E-ELT PROGRAMME
OPTIMOS Study

Slit Mask Manufacturing and Exchange Units Design and Analysis

	Name	Date	Signature
Author	V. De Caprio	16 - FEB - 2010	
Approved by	D. Maccagni	16 - FEB - 2010	
Released by	O. Le Fèvre	---	

Co-authors

Name:	Affiliation:
D. Maccagni L. Chiappetti S. Incorvaia	INAF/IASF - MI INAF/IASF - MI INAF/IASF - MI

Change record

Issue	Date	Section / Paragraph affected	Reason / Initiation Documents / Remarks
1.0	10-10-2009	All	Chapters updated, figures added and minor corrections
2.0	16-02-2010	All	Chapters updated, figures added and minor corrections

Distribution List

Date	Person	Institute	WP/Notes
08-02-2010	Project Staff	INAF IASF- MI; LAM	Draft version – to be updated
16-02-2010	Project Staff	INAF IASF- MI; LAM	*DRAFT FOR COMMENTS*

Table of Contents

Applicable Documents

no.	document name	document number, Iss./Rev.
AD1	E-ELT INTERFACES FOR SCIENTIFIC INSTRUMENTS	E-TRE- ESO-586-0252 - Issue 1
AD2	Common definitions and acronyms	E-ESO-SPE-313-0066 Issue 1
AD3	Requirements for OPTIMOS, a Vis-NIR Multi Object Spectrograph	E-SPE-ESO-531-0262-V1.0
AD4	Instrument development and management plan	E-PLN.DIO.509.1051

Reference Documents

no.	document name	document number, Iss./Rev.
RD1	Impact of GLAO on the design and performances of the OPTIMOS-slits multi-object spectrograph	E.NOT.OPT.531.1007 Issue 1
RD2	Software and Operational Requirements for DIORAMAS masks	E.REP.DIO.509.1052
RD3	Scientific Analysis Report	E.SPS.OPT.531.1024
RD4	Opto mechanical Design and Analysis	E.REP.DIO.509.1054

Acronyms

E-ELT	European Extremely Large Telescope
ESO	European Southern Observatory
AD	Applicable Document
RD	Reference Document
SF	Safety Factor
CoG	Centre of Gravity
FPA	Focal Plane Array
MMUS	Mask Manufacturing Unit System
MEUS	Mask Exchange Unit System
TBD	To be decided
TBV	To be verified
TBC	To be confirmed
FOV	Field of View
MMM	Masks Manufacturing Machine

1. Scope of the Document

This document describes the preliminary mechanical design and the technical solutions of the MMUS and MEUS that are systems of the Optimos-Dioramas Instrument, proposed in response to ESO's "Call for Proposals for a Phase A study for E-ELT PROGRAMME Study". It has been prepared in compliance with AD1 and RD3.

The preliminary designs presented in this document reflect the assumptions and the specifications of the above documents and are subject to modification if these assumptions will be changed in a next study phase. The Documentation Plan, Management Plan and Project Plan of the project are out of the scope of this document and are to be found in AD4.

2. Mask Manufacturing Unit System – MMUS – WP 2610

2.1. Introduction

This chapter describes the global design of the Mask Manufacturing Unit System. The function of this system is to perform the off-line, remotely controlled, mask manufacturing, identification and preparation of the mask reservoirs for the observing run.

The MMUS will be located in a TBD room on E-ELT site. The requirements which mask manufacturing puts on the observatory site as far as the accessibility and the room where mask manufacturing must take place, as well as the requirements set by the need to have the mask reservoirs reach the instrument on the Nasmyth platform, are described in Chapter 5.

2.2 Constraints, Requirements and Specifications

2.2.1 Instrument FOV, mask and slit constraints

⇒ FOV

The OPTIMOS-DIORAMAS instrument field of view measures 1468x1468mm - will be divided in 4 quadrants. In order to hold and position the masks in the field of view, a central dead cross of 30mm is needed.

The four quadrants will be numbered Q1 Q2 Q3 Q4 and colour coded as green blue yellow red. The numbering and position of the 4 quadrants in the instrument field of view assumed in this document it is shown in Figure 1, which assumes a view of the "backbone cross mask" (see paragraph 3.3 for this subsystem) looking towards the sky from the spectrograph side.

Quadrants assigned to the same wavelength range will be contiguous, namely quadrants 1 and 2 will be assigned to the VIS band, and quadrants 3 and 4 to the NIR band.

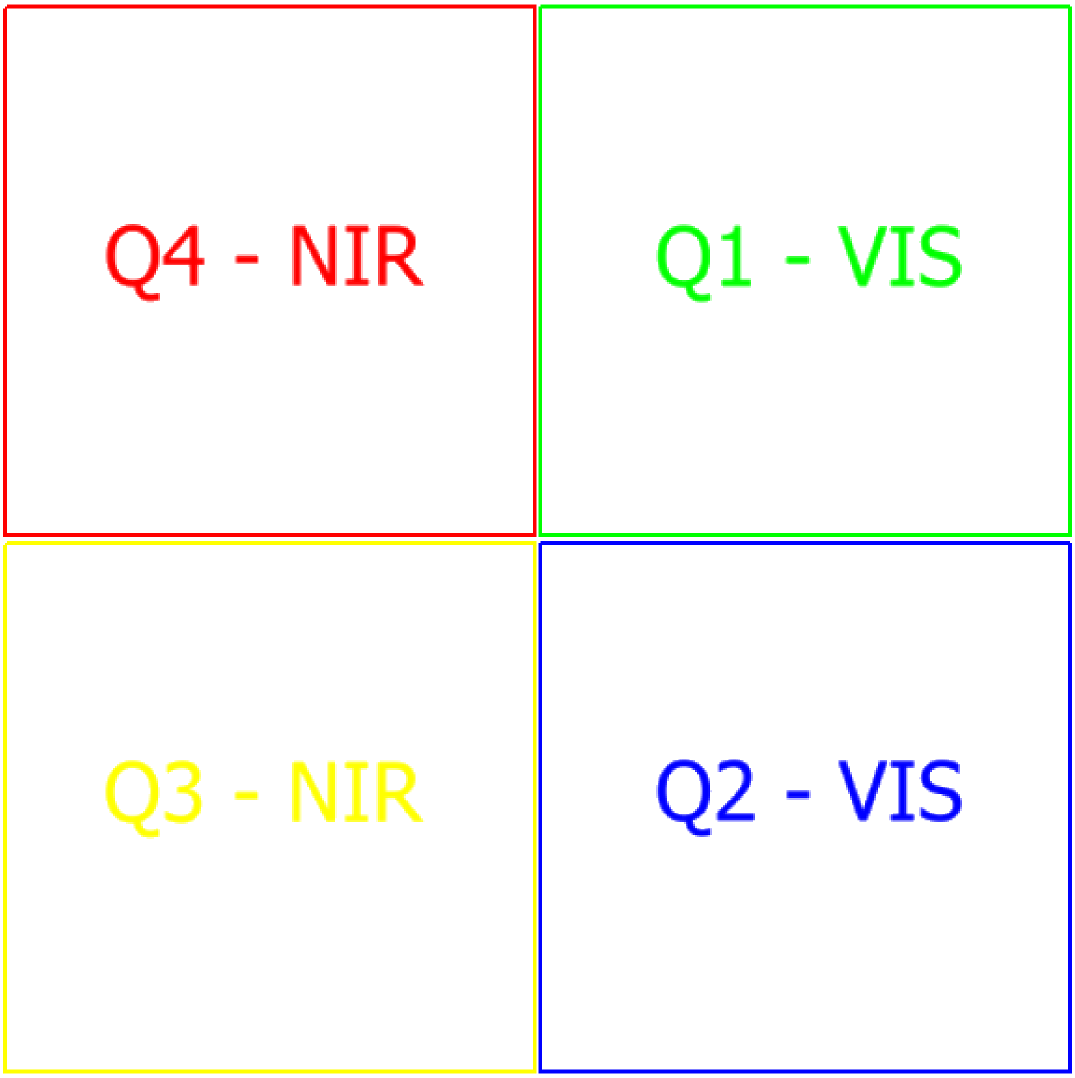


Figure 1 – Dioramas quadrants

Masks need to follow as better as possible the focal plane curvature, hence they are not coplanar. A "pyramidal setting" allows to minimize the defocusing.

Each mask, when in the proper position in the FOV, is tilted with respect to the instrument axis (in order to limit both defocus and vignetting) of ~ 0.7 degree along the mask diagonal.

⇒ Mask physical constraints and requirements

Each mask size will necessarily be larger than the useful quadrant FOV of 719x719mm, i.e. 780x780mm, as schematized in Figure 2.

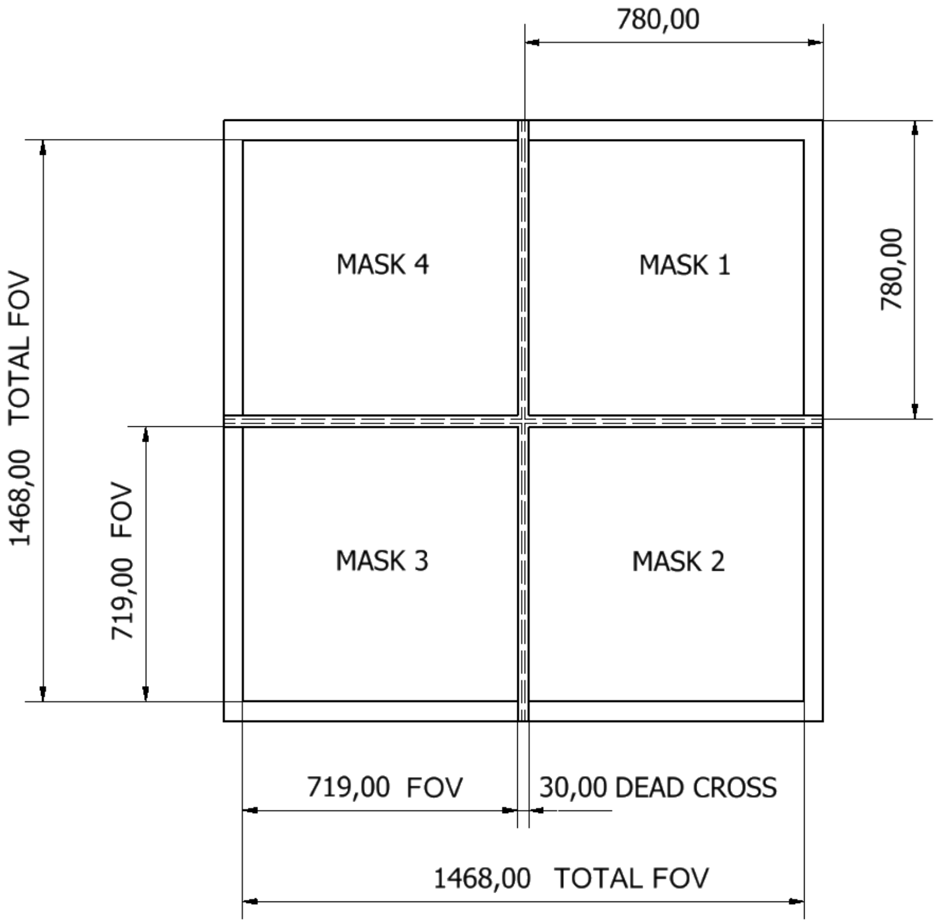


Figure 2 – Optimos FOV dimensions

Figure 2 is only a schematic 2D representation of the focal plane (in reality each mask is tilted with respect to the instrument axis).

Part of the free 49mm border of each mask will contain the mask identifiers - see RD2.

Thickness and physical properties of selected material for the masks are shown in the Table 1.

MATERIAL	Density g/cc	CTE linear @Temperature 0.000 - 100 °C µm/m-°C	Thermal Conductivity W/m-K	THICKNESS mm	PAINTING	WEIGHT Kg
AISI STEEL 1015	7.80	11.9	51.9	0.6	Like Vimos – "black opaque" gloss 2 - 5	2.9

Table 1

The overall requirement on the slit absolute positioning accuracy is 180µm. This accuracy could only be improved at the expense of a higher cost for the laser cutting machine.

Compensation for thermal expansion due to different temperatures during mask manufacturing and at observation time will be done as necessary.

Each mask will also be cut along the bottom edge with two reference marks (e.g. a rectangular and a triangular one – see Figure 3) used to align the mask during final insertion into the Mask Locking Devices, and other marks, around the lateral edges, in order to block the mask inside the locking system.

Figure 3 – Illustrative drawing of reference marks on the mask

The mask blanks shall be produced in the form of sheets already cut in size, painted and packed in pallets.

⇒ **Slit physical requirements**

In each mask shall be cut a number of slits between an indicative minimum of about 40 (0 for the dark mask), and a maximum of about 300, as dictated by the Instrument Science Requirements [Ref: RD3]. The requirements on the slits are shown in Table 2:

	OPTIMOS / DIORAMAS
RMS quality on edge Slit (*roughness)*	30μm
Typical Slit width (minor size) Minimum slit width (minor size)	1.8mm ± 15μm 0.9mm ± 15μm
Typical Slit length (major size)	18mm ± 50μm
Typical Slit shape	rectangular

Table 2

The requirements about curved or tilted slits will be detailed in the next phase (but the case of VIMOS demonstrates they are possible to be cut with a laser machine).

In each mask shall also be cut a number of square apertures for reference objects (in a number between 2 and 5) as dictated by the operational requirements for target acquisition.

2.3 The Masks Manufacturing Machine

The proposed Laser machine for Optimos is a CO_2 sealed laser available on the market, made by SEILASER, (see Figure 4).

The MMM must be capable of:

- Interpret the files containing the list of slit positions and sizes and transform them into cutting instructions;
- Cut Slits into 0.6mm thick painted steel sheet with the required accuracy and speed;
- Cut or engrave the mask identifier code, cut the mask edge and the interfaces with the mask locking device with the required speed.

Figure 4 - Mercury 603 Laser machine

The technical specification of this cutting machine are:

TECHNICAL SPECIFICATIONS

Models	**1313**
Work Area (mm):	1250x1300
Work support (mm):	1360x1550
Upright clearance (mm):	1390
Work table height :	800 - 850 mm
Clearance:	75 mm
Overall dimension W-L (H=1330mm, with class 1):	2090x2830
For laser sources SLAB 1000 W and over: "L"	+1500 mm
Weight:	1500 Kg
Z axis stroke:	0÷80 mm
Sealed laser source:	100÷2000 W and higher
Cutting head focal units:	3.75" - 5" - 7.5"
Vector mode	
X-Y axis work and contour speed:	2000 mm/s max
X-Y maximum speed:	2000 mm/s max
Conveyor advancement speed:	400 mm/s max
Acceleration:	15 m/s^2
X-Y-Z axis resolution:	0,001 mm
Accuracy:	+/- 0.05 mm on the whole area
Static repeatability:	lower than 0.05mm
Raster mode	
Raster speed (Head movement):	2000 mm/s max
Resolution:	up to 1200 DPI
Gray scale:	up to 256 gray tones
General features	
table flatness static system:	+/- 0.5 mm
Conveyor table flatness:	+/- 1 mm
Payload:	50 Kg/m^2
Control:	by external PC via ICARO CAM SW
Interface PC:	Ethernet LAN 10/100 Mbit/s WI-FI wireless 802.11b 2.4 Ghz / 11Mbit/sl
Power supply and power:	380V +/- 10% (3ph+g+n) 50 Hz 11 KW 70 KW
Compressed air:	Min. 20 N/Lit/min. 4-7 bar (oil free)
Assist Gas (option):	O_2/N_2 assist gas with gauge regulator
Operating temperature:	10÷40° C
Relative operating humidity:	10÷85% RH max, non condensing
Storage temperature:	-10÷70° C (H_2O empty circuit)
Options:	Conveyor, loading/unloading double pallet table, CCD camera registration, 3D SW, auto-focus, system of pursuit, capacitive sensor for metal cutting, suction pump, optic barriers for protection (class 4).

Figure 5- MERCURY 603 Laser machine - Technical Specifications

Preliminary tests in standard, i.e. non optimized settings, give us confidence that we can meet the specifications on slit quality.

2.4 Masks – loading/unloading mechanism on the Laser machine

The overall design and the complete characteristics of the assembled custom machine, with the other robotic TBD MMUS components, needed to load mask sheets and unload cut masks into the reservoirs, will be addressed during the following phase of the project.

NOTE:

This will also influence the size of the room in which it will be installed the mask manufacturing machine.

3. Mask Exchange Unit System – MEUS – WP 2620

3.1 Introduction

Once slits and reference apertures have been cut and masks are identified, they will be placed in two reservoirs/transporters, each serving two quadrants. Once the reservoirs/transporters are carried to the Nasmyth platform and placed below the instrument focal plane via a conveyor belt-rail, robotic arms will load/unload the masks in the proper quadrant.
The mask exchange unit system will be composed of three main mechanical subsystems:

- MASKS EXCHANGE ROBOTS;
- FOCAL PLANE MASKS SUPPORT SUBSYSTEM;
- MASKS RESERVOIRS.

3.2 Masks Exchange robots (robots - support structure)

When the instrument is at a fixed reference rotation angle, masks can be exchanged using two robots, able to insert the masks in the focal plane (see Figure 6). The final mechanical characteristics of the robots will be defined during next phase of the project.

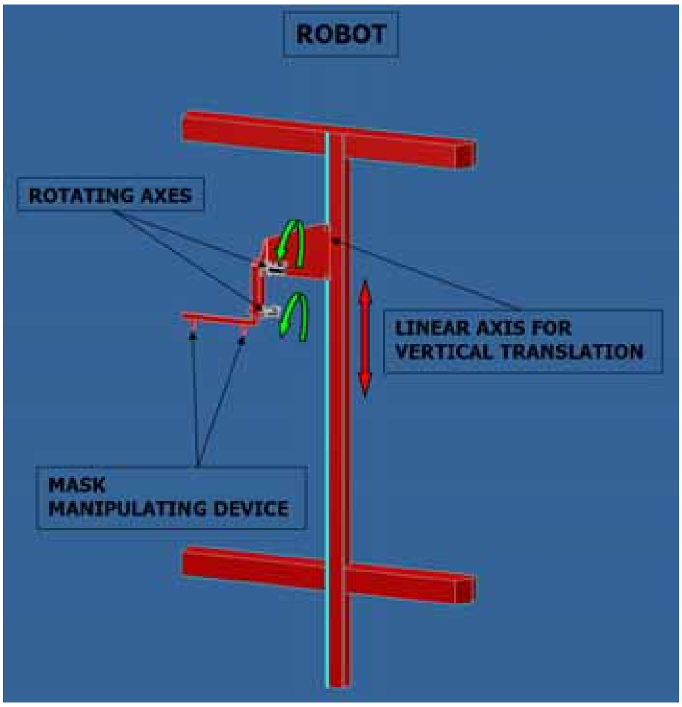


Figure 6 – Schematic of exchange robot

Each robot will be composed of:

- a linear axis for the vertical translation of the masks from the pick up position to the insertion position of the masks;

- two rotating axes, provided with precision reduction gears;
- a special mask manipulating device, able to pick-up and to insert the masks in the Locking Device;
- an optical system, mounted on the pick-up manipulating device, capable to read the mask and reservoir identifiers.

The two robots will be mounted onto a steel support structure. Figure 7 shows the preliminary overall dimension of this sub-system.

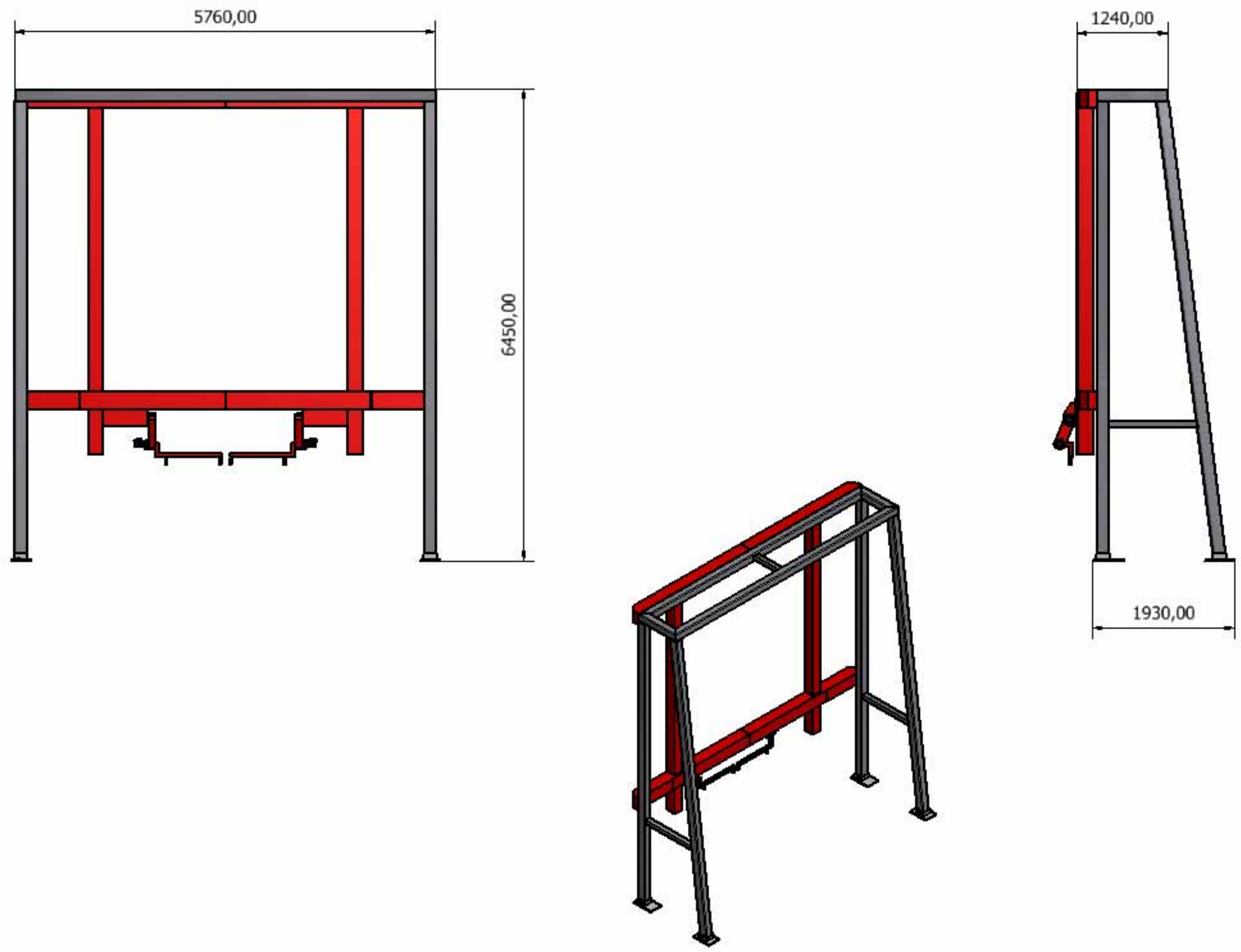
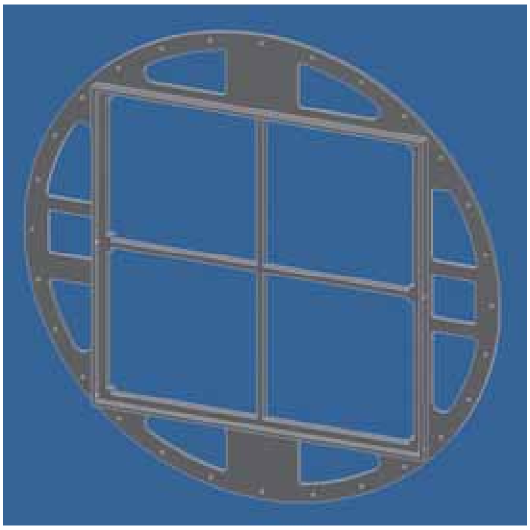


Figure 7 - Overall dimensions of robots support structure

3.3 Focal Plane Masks Support Subsystem (Backbone Cross Mask - Masks Locking Devices)

The Backbone Cross Mask, shown in Figure 8 left panel, will be mounted on the external part of the Dioramas Instrument Rotator.



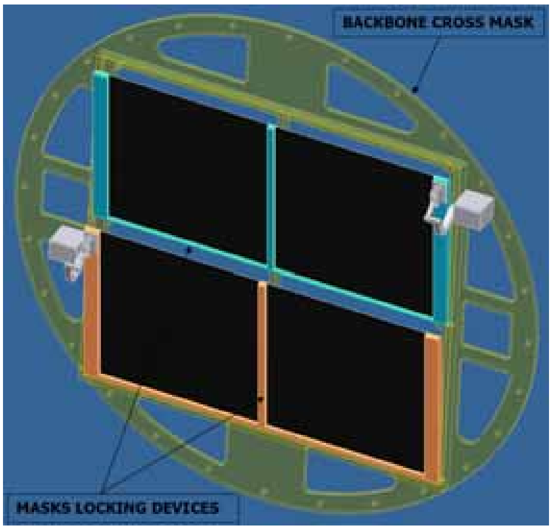


Figure 8 – Backbone cross mask & Mask locking devices

The Masks Locking Devices (show in Figure 8 – right panel) will be mounted on the previous sub-system. The locking devices will have 2 positions:

- open which allows insertion of a mask;
- closed/locked when the mask is inserted.

Two motors will operate the opening/closing of the devices.

When all the masks have been carried in their proper position by the robots, electromagnets, mounted on the Mask Locking Devices, will block the masks in position and the Locking devices will be closed.

The time needed to exchange a full mask set is estimated in 2 minutes, once the instrument has reached the "home" (reference) position.

3.4 Masks reservoirs

We estimate that a minimum of 10 mask sets, i.e. 40 masks, should be made available for each observing night. Masks will be arranged in 1 set of reservoirs (a reservoir set is composed of 2 reservoirs).

Each reservoir will contain masks for 2 predetermined quadrants (VIS and NIR) and thus hold 20 masks (in the next phase will be studied the possibility to increase such number to 24).

The weight of each reservoir, once filled with masks, will be approximately 113kg, and its dimensions approximately 830x460x1200mm (see Figure 9). Each reservoir will be marked with a proper identifier code. There will be a minimum of 2 reservoir sets (typically one at the MMUS and the other one at the Telescope), and a maximum of 4 (the other two could be kept as spare or could supplement the used sets).

For masks transportation, from the MMUS dedicated room to Nasmith platform, see chapter 5.

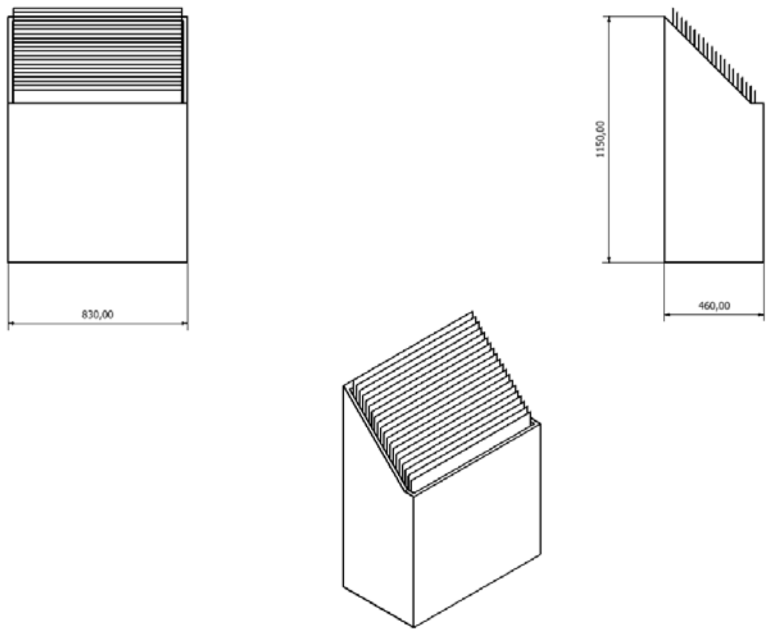


Figure 9 – Masks reservoir; preliminary overall dimension

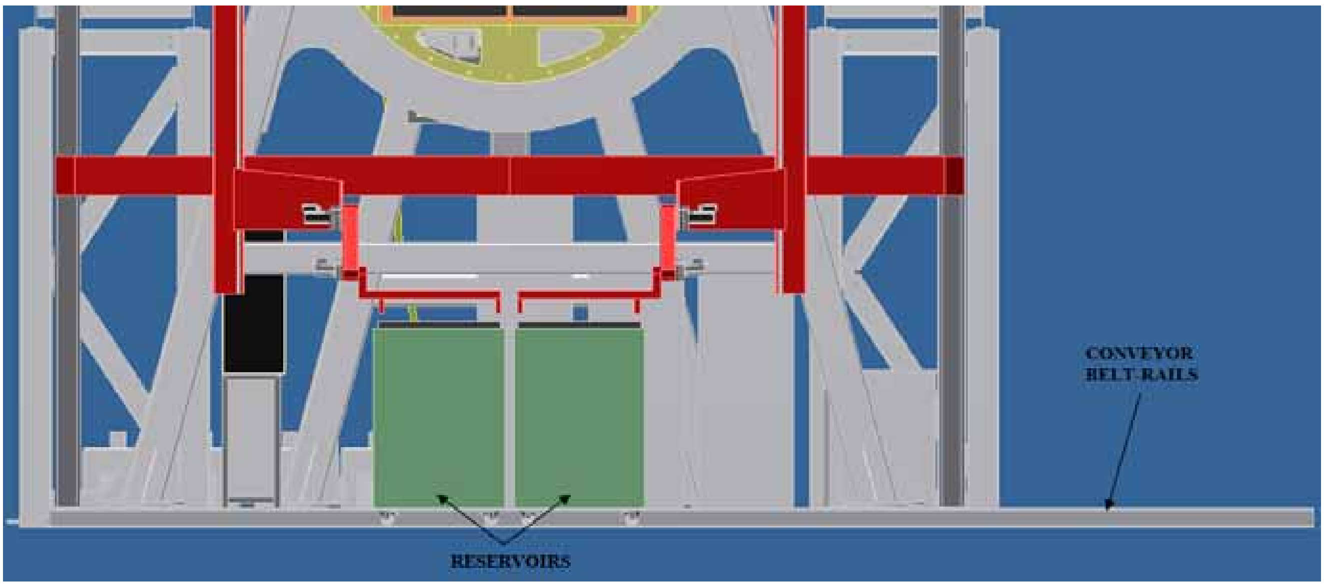


Figure 10 – View of reservoirs and conveyor belt-rails

Currently the capacity of an individual reservoir is twenty masks.

4. Mechanical interfaces information and preliminary mass budget

⇒ The robot support structure will be mounted directly on the upper plates of the connection of the spectrograph to the Nasmyth platform, as shown in Figure 11.

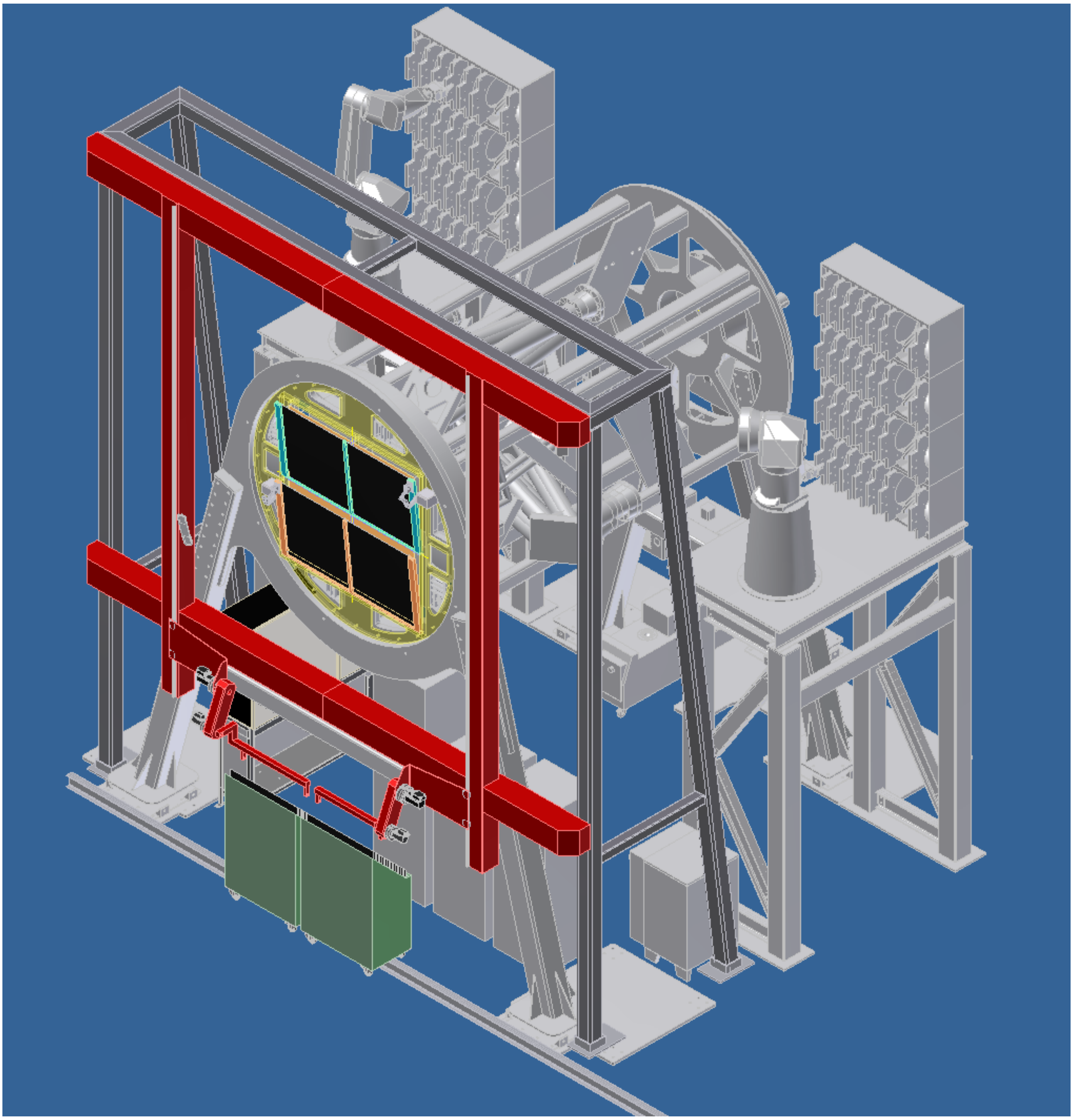


Figure 11 – Support structure connection

⇒ The conveyor belt for the reservoirs has a mechanical interface with the Nasmyth platform, because it will be mounted directly on it.

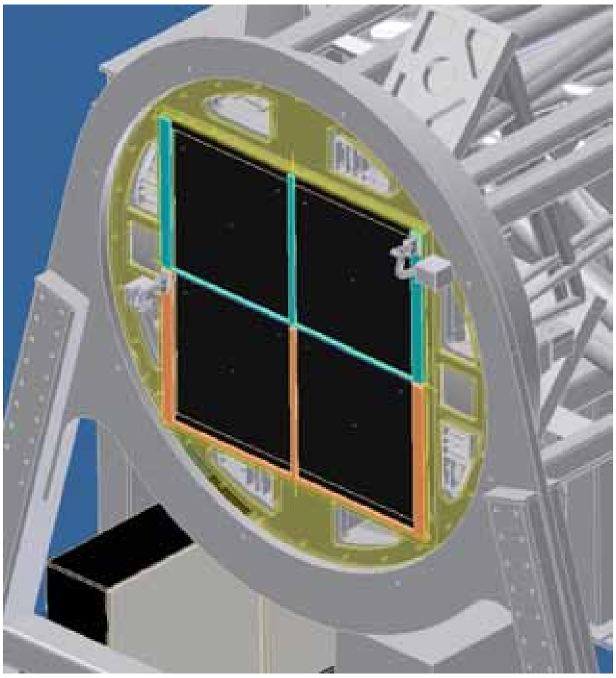


Figure 12 – Backbone cross masks – Instrument rotator

⇒ The backbone cross mask (with the two locking devices) will be mounted on the Instrument Rotator via screwed connections (see Figure 12).

Table 3 shows the preliminary mass budget of the whole MEUS.

COMPONENT	MATERIAL	UNIT MASS (T)	QTY.	TOTAL MASS (T)
Mask Exchange Robots + Bar code readers	N/A	0,52	2	1,04
Mask Exchange Support Structure + Positioning Control	AISI STEEL 1015	1,38	1	1,38
Robot Control Electronic 2000x1950x400	N/A	0,12	1	0,12
Backbone Cross Mask Structure	AISI STEEL 1015	0,35	1	0,35
Masks Locking Device + Motor	AISI STEEL 1015	0,06	2	0,11
Conveyor belt/Rails - 8m	N/A	0,13	1	0,13
Masks Reservoir	N/A	0,06	2	0,11
Masks (780*780) on Nasmith Platform	AISI STEEL 1015	0,0029	40	0,11
TOTAL		--	--	**3,35**
--		--	--	
CONTINGENCY + 10%		--	--	**0,34**
--		--	--	
TOTAL + CONTINGENCY				**3,69**

Table 3 - Preliminary mass budget of the MEU System

5. Mask Unit Requirements

⇒ **Mask manufacturing site**

Mask manufacturing will take place in a dedicated room, where the laser cutting machine and its robotized loading/unloading mechanism will be. Pallets containing the black coated metal sheets (let's assume that a pallet contains from 20 to 40 masks, and thus weighs between 100 and 150 kg) must reach the laser cutting machine loading/unloading mechanism, as well as the mask reservoirs. The size of the room shall not be smaller than 10x8m, and the height between 4-5m

The room must be equipped with air conditioning, power supply and a LAN connection.

⇒ **Mask reservoirs transportation from MMUS dedicated room to Nasmith platform**

The mask reservoirs will have to be transported to the Nasmyth platform where OPTIMOS-DIORAMAS will be. How to do it depends on where the mask manufacturing room is located. In any case, once the reservoirs reach the Nasmyth platform, a conveyor belt/rail will carry them underneath the mask exchange unit. A conveyor belt grabbing the reservoirs is needed because of their weight, and can be the same system used in the mask manufacturing room.

⇒ **Mask disposal**

Once used, the masks will have to be disposed of. This implies that for each observing run there will be something like 120-200 kg of iron to be taken care of.