Safety
RD	Reference Document
RMS	Root Mean Square
RON	Read Out Noise
RTC	Real-Time Computer
SAT	System Architect Team
SCAO	Single-conjugate Adaptive Optics
SEq	Support Equipment
SET	System Engineering Team
SOW	Statement of Work
SQR	System Qualification Review
SR	Strehl Ratio
SRR	System Requirements Review



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SW	Software
TAT	Technical Advisor Team
TBC	To Be Confirmed
TBD	To Be Defined
TBH	To Be Hired
TBW	To Be Written
TCS	Telescope Control Software
TRA	Technology Readiness Assessment
TRL	Technology Readiness Level
TRR	Test Readiness Review
TTF	Tip Tilt & Focus
VCD	Verification Control Document
VLT	Very Large Telescope
WBS	Work Breakdown Structure
WFS	Wavefront Sensor
WP	Work Package



2. RELATED DOCUMENTS

2.1 Applicable Documents

The following applicable documents form a part of the present document to the extent specified herein.

AD1	MAORY (E-ELT MCAO) Technical Specification 254311 Version 1	ESO-
AD2	Common Requirements for ELT Instruments ESO-254547 Version 2	
AD3	Common ICD between the ELT Nasmyth Instruments and the Rest of the ELT System ESO-253082 Version 4	ESO-
AD4	LGSWFS Module Technical Specifications E-MAO-PL0-INA-SPE-002 Version 1D7	
AD5	MAORY Calibration Units User Requirements E-MAO-000-ESO-TNO-002 Version 2D4	
AD6	ICD between the WFS Cameras and the ELT Instruments ESO-302894 Version 2	
AD7	E-ELT Environmental Conditions ESO-191766	
AD8	LGSWFS Analyse Report E-MAO-PL0-IPA-ANR-013 Version 1	

2.2 Reference Documents

The following documents, of the exact version shown herein, are listed as background references only. They are not to be construed as a binding complement to the present document.

RD1	ESO PDM Document Types and Definitions Number ESO-231062 Version 1	
RD2	Systems Engineering General Requirements ECSS-EST-10C Version 3	
RD3	MAORY Management Plan MAO-000-INA-PLA-001_01 Version 1	E-
RD4	MAORY System Overview E-MAO-000-INA-DER-001 Version 1 Draft 1	
RD5	LGSWFS Design report E-MAO-PL0-IPA-DER-012 Version 1 Draft 13	



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RD6 LGSWFS Interface Control Document
E-MAO-PL0-IPA-ICD-014 Version 1 Draft 3



3. SUB-SYSTEM AN OVERVIEW

LGSWFS is a sub-system of MAORY instrument. It is composed by a mechanical structure (LGSWFS structure and translation) to allow a focus translation along the Z axis, and XY translation to align the assembly. A derotator mechanism with onboard the six LGSWFS. Each LGSWFS is composed by a pickup steering mirror, a collimator, a lenslet array, an optical relay, then a camera. The following picture show a design view of the LGSWFS subsystem inside MAORY and LGSWFS sub-system actual design in details.

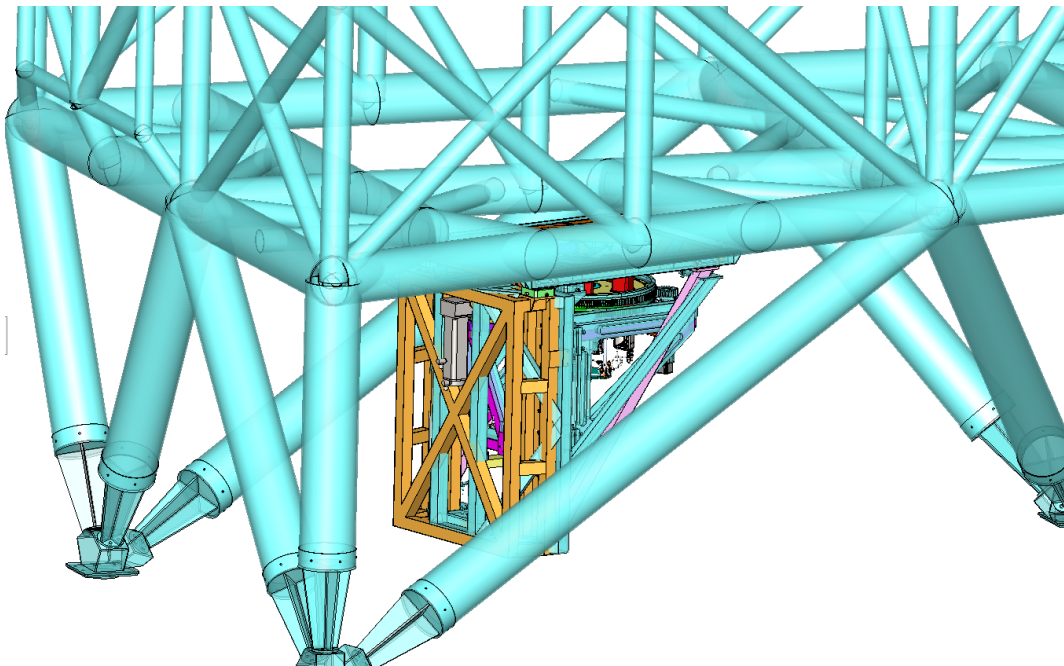


Figure 1: View of the LGSWFS sub-system with the MAORY base frame.

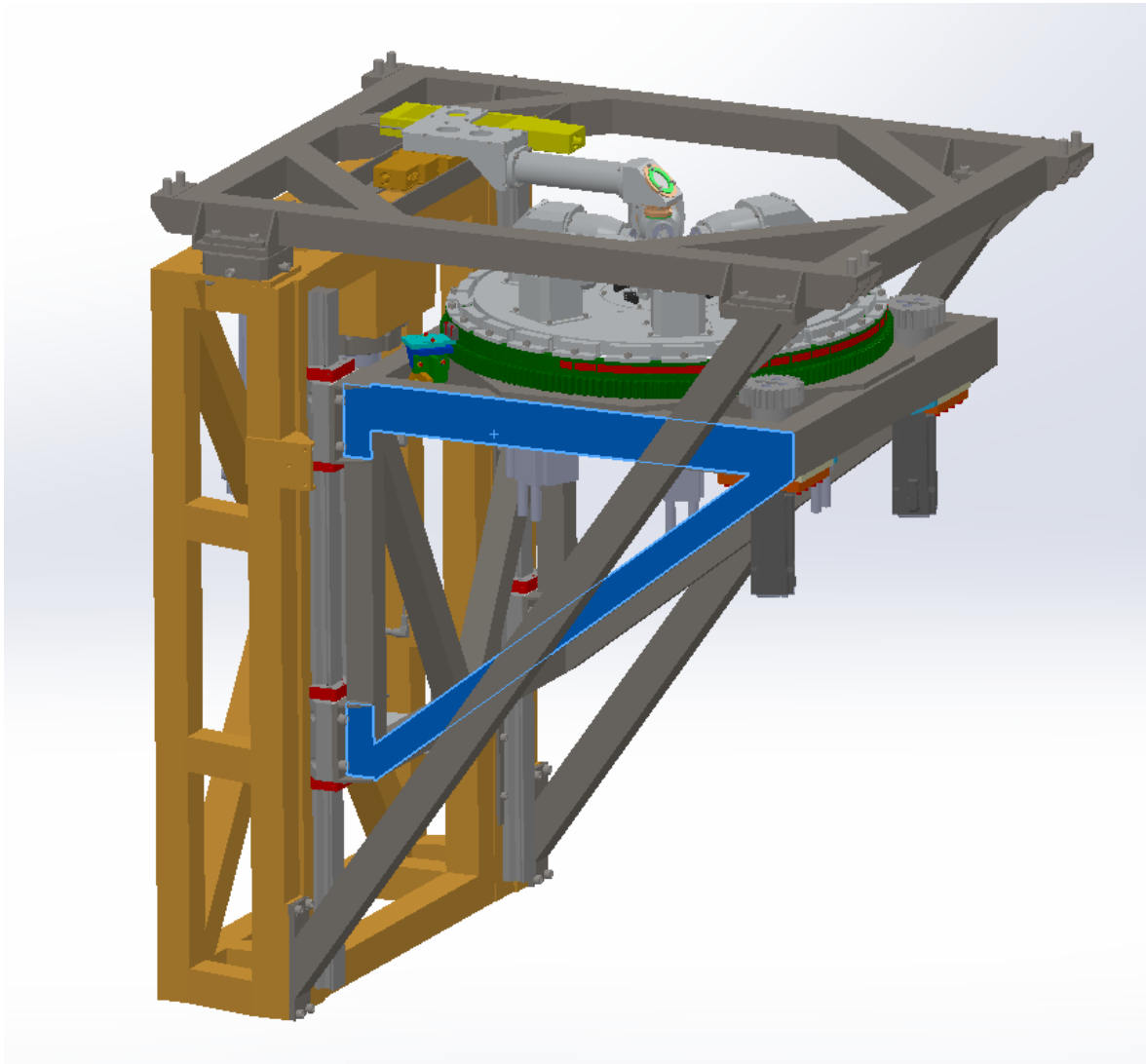


Figure 2: 3D view of the LGSWFS sub-system. The major parts are: a mechanical structure (yellow and dark grey), a derotator (green), and the LGSWFS unit channel (light grey). Above it, a calibration unit is also integrated.

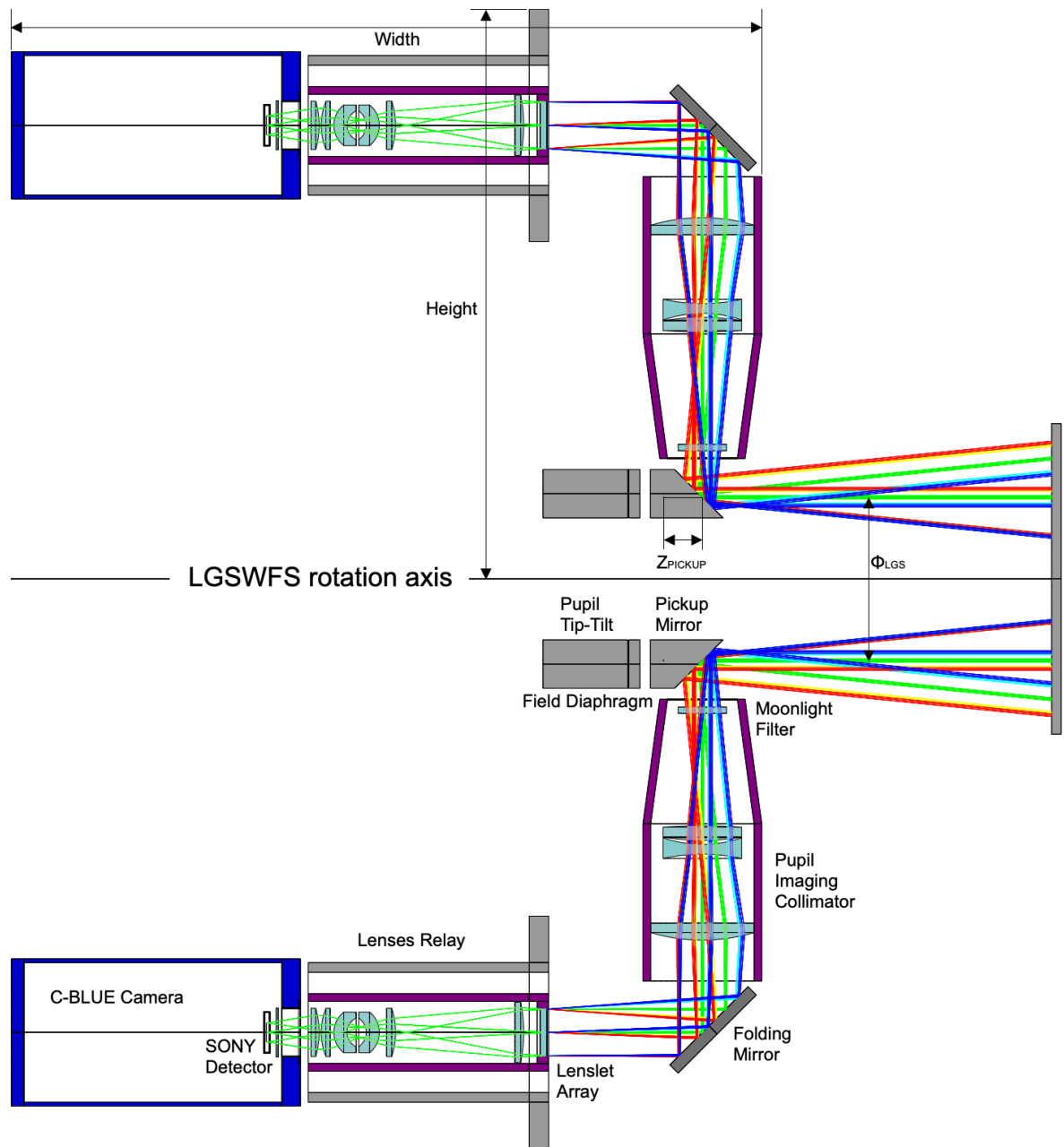


Figure 3: Optical layout of two LGSWFS unit channels. From the pickup mirror, the optical collimator forms a pupil plan on the lenslets and the optical relay forms an image of the lenslet array on the camera (blue rectangle) sensor.

As can be seen from the LGSWFS Analysis Report (AD8), the optimal lenslet array cannot be mounted directly in front of the detector as would be the traditional design for Shack-Hartmann type WFS (because the resulting focal length of the lenslets is shorter than the distance between the protective window and the detector).

Thus, the output focal plane of the lenslet array is re-imaged onto the detector by an optical relay. Since the magnification of this relay can be adapted by design, the pupil diameter on the lenslet array can be imposed independently from the number of sub-apertures and number of pixels per sub-aperture.

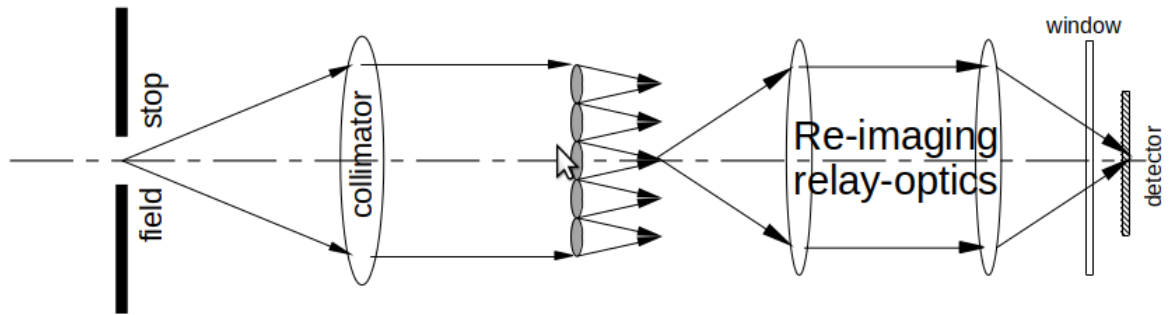


Figure 3-4: Schematics of the Shack-Hartmann lenslet array and re-imaging relay-optics



4. MANAGEMENT

During the MAIT phase, an organisation and schedule is necessary to meet the requirements and the planning. In the following sections the management of the MAIT is described.

4.1 Tasks

The main task that will have to be performed are:

- AIT facility preparation
- AIV tools/handlings/Support equipment procurement and commissioning
- Manufacturing
- Sub-system assembly
- Sub-system integration
- Sub-system test/verification
- Sub-system de-integration for shipping preparation
- Sub-system shipping
- Bill of Materials (BoM) of all the AIV related stuff (mainly the support equipment, described in sec. 6) preparation
- Reliability, Availability, Maintainability and Safety (RAMS) of all the AIV related stuff (mainly the support equipment, described in sec. 6) preparation

4.2 Input

The MAIT activities comes out of the following specification documents and interfaces.

- LDM camera specification document
- LDM specification document
- LGSWFS specification document
- LGSWFS interface document
- MAORY specification document

4.3 Outputs

The output for the PDR and FDR will be the MAIV sub-system document.

The output of the sub-system AIV for the ARR (the review that will occur at the end of the AIV phase, see section 4.5) will be:

- The sub-system fully integrated and tested, delivered to Bologna
- The documentation and drawings described in section 4.5.
- The verification matrix completed
- Performance report document.



4.4 Partner-to-Partner deliveries

Different parts composed the LGSWFS sub-system as the camera. This element will be delivered by ESO after a call for tender or internal development.

Before the delivering, the camera must be validated by ESO in term of initial performance, interface, etc, as referencing in the technical specification document of the cameras.

At the end the LGSWFS sub-system will be delivered to Bologna once ARR flag is green (see §4.5)

4.5 Sub-Systems Acceptance Readiness Review (ARR)

The ARR will be done by the MAORY system team and has the purpose to:

- Verify the sub-systems requirements
- Verify the sub-systems interfaces to MAORY

The ARR shall produce few documents to be successfully concluded, such as:

- the “**sub-system installation and operation manual**”
- the “**sub-system maintenance manual**”
- the “**sub-system final test report**” including the compliance matrix
- the full set of executive drawings

Only after successful conclusion of the ARR, the sub-system will be shipped to Bologna.

4.6 Sub-System AIT organization and responsibilities

TBW for FDR.

4.6.1 Manufacturing

During manufacturing phase, we can divide the responsibilities at different level. Globally the MAIT responsible and the local system engineer are identified to follow this phase. For each group of manufacturing a dedicated persona will be in charge to order, follow and checked the manufacturing element of the LGSWFS sub-system.

Mechanics

The mechanical engineer who designs all pieces and actuator will be in charge of that.

Optics

The optical engineer who designs all lenses make optical design will be in charge of that.

Electronics

The electronical engineer who designs cabinet will be in charge of the manufacturing.

AIT tools

The mechanical, system engineers and the MAIT responsible will be in charge of these tools.



4.6.2 Assembly

The subsystem assembly activities will be done under joint responsibility of the sub-system AIT responsible and of the local system engineer with an eye of the Safety manager. An overall team of 4 persons will participate to the sub-system assembly operations.

4.6.3 Integration

During the integration, the same persons are in charge of the same responsibilities that the previous subsection.

4.6.4 Testing

TBW for FDR

4.7 Shipping preparation

Once the ARR will be successfully concluded, the subsystem de-integration activities will be done under responsibility of the sub-system AIT responsible and of the safety manager.

The overall strategy is to ship the sub-system in one big part (LGSWFS mechanical structure) without optical parts (Collimator, LDM, calibration Unit). TBC for FDR.

The optical parts will be ship in specific boxes as an assembly.

- One for collimator assembly.
- One for LDM assembly.
- On for calibration unit assembly.

Another box will be prepared for the AIT tools.

The shipment preparations, i.e. sub-system packaging, will be under the responsibility of the sub-system AIV responsible (or of an external company)..

The sub-system transport containers will be realized in a way to be re-used for transport from Europe to Chile. The transport from Europe to Chile will be under the responsibility of the system team, but IPAG, responsible of the LGSWFS sub-system, will assist sub-LGSWFS system de-integration activities and its preparation for the shipping.

4.8 AIT Schedule

Several phases are identified for the LGSWFS subsystem. Before FDR and after.

Some prototypes activities should be occurred during the PDR. After FDR, the manufacturing activities should be launched. Then when the flow of delivery will start, testing validation at component level will start. Then the assembly and integration activities. Once the major steps of this activities will be done the sub-system testing phase should be started too. Then the validation phase with ARR.



4.8.1 Prototypes

Two of the sub-assemblies identified in the LGSWFS subsystem will be concerning by a prototyping phase regarding its complexity and importance to reach the specifications.

4.8.1.1 Micro-lens array

A previous experience was done with a first set of micro-lens array (MLA) for HARMONY LDM. This experience shows us that another batch of MLA will be necessary to identify the best manufacture to meet the specification for MAORY. The prospection will be conducted during the 2021 year.

4.8.1.2 Optical relay in LDM assembly

This prototype will be conducted from the beginning of 2021 to the middle of the same year. So, during the PDR. The idea is to test the optomechanical design to perform it. 6 months will be necessary.

4.8.1.3 Derotator

The idea here is to test a prototype realized by MPE for MICADO instrument. This activity will be occurred during the first half of the 2021 year. The objective is to learn about control command for this type of derotator (2 motors).

4.8.2 Schedule

In term of manufacturing, optics will be launched in first. These elements take several months to be manufactured.

The LDM camera is also one of the devices should be order fast after the FDR.

- 1) Optic et camera
- 2) LDM mechanics and collimator and AIT Bench.
- 3) Structure support tool
- 4) Mechanical translation and rotation structure
- 5) Electronics controller
- 6) AIT Tools

4.9 Resources (FTEs)

During the last twenty years ago, IPAG was in charge of several instrument like NAOS, AMBER, SPHERE, PIONEER, and a participation in NAOMI, GRAVITY. A very good experience is present in the IPAG staff about instrument integration.

For the LGSWFS subsystem in MAORY, a mechanical engineer, system engineer, optical engineer and instrumentalist engineer are present to realize this subsystem.





4.10 AIT Project Meetings and Reviews

- PDR Intermediate Readiness Meeting (IRM): a few months before the PDR (to be agreed between the partners), a draft version of the AIT procedure, of the AIT schedule, of the FTEs and of the Verification Matrix shall be available, in a way to make an intermediate readiness meeting with the aim to anticipate possible problems/issues as much in advance as possible, and to have the right time to counteract; Videocon may also be possible.
- FDR IRM: similarly, to the PDR IRM, a few months before the FDR (to be agreed between the partners), an advanced draft version of the AIT plan shall be available, in a way to make an intermediate readiness meeting with the aim to anticipate possible problems/issues as much in advance as possible, and to have the right time to counteract; Videocon may also be possible.
- Integration Readiness Meeting: The Integration Readiness Meeting (IRM) is a meeting which will take place during the MAIT phase at the end of the manufacturing phase, after delivery of the major sub systems/components, before starting the real AIT of the sub-system. The purpose of the IRM is to check that all the components are in specification, in a way to ensure that the sub-system AIT can start. Another purpose is to double-check that the activities to be carried out in AIT phase at sub-system level are clearly identified, sorted out and properly scheduled, with properly assigned resources and well assigned responsibilities, and the success criteria for all activities are clear; Videocon may also be possible.
- Test Readiness Meeting: a few months prior to the end of the AIT phase a Test Readiness Meeting (TRM) will be held to check the AIT process status vs AIT schedule; Videocon may also be possible.
- ARR, described in section 4.5; face to face meeting strongly suggested.

4.11 ESO staff involvement

TBW for FDR

4.12 Training

TBW for FDR

4.13 Safety

Safety during AIT both at instrument and at sub-system level is considered of very high importance by the MAORY team. Regular safety briefings will be conducted at the start of each working day/main task, coordinated by the on-site safety responsible. Attendance of safety meeting by the team, local support staff, and safety responsible is mandatory prior to any major activity which every team member will be strongly requested to stick to and follow local safety rules related to:

1. "Safety Introduction course" completed.
2. Wear the proper safety equipment in line with their activities and corresponding working area.
3. Follow instructions when using or being close to special hoisting, lifting, handling tools.



4. Follow instructions when using or being close to light sources, in particular high power Mid Infra-Red laser sources.

5. Follow instructions when using or being close to cryogenic equipment, in particular Liquid Nitrogen cooling systems.

In particular, we identify the following safety related issues, that will further be addressed before FDR in the RAMS DOC (Ref), here reported in arbitrary order:

- Electro Static Discharge – ESD wrist straps
- Eye protection - laser goggles, safety glasses
- Hearing protection
- Working at height – safety harness
- Hoisting, lifting and handling of heavy equipment
- Safety gloves, safety shoes & helmets
- Interlocks
- High voltage
- Emergency stops
- Cryo-Vacuum safety
- Harmful gasses - O₂ measurements
- CE certification for handling tools
- Mental overload, stress and strain
- Operator overload – sharing responsibility during critical operations
- Fire extinguishers
- First aid kits

4.14 Risks

During AIV phase, several risks are present inherent of any activities.

For the LGSWFS sub-system, the major risk identify are:

- Electrical
- Crushing
- Fall
- Laser

4.14.1 Electrical risk

This risk is inherent of any activities with electrical device. To prevent this risk, several collective protections are present in the building like differential disconnecter, emergencies stops and training of the team. etc. The level of this risk is considered low.



4.14.2 Crushing

This risk is present with different activities in this sub-system. Loading mechanical structure with crane, and mechanical movement with actuator (translation and rotation).

To prevent this risk, the area will be materialized by marking on the floor, personal equipment will be used like safety helmet, safety shoes, gloves. Safety casing for rotator will be used to prevent crushing with hands. Emergency stop for this mechanism will be present too.

4.14.3 Fall

LGSWFS sub-system is vertical assembly. The top of the sub-system will be at 2m from the floor. Some activities will be occurred at this level, so the fall risk appear. For these activities, a scaffolding will be necessary. Personal equipment too, like safety helmet or safety harness.

4.14.4 Laser

The LGSWFS sub-system is design for 589nm wavelength. Some source as laser will be used for alignment, test and validation.

The idea here is to use these sources at minimum power and as most possible with a fibre to expand the beam at the exit of the source. However, we will used different optical alignment tool, and this increase the risk.

For each activity, a study of the maximum exposition will be conduct by the laser referent person. If need, dedicated glasses will be use by the staff.

4.15 External expertise

TBW for FDR

4.15.1 Packaging and transport

An external expertise could be used for packaging and transport. A special service of INSU CNRS have the expertise of that (ULISSE) with a recognized expertise. (SPHERE for example).

An expertise for dumping inside the boxes will be necessary especially.

This section will be more explain for FDR.



5. FACILITIES AND HANDLING DEVICES

In this section, information concerning the facilities dedicated to the AIT is given. For the sake of clarity:

- we call Facility (Fac) a permanent installation, such as an assembly hall, a laboratory, a clean room, a workshop
- we call Handling Device (HD) whatever device (which may be permanent like an overhead travelling crane or movable such as a jib crane or a trans-pallet or a cherry picker) useful to handle/move/position equipment, which are normally commercial products
- we call Support Equipment (SEq) whatever handling tool which must be designed and realized on purpose to achieve a certain AIT task, such as a trolley to allow moving and storing the LOR system for example

The first two items are described in this section, the last item (SEq) is described in sec. 6.

5.1 Institute, Location, Premises

The IPAG integration facility are located near Grenoble in France, on the University Campus at Saint-Martin d'Hères precisely. The laboratory is accessible by tram in 20 minutes from the train station, car with the highway and in 1h30 for Saint Exupéry airport (LYON).

5.2 Integration Hall (or laboratory)

The main integration and test hall is currently hosting most of the facilities needed for the AIT operations, like sufficient access to power, cooling water, liquid nitrogen.

This integration hall is a clean room ISO8. A clean room ISO 7 will be installed during 2021 year to make a sufficient area to put the LGSWFS assembly into.

The current hall is 5.4 meters high, equipped with an overhead crane (~5 tons). The other dimensions are 10 meters large and 15 meters deep. The access door is 3m40 large and 3m high. An electronic workshop and a mechanical workshop are located in the same building allowing to take care of small maintenance/emergency operations.

Note that during integration activities, other activities for HARMONY occurred at the same time. We need to share the surface area with these other projects.

Another room located near the integration hall, will be used for optical test bench. A direct access between the integration hall and this room allowed to keep the same environmental conditions.



Figure 6: View of the integration room at IPAG during the integration of instrument SPHERE (2013).

5.2.1 Requirements

For this integration hall the following requirement are necessary:

- Electrical power
- Cooling system
- Clean room ISO 7.

5.2.2 Drawings

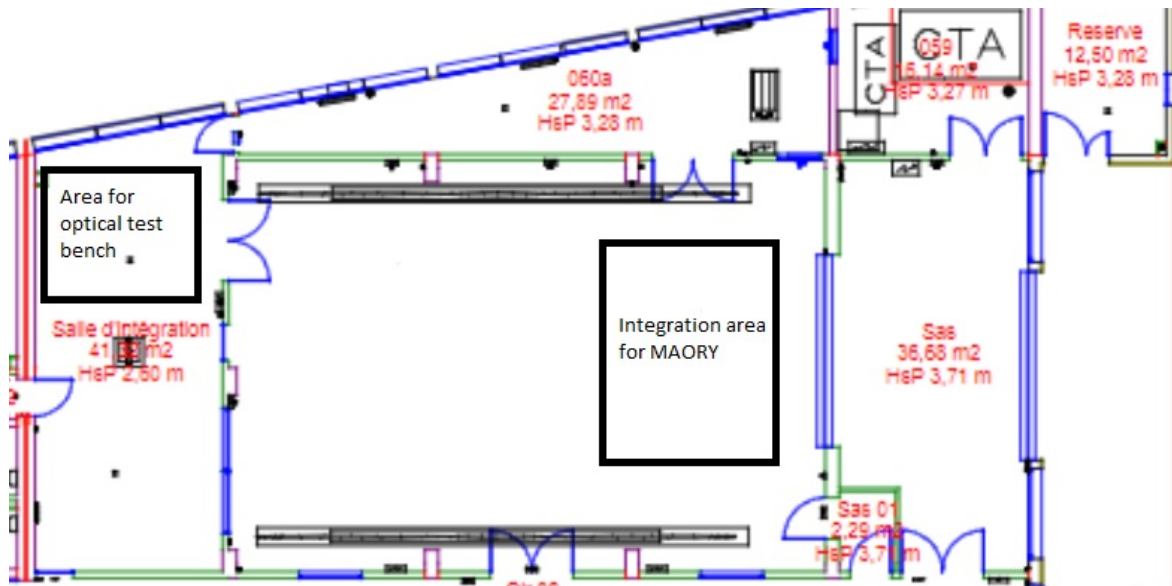


Figure 7: drawing of the integration hall and the integration room. The black area drawing show the space allocated for the project.

5.2.3 Crane

The integration hall crane, is periodically verify and tested for a load of 5tons. It could be used on the most part of the integration hall. An authorization is mandatory to use it. One person of the team has this certificate.



Figure 8: Picture of the integration hall crane.

5.2.4 Workshops

The IPAG workshop is near the integration hall. This proximity allows us to modify small mechanical pieces easily. Two turning machines, two milling machines, one vertical drill equipped the 48 m² of the workshop. To clean the piece an ultrasound tank is dedicated for that.



Figure 9: view of the work shop at IPAG near the integration hall.

5.2.5 Handling devices

Two trans-pallets are available to manutention with a capacity of load of 2 tons.

A scissor-lift is also available at the delivery platform with the same capacity of load.



Figure 10: Example of handling device available at IPAG.



Figure 11: Trans-palet available at IPAG with a capacity of 2 tons.



5.3 Cleanliness

The integration hall is a clean room ISO 8. A dedicated cleanroom mobile ISO7 inside the integration hall will be used for the assembly and integration steps of the LGSWFS sub-system.

This cleanroom will be in place at the beginning of 2021 year.



Figure 12: cleanroom is building inside the integration hall at IPAG. (2021 January)

IPAG have a tool to verify these specifications (air particles counter).

5.4 Storage

A sas area will be used to store boxes. In the case of critical element like optic or electronic, integration room will be used to store these elements before assembly and integration.

5.5 Facilities and Handling Devices Summary

If more than one facility is available for the AIT operations (for example main assembly hall, optical laboratory, clean room, mechanical workshop, electronic laboratory, ...), they must be listed here with a reference name, as shown in the example of the following table:

Facility code	Description	Notes
PF0-Fac-01	Main Assembly Hall	Safety shoes and helmets, or mobcap and blouse required
PF0-Fac-02	Optical Lab	Mobcap, blouse
PF0-Fac-03	Clean Room	Clean Room clothes required
PF0-Fac-04	Electronic Lab	



Here after the handling device with requirement to use it.

Handling Device code	Description	Notes
PF0-HD-01	Main Assembly Hall permanent crane (5T max load)	Patent needed to operate it Helmet and safety shoes required CE required
PF0-HD-02	Movable Jib Crane (1T max load)	Helmet and safety shoes required CE required
PF0-HD-03	Trans Pallet (2T max load)	Safety shoes required CE required
...	...	



6. SUPPORT EQUIPMENT

All support equipment's are described here after. The mandatory phases, and the different locations, where to be operate. The following table summarizing all the SEq characteristics.

SEq/HT code	Description	AIT phase A/I/T/P/S	Deliverable to Bologna	Deliverable to Chile
PF0-SEq-01 1	Standing Support Frame	A/I/T	Yes	Yes
PF0-SEq-02	Camera Validation Bench	A	No	No
PF0-SEq-03	Validation LDM Bench	A	No	No
PF0-SEq-04	Validation Collimator Bench	A	No	No
PF0-SEq-05	Camera Alignment Tool	A/I...	Yes	Yes

Where in the field AIT phase the meaning is:

- A stands for Assembly
- I stands for Integration
- T stands for Test
- P stands for Packaging
- S stands for Storage

6.1 Standing Support Frame (SSF)

The SSF is a SEq needed to hold the overall SSF opto-mechanics for assembly integration and test operations. In fact, this SSF replace the frame structure of MAORY at IPAG for LGSWFS sub-system. The SSF is a big structure, equipped with three eyebolt (lifting rings) which can be installed on three dedicated threaded holes M18. Using them, the SSF can be positioned, using the crane, everywhere in the assembly hall at IPAG or Bologna. It could take several optical too to simulate the entrance beam, etc.

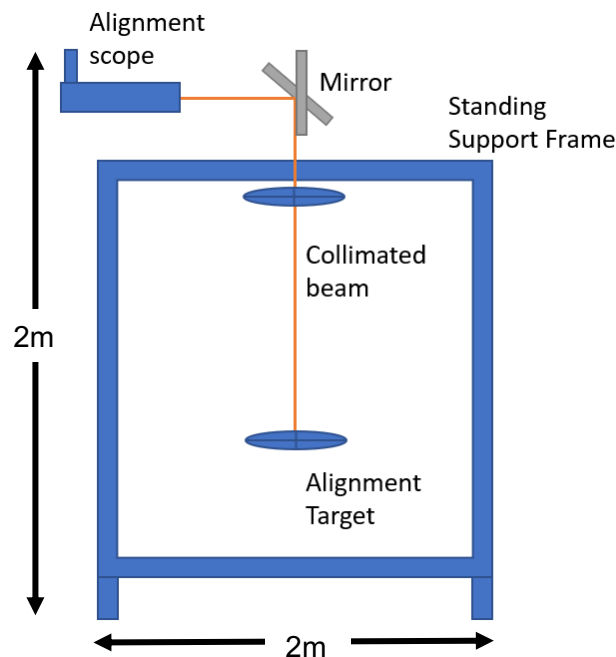


Figure 13: schematic view of the standing support frame. This element could take several optical tools to simulated the entrance beam or to help the alignment phase.

6.1.1 SSF Purpose and functionality

The SSF is needed to store in rest position the LGSWFS subsystem.

6.1.2 Manufacturing

The SSF design will be done by IPAG.

The SSF construction will be out-sourced to an external company.

6.1.3 Description

The system can be seen in Figure 1Figure 13. It consists of a tubular structure creating a supporting structure for the overall LGSWFS subsystem, to which it is connected through the fixing points. The SSF is equipped with four wheels, to allow the movement of the LGSWFS. Every wheel is equipped with a break, to void undesired SSF movement. It is also equipped with a cover (to protect the SSF against dust) connected to the SSF.

6.1.4 Way to be operated

The SSF has to be positioned in an area reachable with the crane. The 3 eyebolts have to be positioned on the dedicated threaded holes on the LGSWFS. All the cables shall be disconnected. The 3 handing slings (with maximum load of 1 ton) are passed thought the eyebolt.

The SSF must be operated by a minimum of 2 persons.



6.1.5 Special tools needed

- For the installation of the LGSWFS on the SSF, the crane (minimum 1 Ton) is necessary for the movement.
- Generic workshop tools are needed for the fixation of the LGSWFS to the SSF.
- Generic workshop tools are needed for the fixation of the cover to the SSF.
- For the SSF movement, the operators shall use the dedicated handlers, shown in Fig. (TBD).

6.1.6 AIT phase when needed

The SSF is needed for assembling, integration and test operations at IPAG and Bologna.

6.1.7 Deliverable

The SSF is a deliverable to Bologna and to Chile, for whatever phase will need to safely store the LGSWFS.

6.1.8 Hazard and Safety issues

The SSF must be operated in the following way:

- The cover of the SSF must be in position before moving it
- A minimum of 2 persons are necessary for the SSF handling/movement
- The SSF must be moved by acting on the dedicated handlers, as indicated in section 6.1.5
- Every operator shall wear safety shoes, safety gloves and helmet
- The maximum floor slope that can be dealt with is 5 degrees with two operators moving the SSF
- As soon as the SSF is in the desired position, breaks on the four wheels must be activated

No Major Hazards have been identified.

Here, the reference to the RAMS document shall be inserted.

TBW for FDR.

6.2 Camera Validation Bench (CVB)

6.2.1 CVB Purpose and functionality

This bench is needed to validate the LDM Camera provided by ESO. The main functionality is to make a uniform illumination for the camera.

6.2.2 Manufacturing

The CVB will be built at IPAG with commercial stuffs. The major part of this bench (an integrated sphere) already exists at IPAG.



6.2.3 Description

This bench Figure 14. is composed by an Integrated Sphere tool which give a planar uniformity illumination (1% over 40mm diameter), a computer to drive the camera, a chiller to cool down the detector, and some optomechanical components to clamp and adjust the camera on the bench.

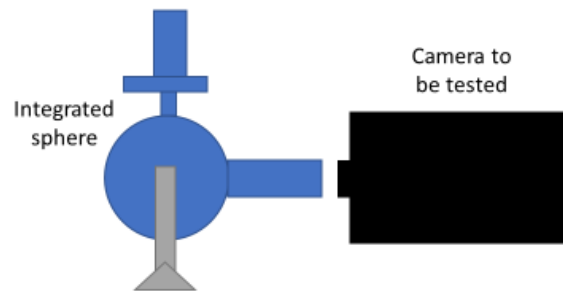


Figure 14: Schematic view of the CVB.

6.2.4 Way to be operated

The CVB is located on an optical laboratory PF0-Fac-02 in IPAG Building. It will be a standalone bench. The camera is installed on its bench in front of the integrated sphere.

The CVB must be operated by 1 person.

6.2.5 Special tools needed

- Only equipment required to operate the camera is needed (chiller, computer).
- A dimming light will be used not to interfere with the bench.

6.2.6 AIT phase when needed

The CVB is needed for validation manufacturing component.

6.2.7 Deliverable

The CVB is not a delivered stuff.

6.2.8 Hazard and Safety issues

No Major Hazards have been identified.

Here, the reference to the RAMS document shall be inserted.

6.3 LDM Validation Bench (LVB)

6.3.1 Purpose and functionality

This bench is need to validate the LDM part. The main functionality is to make a beam with the same characteristics of the collimator at entrance of lenslets. This bench allows to validate each LDM in term of image quality, field of view, etc.



6.3.2 Manufacturing

The LVB will be built at IPAG with commercial stuffs.

6.3.3 Description

This bench can be seen in the Figure 15. It is composed by an optical table, a source at 589nm, lenses and some opto-mechanical mounts to fix the LDM.

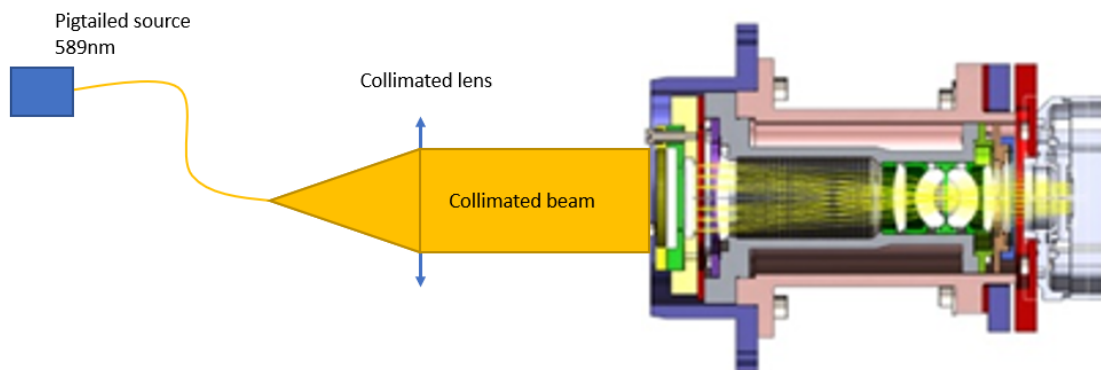


Figure 15: Schematic view of the LVB.

6.3.4 Way to be operated

The LVB is located on an optical laboratory PF0-Fac-02 near the integration hall in IPAG Building. It is a standalone bench. The LDM is installed on its bench.

The LVB must be operated by 1 person.

6.3.5 Special tools needed

- Only equipment required to operate the camera is needed (chiller, computer).
- A dimming light will be used not to interfere with the bench.

6.3.6 AIT phase when needed

The LVB is needed for validation assembly part.

6.3.7 Deliverable

The LVB is not a delivered stuff but should be used at Bologna in case of problem.

6.3.8 Hazard and Safety issues

Safety recommendation about laser Hazard,

The source must be used at minimum power.

No Major Hazards have been identified.

Here, the reference to the RAMS document shall be inserted.



6.4 Collimator Validation Bench (CoVB)

6.4.1 Purpose and functionality

This bench is need to validate the collimator. The main functionality is to make a reference beam with the same characteristics of the entrance beam of the LGSWFS sub-system. This bench allows to validate each collimator in term of image quality, field of view, etc.

6.4.2 Manufacturing

The CoVB will be built at IPAG with commercials stuffs and a wavefront analyser.

6.4.3 Description

This bench can be seen in the picture Y. It is composed by an optical table, a source at 589 nm, some lenses to form the reference beam, some opto-mechanical mounts to fix the collimator, and a wavefront analyser.

6.4.4 Way to be operated

The CoVB is located on an optical laboratory PF0-Fac-02 near the integration hall in IPAG Building. It a standalone bench. The LDM is installed on its bench.

The CoVB must be operated by 1 person.

6.4.5 Special tools needed

6.4.6 AIT phase when needed

The CoVB is needed for validation assembly part.

6.4.7 Deliverable

The CoVB is not a delivered stuff.

6.4.8 Hazard and Safety issues

No Major Hazards have been identified.

Here, the reference to the RAMS document shall be inserted.

6.5 Camera Alignment Tool (CAT)

6.5.1 Purpose and functionality

This tool will be used to align the mechanical translation and rotation structure assembly on the reference beam provided by the SSF.

The CAT will be built at IPAG with commercials stuffs.

6.5.2 Description

This tool can be seen in the picture Y. It is composed by an objective and a camera.



6.5.3 Way to be operated

The CAT must be operated by a 1 person.

6.5.4 Special tools needed

6.5.5 AIT phase when needed

The CAT is needed for validation integration.

6.5.6 Deliverable

The CAT is a delivered stuff. TBD

6.5.7 Hazard and Safety issues

No Major Hazards have been identified.

Here, the reference to the RAMS document shall be inserted.

6.6 Assembly alignment tools

Several tools will be design and manufactured to help us assembly operation and alignment.

- For interface between MAORY Frame and the LGSWFS subsystem
- For optical relay in LDM assembly
- For collimator
- Others

6.6.1 Interface System Frame

This tool is an important part of the integration strategy of the LGSWFS subsystem to MAORY base frame. The idea is to have two twin tools to allow a good alignment form each side. This tool will have different targets to materialize the position of the beam in entrance of the LGSWFS subsystem. This element will be designed and specified after PDR.



7. MAIT

In this section, MAIT process is described in detail. All the major components manufacturing is taken in count and the strategy for each is described.

The main flow chart of activities is represented here after.

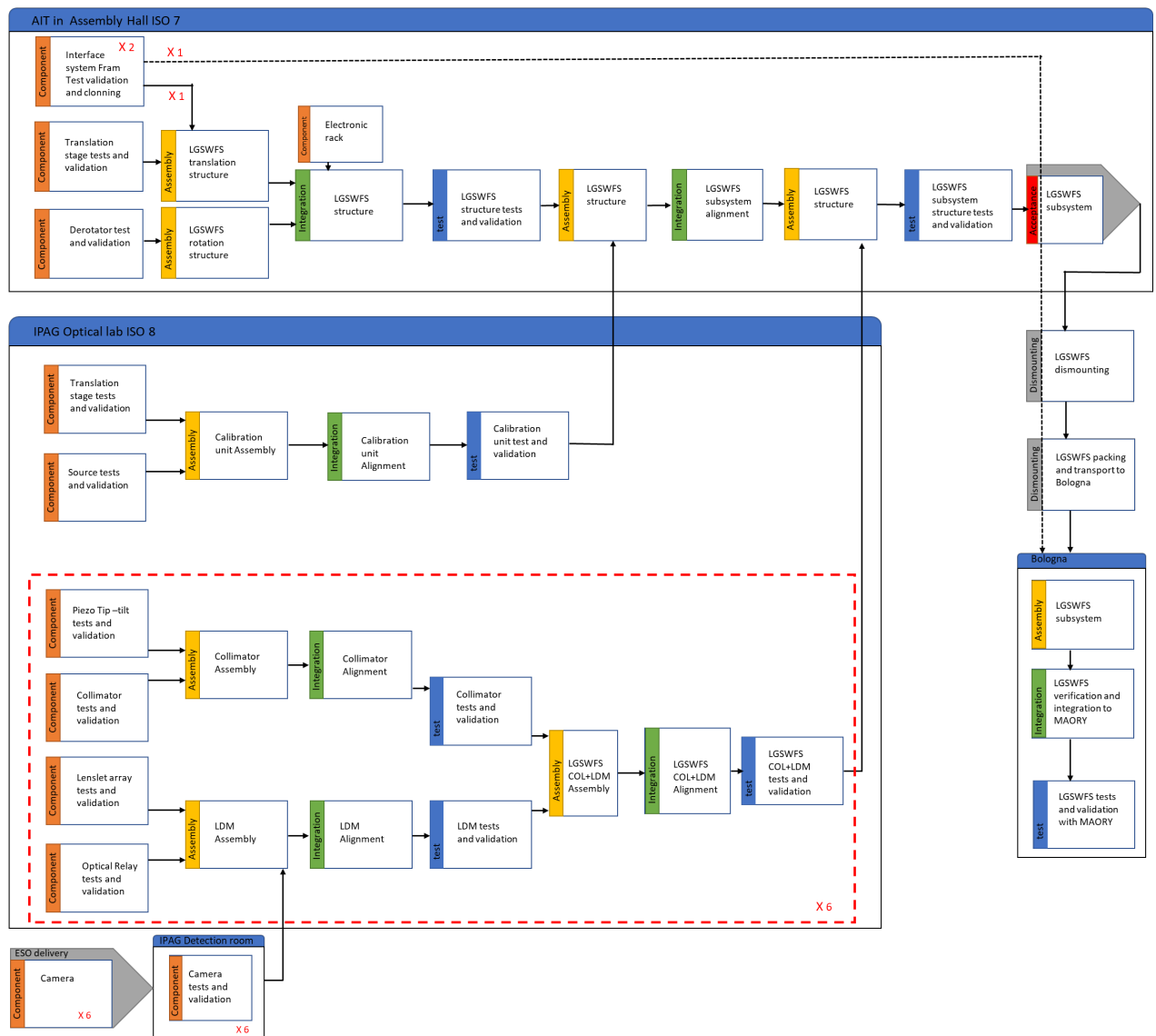


Figure 16: AIT flow chart for LGSWFS subsystem. The activities begin with component (orange box) tasks. After individual tests, small assembly (yellow box) are done. With the alignment of all elements, integration (green box) tasks begins. Then several tests (blue box) are done to validate these parts of the LGSWFS subsystem. Once different parts are validated, they are integrated together to form the LGSWFS subsystem. Systems tests are done to validate the subsystem at IPAG before dismounting and shipping to Bologna.



7.1 Manufacturing

The manufacturing chapter is segmented with the different type of element composing the LGSWFS sub-system. After a brief talk about the strategy of manufacturing, a table summarises all these data and lists the different validation tests at level component.

7.1.1 Optics

The LGSWFS unit channel is composed by four major optical elements:

- Pickup mirror
- Collimator
- Micro-lenses
- Optical relay lenses
- Entrance windows camera

7.1.1.1 Pickup mirror

This element is on the shelf. Several manufacturers are identified (see analyse report). The actual choice is PI S-325. TBC for FDR.

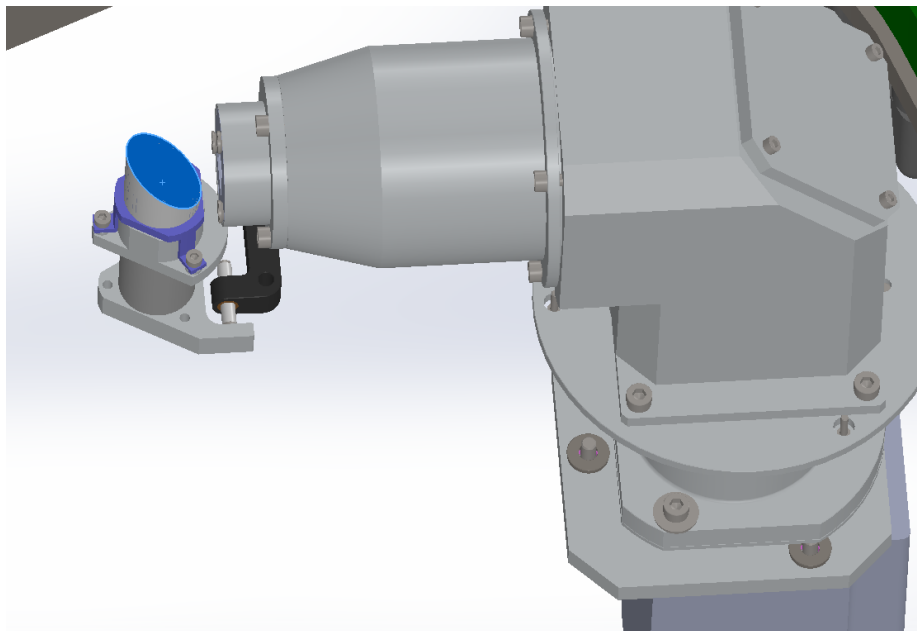


Figure 17:View of the pickup mirror in blue.

Manufacturing/ Procurement ID	PF0-M-01
Component	Pickup Mirror
Responsible	TBD
Provider	External company (Edmund, NEWPORT, THORLABS, Others)
Requirements	Reference to the doc. "Technical Specifications and SoW of component #"



MAORY LGS WFS MAIT Plan

Doc. Number: E-MAO-PL0-IPA-PLA-015
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Intermediate meetings	Kick-off, finalization of the requirement, mid-term, acceptance meeting (face to face or remote)
Test policy	At IPAG, to be tested by the team.
Shipping policy	Reference to the doc. "Technical Specifications and SoW of component #"
Main Test to be performed	Reference to the doc. "Technical Specifications and SoW of component #" Reflectivity, mirror flatness ($\lambda/10$), scratch and digs)
Deliverables	The company shall deliver the design document, the test plan, the final executive drawings, the surface quality, reflectivity,
	The following is applicable partially tested in house; one table for each test.
Test ID	PF0-M-01-T-01
Type of test	Mirror flatness
Facility	PF0-Fac-02 Optical lab
Goal	To measure the mirror flatness over the full pupil
Pass/Fail criterium	With reference to "Technical Specifications and SoW of component #", the test is passed if the flatness is better than $\lambda/10$ rms
Handling Devices	NONE
Support Equip.	Interferometer or HASO,
Other Tools/Lab equipment	Normal lab tools/holders
Safety and Hazards	Optical gloves to protect the mirror shall be used, mobcap, and mask.
Cleanliness	TO BE PROVIDED FOR THE FDR
Team	Internal 1 person, no external personnel required
Duration	TBD
Sequence	Standard interferometric test with the mirror positioned on the collimated beam or with an HASO and a reference beam.
Test ID	PF0-M-01-T-02
Type of test	Scratch and digs
Facility	PF0-Fac-02 Optical lab
Goal	Evaluate the scratch and digs on the mirror
Pass/Fail criterium	With reference to "Technical Specifications and SoW of component #", the test is passed if the scratch is better than TBD and digs is better than TBD
Handling Devices	NONE



Support Equip.	Reference scratch and digs tools
Other Tools/Lab equipment	Normal lab tools/holders
Safety and Hazards	Optical gloves to protect the mirror shall be used, mobcap, and mask.
Cleanliness	TO BE PROVIDED FOR THE FDR
Team	Internal 2 persons, no external personnel required
Duration	TBD
Sequence	For each type of default, a comparison with the reference tools is done by two persons.

7.1.1.2 Lenslet Array

Series of Lenslet Array prototypes were made in HARMONY project by LAM during 2019. IPAG tested one of them during the beginning of 2020. This feedback helps us to specify the micro-lenses for MAORY LGSWFS.

For manufacturing, four or five compagnies are identified to make this optic. An uncertain point is about the prize. This can be very different between two companies.

These micro-lenses are specific in that they have lenses on both sides of the substrate. A PV of manufacturing will be asked by IPAG to the manufacturer during the delivery of the micro lens, and a dedicated test-setup will be used to check the conformity of each component to the manufacturers PV. An attention point will be done on the gap transition between each micro lens.

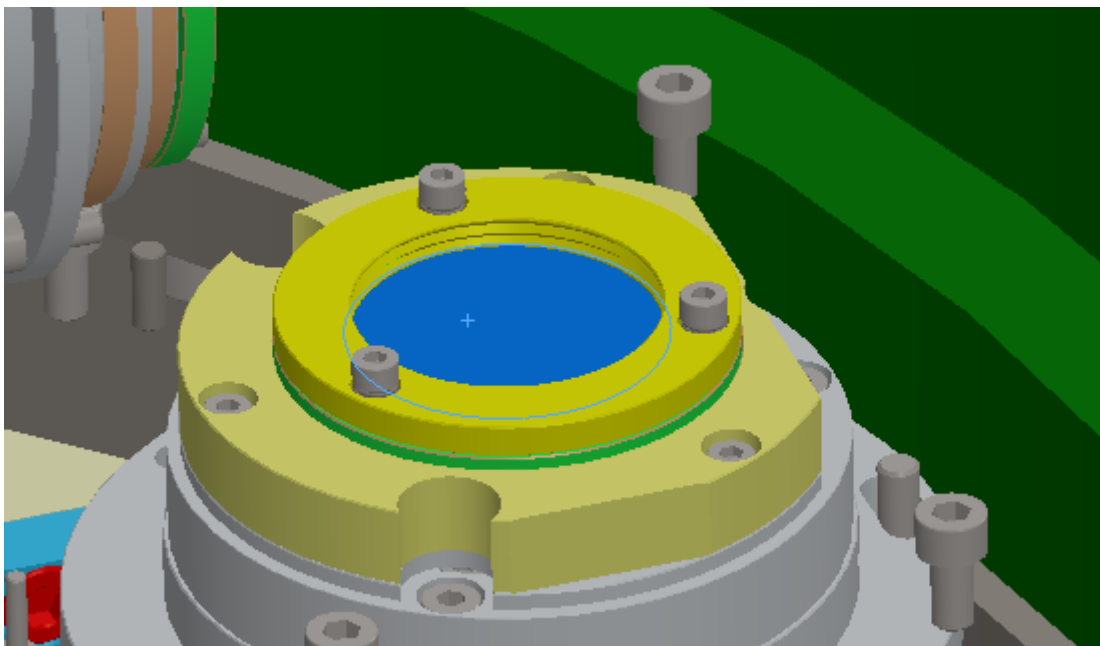


Figure 18: Localisation of the MLA in blue.

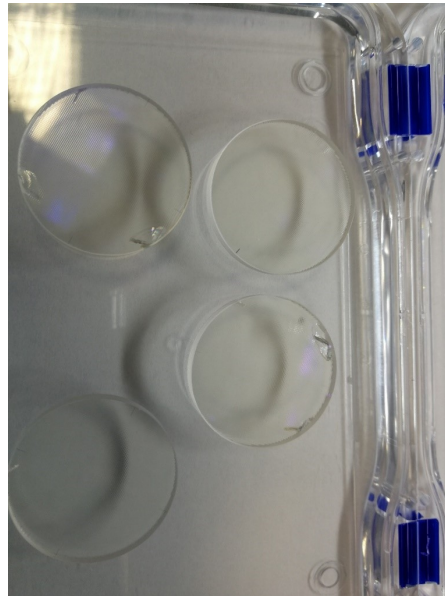
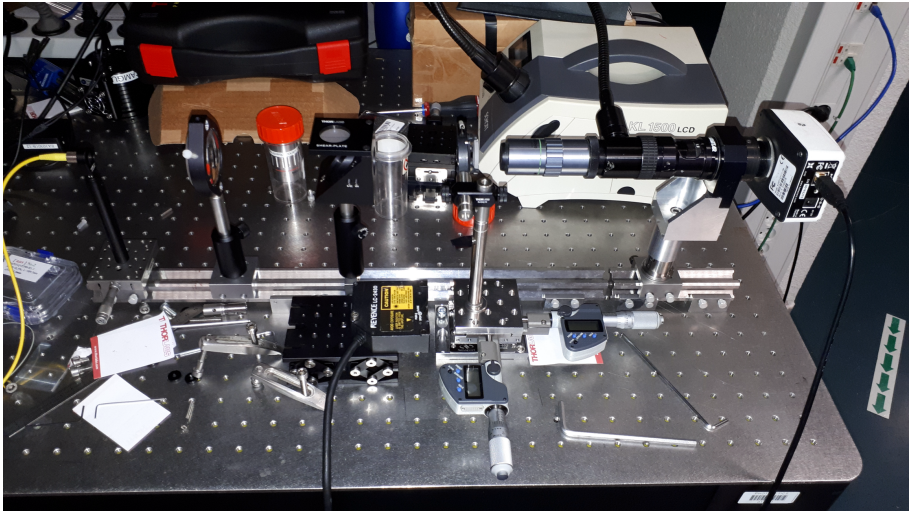


Figure 19: Example of a MLAs.

Manufacturing/ Procurement ID	PF0-M-02
Component	Micro lenses array
Responsible	TBD
Provider	External company (AMUS, etc...)
Requirements	Reference to the doc. "Technical Specifications and SoW of component #" TBW
Intermediate meetings	Kick-off, finalization of the requirement, mid-term, acceptance meeting (face to face of remote)
Test policy	Both The company send us the test results. The MLA is sent to us only if requirements are ok or after a green light by us.
Shipping policy	Reference to the doc. "Technical Specifications and SoW of component #"
Main Test to be performed	Reference to the doc. "Technical Specifications and SoW of component #" Focal length, field of view, cross talk light,
Deliverables	The company shall deliver the design document, the test plan, the final executive drawings, the final test report including compliance matrix, and the HW component #
	The following is applicable only for the system to be tested in partially tested in house; one table for each test.
Test ID	PF0-M-02-T-01



Type of test	Effective focal length
Facility	PF0-Fac-02 Optical lab
Goal	To measure the effective focal lens of micro lens.
Pass/Fail criterium	With reference to "Technical Specifications and SoW of component #", the test is passed if the focal length is TBW
Handling Devices	NONE
Support Equip.	Dedicated bench with optical microscope tool.
Other Tools/Lab equipment	Normal lab tools/holders
Safety and Hazards	Optical gloves to protect the mirror shall be used
Cleanliness	TO BE PROVIDED FOR THE FDR
Team	Internal 1 person, no external personnel required
Duration	2 hours
Sequence	<p>The MLA is put in the bench.</p> <p>With the micrometric translation stage, several pictures are done on the MLA with the collimated beam.</p>  <p>Example of the dedicated bench with a pigtailed light source, a collimated lens, the MLA then the optical microscope with a camera.</p>
Test ID	PF0-M-02-T-02
Type of test	Field of view
Facility	PF0-Fac-02 Optical lab
Goal	The goal is to measure the field of view of several micro lens.



Pass/Fail criterium	With reference to "Technical Specifications and SoW of component #", the test is passed if field of view is better than TBW
Handling Devices	NONE
Support Equip.	Dedicated bench with optical microscope tool.
Other Tools/Lab equipment	Normal lab tools/holders
Safety and Hazards	Optical gloves to protect the mirror shall be used
Cleanliness	TO BE PROVIDED FOR THE FDR
Team	Internal 1 person, no external personnel required
Duration	2 hours
Sequence	The same set up is used. The pigtailed source is move with a micrometric stage on the object plan. For several positions of the source, we record the image produced by the micro-lens. With this measure, an evaluation of the transition gap could be done.
Test ID	PF0-M-02-T-03
Type of test	Image quality
Facility	PF0-Fac-02 Optical lab
Goal	The goal is to measure the image quality of several micro lens.
Pass/Fail criterium	With reference to "Technical Specifications and SoW of component #", the test is passed if field of view is better than TBW
Handling Devices	NONE
Support Equip.	Dedicated bench with optical microscope tool.
Other Tools/Lab equipment	Normal lab tools/holders
Safety and Hazards	Optical gloves to protect the mirror shall be used
Cleanliness	TO BE PROVIDED FOR THE FDR
Team	Internal 1 person, no external personnel required
Duration	2 hours
Sequence	The same set up is used. The pigtailed source is on the optical axis. At best focus, 10 images is recorded. This measurement is repeated for several micro lens on the array.



7.1.1.3 Collimator and Optical relay lenses

This optical element is composed by several lenses. The global design is achieved but the details depend of the result with micro lenses and the camera.

In any cases, the lenses which will be used, are standard in term of manufacturing, so no risk are identify for this element.

A mirror is used to fold the beam. No difficulties are identified with this element.

The company shall deliver the test report about each lenses and mirror for focal length, surface quality, size, antireflective layer

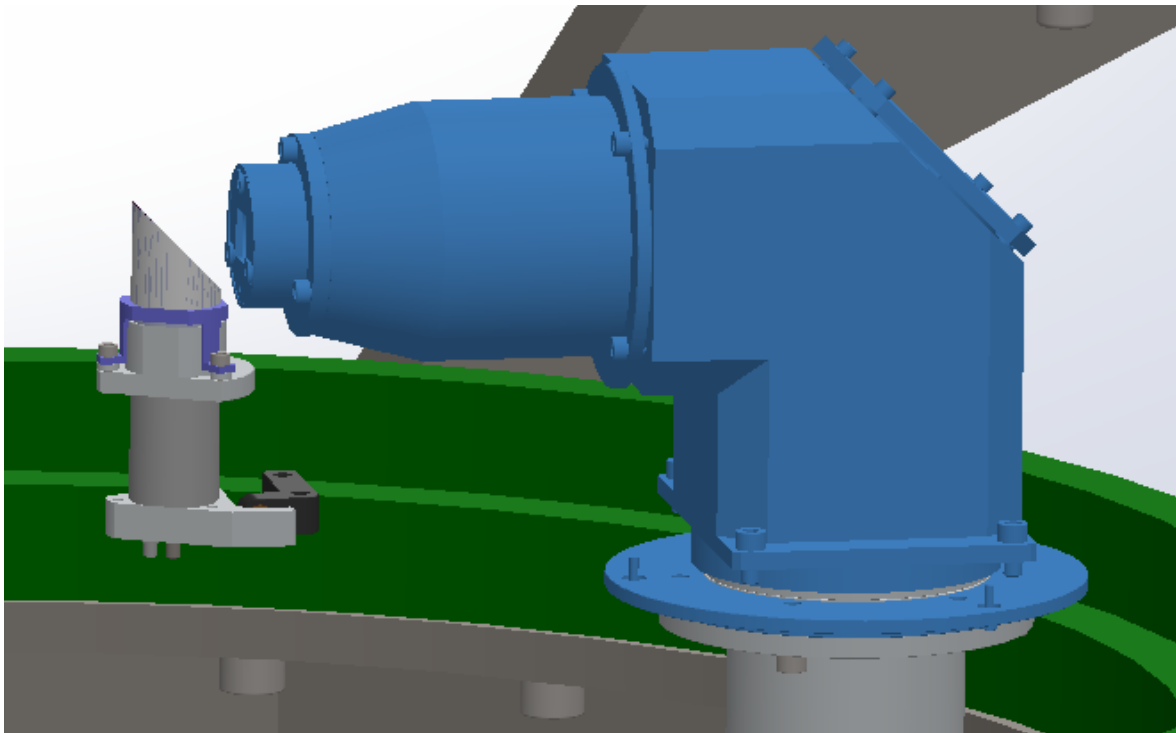


Figure 20: View of the collimator in blue.

Manufacturing/ Procurement ID	PF0-M-03
Component	Collimator
Responsible	Optical Engineer (IPAG)
Provider	External company (or Partner Institute or External Institute)
Requirements	Reference to the doc. "Technical Specifications and SoW of component #" TBW
Intermediate meetings	Kick-off, finalization of the requirement, mid-term, acceptance meeting (face to face of remote)
Test policy	At company premises



	“No participation to the final test of institute personnel is foreseen”).
Shipping policy	Reference to the doc. “Technical Specifications and SoW of component #”
Main Test to be performed	Reference to the doc. “Technical Specifications and SoW of component #” Focal length, surface quality, size, antireflective layer,
Deliverables	The company shall deliver the design document, the test plan, the final executive drawings, the final test report including compliance matrix, and the HW component #

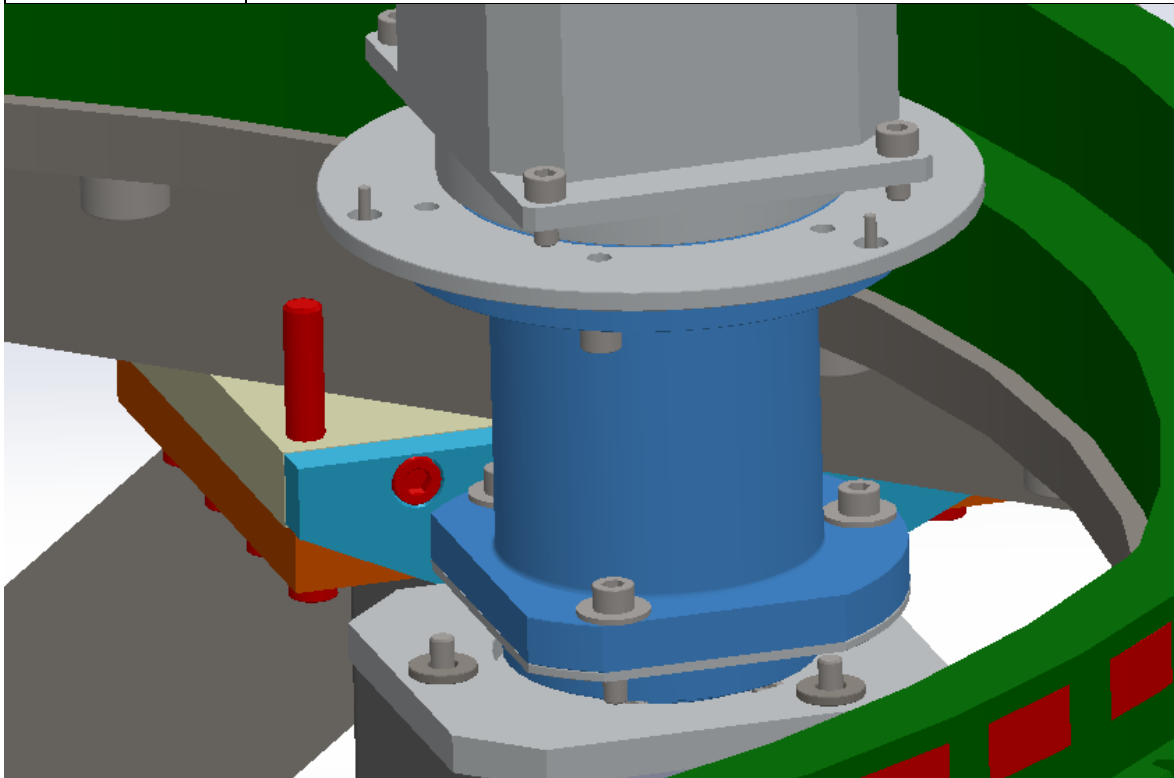


Figure 21:View of the optical relay in blue.

Manufacturing/ Procurement ID	PF0-M-04
Component	Optical relay
Responsible	TBD
Provider	External company (or Partner Institute or External Institute)
Requirements	Reference to the doc. “Technical Specifications and SoW of component #” TBW
Intermediate meetings	Kick-off, finalization of the requirement, mid-term, acceptance meeting (face to face or remote)
Test policy	At company premises



	“No participation to the final test of institute personnel is foreseen”.
Shipping policy	Reference to the doc. “Technical Specifications and SoW of component #”
Main Test to be performed	Reference to the doc. “Technical Specifications and SoW of component #” Focal length, surface quality, size, antireflective layer,
Deliverables	The company shall deliver the design document, the test plan, the final executive drawings, the final test report including compliance matrix, and the HW component #

Here after a summary of the test done on the optics

Test	remarques	Who	
		IPAG	Manufacturer
Dimensions	Diameter, thickness	✓	✓
Curvature			✓
Focal distance	EFL	✓	✓
Rugosity	Lambda/X		✓
Spectral transmission	Over the spectral range	✓?	✓
Material	Type and refractive index		✓

7.1.1.4 Entrance windows camera

This element is a part of the camera. IPAG specify the quality performance of this windows. An inspection of this windows will be done for each camera.

Manufacturing/ Procurement ID	PF0-M-05
Component	Windows camera
Responsible	TBD
Provider	External company (or Partner Institute or External Institute)
Requirements	Reference to the doc. “Technical Specifications and SoW of component #” TBW
Intermediate meetings	Kick-off, finalization of the requirement, mid-term, acceptance meeting (face to face or remote)
Test policy	At company premises “No participation to the final test of institute personnel is foreseen”.
Shipping policy	Reference to the doc. “Technical Specifications and SoW of component #”



Main Test to be performed	Reference to the doc. "Technical Specifications and SoW of component #" Inspection
Deliverables	The company shall deliver the design document, the test plan, the final executive drawings, the final test report including compliance matrix, and the HW component #

7.1.2 Mechanics

Mechanics could be split in four main elements:

- The mechanical structure for LGSWFS
- Derotator
- Pupil tip-tilt
- Mechanical components for optics

7.1.2.1 LGSWFS Structure

This element is under definition. IPAG design and produced drawings. Several manufacturers are identified to realize this structure. A verification will be done at the company.

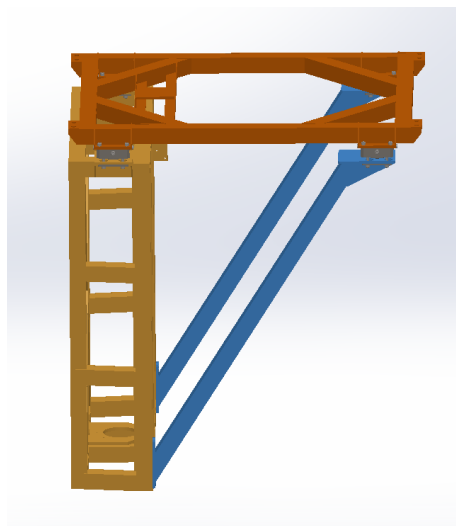


Figure 22: View of the LGSWFS structure.

Manufacturing/ Procurement ID	PF0-M-06
Component	LGSWFS Structure
Responsible	Mechanical Engineer.
Provider	External company (or Partner Institute or External Institute)



Requirements	Reference to the doc. "Technical Specifications and SoW of component #" TBW
Intermediate meetings	Kick-off, finalization of the requirement, mid-term, acceptance meeting (face to face or remote)
Test policy	At company premises. The Sub-system AIV responsible TMO will participate at the acceptance test at the company premises with the mechanical engineer.
Shipping policy	Reference to the doc. "Technical Specifications and SoW of component #"
Main Test to be performed	Reference to the doc. "Technical Specifications and SoW of component #" Dimensional measurement
Deliverables	The company shall deliver the final test report including certificate of material.

7.1.2.2 LGSWFS focusing mechanism

This element is on the shelf. Lot of iteration with companies are done to determine the best solution.

A test report will be done by the manufacturer and some test like precision positioning will be done at IPAG.

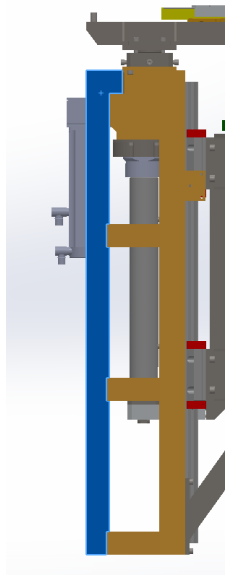


Figure 23: Localisation of the LGSWFS focusing mechanism

Manufacturing/ Procurement ID	PF0-M-07
Component	LGSWFS translator
Responsible	MBO
Provider	External company (Ewellix (actuator) and Schneeberger (rails))



Requirements	Reference to the doc. "Technical Specifications and SoW of component #" Recall the most important here
Intermediate meetings	Kick-off, finalization of the requirement, mid-term, acceptance meeting (face to face or remote)
Test policy	At company premises / in house / partially in house / both The Sub-system AIV responsible MBO will participate at the acceptance test at the company premises. (or "No participation to the final test of institute personnel is foreseen").
Shipping policy	Reference to the doc. "Technical Specifications and SoW of component #"
Main Test to be performed	Reference to the doc. "Technical Specifications and SoW of component #" Recall the test of the most important requirements to be verified here
Deliverables	The company shall deliver the design document, the test plan, the final executive drawings, the final test report including compliance matrix, and the HW component #
	The following is applicable only for the system to be tested in house/partially tested in house; one table for each test.
Test ID	PF0-M-01-T-01
Type of test	Range of positioning
Facility	PF0-Fac-02 Optical lab
Goal	To measure the mirror flatness over the full aperture
Pass/Fail criterium	With reference to "Technical Specifications and SoW of component #", the test is passed if the flatness is better than $\lambda/10$ rms
Handling Devices	NONE
Support Equip.	Interferometer
Other Tools/Lab equipment	Normal lab tools/holders
Safety and Hazards	Optical gloves to protect the mirror shall be used
Cleanliness	TO BE PROVIDED FOR THE FDR
Team	Internal 1 person, no external personnel required
Duration	1 Hour
Sequence	Standard interferometric test with the mirror positioned on the collimated beam
Test ID	PF0-M-01-T-02
Type of test	Precision positioning
Facility	PF0-Fac-02 Optical lab



Goal
Pass/Fail criterium
Handling Devices	
Support Equip.	
Other Tools/Lab equipment	
Safety and Hazards	
Cleanliness	
Team	
Duration	
Sequence	

7.1.2.3 LGSWFS Derotator

This is one of the challenging pieces. IPAG identified different on the shelf components and a prototype made by MPE for Micado Instrument.

A trade-off between the different well-known solutions occurred in the team.

The MPE derotator will be tested during 2021 at IPAG to see if this solution could meet the required specification.

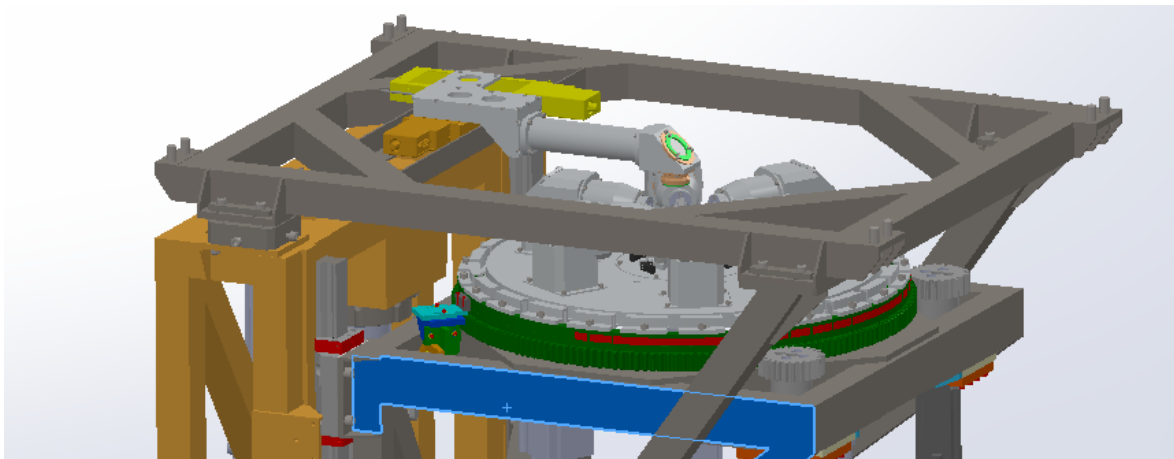


Figure 24: View of the derotator (type MPE) in green.

Manufacturing/ Procurement ID	PF0-M-08
Component	LGSWFS derotator
Responsible	System engineer and mechanical engineer.
Provider	External company (or Partner Institute or External Institute)



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Requirements	Reference to the doc. "Technical Specifications and SoW of component #" Recall the most important here
Intermediate meetings	Kick-off, finalization of the requirement, mid-term, acceptance meeting (face to face or remote)
Test policy	At company premises / in house / partially in house / both The Sub-system AIV responsible will participate at the acceptance test at the company premises. (or "No participation to the final test of institute personnel is foreseen").
Shipping policy	Reference to the doc. "Technical Specifications and SoW of component #"
Main Test to be performed	Reference to the doc. "Technical Specifications and SoW of component #" Recall the test of the most important requirements to be verified here
Deliverables	TBD
	The following is applicable only for the system to be tested in house/partially tested in house; one table for each test.
Test ID	PF0-M-01-T-01
Type of test	Mirror flatness
Facility	PF0-Fac-02 Optical lab
Goal	To measure the mirror flatness over the full aperture
Pass/Fail criterium	With reference to "Technical Specifications and SoW of component #", the test is passed if the flatness is better than $\lambda/10$ rms
Handling Devices	NONE
Support Equip.	Interferometer
Other Tools/Lab equipment	Normal lab tools/holders
Safety and Hazards	Optical gloves to protect the mirror shall be used
Cleanliness	TO BE PROVIDED FOR THE FDR
Team	Internal 1 person, no external personnel required
Duration	1 Hour
Sequence	Standard interferometric test with the mirror positioned on the collimated beam
Test ID	PF0-M-01-T-02
Type of test	Mirror reflectivity
Facility	PF0-Fac-02 Optical lab
Goal



Pass/Fail criterium
Handling Devices	
Support Equip.	
Other Tools/Lab equipment	
Safety and Hazards	
Cleanliness	
Team	
Duration	
Sequence	

7.1.2.4 Pupil Tip-tilt

This component is on the shelf. Several manufacturers are identified (See analyse report). An attention on the performance to meet the requirement will be done with several tests.



Figure 25: example of tip-tilt mechanism (PI).

Manufacturing/ Procurement ID	PF0-M-09
Component	Pupil tip-tilt
Responsible	TBD
Provider	External company (or Partner Institute or External Institute)
Requirements	Reference to the doc. "Technical Specifications and SoW of component #" TBW



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Intermediate meetings	Kick-off, finalization of the requirement, mid-term, acceptance meeting (face to face or remote)
Test policy	At IPAG One person of IPAG will test this component to validate the performance.
Shipping policy	Reference to the doc. "Technical Specifications and SoW of component #"
Main Test to be performed	Reference to the doc. "Technical Specifications and SoW of component #" Angle range, Velocity, Precision positioning
Deliverables	The company shall deliver the design document, the test plan, the final executive drawings, the user manual.
	The following is applicable only for the system to be tested in house/partially tested in house; one table for each test.
Test ID	PF0-M-09-T-01
Type of test	Angle range
Facility	PF0-Fac-02 Optical lab
Goal	To measure the angle range of the tip-tilt actuator
Pass/Fail criterium	With reference to "Technical Specifications and SoW of component #", the test is passed if the angle range is better than TBW
Handling Devices	NONE
Support Equip.	Autocollimator
Other Tools/Lab equipment	Normal lab tools/holders
Safety and Hazards	High voltage
Cleanliness	TO BE PROVIDED FOR THE FDR
Team	Internal 1 person, no external personnel required
Duration	1 Hour
Sequence	A flat mirror is fix on the mechanism. This assembly is put in front of the autocollimator. A preliminary alignment is done to put the tip-tilt at the middle of the autocollimator range. The maximum command is sent to the tip-tilt. The angle value is read on the autocollimator. This measurement is repeated 20 times to evaluate the repeatability. This test is done for the two axis.



Test ID	PF0-M-09-T-02
Type of test	Absolute Precision positioning
Facility	PF0-Fac-02 Optical lab
Goal	The goal is to measure the absolute precision positioning
Pass/Fail criterium	With reference to "Technical Specifications and SoW of component #", the test is passed if the angle range is better than TBW
Handling Devices	N.A.
Support Equip.	Autocollimator
Other Tools/Lab equipment	Normal lab tools/holders
Safety and Hazards	High voltage
Cleanliness	TO BE PROVIDED FOR THE FDR
Team	Internal 1 person, no external personnel required
Duration	1 Hour
Sequence	The same setup is used. From random position, the tip-tilt actuator goes to a position. We measure this position with the collimator. This sequence is repeated 20 times.
Test ID	PF0-M-09-T-03
Type of test	Velocity
Facility	PF0-Fac-02 Optical lab
Goal	The goal is to measure the velocity of tip-tilt actuator
Pass/Fail criterium	With reference to "Technical Specifications and SoW of component #", the test is passed if the angle range is better than TBW
Handling Devices	N.A.



Support Equip.	Keyence laser distance measurement without contact
Other Tools/Lab equipment	Normal lab tools/holders
Safety and Hazards	High voltage
Cleanliness	TO BE PROVIDED FOR THE FDR
Team	Internal 1 person, no external personnel required
Duration	1 Hour
Sequence	<p>The tip-tilt with mirror is put in front of the Keyence. The goal is to measure the velocity of the tip-tilt to go on a position and come back.</p>

7.1.2.5 Mechanical components for optics

These pieces are the most sensitive. A special tolerance will be applied to manufacturer. This will be measure at the delivery (see component test section). The design of the optical relay (invariant gravity) allows an auto centring design for optics with the gravity. Some adjustments must be done with the prototype version to fulfil the requirement of the optical design and make easy the integration task.

Some degrees of freedom are necessary to align optical relay on the camera. This point complexify a little bit the design and to the number of pieces.

A prototype for the optical relay will be done during the first part of the 2021 year.



One of the possible solutions is to manufacturing these mechanical components by the same manufacturer of the lenses, to received mounted and aligned optical relay. This strategy is for expensive but with a mini serial manufacturing, this possibility could be sense.

7.1.3 Camera

ESO will be in charge of procurement of the cameras for the consortium. ESO will lead the call for tender for this point. IPAG in collaboration with INAF and ESO (TBC), will be in charge of the technical specification document for this call for tender.

7.1.3.1 Definition

Camera is defined as the detector with body packaging.

7.1.3.2 Providers

A set of 6 cameras is need for the LGSWFS subsystem (one per laser guide star) plus 1 spare.

At this step of the project, the consortium chose the ESO baseline camera.

If possible, IPAG would like the same camera as the HARMONY project to mutualize.

IPAG will process at different validation tests for each camera.

Test	remarques	Who	
		IPAG	Manufacturer
Dimensions		✓	✓
Photon transfer curve		✓	✓
Linearity		✓	✓
Remanence			✓
Readout noise	RR-PL0-1.2.4.11, < 3e- Goal: 1e-	✓	✓
Dark current	< 50e-/s/px	✓	✓
Framerate	RR-PL0-1.2.4.18	✓	✓
Quantum efficiency			✓
Cosmetic		✓	✓
Cold test		✓	
Thermal interfaces		✓	✓

Manufacturing/ Procurement ID	PF0-M-10
Component	LGSWFS Camera
Responsible	TBD



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Provider	External company (or Partner Institute or External Institute)
Requirements	Reference to the doc. "Technical Specifications and SoW of component #" TBW
Intermediate meetings	Kick-off, finalization of the requirement, mid-term, acceptance meeting (face to face or remote)
Test policy	At company premises / both The Sub-system AIV responsible TMO and system engineer will participate at the acceptance test at the company premises.
Shipping policy	Reference to the doc. "Technical Specifications and SoW of component #"
Main Test to be performed	Reference to the doc. "Technical Specifications and SoW of component #" Quantum efficiency, readout noise, function transfer curve, framerate, cosmetic
Deliverables	The company shall deliver the design document, the test plan, the final executive drawings, the final test report including compliance matrix, and the HW component #
	The following is applicable only for the system to be tested in house/partially tested in house; one table for each test.
Test ID	PF0-M-10-T-01
Type of test	Photon transfer curve
Facility	PF0-Fac-02 Optical lab
Goal	To measure the photon transfer curve to deduce the linearity and readout noise.
Pass/Fail criterium	With reference to "Technical Specifications and SoW of component #", the test is passed if TBD
Handling Devices	NONE
Support Equip.	Integrated sphere
Other Tools/Lab equipment	Normal lab tools/holders
Safety and Hazards	Optical gloves to protect the mirror shall be used
Cleanliness	TO BE PROVIDED FOR THE FDR
Team	Internal 1 person, no external personnel required
Duration	1 Hour
Sequence	Camera is placed in front of the integrated sphere. For different flux, an image is recorded. The same measurement is done for a flux with different integration time (DIT).
Test ID	PF0-M-10-T-02



Type of test	Framerate
Facility	PF0-Fac-02 Optical lab
Goal	To measure the framerate.
Pass/Fail criterium	With reference to "Technical Specifications and SoW of component #", the test is passed if TBD
Handling Devices	NONE
Support Equip.	Shutter or stroboscopic source.
Other Tools/Lab equipment	Normal lab tools/holders
Safety and Hazards	Optical gloves to protect the mirror shall be used
Cleanliness	TO BE PROVIDED FOR THE FDR
Team	Internal 1 person, no external personnel required
Duration	1 Hour
Sequence	Camera is place in front of the integrated sphere with shutter (or stroboscopic source). The shutter open and close for the nominal value of framerate. Camera record several images.
Test ID	PF0-M-10-T-03
Type of test	Cosmetic
Facility	PF0-Fac-02 Optical lab
Goal	To measure the death pixels repartition over the detector
Pass/Fail criterium	With reference to "Technical Specifications and SoW of component #", the test is passed if TBD
Handling Devices	NONE
Support Equip.	Integrated sphere
Other Tools/Lab equipment	Normal lab tools/holders
Safety and Hazards	Optical gloves to protect the mirror shall be used
Cleanliness	TO BE PROVIDED FOR THE FDR
Team	Internal 1 person, no external personnel required
Duration	1 Hour
Sequence	Camera is place in front of the integrated sphere. For different flux, an image is recorded. The same measurement is done for a flux with different integration time (DIT).
Test ID	PF0-M-10-T-04



Type of test	Readout noise
Facility	PF0-Fac-02 Optical lab
Goal	See photon transfer curve
Pass/Fail criterium
Handling Devices	
Support Equip.	
Other Tools/Lab equipment	
Safety and Hazards	
Cleanliness	
Team	
Duration	
Sequence	
Test ID	PF0-M-10-T-05
Type of test	Linearity
Facility	PF0-Fac-02 Optical lab
Goal	See photon transfer curve
Pass/Fail criterium
Handling Devices	
Support Equip.	
Other Tools/Lab equipment	
Safety and Hazards	
Cleanliness	
Team	
Duration	
Sequence	
Test ID	PF0-M-10-T-06
Type of test	Cold test
Facility	PF0-Fac-02 Optical lab



Goal	Verified if camera can work in the environment ELT conditions
Pass/Fail criterium	With reference to “Technical Specifications and SoW of component #”, the test is passed if the camera works between 0°C and 20°C.
Handling Devices	NONE
Support Equip.	Climatic chamber
Other Tools/Lab equipment	Normal lab tools/holders
Safety and Hazards	Optical gloves to protect the mirror shall be used
Cleanliness	TO BE PROVIDED FOR THE FDR
Team	Internal 1 person, no external personnel required
Duration	1 weeks
Sequence	Camera is place in the climatic chamber. An attention is done about drying. The camera is cooled down and several images are taken during the cool down. Once at temperature, acquisition continue during 1 hour. Then a warm up sequence is started to come back to ambient temperature.

7.2 Sub-system Assembly

The assembly phase is described here. The necessary tools, and several information’s to conducted this phase is also indicated.

Once the different components are validated, we can assemble to for the different parts of the LGSWFS sub-system.

We can identify these parts:

- LGSWFS translation structure (mechanical)
- LGSWFS rotation structure (mechanical)
- LDM Assembly
- Collimator Assembly
- Calibration Unit Assembly

With these assembly, one element could be considered too, the mechanical structure tool. This element allows us to mount all the LGSWFS sub-system in final configuration.

7.2.1 LGSWFS translation structure assembly

This part is composed by a mechanic welded, guided rails, translation actuator and a fixation structure.

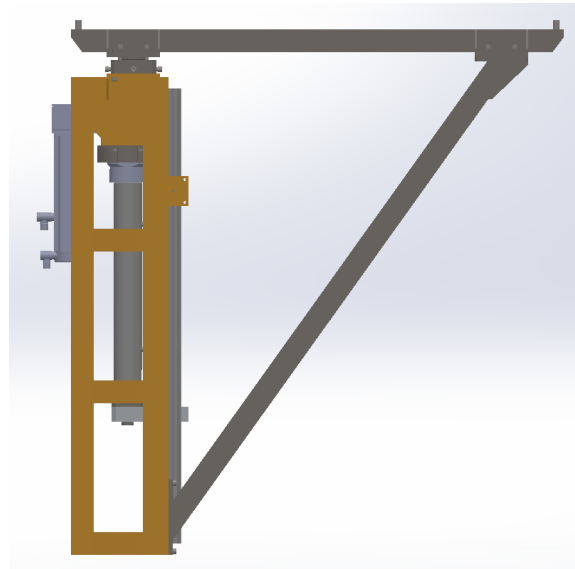


Figure 26: View of the LGSWFS translation structure assembly (preliminary design).

The following table show the different step to assemble this part of the LGSWFS sub-system.

Assembly ID	PF0-AI-01
Title	LGSWFS translation structure installation
Responsible	TBD
Pass/Fail criterion	Translation working with the requirement precision
Facility	PF0-Fac-01 Main Assembly Hall
Handling Devices	TBD
Support Equipment	TBD
Other Tools/Lab equipment	TBD
Safety and Hazards	Safety shoes and helmets are required
Cleanliness	TO BE PROVIDED FOR THE FDR
Team	Internal 2 persons, no external personnel required
Duration	TBD
Sequence	<ul style="list-style-type: none"> - Assemble the different part with nominal position (TBD) - Add the motor of the translation -



7.2.2 LGSWFS rotation structure assembly

We consider here the following element:

- Rotator mechanism
- Mechanical structure which swears this mechanism.

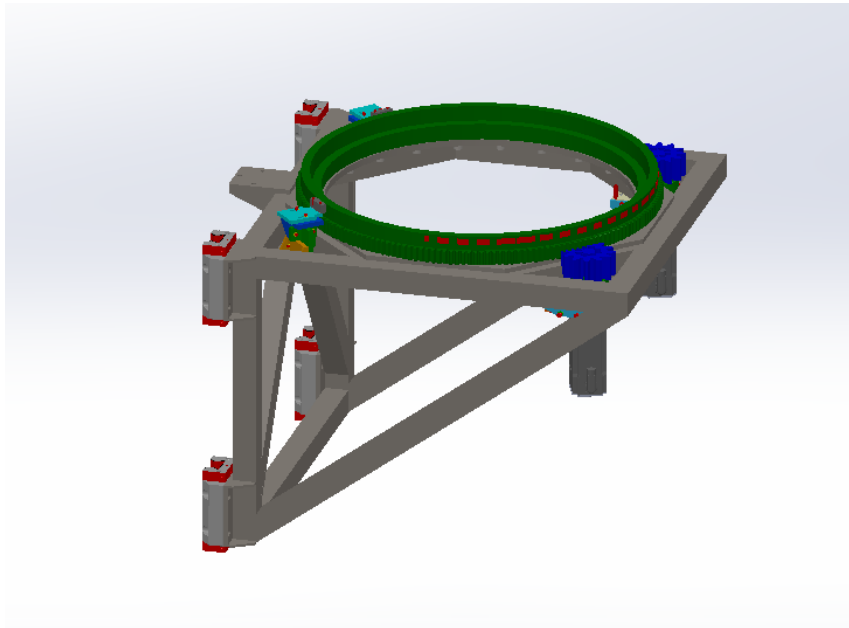


Figure 27: view of the rotation structure.

Assembly ID	PF0-AI-02
Title	LGSWFS rotation structure installation
Responsible	TBD
Pass/Fail criterion	Translation working with the requirement precision with this news assembly added Rotation working smoothly
Facility	PF0-Fac-01 Main Assembly Hall
Handling Devices	TBD
Support Equipment	TBD
Other Tools/Lab equipment	TBD
Safety and Hazards	Safety shoes and helmets are required
Cleanliness	TO BE PROVIDED FOR THE FDR



Team	Internal 2 persons, no external personnel required
Duration	TBD
Sequence	<ul style="list-style-type: none">- Fix the rotator on the mechanical structure- Add the two motors

7.2.3 LDM assembly

LDM is composed of 3 parts:

- Micro-lenses array (MLA)
- Optical Relay
- Camera

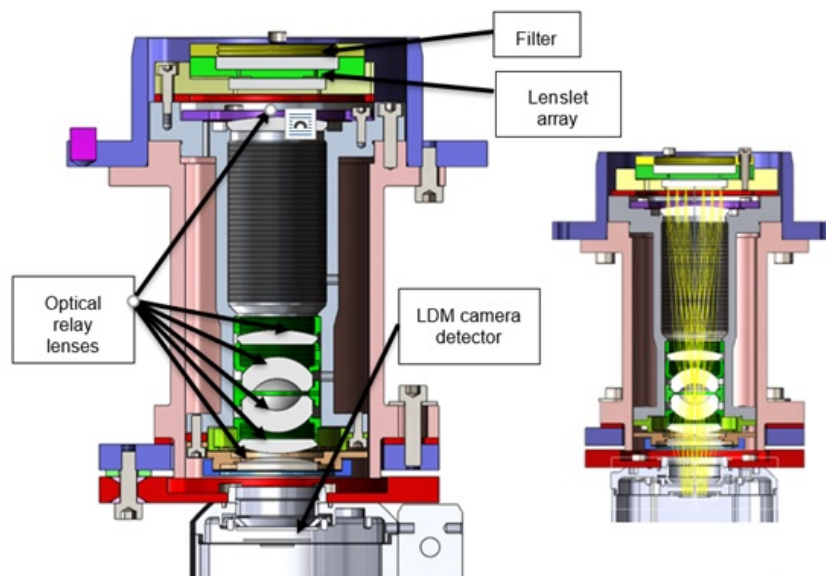


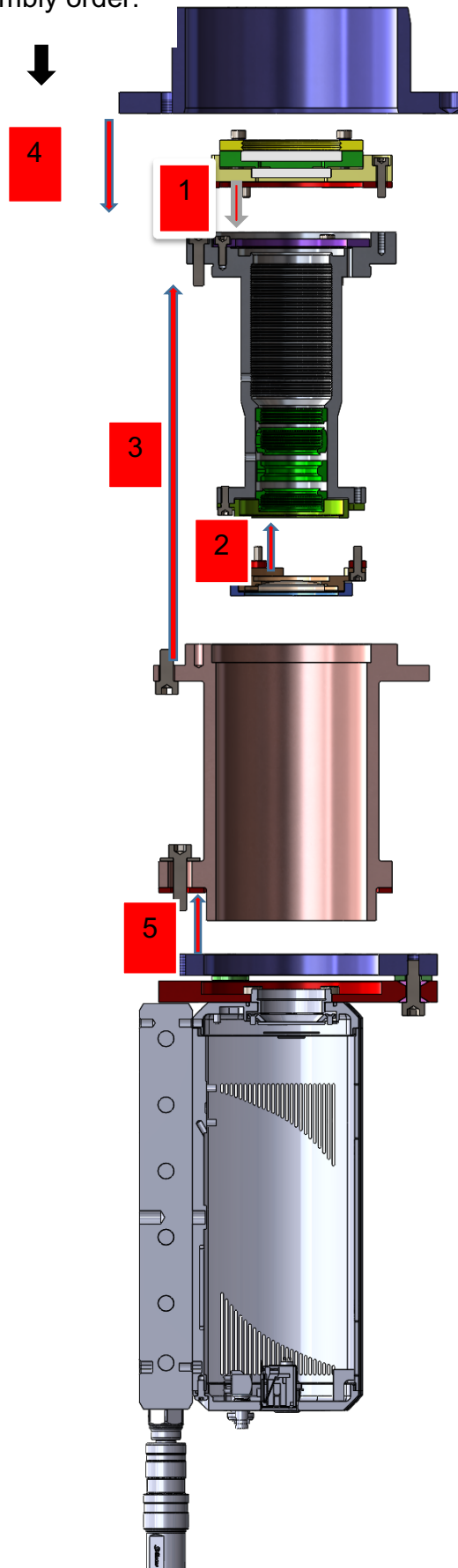
Figure 28: Optics and mechanicals support inside LDM. At right a view with optical ray tracing.

After test at components level and validations, each part of the LDM is assembled to form the LDM assembly.

The LDM assembly is composed of several sub-systems. In general, position adjustments are placed between each subsystem:



Assembly order:



LGSS bench interface

Filter and lenslet mounting

Optical relay lenses mounting (except L6)

L6 mounting box

Mechanical housing

LDM camera assembly with tip-tilt adjustment



Figure 7-29. LDM assembly

- Optical relay lenses mounting:

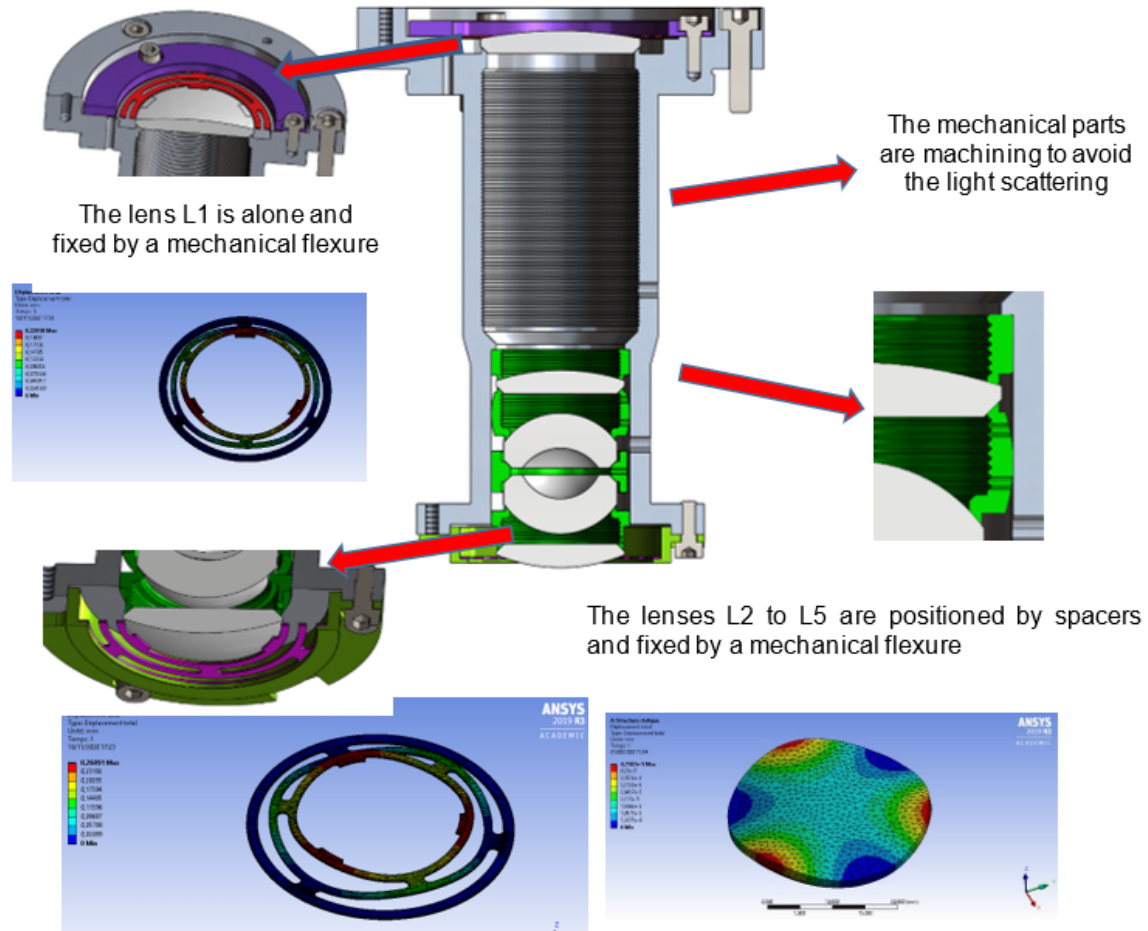
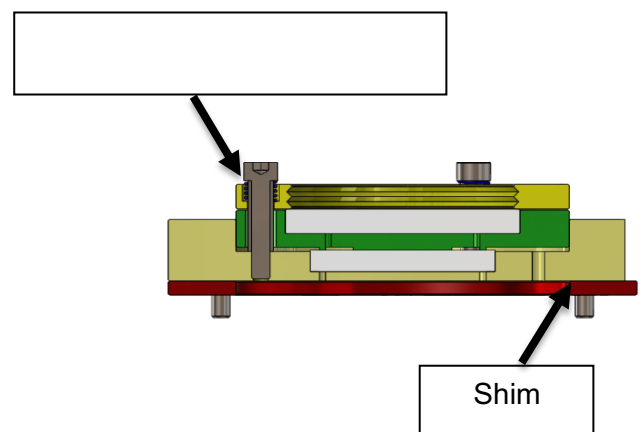


Figure 30: lenses mounting

All the mechanical flexures are calculated by Ansys software to avoid stress on the lenses. The lenses mounting should be done by a compagny. In this case an mounting solution should be provide by this compagny.

- Micro-lens array assembly:



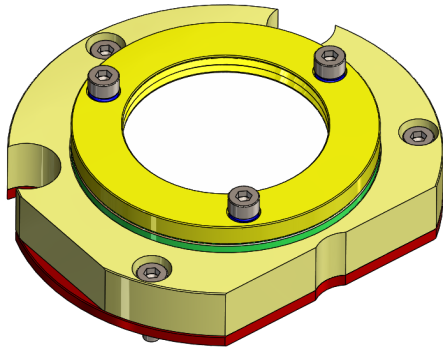
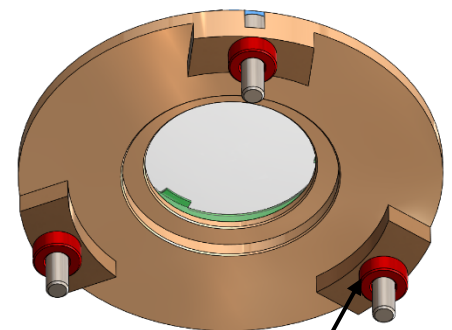
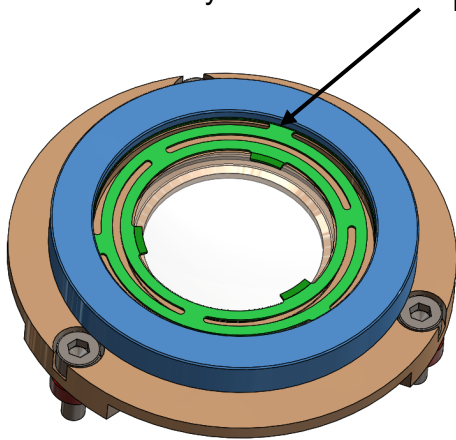


Figure 31: Micro-lens array assembly

The micro lens array and the filter are fixed together. 3 springs allow a smooth fixation. The assembly can be adjusted versus the optical relay in x and y directions (with a tool) and in Z direction (with a shim). The X and Y positioning is described below.

- L6 lens assembly:

The lens L6 is fixed by a mechanical flexure



Optical magnification shims

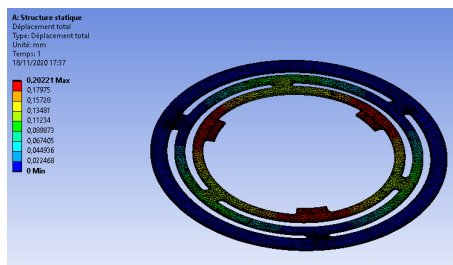


Figure 7-32. L6 lens assembly



The lens L6 is fixed alone to adapt the optical magnification (by modification of the length between L5 and L6).

- Camera assembly:

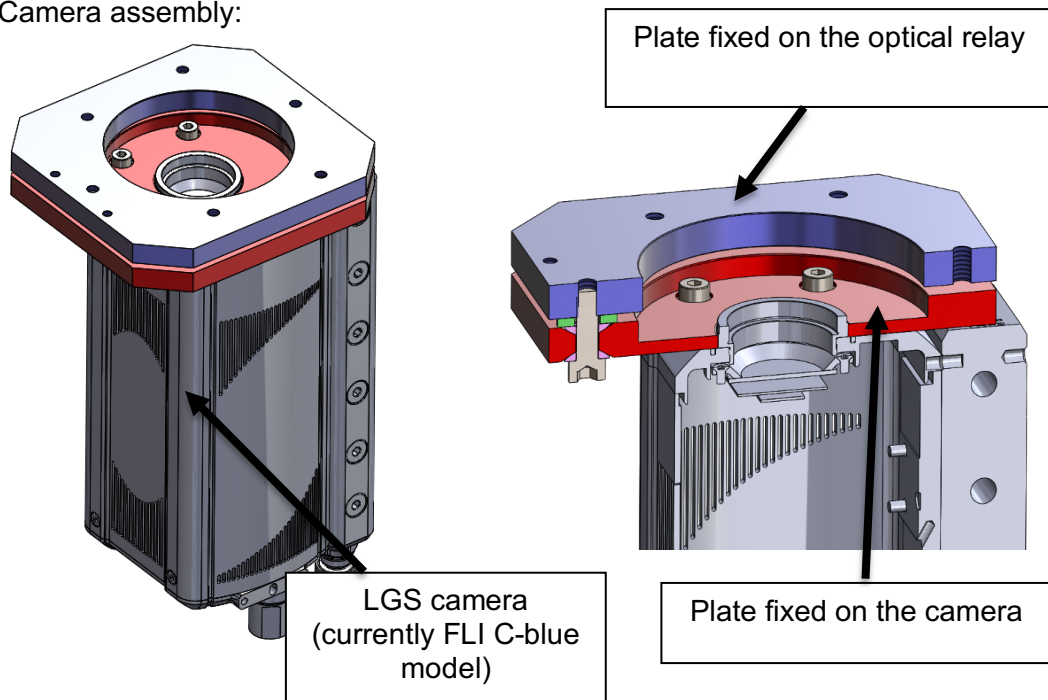


Figure 33: Camera assembly

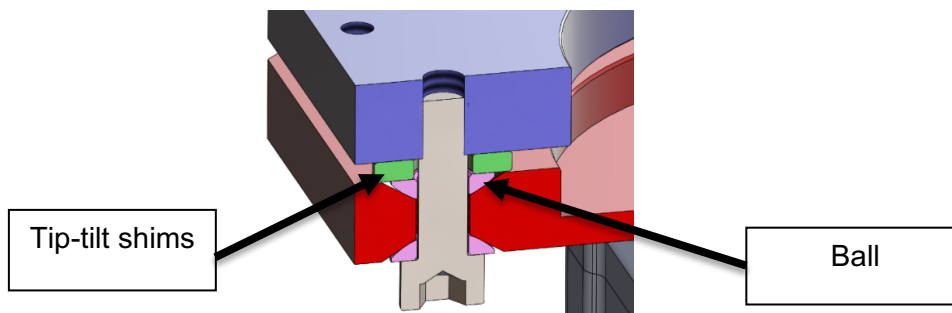


Figure 34: Tip-tilt adjustment of the camera

The camera providers indicate us that the detector is not exactly positioned:

For the Sony detector camera (data):



Positioning accuracy	Position			Tilt		
	X	Y	Z (Focus)	Rx	Ry	Rz
Sensor A relative to CS-Mount axis B	±0.484mm	±0.484mm	+0.295mm -0.195mm	±1.18°	±1.04°	±1.89°
Sensor A relative to front panel H7 mounting holes C	±0.509mm	±0.509mm	+0.295mm -0.195mm	±1.18°	±1.04°	±1.94°

For the LISA camera (ESO ICD between the WFS Cameras and the ELT Instruments):

ALICE/LISA						
	X	Y	ρ	θ	ϕ	Z
Accuracy (PTV)	$\sqrt{X^2+Y^2} < 2 \text{ mm}$		$< 1^\circ$	$< 4^\circ$	$< 4^\circ$	$< 0.5 \text{ mm}$
Stability (PTV)	$< 4 \mu\text{m}$	$< 4 \mu\text{m}$	$< 1 \text{ arcmin}$	$< 0.15^\circ$	$< 0.15^\circ$	$< 20 \mu\text{m}$
Reference	Centre of the Detector surface with respect to reference point A in related camera design volume			Image surface of the Detector with respect to the contact surface of the Front Reference Mounting Plate		

Tip-tilt and Z positioning are assumed by 3 shims installed on spherical balls.
 The X and Y positioning is described below.



Assembly ID	PF0-AI-03
Title	LDM Assembly
Responsible	TBD
Pass/Fail criterion	LDM requirement are fully filled.
Facility	PF0-Fac-02 Optical lab
Handling Devices	N.A.
Support Equipment	
Other Tools/Lab equipment	Normal lab tools/holders
Safety and Hazards	Gloves, mobcap, mask
Cleanliness	TO BE PROVIDED FOR THE FDR
Team	Internal 2 persons, no external personnel required
Duration	1 week per LDM.
Sequence	<ul style="list-style-type: none"> – Insert MLA and filter in the micro lens mounting. – Insert lenses in the optical relay mounting. – Insert L6 lens in its mount. – Insert L6 mounting lens in the optical relay – Insert the optical relay in the mechanical housing – Fix the LDM interface – Then fix the camera. – On the LDM bench, verify the requirement with an image of the MLA on the detector.

7.2.4 LGSWFS Collimator assembly

The collimator assembly is composed by two parts. A mechanical piece with several lens and a mirror named the collimator and the steering mirror to inject the beam inside the collimator.

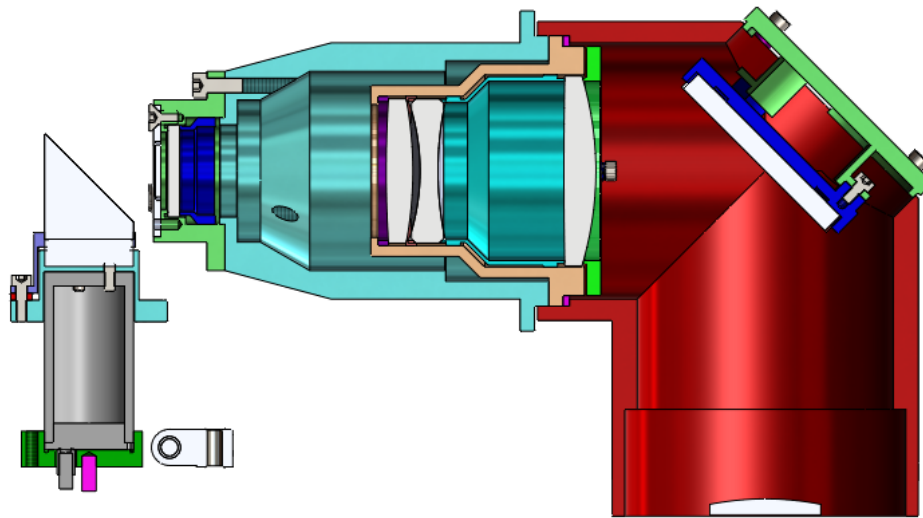


Figure 35: cut view of the collimator assembly. From left to the right we have a glass windows, the first lens, the second lens, then the folding mirror.

The different steps for the assembly are described inside the following table.

Assembly ID	PF0-AI-04
Title	Collimator Assembly
Responsible	TBD
Pass/Fail criterion	Collimator requirements are fully filled. (image quality, field of view)
Facility	Optical assembly room
Handling Devices	TBD
Support Equipment	TBD
Other Tools/Lab equipment	TBD
Safety and Hazards	Gloves, mobcap, mask
Cleanliness	TO BE PROVIDED FOR THE FDR
Team	Internal 2 persons, no external personnel required
Duration	TBD
Sequence	<ul style="list-style-type: none"> - Insert and adjust the first lens at nominal position in the opto-mechanical mount (orange piece). - Add the spacer then put the second lens in place.



	<ul style="list-style-type: none">- Block the second lens with the dedicated mechanical piece and specified screws with springs.- Insert this small assembly in the mechanical collimator piece with the glass window- Mount the folding mirror in its mount.- Fix this mount on the dedicated collimator piece.- Adjust the mirror at the nominal position-
--	---

7.2.5 LGSWFS Calibration unit assembly

This calibration unit is composed by several mechanical pieces, lenses, translation stages, fibered sources.

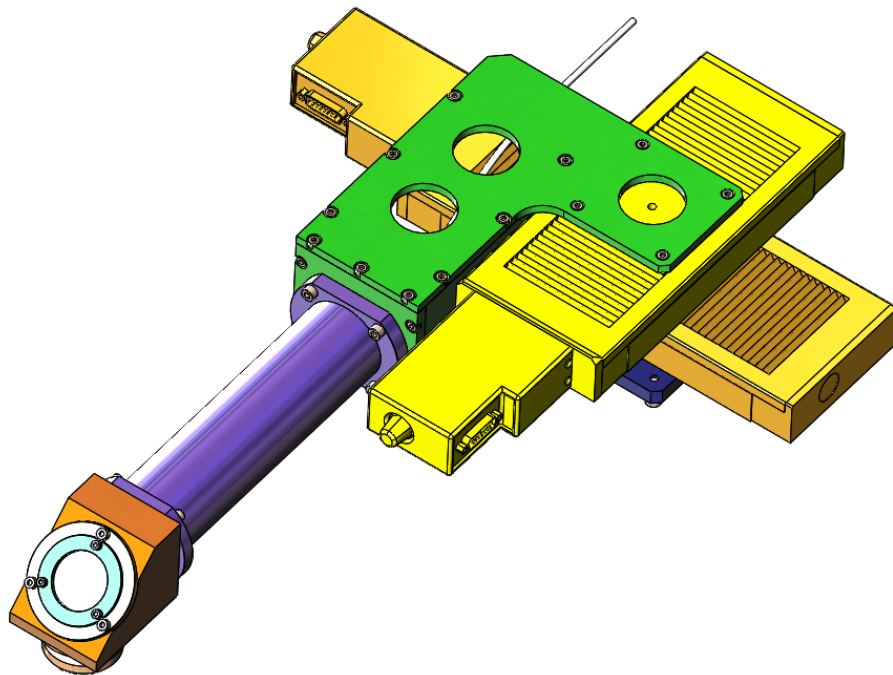


Figure 36: View of the calibration unit. Two translation stage perpendicular mounted to form XY translation.

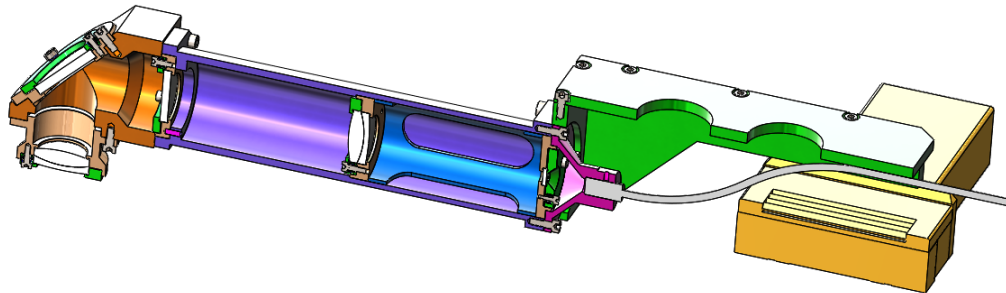


Figure 37: Cut view of the calibration unit arm. A pigtailed source is placed at the focus plane of a lens to form a collimated beam to a flat mirror. This mirror guides the beam to a second lens which forms a beam with the good aperture.

Assembly ID	PF0-AI-05
Title	Calibration Unit Assembly
Responsible	TBD
Pass/Fail criterion	Calibration unit procure the good beam shape with the good image quality. All translations are fully operational.
Facility	Optical assembly room
Handling Devices	TBD
Support Equipment	TBD
Other Tools/Lab equipment	TBD
Safety and Hazards	Gloves, mobcap, mask
Cleanliness	TO BE PROVIDED FOR THE FDR
Team	Internal 2 persons, no external personnel required
Duration	TBD
Sequence	<ul style="list-style-type: none"> - Insert the different optical element on the opto-mechanical pieces - Assemble these elements to form the calibration unit with stages - Connect the fiber - Check the image quality at the end of the calibration unit.

7.2.6 Cover assembly

TBD



7.3 Sub-system Integration

The different parts of the LGSWFS are now assembled. Here we describe the different integration steps.

As we shown on the MAIT schema, each assembly task is followed by an integration task to align the optics and mechanical element which composed the different sub-system.

Here after, a description of these integrations is done.

7.3.1 LGSWFS integration structure

This part is the union of the two main structure parts:

- Translation structure assembly
- Rotation structure assembly

The first step is to union these two parts.

The translation rotation structure is fixed under the SSF tool equipped by the ISF tool.

Make the cabling for motors.

Once it is done, we need to align the axis of the rotation with the axis of the translation. An alignment camera tool will be used to realize this alignment.

A fine tuning of the rotator alignment will be made at this step with alignment camera tool located at the centre of the WFS rotation plate. With this tool we want to measure and adjust the centre of rotation for the pupil plan and focal plan simulate by the support structure tool.

With the translation we can check if the rotator is well perpendicular to the optical axis simulate by the support structure tool.

A complete set of precision tests are done to validate the LGSWFS structure.

After this validation this part is ready to welcome the calibration unit assembly then the LGSWFS assembly.

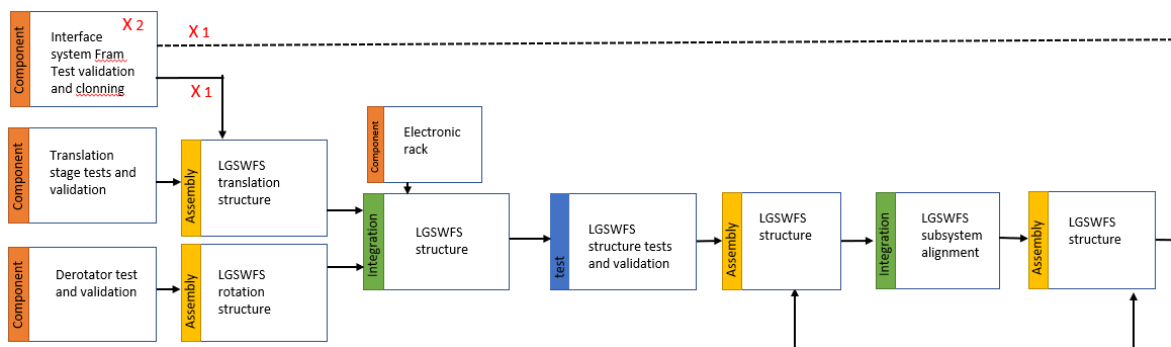


Figure 38: schema of the different steps for LGSWFS integration structure.

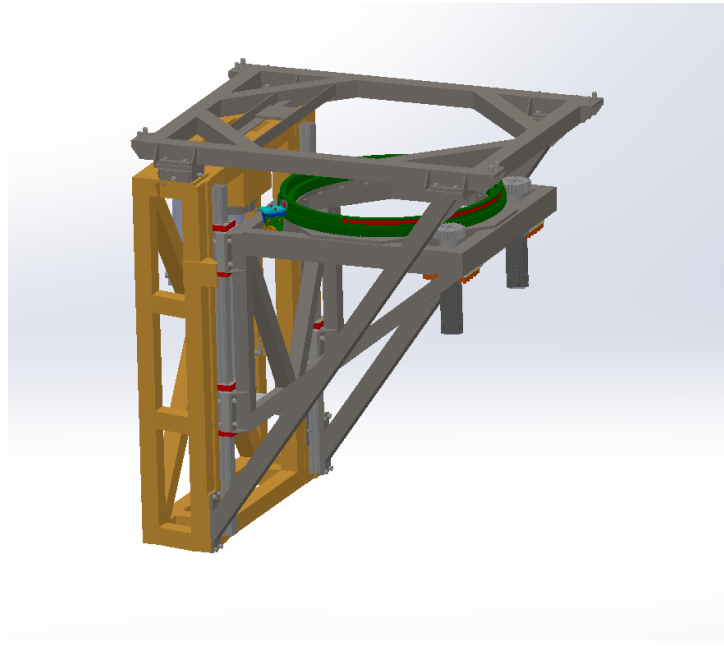


Figure 39:View of the union of main two main structure of LGSWFS.

7.3.2 LGSWFS Calibration Unit integration on LGSWFS structure

The calibration unit simulate the same beam as the stellar beam in entrance of the sub-system.

The alignment of the optics and the translation stage will be done and checked with a wavefront analyser for the optics, and a gauge for the perpendicular of the stage.

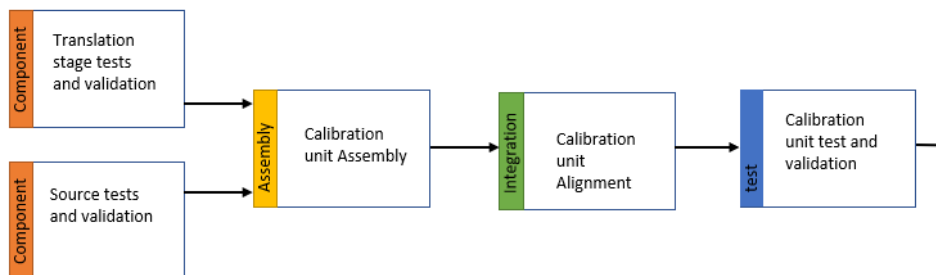


Figure 40: schema of the calibration unit integration.

After the validation, the calibration unit is integrated to the LGSWFS structure. The alignment consists of a calibration of the reference position (the camera alignment tools is used) for each position of LGSWFS.

7.3.3 LGSWFS Collimator integration on LGSWFS structure

The collimator structure is composed by two parts. A steering mirror to inject the beam inside the collimator and, the collimator, the main part with the lenses and a mirror to propagate the light to the LDM like a collimated beam.

The integration of this to parts begin by the position of the steering mirror.



The idea is to use a reference beam of the CoVB tool.

We place the steering mirror at its nominal position. We fix with pin two alignment targets to materialize the beam direction.

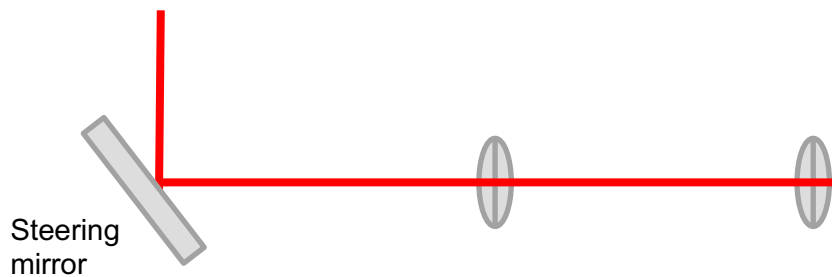
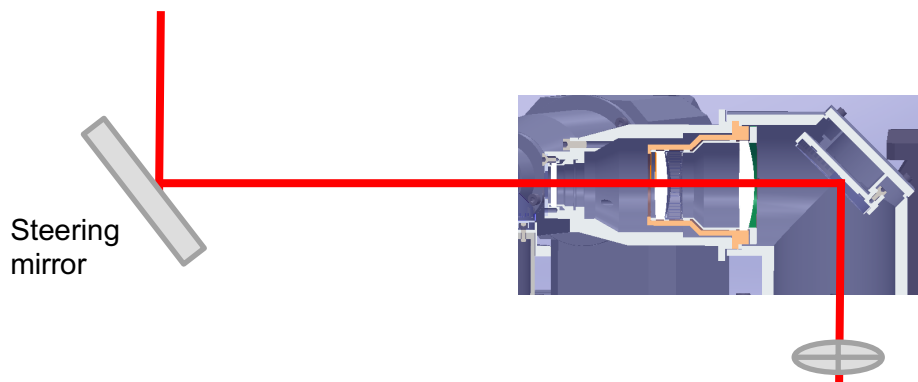


Figure 41: schema alignment principle for steering mirror.

Once the steering mirror is fixed, we can add the collimator.

The alignment targets are removed and we fix the collimator at its nominal position.



An alignment target is placed inside the LDM hole. The collimator position is adjusted to centre the beam on the alignment target.

Once this step is done, the target is removed and replaced by a wavefront analyser to check the quality of the beam. As the collimator is already validated, only tip-tilt and astigmatism aberration should be present at this alignment step. By shimming we align the collimator and reduce the aberration. The value (rms) of residual aberration needs to be defined for this step.

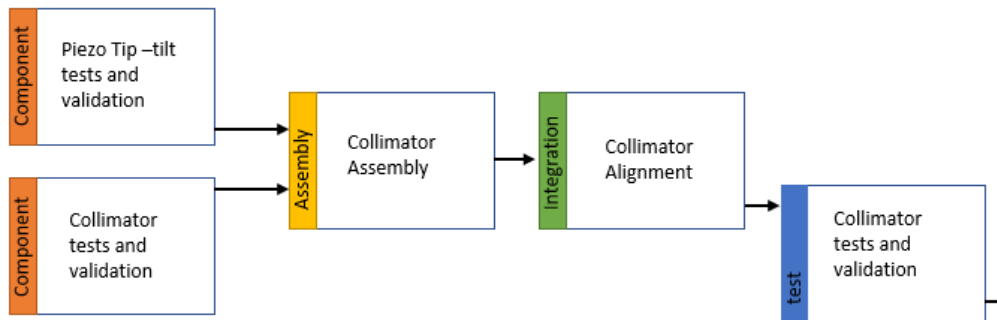


Figure 42: Schema of the different steps for Collimator integration.

A second step of integration will be done with the LDM assembly to form a LGSWFS subassembly.

7.3.4 LDM integration.

The LDM is assembled. A step of alignment should be done to meet the requirements. Before, we notice that the LDM could be manufactured by the optic manufacturer too. So, this step of alignment could be already done by the manufacturer.

With the LVB, each LDM is aligned and tested.

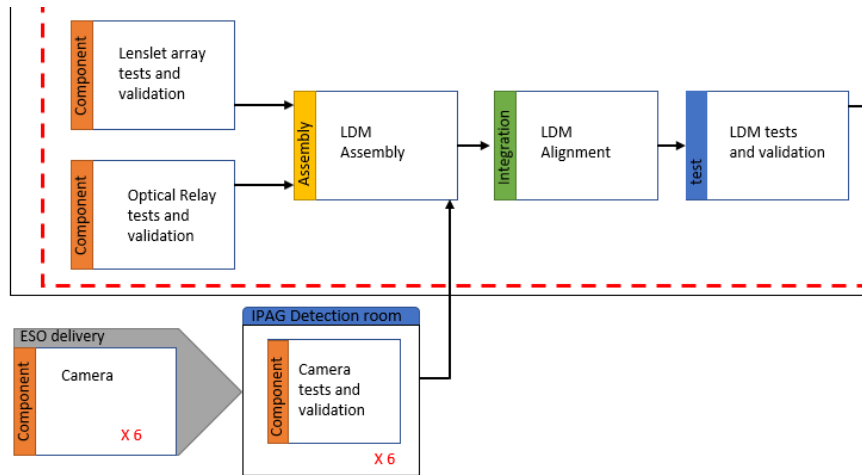


Figure 43: Schema of the AIT activities for LDM.

Once this step is done, the collimator is added to form a LGSWFS subassembly.

An alignment of these two assemblies is done and tested at this end to verify the performance before integration on the LGSWFS structure.

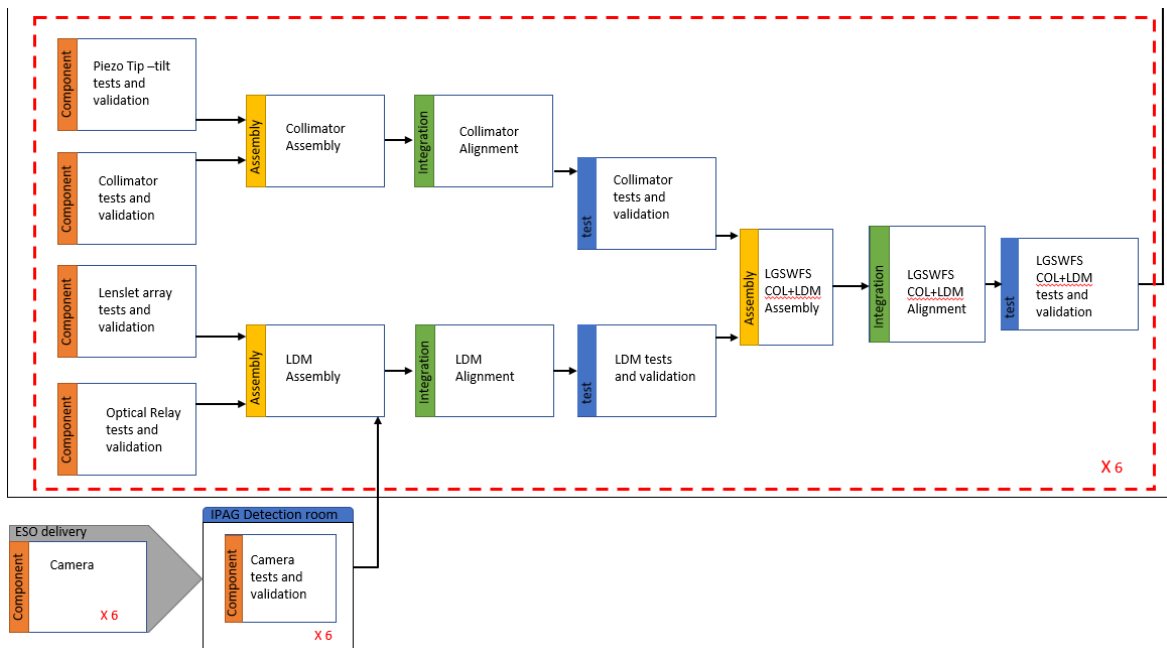


Figure 44: View of the complete schema for the LGSWFS AIT activities

In the LGSWFS structure, the support plate on the rotator has 6 places for LGSWFS.

The first step is to fix the first LGSWFS on its nominal position (TBD).

A reference beam formed by the support structure tools or the calibration unit (integrated before) simulated the good position. The alignment is checked with the image of the lenslet array on the LDM camera. At this step we can use the wavefront sensor capacity of each LDM to perform the alignment (Tip-tilt, astigmatism).

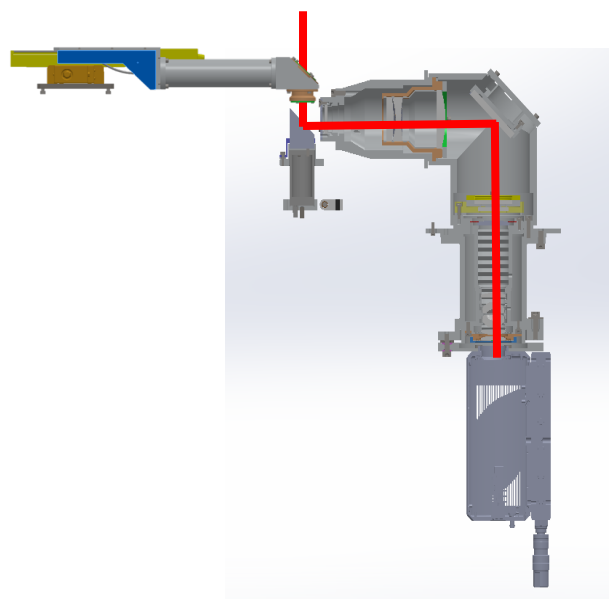


Figure 45: cut view of the collimator with LDM assembly. The red line represents the reference beam. The calibration unit is positioned to simulate the same reference beam.



7.3.5 LGSWFS Electronic cabinet

The electronic cabinet is composed by various drivers for motors, power supply unit, etc.

The form factor define by the project is 19” in large.

The integration consists of insert all elements corresponding to the plan define in the design report document (RD5). When each element is in place, cabling can start with the art rules.

With the thermal aspect, a cooling system shall be necessary to respect the requirements. This system will be tune to adjust the skin temperature.

7.4 Sub-System Test

To verify that the LGSWFS subsystem fit the requirement, several system tests are identified. The tests are organized with the following’s sections:

- Functional tests
- Characterization test
- Performance tests
- Environmental test

This table list all system tests for the LGSWFS subsystem and where they will be done.

Test	remarques	Who	
		IPAG	Bologna
Translation	RR-PL0-1.3.2.13, RR-PL0-1.3.2.16, RR-PL0-1.3.2.17, RR-PL0-1.3.2.18 (Range, speed, precision, resolution)	✓	
Rotation	RR-PL0-1.2.4.1, RR-PL0-1.2.4.3, RR-PL0-1.2.4.4, RR-PL0-1.2.4.2 (Range, precision, resolution, velocity)	✓	
Emergencies test		✓	✓
Common Path Aberrations		✓	✓
Optical transmission	RR-PL0-1.2.4.23	✓	
Pupil tracking	RR-PL0-1.2.4.26, RR-PL0-1.2.4.27 (Range, Precision)	✓	✓
Field of view	RR-PL0-1.2.4.12	✓	✓
Wave front error measurement	RR-PL0-1.2.4.25	✓	✓
Distortion		✓	
Elongated spot		✓	✓
Thermal test		✓	
EMC Test	RR-PL0-2.10.12.1	✓?	✓



Grounding Test		✓	✓
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7.4.1 Functional tests

7.4.1.1 Translation

The translation is used to adjust the focus of the LGS. Several tests are identified like:

- precision positioning
- backlash
- range of travel

Test ID	PF0-T-01
Title	Translation test
Type	Functional test
Requirements	LGSWFS integration structure assembly
Responsible	TBD
Goal	Characterize the focusing translation (precision, backlash, range, speed, resolution) with the full LGSWFS subsystem)
Pass/Fail criterium	PASS if measurement meet requirements Range: 350mm, Speed: 1mm/s each direction, Precision: 0.1mm, Resolution: 0.01mm
Facility	PF0-Fac-01
Support Equipment	TBD
Other Tools/Lab equipment	TBD
Safety and Hazards	TBD
Cleanliness	TBD
Team	TBD
Duration	TBD
Procedure/ Sequence	TBD

7.4.1.2 Rotation

The rotation is used to adjust the position of the LGSWFS to the LGS. Several tests are identified like:

- precision positioning



- velocity law
- backlash
- range of travel

Test ID	PF0-T-02
Title	Rotation test
Type	Functional test
Requirements	LGSWFS integration structure assembly
Responsible	TBD
Goal	Characterize the rotation (range, precision, resolution, speed) with the full LGSWFS subsystem.
Pass/Fail criterium	PASS if measurement meet requirements: Range, 1,5° to 60°, speed: 1°/s, precision: 0.01°, Resolution: 0.001°
Facility	PF0-Fac-01
Support Equipment	TBD
Other Tools/Lab equipment	TBD
Safety and Hazards	TBD
Cleanliness	TBD
Team	TBD
Duration	TBD
Procedure/ Sequence	TBD

7.4.1.3 Emergencies test

In case of power failure, the LGSWFS sub-system need to go in safe status. The main risk is that the focus mechanism goes down with its own load. By design this risk in take in count but a test need to valid the system.

The idea is to equip the LGSWFS structure with accelerometers to measure the constraints on the sub-system to adjust the safety devices.

This test will be done without optics. The load will be simulated by mechanical pieces.

Test ID	PF0-T-03
Title	Emergency test
Type	Functional test



Requirements	LGSWFS integration structure assembly without optics. The
Responsible	TBD
Goal	Test if the emergency safety device are well defined to protect the subsystem.
Pass/Fail criterium	PASS if no break are identified and system works. TBD
Facility	PF0-Fac-01
Support Equipment	TBD
Other Tools/Lab equipment	TBD
Safety and Hazards	TBD
Cleanliness	TBD
Team	TBD
Duration	TBD
Procedure/ Sequence	TBD

7.4.2 Characterization tests

7.4.2.1 Common Path Aberrations

Each LGSWFS unit have its proper aberration. This aberration needs to be calibrated to take in account for the AO commands. This measurement is needed for each of six units.

The idea is to make a reference wavefront in entrance of the LGSWFS and measure the aberration with the LDM WFS.

The reference wave front could be done by a Fizeau interferometer with a calibrator.

A stability during several hours (TBD) is required.

Test ID	PF0-T-04
Title	Common Path Aberrations
Type	Characterization test
Requirements	LGSWFS integration structure assembly, all optics integrated and aligned.
Responsible	TBD
Goal	Measure the NCPA with few nm (RMS) during several hours.
Pass/Fail criterium	TBD
Facility	PF0-Fac-01
Support Equipment	TBD



Other Tools/Lab equipment	TBD
Safety and Hazards	TBD
Cleanliness	TBD
Team	TBD
Duration	TBD
Procedure/ Sequence	TBD

7.4.3 Performance tests

7.4.3.1 Optical transmission

The goal of this test is to measure the transmission of the LGSWFS to estimate the limit magnitude.

The idea is to use the calibration unit a reference source. The flux emitted by the source is measure with a calibrated power-meter

With the knowledge of the quantum efficiency of each LDM detector, we integrated all the flux in the LDM detector to deduced the transmission.

Test ID	PF0-T-05
Title	Optical transmission
Type	Performance tests
Requirements	LGSWFS integration structure assembly, all optics integrated and aligned. Calibration unit calibrated
Responsible	TBD
Goal	Measure the optical transmission of the LGSWFS subsystem to meet the requirement. From dichroic to detector including QE
Pass/Fail criterium	PASS if transmission is > TBW
Facility	PF0-Fac-01
Support Equipment	TBD
Other Tools/Lab equipment	TBD
Safety and Hazards	TBD
Cleanliness	TBD



Team	TBD
Duration	TBD
Procedure/ Sequence	TBD

7.4.3.2 Pupil tracking

The goal of this test is to measure how the derotator with the steering mirror track the pupil plan.

The calibration unit is used for that.

Test ID	PF0-T-06
Title	Pupil tracking
Type	Performance test
Requirements	LGSWFS integration structure assembly, all optics integrated and aligned. Calibration unit calibrated
Responsible	TBD
Goal	Measure the range and precision of pupil tracking Range: $\pm 3\%$ (TBC) of diameter of the pupil Precision: 0.1% pupil size
Pass/Fail criterium	PASS if TBW
Facility	PF0-Fac-01
Support Equipment	TBD
Other Tools/Lab equipment	TBD
Safety and Hazards	TBD
Cleanliness	TBD
Team	TBD
Duration	TBD
Procedure/ Sequence	TBD

7.4.3.3 Wave front error measurement

Each LGSWFS need to measure the wave front with an accuracy of TBW as describe on the RR-PL0-1.2.4.25 requirement.

This test measures this performance with a flat incoming wavefront with 1000ph/sub-ap/frame.



Test ID	PF0-T-07
Title	Wave front error measurement
Type	Performance test
Requirements	LGSWFS integration structure assembly, all optics integrated and aligned. Calibration unit calibrated
Responsible	TBD
Goal	Measure the precision of wavefront error
Pass/Fail criterium	PASS if the measurement meets the specification TBW
Facility	PF0-Fac-01
Support Equipment	TBD
Other Tools/Lab equipment	TBD
Safety and Hazards	TBD
Cleanliness	TBD
Team	TBD
Duration	TBD
Procedure/ Sequence	TBD

7.4.3.4 Field of view

LGSWFS has a requirement about field of view.

The goal here, is to measure it with the calibration unit.

The translation movement of the calibration unit is used to sensing all the field of view of the LGSWFS unit. A criterion (TBD) is used to estimate the edge of the field of view.

Test ID	PF0-T-08
Title	Field of view
Type	Performance test
Requirements	LGSWFS integration structure assembly, all optics integrated and aligned. Calibration unit calibrated
Responsible	TBD
Goal	Measure the field of view in arcsec 16.8x16.8 arcsec square FOV
Pass/Fail criterium	PASS if the measurement meets the specification TBW



Facility	PF0-Fac-01
Support Equipment	TBD
Other Tools/Lab equipment	TBD
Safety and Hazards	TBD
Cleanliness	TBD
Team	TBD
Duration	TBD
Procedure/ Sequence	TBD

7.4.3.5 Distortion

Each LDM are already characterize in term of distortion. Here the idea is to make the same measurement with all the optics for each WFS unit (collimator, LDM).

Test ID	PF0-T-09
Title	Distortion
Type	Performance test
Requirements	LGSWFS integration structure assembly, all optics integrated and aligned. Calibration unit calibrated
Responsible	TBD
Goal	Measure the distortion to meet the requirement TBW
Pass/Fail criterium	PASS if the measurement is < TBW
Facility	PF0-Fac-01
Support Equipment	TBD
Other Tools/Lab equipment	TBD
Safety and Hazards	TBD
Cleanliness	TBD
Team	TBD
Duration	TBD
Procedure/ Sequence	TBD



7.4.3.6 Elongated spot

The shape of the laser guide star depends of the altitude of the LGS and the shape of the sodium layer. Elongated spot will form on the LGSWFS. This shape could decrease the performance of this sys-system.

The idea here is to use the special source in entrance of the subsystem (or in MAORY) to measure the wavefront with this elongated source.

Several elongated sources will be used to simulate the different altitudes. This test excludes the differential elongation between the WFS unit. This test will be performed at Bologna with all MAORY instrument. TBC

Test ID	PF0-T-10
Title	Elongated spot
Type	Performance test
Requirements	LGSWFS integration structure assembly, all optics integrated and aligned. Calibration unit with elongated spot.
Responsible	TBD
Goal	Measure the precision of WFS with an elongated spot
Pass/Fail criterium	TBW
Facility	PF0-Fac-01
Support Equipment	TBD
Other Tools/Lab equipment	TBD
Safety and Hazards	TBD
Cleanliness	TBD
Team	TBD
Duration	TBD
Procedure/ Sequence	TBD

7.4.4 Environment test

7.4.4.1 Thermal test

The LGSWFS sub-system will be used in ambient temperature at ELT. The ambient temperature could be start in average from 0°C to 20°C. During MAIT at IPAG, a thermal test is necessary to validate the sus-system at theses temperature.

IPAG have already an experience of this test with the integration of the SPHERE instrument.



Here the sub-system is small regarding the SPHERE instrument so different solutions should be considered.

- A frigorific truck
- A thermal tent
- A climatic chamber.

For this test, the following procedure should be considered:

- The LGSWFS sub-system is installed on a frigorific truck
- All electronic rack stays outside the truck.
- Several temperature and humidity sensors are installed on the sub-system
- The system is cool down from the ambient to 0°C.
- Several steps are done at 10°C, 5° then 0°C
- For each temperature functional test are done (translation and rotation) and some performance test as image quality on LDM.

Test ID	PF0-T-11
Title	Thermal Test
Type	Environmental test
Requirements	LGSWFS integration structure assembly, all optics integrated and aligned. Calibration unit and thermal chamber.
Responsible	MAIT responsible
Goal	Check if performance and functional requirement work at the nominal operational temperature
Pass/Fail criterium	PASS if TBW
Facility	PF0-Fac-01
Support Equipment	TBD
Other Tools/Lab equipment	TBD
Safety and Hazards	TBD
Cleanliness	TBD
Team	TBD
Duration	TBD
Procedure/ Sequence	TBD



7.4.4.2 EMC Test

The sub-system LGSWFS use electronic devices. A requirement exists about the EMC. This test will be performed at Bologna with all MAORY Instrument. TBC

Test ID	PF0-T-12
Title	EMC Test
Type	Environmental test
Requirements	LGSWFS subsystem fully complete
Responsible	ESO TBC?
Goal	Verify that electronic device, respect the ICD in terms of electromagnetic field.
Pass/Fail criterium	PASS if EMC are < TBW
Facility	PF0-Fac-01 or Bologna
Support Equipment	TBD
Other Tools/Lab equipment	TBD
Safety and Hazards	TBD
Cleanliness	TBD
Team	TBD
Duration	TBD
Procedure/ Sequence	TBD

7.4.4.3 Grounding Test

To prevent any damages for persons and electronic devices, a grounding test will be performed at IPAG.

Test ID	PF0-T-13
Title	Grounding Test
Type	Environmental test
Requirements	
Responsible	Electronic engineer
Goal	Verify that all mechanical structure, cabinet and electronic device are linked to ground.



Pass/Fail criterium	The test is pass if the value of all measurements for LGSWFS subsystem is under TBD Ohms.
Facility	PF0-Fac-01
Support Equipment	TBD
Other Tools/Lab equipment	TBD
Safety and Hazards	TBD
Cleanliness	TBD
Team	TBD
Duration	1 hour
Procedure/ Sequence	For several parts of the subsystem, with resistant measurement tool, the resistant (Ohm) with the earth is measure.

7.5 Sub-system Inspection

TBW for FDR

Inspection ID	
Title	
Requirements	
Responsible	
Goal	
Pass/Fail criterium	
Support Equipment	
Other tools/lab equipment	
Safety and Hazard	
Team	
Duration	
Procedure	



8. HANDLING, PACKAGING AND TRANSPORT

Several considerations are taken in a count for handling packaging and transport.

8.1 Handling

Several parts of the LGSWFS subsystem shall be handling for assembly and integration operations.

The description of overall operations of handling will be done for FDR.

8.2 Packaging

All the transport boxes shall be compliant with the requirements that apply to transport from Europe to Chile.

TO BE DEFINE FOR FDR.

8.3 Transport

The sub-system LGSWFS will be transported from IPAG to Bologna in their individual transport containers. For transport to Chile, we recommend to ship the sub-system the same way it will travel from the AIT facility to Bologna, using the same boxes. The barrier bag shall be changed with new ones.

Insurance for the total value of the transported goods will be issued (type of insurance will be agreed with system group). The shipping company and the insurance representative shall be present at the boxes closure and loading operations, and shall also be present at boxes arrival to watch unloading operations, check the integrity of the shock and tip-tilt indicators and inspect the box content.



9. Verification Matrix

The following table is the verification matrix where the column V is fill with:

- D: Design
- I: Inspection
- A: Analysis
- T: Test

And the compliance status can be

- C: Compliant
- N: Not compliant
- P: Partially compliant

Note: The following verification matrix is in a very preliminary state. It will be updated during the development of the project.



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Req no	Title	Comments	PDR	FDR	SAR	PAE	PAC	Status
RR-PL0-1.3.2.22	Telecentricity tolerance		A	A				
RR-PL0-1.2.4.21	Pupil blur		A	A				
IF-SF0/PL0-1.3.2.7	Pupil distortion		A	A				
IF-PL0-1.3.2.21	Diameter variation pupil		A					
RR-PL0-1.2.4.22	Relay optical quality		A					
RR-PL0-1.3.2.20 & RR-PL0-1.2.4.6	Number and positioning LGSWFS		D					
RR-PL0-1.2.5.2	Operation of LGSWFS		D					
RR-PL0-1.2.4.20	Jitter correction offload		D					
RR-PL0-1.3.2.14	Common focus		D					
RR-PL0-1.3.2.13	Translation range		D					
RR-PL0-1.3.2.16	Translation speed		D					
RR-PL0-1.3.2.17	Translation precision		D					
RR-PL0-1.3.2.18	Translation resolution		D					
RR-PL0-1.2.4.1	Rotational range		D					
RR-PL0-1.2.4.3	Min rotational precision		D					
RR-PL0-1.2.4.4	Min rotational resolution		D					
RR-PL0-1.2.4.2	Min rotational velocity		D					





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Req no	Title	Comments	PDR	FDR	SAR	PAE	PAC	Status
RR-PL0-1.2.4.26	Pupil tracking range		D					
RR-PL0-1.2.4.27	Pupil tracking precision		D					
RR-PL0-1.2.6.1	Calibration source existing		D					
RR-PL0-1.2.6.2	Calibration source patrolling		D					
RR-PL0-1.2.6.3	Calibration source intensity		D					
RR-PL0-2.2.4.5	Operational states		D					
RR-PL0-1.2.4.25	WFE sensing performances		A					
RR-PL0-1.2.4.9	LGSWFS type		D					
RR-PL0-1.2.4.9	LGSWFS number of subaperture		D					
RR-PL0-1.2.4.24	Type of detector		D					
RR-PL0-1.2.4.10	LGS plate scale		A,D					
RR-PL0-1.3.2.1	Unvignetted FOV to LGSWFS		A					
RR-PL0-1.2.4.12	Field stop FOV of LGSWFS		D					
RR-PL0-1.3.2.9	Ghosting		A					
RR-PL0-1.3.2.10	Background contamination		A					
RR-PL0-1.2.4.18	Operational framerate		I					



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Req no	Title	Comments	PDR	FDR	SAR	PAE	PAC	Status
RR-PL0-1.2.4.11	Pixel noise		I					
RR-PL0-1.2.4.23	LGSWFS throughput		A					
RR-PL0-1.1.1	Environmental conditions		D					
RR-PL0-1.3.2.11	Design gravity invariant		D					
RR-PL0-1.1.2	Earth-quake survival conditions		A					
RR-PL0-1.3.1	<i>Common ICD between the E-ELT and instrument</i>		I					
RR-PL0-1.3.2	Comply to LGSWFS ICD		I					
RR-PL0-1.3.3.1	LGS mounting repeatability		D					
RR-PL0-1.2.4.28	Mechanical references		-					
RR-PL0-1.3.3.2	LGS alignment accuracy		D					
RR-PL0-1.3.3.3	LGS alignment range		D					
RR-PL0-1.2.2.1	Dimension valid at 20°C		I					
RR-PL0-1.2.2.2	Dummy frame		D					
RR-PL0-1.4.4	Handle independently		D					
RR-PL0-1.2.5.1	LGSWFS camera module as LRU		D					
RR-PL0-1.4.5	Mount/dismount without alignment		D					



MAORY LGS WFS MAIT Plan

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