



E-ELT PROGRAMME

OPTIMOS Study

Software and Operational Requirements for DIORAMAS masks

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**TITLE: Software and Operational Requirements for DIORAMAS masks**

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Abbreviations

| Abbreviation | Definition |
|--------------|----------------------------------|
| TBC | To Be Confirmed |
| TBD | To Be Decided |
| TBV | To Be Verified |
| DRS | Data Reduction Software |
| GUI | Graphical User Interface |
| ICS | Instrument Control Software |
| LCU | Local Control Unit |
| MEUS | Mask Exchange Unit (Svstem) |
| MMJ | Mask Manufacturing Job |
| MMR | Mask Manufacturing Report |
| MMUS | Mask Manufacturing Unit (Svstem) |
| MPS | Mask Preparation Software |
| MSF | Mask Slit File |
| P2PP | Phase 2 Proposal Preparation |
| RST | Reservoir Status Table |

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1 Scope

This document supplements the phase A deliverable documents giving additional details on the operational and software requirements for DIORAMAS mask production and handling.

1.1 Textual conventions

Terminology items when they are first introduced, or items to be highlighted or emphasized are shown *with this appearance*.

Items with parametric values subject to change, confirmation or definition, and in general items which are subject to decision (TBD), confirmation (TBC) or verification (TBV) are shown *with this appearance*.

References to external documents or to sections of the present document are shown *with this appearance*.

A definition or decision to be taken in the next phases of the project is indicated *with this appearance*.

2 Applicable Documents

2.1 Applicable Documents

The following applicable documents form a part of the present document to the extent specified herein. In the event of conflict between applicable documents and the content of the present document, the content of the applicable document shall be taken as superseding.

| n. | Title | Reference |
|-----|--|--------------------|
| AD1 | Opto mechanical Design and Analysis | E.REP.DIO.509.1054 |
| AD2 | Systems Design and Analysis | E.REP.DIO.509.1053 |
| AD3 | Scientific Analysis Report | E.SPS.OPT.431.1024 |
| AD4 | Slit Mask Manufacturing and Exchange Units Design and Analysis | E.TRE.DIO.509.1056 |

In particular all the values of physical sizes and quantities, number and names of items concerning DIORAMAS masks and related systems and subsystem are reported here for reference, but the official values shall be those in AD1 and AD2.

2.2 Reference Documents

In the event of conflict between reference documents and the content of the present document, the content of this document shall be taken as superseding.

| n. | Title | Reference |
|-----|--|--------------------|
| RD1 | Operational Concepts Definition | E.PLN.OPT.531.1021 |
| RD2 | DIORAMAS Observing Configuration Table | E.TRE.DIO.509.1061 |
| RD3 | Calabretta, Valdes, Greisen & Allen 2004, WCS paper IV, "Representations of distortions in FITS World Coordinate Systems", draft | |

In particular details not described in RD1 should be derived from the present document.



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3 Instrument and mask constraints

3.1 Preliminary definitions

3.1.1 Quadrant

The DIORAMAS instrument field of view will be divided in 4 disjoint **quadrants**.

Quadrants will be numbered **Q1 Q2 Q3 Q4** (and colour coded e.g. in GUIs as green blue yellow red). The numbering and position of the 4 quadrants in the instrument field of view assumed in this document is schematically shown in figure below, which assumes a view of the backbone cross mask looking at the sky from the spectrograph side (a drawing in scale is reported in [AD4]).

| | |
|----|----|
| Q4 | Q1 |
| Q3 | Q2 |

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

3.1.2 Mask set

A DIORAMAS spectroscopic exposure will require that a mask is loaded in each of the quadrants. The collection of 4 masks to be used in each exposure will be called a **mask set**.

A mask set will be identified by a **mask set identifier** (which should be linked to or hopefully identical to the exposure or field or other unique identifier used by the scheduler: the same mask set will be typically used for one sky spectroscopic exposure, one flat field exposure and one calibration lamp exposure).

Each mask in the mask set will be identified by a **mask identifier**, which will be constituted by the mask set identifier and a **quadrant affix** (prefix or suffix) inclusive of the quadrant number.

3.1.3 Special masks

There will be exposures of technical nature, or other technical operations (integration, alignment, calibration) which will also require masks (typically with a pattern of fiducial marks), which are referred below as **special masks**.

3.1.4 Dark masks

There will be cases (as described in the DIORAMAS configuration table [RD2]) where only one of the bands (visual or IR) will be operated in spectroscopic mode. To prevent stray light, the 2 quadrants in the other band will be occupied by permanent masks with no slits, which are termed **dark masks**.

In this case the mask set proper will be made of just the 2 normal masks, while a **composite mask set** can be considered including 2 normal and 2 dark masks, each with its own identifier.

3.1.5 Reservoir

The **reservoirs** will be the containers where manufactured mask are stored to be transported to the telescope, and kept available when not loaded.

A **reservoir set** is constituted by 2 reservoirs, which will be used together at the telescope.



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The individual reservoirs in a set will be termed Visible (VIS) and Near InfraRed (NIR) reservoir, and each of them will contain masks for 2 predetermined quadrants. The association between reservoir and quadrants will be as in the following table.

| Reservoir | contains quadrants |
|-----------|--------------------|
| VIS | 1 and 2 |
| NIR | 3 and 4 |

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 supplement the used sets). Each set will be duly identified e.g. by a letter code (*A B ...*).

3.2 Mask physical constraints

The *mask size* will be 780 x 780 mm, where the *useful area* for spectroscopy will be 719 x 719 mm. The *axes* of the mask will be termed *X* and *Y* where *Y* is the axis parallel to the dispersion direction. The *material* of the mask will be low carbon steel of *thickness* 0.6 mm, and *thermal expansion coefficient* of 11.9 micron/m C

The mask shall be *coated* with a VIMOS-like black paint

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

3.3 Slit physical constraints

In each mask shall be cut a number of *spectroscopic slits* between an indicative minimum of about 40 (0 for dark masks) and a maximum of about 300, as dictated by the *AD3*.

The size of the slits will be a *minor size* (width in spectroscopist's jargon) larger or equal to 0.9 mm and a typical *major size* (length in spectroscopist's jargon) of 18 mm where the major size is the dimension perpendicular to the dispersion direction.

The requirements about *curved 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 be cut also a number of *square* apertures for *reference objects* (in a number between 2 and 5) as dictated by the operational requirements for target acquisition [*RD1*].

Special masks may require aperture of different shapes (e.g. round holes).

The requirements on the relative positioning of slits between each other in such a way to optimize the coverage on the sky are described in *Section 5*.

4 Pre-observation operational requirements

The *Mask Preparation Software MPS* [see section 5] will be run by the observer at home. In case of pre-imaging observations it will require in input a set of images in the target sky area for the 4 (or 2) quadrants, and in all cases a potential target catalogue supplied by the user.

The user shall decide whether one or more spectroscopic exposures will be required (with different targets to improve coverage), and, assisted by the software, will place slits (for compulsory and software selected targets) and reference objects onto each planned mask.

The position (and type) of apertures is required to be in image pixels for the DRS and convertible into mm *from mask optical axis TBC* for what mask manufacturing is concerned (using suitable



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transformation matrices generated by calibration and distributed with MPS). They will be written to *Mask Slit Files MSF* (submitted back to the *appropriate ESO repository*). Such files will be identified with an exposure identifier concatenated with a quadrant affix, which can be later used to generate the mask set and mask identifiers.

5 Mask Preparation Software

Mask Preparation Software (MPS) is the software needed to prepare the slit masks used by DIORAMAS for the MOS (Multi Object Spectroscopy) observations.

MPS basically will perform two operations:

- selection of the objects to be spectroscopically observed
- positioning and drawing of the slits to be cut on the masks

DIORAMAS MOS observations will be performed by using masks with slits in correspondence of the objects to be spectroscopically observed. As the instrument field of view is a mosaic of 4 contiguous quadrants, MOS observations can be performed by the use of 4 masks, one per channel (or exceptionally using only 2 masks in the 2 visible or in the 2 IR channels, with the other using dark masks).

So, if the observer is starting from pre-imaging observations and up to 4 input catalogs (1 per channel), or if one is starting from the input catalogs only without pre-imaging, MPS will produce 4 output catalogs (1 per channel) to be used to build 4 masks (1 per channel).

5.1 User requirements

5.1.1 Object selection

MPS will provide two different possibilities of object selection, an *automated* and a *manual* one. They may or may not be using images obtained during pre-imaging observations.

5.1.1.1 Automated selection

As the number of objects and slits involved at this stage is very large, MPS will provide the user with an automated tool to place slits upon objects and maximize their number. Slit positioning shall respect DRS (Data Reduction Software) constraints. In fact, DRS needs that spectra produced by slits must not overlap in both dispersion and spatial directions. Moreover we have to consider that each first order spectrum is coupled with a second order spectrum, which will contaminate the first order spectrum of the slit above. The contaminating second order can be subtracted from the contaminated first order as if it were sky only if it overlaps completely along the spatial direction. These two requirements imply that slits must be perfectly aligned along dispersion direction and their minimum distance must be larger than the wavelength range of interest of the spectra. Since the cameras will disperse the spectra on 4kx12k pixel detectors, if the spectrum length is e.g. between about 2000 to 8000 in the visible and in the NIR range, the maximum number of slits at the same spatial coordinate, considering a possible overlap outside of the selectable wavelength range of interest, would be between 1 and 3 in both ranges. About 40 spectra could be typically packed side by side in the spatial direction.

5.1.1.2 Manual selection

MPS shall also provide the user with a manual and interactive selection of objects to be spectroscopically



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observed. The user will have the possibility to select some particular object he wants to observe (**compulsory objects**) or to exclude some objects from the observations (**forbidden objects**) or to select some objects for different purposes such as the objects used for mask alignment (**reference objects**). There will also be the possibility to draw and place tilted or curved slits. Tilted slits could also be generated during the automatical phase if a position angle is provided in the input catalogue, and also the handling of the objects forbidden because masked by the guide star probes should be automatized.

5.1.2 MPS parameters

The user will have the possibility to set the **slit width** and the amount of sky on each side of the object to be observed in the slit (**sky region**). He will also have the possibility to select the **dispersive element** and optionally the **wavelength range of interest** of the MOS observation to be performed.

5.1.3 Astronomer catalogs

MPS will work starting from an DIORAMAS image (in the case of pre-imaging observations), to which a catalog of objects is associated. The catalog can be derived from the image itself or from some other astronomical data-set. In this case, a tool to correlate the celestial coordinates of the objects in the catalog with the image coordinates will be provided.

If pre-imaging observations are omitted, MPS will use the supplied catalog only.

5.2 Software Requirements

No particular requirements are foreseen for this package

5.3 MPS Operation flow

Once the user has loaded the eventual pre-imaging frame and the pre-imaging catalog he will manually select the special objects [see 5.1.1.2] and eventually draw tilted or curved slits.

Then the user will set the MPS input parameters and will run the tool for the automated slit positioning.

During this step MPS will produce the output catalog where the positions and the geometry of the placed slits are listed. DRS will need positions in pixels and may benefit of positions in celestial coordinates. The MMUS requires positions in mm.

5.4 Interfaces

5.4.1 MPS input

MPS needs a **catalog** (ASCII file) of positions and radii (projected on the spatial direction) of the objects to be observed. Coordinates can be in pixels or in astronomical coordinates. It needs also of the **conversion matrix** from sky to CCD and viceversa. Some parameters, such as the **slit width**, the **sky region** and the **disperser** type, have to be set. When non-standard slits (tilted or curved) are requested, since the selection of peculiar objects is manual and interactive, MPS will also need an image of the field or additional source information in the catalog (e.g. position angle, stellarity, magnitudes, ...). MPS will also read one or more **configuration files** where the information about the dispersive element, the spectrum length, the pixel size, the file and directory pathname etc. are stored.



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5.4.2 MPS output

The logical output of MPS is a slit catalog. This is split in one file per quadrant.

It is proposed to use a single kind of file (**MSF**) where the geometry and positions of the placed slits are sequentially listed for both the (indirect) interface with MMS and DRS. We propose to use a FITS binary table format, and use the World Coordinate System conventions proposed in WCS Paper IV (**RD3**). The positions in the required units will be either available as table columns, or could be computed from WCS header keyword in standard way. See [7.4.1 below](#).

5.4.3 Graphical User Interface

MPS will also provide a graphical user interface. By this interface the user will be able to display the photometric images (if used) and catalogs and an interactive tool will be provided to the user to operate the choice of spectroscopic targets by cursor selection and to draw and place tilted or curved slits. This interface will also supply some catalog handling and overlay capabilities in order to allow the user to plot slit and spectrum contours upon the image or plot them into a file.

5.4.4 External interfaces

MPS will not interface directly with MMS or DRS. It will be probably integrated with a **TBD ESO tool** (like P2PP or analogous) which interfaces with some **TBD ESO Repository**, where the MPS output files will be deposited to be used in later stages.

5.5 Implementation issues

As the package will be distributed to the astronomer it will be based on some common, open source or free software. It should also be easily installed on the most popular operating systems.

As reference example we assume the VIMOS MPS (vmmps), with a design goal to achieve a greater automatization.

6 Mask manufacturing operational requirements

Mask manufacturing (and storage into the reservoirs) will be handled by a dedicated hardware system (**Mask Manufacturing Unit, MMUS**), inclusive of a laser cutting machine, and controlled by the **Mask Manufacturing Software MMS**.

The MMUS laser machine will be bought off the shelf (like e.g. the case of the LPKF machine for VIMOS) and interfaced with the other robotic MMUS components needed to load mask sheets and unload cut mask into the reservoirs.

These items will be addressed only during the following phase of the project.

The MMS shall receive from some **TBD ESO Scheduling s/w** a request (termed **Mask Manufacturing Job MMJ**) which will be a list of mask identifiers (grouped by mask sets) accompanied by the associated Mask Slit Files.

The eventual conversion of MSFs into proprietary formats which can be required by the cutting machine depends on the *choice of the laser machine manufacturer*.

The MMS shall return to the **TBD ESO Scheduling s/w** a report (termed **Mask Manufacturing Report MMR**) and eventually a **Reservoir Status Table RST**.



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6.1 Cut requirements

There is an overall requirement on the **positioning accuracy** of the slit (centres) of 180 micron, which will be budgeted between the laser cutting machine and the robot in the Mask Exchange Unit. Compensation of **thermal expansion** for different temperatures while cutting and at observation time will be done as necessary.

Besides slits, reference objects (see 3.3 above) and mask identifiers (see 8 below), each mask will also be cut along the bottom edges with two **reference marks** (e.g. a rectangular and a triangular ones) used to align the mask during insertion at the instrument. Other marks (blocking holes on lateral edges.) will be added as necessary. The edges of the mask will not be cut by the laser machine (the sheets shall be produced in measure) but the corners will be rounded.

6.2 Operational flow and MMUS requirements

The laser machine will need (to begin mask cutting) a device to pick up blank sheets to be cut from the pallets where they are provided, and will need to hold them in position during the cut.

It is **TBV** whether the selected laser machine or the software associated to it has to produce a way to control, monitor and calibrate the positioning accuracy (e.g. the VIMOS LPKF machine had a periodic calibration built in the software which compensated for motor backlashes) or whether the accuracy shall be assessed (**during acceptance only ?**) with external means.

It is **TBV** whether the laser machine will have an autonomous way (like the VIMOS LPKF one) of optimizing the order of cuts or whether this has to be supplied explicitly by MMS. It is also **TBV** whether MMS needs to provide a graphical way to follow the progress of the cuts if this is not provided by the laser machine native s/w (which the VIMOS LPKF machine had).

The laser machine shall cut all apertures (slits, reference object holes and edge markers etc.), then it shall write the mask identifier on the mask. It is **TBD** whether this is cut in form of a (1-d) barcode (like in the case of VIMOS) or is engraved (without a passthru cut) in form of a 2-d code. The issue of identifiers is addressed in **section 8**.

The order of production of masks in a MMJ will be such that all masks in a mask set are produced together in a sequence. The mask set will be declared **unsuccessful** if a failure forbids to produce all the 4 masks in the set (2 masks for composite sets including dark masks). The destiny of already produced masks in a failed mask set is **TBC** (the easiest solution is probably to leave them in the reservoirs; they will never be requested at the instrument since they do not exist as successful in the MMR; they will be discarded when the reservoir is returned from the telescope together with the other (good) masks). The order of production of the masks for the different quadrant in the same mask set will be optimized according to the way masks are stored in the 2 reservoirs.

The modality to empty used reservoirs and dispose of used masks is **TBD**.

Anyhow there will be no provision for offline storage of a masks. Once a reservoir is dismantled from the telescope, irrespective of the fact the masks were used in actual exposures or the exposures were not executed for any reasons, the masks will be discarded. If a mask with the same slit arrangement (i.e. the same MSF) is required later, it will be cut afresh. This is the so-called "**no-reuse-of-mask policy**".

An operational implication of such policy is that lamp calibration and flat field exposures shall be performed during the same observing session when the masks are in the reservoir for observations. And that if an observation is unsuccessful (e.g. observing night cut short for any reason) and shall be repeated at a later times, the masks required shall be manufactured again afresh.

There is an exception to the above policy which concerns dark masks. A set of 4 dark masks shall be permanently stored in predefined positions in the reservoir, and a mechanical arrangement shall avoid that



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they be discarded. Note that typically only 2 dark masks will be used jointly with 2 normal masks in a composite set.

Elementary high level operations which will be *presented as requirements* for the MMUS hardware associated software will be

- ◆ initial switch on and final switch off procedures
- ◆ putting blank mask pallet or container ready for loading
- ◆ connecting reservoirs for storage of manufactured masks
- ◆ pick up blank sheet
- ◆ manufacture (cut) mask
- ◆ store manufactured mask in reservoir
- ◆ optional calibration of the motion systems

It is *TBD* whether emptying returned reservoirs and discarding all masks will be a function for the MMUS or just a manual mechanically assisted offline operation (probably the latter).

Elementary high level operations which will be *considered as requirements* for MMS proper will be the following :

- ◆ retrieve or inspect MMJ orders coming from *TBD ESO Scheduling s/w*
- ◆ open MMJ order for execution
- ◆ optional conversion of all MSFs in the order to proprietary MMUS-required format
- ◆ perform mask manufacturing (will command pick up blank sheet, cut mask and store mask in reservoir to the machine)
- ◆ update RST recording which mask is stored in which slot
- ◆ update MMR recording which masks have been produced and declaring mask set successful when all masks in the set are completed
- ◆ making available MMR to *TBD ESO Scheduling s/w*

Lower level operations in which all the above can be expanded will be detailed *at a later stage*.

7 Mask Manufacturing Software

The MMUS will not be part of the instrument mounted on the Nasmyth focus, but an “independent” unit which is operated by its own software. We assumed that, likewise for VLT operations, there will exist some ELT s/w (e.g. a scheduler, OS, or whatever) which will take care of passing the relevant information to and from the MMUS, which in this sense will operate autonomously, having only clear and well defined interfaces with the ELT environment. This is what has been referred above and below as *TBD ESO Scheduling s/w*

7.1 User requirements

The purposes of the *Mask Manufacturing Software (MMS)* are :

- Assist the operator of the Mask Manufacturing machine (or Unit, MMUS) in the production of DIORAMAS masks up to their storage in the reservoirs to be transferred to the spectrometer.
- MMS shall receive from *TBD ESO Scheduling s/w* the manufacturing orders (prepared by MPS) listing the masks required to be stored in the reservoirs for one or more consecutive nights
- MMS shall convert the Mask Slit Files (MSFs), prepared by MPS and describing the placement, shape, size, etc. of slits on a mask, into the specific units and format required by the (presumably proprietary) software controlling the cutting machine. Slits as described in the MSFs will include also holes for reference objects. The conversion stage will presumably include also the addition of mask markups not described in the MSF (e.g. mask identifiers, edge



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features, etc.). If required, the conversion will take into account variations due to **temperature difference** between observation and manufacturing phases.

- MMS shall schedule and control the cutting of slits and other markups in the spectroscopic masks
- MMS shall control the robotized insertion of the masks in the reservoirs. In particular one shall record in RST the identifier of the mask associated to each slot position in the reservoirs
- MMS should deal with the identification of alternate reservoir sets (see 8.3).
- MMS should maintain a calibration table of slot positions in reservoirs if these are required for correct robot operation
- MMS shall return to *TBD ESO Scheduling s/w* a manufacturing report which, for each mask requested in the manufacturing order, shall tell whether the mask was successfully produced, and in which reservoir and slot is stored.
- In addition MMS shall be able to deal autonomously with special masks which can be required for sporadic or periodic calibration, maintenance or instrument integration activities. In some cases, these masks could be manually designed and therefore not be described by MSFs supplied by MPS.
- MMS shall be able (*TBC*) to control the emptying of the reservoirs before a new production session. Masks in the reservoirs shall be discarded, with the exception of dark masks.
- MMS shall contain in editable **configuration files** all parameters relevant to the mask conversion (e.g. offsets between optical axis and mask centre), the MMUS (e.g. tools or speed used for slit cutting), the robotized reservoirs (e.g. slot positions).
- MMS shall allow to edit and test the configuration files, and to test and calibrate the mechanical units of the MMUS (*TBC*).

7.2 Software Requirements

MMS is not a memory or CPU intensive task, and therefore it does not have specific requirements in these areas.

The issue of the Operating System under which MMS will run will depend on external constraints (primary and secondary) not known at the current stage.

Secondary constraints will be e.g. the choice of a standard s/w environment for EELT, or the security policy adopted for EELT.

The primary constraint will be dictated by the industry standards followed (and the software supplied) by the manufacturer of the cutting machine, whose details are yet unknown.

For instance, in the VIMOS case, the manufacturer of the laser machine used for mask cutting (LPKF) used a proprietary format to describe markups on the mask, and had proprietary software modules to control the laser machine, and to convert from CAD standard formats to the proprietary format. These modules ran using a manually operated GUI, and under some flavour of MS Windows. We were able to request to the firm the addition of a batch mode, and support under the particular flavour (Windows NT) chosen at the time (which required a waiver by ESO), but not, for instance, support under Unix or disclosure of the proprietary format.

What we wrote for VIMOS was the conversion from our table of slits into the selected CAD format, all the s/w to manage the orders we received from ESO and the reports sent back to ESO, and the one to keep track of what was stored in the equivalent of reservoirs.

For DIORAMAS we will definitely deal in house with the analogous to the latter, i.e. what we call **MMS proper**. But concerning the machine it is possible that it will be assembled custom and integrated with the unloading mechanism. So maybe the software delivered from the company will just be libraries to control the various mechanisms and devices and we will take care also of the user interface.



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In absence of particular constraints from the machine manufacturer and from ESO, our preferences would be to run under some flavour of Linux (or Unix), and to develop our own programs and GUIs under Java. We would be glad to use other coding standards (GUI and languages) suggested by ESO, if these would allow to share some of the code with the instrument s/w (e.g. mask and reservoir slot identification, control of robotized access to the reservoir). But we cannot be sure that anything of this will be allowed (or convenient, or cost-effective) by the machine manufacturer.

An alternative possibility to be investigated would be to develop our own software wrappers in our preferred environment (OS, Java) and run any proprietary s/w requiring Windows in an emulator (e.g. VMWare, VirtualBox) which should however have scripting capabilities.

Other requirements (interface requirements) are :

- MMS shall have a network (TCP/IP) interface, and support an adequate protocol to exchange orders, reports and associated files (e.g. rsync, NFS, ftp etc.) with *TBD ESO Scheduling s/w*
- MMS shall have adequate communication ports to communicate with the cutting machine proper (in order to move the masks, cut slits and other markups, and configure and control the machine).
- MMS shall have adequate communication ports to communicate with the robotized unit which will move the reservoirs and load the masks into them.
- MMS shall have adequate communication ports to communicate with devices used for mask and reservoir identification *TBC*. (i.e. barcode readers identical to those used in the MEUS robot)..

7.3 Interfaces

MMS will be interfaced only with *TBD ESO Scheduling s/w*. At this stage, we assume that such interface will be at the basic level of “file exchange”, and we list what are the information to be passed back and forth. Details on these interfaces will have to be revised *at a later stage*, when also the ELT environment will be at a higher level of definition.

7.3.1 Input interfaces

The inputs to MMS (to be received by the ELT environment) will be:

| | |
|---------------------------|---|
| Mask manufacturing orders | |
| name | <i>timestamp.MMJ</i> |
| format | ASCII files |
| layout | <ul style="list-style-type: none"> • one header line repeating the file name (for verification) • another header line with <i>nmask</i>, the number of masks • <i>nmask</i> lines each with a mask identifier string |

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| Mask Slit Files | |
|-----------------|---|
| name | <i>mask-identifier.MSF</i> |
| format | FITS files |
| layout | <p><i>will be finalized in the next phase, as example it might contain</i></p> <ul style="list-style-type: none"> • one header keyword with mask identifier • one header keyword with <i>nslit</i>, the number of normal slits • one header keyword with <i>ncurve</i>, the number of curved slits • header keywords with WCS and transformation matrices from sky to CCD and from CCD to mm • <i>nslit</i> table rows with the x y position and sizes of the slit • <i>ncurve</i> table rows with the 9 (8 Bezier + the slit minor size) coefficients for curved slits |

7.3.2 Internal interfaces

An eventual internal interface within MMS will be represented by

| Machine Cutting Files (<i>provisional name</i>) | |
|---|-----------------------------------|
| name | <i>mask-identifier.TBD</i> |
| format | <i>CAD or proprietary formats</i> |
| layout | <i>TBD</i> |

It is possible that there will be more than one internal interface according to cutting machine manufacturer requirements. E.g. VIMOS had a CAD intermediate format (Gerber file) and a LPKF proprietary format (LMD files).

7.3.3 Output interfaces

The outputs of MMS (to be sent back to ELT environment) will be

| Mask manufacturing (termination) reports | |
|--|---|
| name | <i>timestamp.MMR</i> |
| format | ASCII files |
| layout | <ul style="list-style-type: none"> • one header line repeating the file name (for verification) • another header line with <i>nmask</i>, the number of masks • <i>nmask</i> lines each with a mask identifier string and a status code (digit or string) |

If required one can make available also the Reservoir Status Table (which is otherwise used internally, which could have a layout like this

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| Reservoir Status Table | |
|------------------------|---|
| name | <i>reservoir id.RST</i> |
| format | ASCII files |
| layout | as many lines as slots in a reservoir with each line containing : <ul style="list-style-type: none"> • (optionally the quadrant id) • either the full mask identifier, or the predefined value “empty” or the predefined value “unused” |

7.3.4 Other interfaces

For hardware interfaces: see the various ports described in the interface requirements given in [7.2 above](#)

Mask and reservoir identifiers will be also used by ICS to access a particular mask when required, and therefore some way (typically the RSTs) to pass them “up” to *TBD ESO Scheduling s/w* (unless the autonomous reservoir scan described in [12.2.5](#) is considered sufficient).

Internal configuration files will be defined in the next phase. It is likely that each reservoir will be described by a calibration file which for each slot will list the position in mm or alike (and could list a flag to declare a slot as out of use for any purpose).

Some of the information contained in the configuration files might need to be known also to ICS (e.g. slot positions in the reservoirs). This is a sort of permanent interface which will need to be updated very seldom.

7.4 Conceptual flow

The operational flow of the DIORAMAS MMS will be similar, though simplified, to the VIMOS one, and it is sketched in:

- *TBD ESO Scheduling s/w* will provide through a suitable network protocol (rsync, NFS, ftp) a *mask manufacturing order* which will list the identifiers of all masks to be (cut and) inserted in the reservoirs for one or more consecutive nights. For all spectroscopic masks, the associated MSFs shall also be supplied. The case of special and dark masks is described in [section 14](#).
- The *mask manufacturing order* will be identified by a name (including a time stamp) and a status (which can assume the values of “*being transmitted*” or “*transmission completed*”)
- Only orders in the latter status will be processed by the following steps.
- At this stage MMS will be required to mount the mask reservoirs, which should be preliminarily emptied of all masks they contain, with the exception of dark masks.
- Also at this stage a *mask manufacturing report* will be initialized (it will share the same name as the corresponding order, with a different file extension) in status “*in preparation*”. It will list all requested masks with a “*unsuccessful*” (or “*undefined*”) status.
- A first step (1) will convert all MSFs in the units and format required for slit cutting, adding any other non-slit markup. The output of this step will be provisionally called MCF (Mask Cutting File), and deposited in a staging area. If required, the conversion will take into account any temperature dependence
- A second step (2) will command the machine to cut each mask according to the content of the



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MCF. The masks will be duly identified cutting or engraving their identifier onto the mask (see section 8).

- A third step (3), immediately following the second mask by mask, will command the robotized unit to insert the mask in a slot of a reservoir. *Optionally TBV* this stage may verify (read) the identifier. Finally this step will change the status of the mask in the *mask manufacturing report* to “*successful*” and/or record the slot in which it is stored.
- For special masks the previous steps can be replaced as described in section 14.
- An unrecoverable error in any of the previous steps will either retain the status of the mask in the report as “*unsuccessful*” or set a detailed error code indicating the type of failure. Subsequent steps will be skipped.
- At the end of all masks in an order, the staging area will be cleared and the *mask manufacturing report* set to status “*completed*”.
- Completed reports (and only them) will be available to ELT s/w for retrieval and deletion.
- At the very end the reservoirs will be unloaded and made available for transport to the instrument.
- It is TBD whether a *mask manufacturing order* shall necessarily contain all the masks for an observing run (one or more consecutive nights) or whether MMS should be able to process further orders in sequence until the maximum capacity of the reservoirs is reached.
- It shall be noted that the masks in a reservoir can be used at the instrument repeatedly until the reservoir is not dismantled (e.g. for observation, lamp and flat field exposures, or also in consecutive nights in case of long observing programs or failures), but once the reservoir is brought back to the MMUS it is emptied and its masks are thrown away (with the exception of dark masks).

8 Mask identifiers

Assuming to have a number of different masks available for each night, the problem of mask identification must be addressed.

One can consider two reasons to identify the masks, and equivalently two reasons to identify the reservoirs.

- Identification of the reservoirs may be required to associate a reservoir in a set to a couple of quadrants, and forbid that masks of the wrong quadrant be inserted in it, or that the reservoir of a given quadrant is mounted at an incorrect position at the instrument. Since there will be two reservoirs set (e.g. while one is at the instrument the other one is at the MMUS) it is also important to know which one is in use, since it might have implications in the way robotized units will access it (e.g. reading the slot position from a calibration table).
- Identification of the mask shall not only identify the quadrant (to prevent insertion of masks in the wrong place), but also identify the observation to which a mask belongs

8.1 The rationale of mask identification

The rationale for mask identification is that masks shall be associated to exposures, and ultimately to observing programs. And of course the right mask shall be used at the right moment.

The ideal approach would be if the same identifier generated during the MPS or P2PP observation preparation phase could be propagated throughout.

This approach was not followed for VIMOS, mainly because the observation identifiers are long strings, unsuitable to be cut as barcodes in the masks (most of the codes deal only with numeric values, and this is



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in particular valid for the 2/5 interleaved code which allows to use both white and black parts of the barcode as codifying, i.e. to minimize the space and time used to cut the barcode).

If the original string code cannot be written solidally onto the mask, a mapping between the observation id and a numeric code shall be done somewhere.

In the case of VIMOS a rather cumbersome solution was implemented. A 6-digit code *qnnnnn* was used, where the first digit *q* was the quadrant number and *nnnnn* was a sequential mask set number. Since the latter number shall be kept unique (and its recycling managed), a special layer of software (*vmmscs*) was introduced to keep track of the mapping, use the code to tag masks and name MSFs for the MMJ and retrieve the info from the report, and propagate it back to the other software tiers and ultimately to ICS. Additional table files, also propagated, kept track of which mask was in which slot using such identifier (analogous to the RST imagined for DIORAMAS).

While the latter issue can be simplified if an autonomous reservoir scan is implemented in the MEUS (see 12.2.5 below), it still complicates life with redundant software tiers (considering also that the *ESO s/w responsible of issuing manufacturing orders is unknown*), so we considered ways to simplify it.

8.2 Possible identification formats

Let's take for example's sake the case of a VIMOS-like identifier and mask code : if we look in the ADP example quoted in the *vmmps* manual on ESO web site, for instance we find identifiers like this, where one can clearly see things like the program id, a timestamp, a field id, the instrument and grism, and last but not least the quadrant: The part indicated in blue is a comprehensive identifier, whose concatenation we'll use below in the examples:

```
PAF.ID "073.A-0602C+3.18+2004-05-12T15:50:50.001+1"
PAF.NAME "wfi16_vm_LR_Red_M1Q1.adp"
```

Such identifiers would have been ultimately translated (mapped) to a mask identifier like e.g. 104321, where the first digit indicates the quadrant and the other 5 are the mask set sequential number.

The figure below gives the full string barcode using the *ASCII code 39*



The figure below gives instead the 6-digit 2/5interleaved code (this VIMOS-like solution is viable at the price of the software complications described above)



Note that the numeric 2/5 code is shown in a realistic size, readable with a real barcode reader (the thin bar is 0.08 cm, as was used for real VIMOS masks, while the code height is 1 cm, i.e. some 3 times higher than it was used, for clarity of display), while the ASCII code is shown with a 4 times smaller bar width to fit into the page (so a real one is likely to be prohibitively large), and is untested.

The figures below give instead the full string barcode compacted with some 2-dimensional codes like *Aztec*, *QRCode*, *DataMatrix* and *PDF417*. In principle all these codes can store some 2000 characters, although all implementation descriptions suggest to limit in practice to 800 characters.

The unit size has been chosen for clarity of display to 0.12 cm for the three "square" codes (which is double the size suggested as default) and to 0.08 cm for PDF417 (which is about 3 times the suggested default of 0.03 cm). Real dimensions would require testing (*in the next phase*) of the compatibility between readers and laser machine generated codes.

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Aztec



QR code



DataMatrix ECC200



PDF417

It is apparent that the 2-d barcode meet the requirement of software simplification. The choice between 1-d barcode or 2-d barcode will be *resolved during the next phase*, with a preference to use the larger capacity 2-d code. The driving argument for the choice will be the capability of common types of barcode reader to read such code exploiting the contrast between the black painted surface of the mask, and the unpainted engravings. In fact the 2-d codes, since they include black and white holes, are not suitable to be cut in the masks, but shall be engraved. What also remains to be *verified in the next phase* is the choice of the code (for some of them, although in the public domain, the documentation shall be bought from ISO), We considered briefly the possibility to use RFID labels, which also have a large data capacity and could store long string identifiers, but they require to be glued to the masks, which is an additional manual operation, and makes them inferior to codes solidally cut or engraved in the mask.

8.3 Reservoir identification

A label with a barcode of the same type used for the masks, and containing predefined standard string values (different from mask identifiers), can be permanently attached to the Reservoirs, so that the MEUS robot can move to a predefined position to read and verify the reservoir identity.

9 Reservoir physical constraints

The *capacity* of a reservoir is 20 masks shared between 2 quadrants as explained above. This means a maximum of 10 spectroscopic exposures (10 mask sets) will be possible in run with a given reservoir set (typically one night).

The *size and weight* of a reservoir will be 830x460x1150 mm and 55 kg (plus 58 kg for the masks). The mechanical layout of a reservoir (with masks inserted in staggered positions) is shown in [\[AD1 and AD4\]](#)

Reservoirs shall carry *visual and mechanical identification* of the set they belong (A, B ...) and of their position at the telescope (VIS or NIR), as described in [8.3](#).

The MMS shall produce a *RST Reservoir Status Table* which will list, for each reservoir and slot the mask identifier of the mask stored in it. The identifier can also assume the “empty” or “unused” value (the latter shall forbid insertion of masks in the slot). Whether such table is transmitted to *TBD ESO Scheduling s/w* along with the MMR and later used by ICS is *TBV*.



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10 Exchange of reservoirs with the telescope

Once the manufacturing of all the masks required for the next observing night or run is completed and all masks are stored in a reservoir set, the two reservoirs shall be transported up to the telescope using a *to be agreed with ESO* Transport System.

Contextually, the used reservoirs dismantled from the telescope shall be transported (using the same Transport System) down to the MMUS location, where they shall be emptied, with the exception of the dark masks (e.g. using some mechanical provision). Used masks will be thrown away.

The empty reservoirs (but with dark mask in their assigned slots) shall then be mounted onto the MMUS in order to start a new manufacturing cycle.

11 Loading reservoirs onto the telescope

Transfer of the reservoirs from/to the instrument platform shall occur in *to be agreed with ESO* modality. One will have first to unload the reservoirs currently at the telescope, park them temporarily somewhere, and load the new ones.

Replacement of a second reservoir set with a supplementary set during the observing run is *TBD*.

11.1 Loading

The two VIS and NIR reservoirs of a set shall enter the instrument cover in a fixed predetermined order. Some form of mechanical failsafe is necessary to e.g. connect the two reservoirs in a “train” only in such fixed order (e.g. VIS first and NIR next or vv).

It is recommended that reservoir sets are identified both visually with a label for the operator, and by a barcode identifiers (see [8.3 above](#)) read by the MEUS robot (when the instrument is on).

Loading will then follow (provided unloading has already been executed) as follows, presumably as a manual offline operation (it shall not require the instrument to be controlled by s/w but presumably requires some electrical power):

- ◆ open guillotine cover (not part of the MEUS)
- ◆ attach train of the two reservoirs
- ◆ move train to home position
- ◆ close guillotine cover

There will be Reservoir Presence Sensors (likely a couple of switches) provided by and interfaced to WP5000 and possibly also to the MEUS robot, but they won't be accessible in this manual phase *TBD*.

11.2 Unloading

Unloading of the reservoir set used during the last observing night will be done, also presumably as a manual offline operation, when all observations (inclusive of flat fields and lamp calibration) on the masks contained in such reservoirs have been completed. It requires the following steps:

- ◆ open guillotine cover (not part of the MEUS)
- ◆ slide out train of the two reservoirs
- ◆ (close guillotine cover if loading does not follow immediately)

The two reservoirs in the train shall then be decoupled and transported down to the MMUS, where their content shall be disposed of before reusing the reservoirs.

Eventually one could immediately replace the reservoir set with a supplementary one if available at the platform *TBD*.



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12 Mask exchange requirements

12.1 Preliminaries

The **Mask Exchange Unit (MEUS)** will be described in detail in [AD1, AD2 and AD4].

It is composed of (or requires control or access to) the following components:

- ◆ (requires access to) the operating reservoir set, in the form of 2 reservoirs positioned in fixed positions under the robotic arms (see below). The presence or absence of the reservoirs in the appropriate position shall be sensed by the Reservoir Presence Sensors (WP5000 task). The signal of such sensors might also be fed to the MEUS as interlock inhibiting robot operation if no reservoirs are present. The identifier of the reservoir set should also be sensed via barcode (MEUS task).
- ◆ (includes and controls) 2 independent **robotic arms** with a vertical excursion of about 5.4 m in the vertical (Y) direction. The left and right arm serve the left and right reservoir and the associated couple of quadrants
- ◆ Each arm is equipped with a **mask manipulating device** with movements along 2 degrees of freedom (probably two rotational axes which, coupled with the main arm motion, will allow a step-wise fine Y-and-Z movement to search masks in the reservoirs, and a tilting movement for mask insertion in the locking devices described below).
- ◆ Each manipulating device is equipped with a reader capable to read the mask and reservoir identifiers (see [section 8 above](#))
- ◆ (includes and controls) the 4 **mask locking devices** (retainers, one per quadrant, however these will be operated only in couples, one for top quadrants and one for bottom quadrants)
- ◆ the locking devices will be fixed to an appropriate interface plate (**backbone cross mask**) attached in front of the instrument rotator. The locking devices can be operated only when the plate (and hence the entire instrument) is rotated in a predefined reference position.
- ◆ the locking devices will have 2 positions/states : open which allows insertion of a mask, and closed/locked when the mask is inserted. If no masks are inserted (e.g. for imaging observations) the locking devices shall be in closed position.

What follows is a list of functions which can be considered at a same time as operational requirements on the MEUS and on the ICS which commands it. Detailed requirements will be passed *in the next phase* to the MEUS manufacturer, whose offer currently foresees “*control software with manual, semi-automatic, automatic and remote modalities*” where “remote” is detailed as “*point to point Ethernet connection to an external workstation*”. The baseline communication protocol is proprietary standard, however variants could be negotiated.

We propose tentatively to assign the topmost level operations to ICS (using remote modality) and the middle and low level operations to the MEUS imbedded s/w.

12.2 Topmost level operations

The following elementary operations are required to support spectroscopic observations at the highest level. Their execution requires access (e.g. expansion into low level commands within the robot) to lower level functions.

Fallback operations in case of partial failures (e.g. absence of one reservoir, failure of one quadrant) are not described now but *will be detailed in the next project phase*.



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12.2.1 Initialization

Before commencing a sequence of spectroscopic observations (including sky, flat field or lamp exposures), the following conditions shall be verified (sensed and/or commanded)

- ◆ (the instrument cover shall be closed and light-tight)
- ◆ Both reservoirs shall be correctly present in their home position
- ◆ (The identifier of the reservoir set shall be sensed)
- ◆ All units of the robot shall be switched on
- ◆ The robotic arms shall be in their home position.
- ◆ The robotic manipulators shall be in their rest condition
- ◆ The mask locking devices are assumed to be empty and closed

12.2.2 Search an load mask set with identifier “id”

This operation is pre-requisite to the beginning of any spectroscopic exposure (except when a continuation exposure on the same mask currently loaded is required).

As a pre-requisite to it, the **unload current mask set** (see 12.2.3) shall have been executed at the end of the previous exposure or at termination of the previous observing run.

The **search and load mask set with identifier** command receives a single parameter, which is a **mask set identifier**, and is parallelized/serialized in the following middle or low level operations:

- ◆ rotate instrument to reference position (not a MEUS function)
- ◆ open all mask locking devices
- ◆ search in VIS reservoir and load in top quadrant with identifier
- ◆ search in VIS reservoir and load in bottom quadrant with identifier
- ◆ search in NIR reservoir and load in top quadrant with identifier
- ◆ search in NIR reservoir and load in bottom quadrant with identifier
- ◆ (verify all masks loaded and send OK; eventually update internal table with reservoir status)
- ◆ close all mask locking devices
- ◆ move robotic arms to home or rest position

Operations on the left and right reservoir and robotic arm can occur in parallel, while operations on the 2 quadrants served by the same arm will occur in sequence.

The **search in reservoir and load in quadrant** functions are described in 12.3.2 below.

12.2.3 Unload current mask set

This operation shall be executed at the end of each spectroscopic exposure if the same masks are not required in the next exposure. This operation shall be executed unconditionally before going to imaging mode, or before switching off the instrument.

The **unload current mask set** command has no parameters and is parallelized/serialized in the following middle or low level operations:

- ◆ rotate instrument to reference position (not a MEUS function)
- ◆ open all mask locking devices
- ◆ unload top quadrant to VIS reservoir
- ◆ unload bottom quadrant to VIS reservoir
- ◆ unload top quadrant to NIR reservoir
- ◆ unload bottom quadrant to NIR reservoir
- ◆ (eventually update internal table with reservoir status)



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- ◆ (the mask locking devices may remain open or closed; they could remain open if a new load shall follow, and they shall be closed if the instrument has to be switched off or rotated without masks; this can be commanded invoking the individual lower level function)
- ◆ move robotic arms to home position

Operations on the left and right reservoir and robotic arm can occur in parallel, while operations on the two quadrants served by the same arm will occur in sequence. Execution of this function presupposes that the position of empty reservoir slots (i.e. from where the current masks were extracted) has been memorized.

12.2.4 Going offline

At the end of a sequence of spectroscopic observations, or anyhow before switching off the instrument the following conditions shall be verified (sensed and/or commanded).

- ◆ All the masks shall be unloaded from the instrument (see 12.2.3. above)
- ◆ The mask locking devices shall be closed
- ◆ The mask manipulators shall be commanded to their rest condition
- ◆ The robotic arms shall be commanded to their home position
- ◆ The reservoirs shall be free to be later manually unloaded (see 11.2 above)
- ◆ finally it shall be possible to power off the MEUS

12.2.5 Reservoir set scan

The need or convenience of an autonomous *reservoir set scan* operation inside the MEUS is *TBV*. It is possible that knowing in advance which mask is in which reservoir slot is not needed by the “search and load” function. It might be however useful for diagnostics.

As a fallback the MEUS could always operate without it, using the RST prepared by the MMS (and kept up to date by ICS !), if such file is propagated to the ICS (of course one should ensure that it is the RST corresponding to the particular reservoir set present at the instrument).

The reservoir scan shall build a table of mask identifiers associated to slots in each reservoir (*TBD* either in memory in the robot LCU, or returned to ICS). *Alternatively* the reservoir scan can just return the list of masks present in each reservoir (and *eventually* their order of appearance e.g. from back to front) without keeping track of the slot number.

A scan function can be implemented like this:

- ◆ Move robotic arm to the “reading position” just above the reservoirs
- ◆ Either move the manipulator with reader (fine step-wise movement in Z and Y) at precalibrated slot positions for each slot, and read the identifier of the mask present in the slot ...
- ◆ ... or move manipulator with reader by fixed steps (e.g. from back to front) in the proximity of expected slot positions, and read the identifier of the mask ...
- ◆ ... or move manipulator with reader nearly continuously until the reader detects a mask, record the reading and continue scan until the entire reservoir has been scanned

The latter case is suitable to build a plain list of masks per reservoir, and needs to deal only with successful reads. The intermediate case is suitable both for a plain list, or a tentative mask per slot list. The first case is suitable for a mask per slot list. Both the first and intermediate case need some way to deal with empty slots (e.g. letting the reader time out if no code is read).

It could be a software task to split the mask list of each reservoir in two separate lists per quadrant (since masks of 2 quadrants will share the same reservoir).

The reservoir set scan shall be parallelized in two independent middle level operations : *scan VIS reservoir* and *scan NIR reservoir*.



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12.3 Middle and low level operations

12.3.1 Individual reservoir scan

The implementation of the intermediate level operations *scan VIS reservoir* and *scan NIR reservoir* is the same (described above under reservoir set scan), where one is commanded on the right robotic arm and the other one on the left robotic arm.

12.3.2 search in reservoir and load in quadrant

The individual *reservoir/quadrant search and load* function requires three parameters:

- ◆ the *reservoir* to operate (VIS or NIR)
- ◆ the *quadrant* to operate (which can be top or bottom, or the appropriate quadrant number as given in table in 3.1.5 above). If it is top or bottom the software could compute the quadrant number itself.
- ◆ an *identifiant*, which can be either a mask set identifier or a mask identifier. If the identifier is a mask set identifier, the software can compute the mask identifier affixing to it the (eventually computed) quadrant id

The function is in turn split in a sequence of low level operations:

- ◆ move (left or right) robotic arm to the "*begin reading position*" just above the reservoirs
- ◆ search for the mask until the requested identifier is read (if no mask is found abort procedure and return error). The movements of the robotic arm, manipulator and reader are the same described above for reservoir scan
- ◆ grab mask (which in turn could expand into: open manipulator, move down a bit, close manipulator)
- ◆ extract mask entirely from reservoir
- ◆ retract mask to the arm normal course
- ◆ lift mask on top of quadrant (this is a movement of the robotic arm to a predefined y position higher than the quadrant mask locking device, where the position is different for the top or bottom quadrants (*quadrant preloading position*))
- ◆ all mask locking devices shall already be in the open position
- ◆ insert mask (this is a tilt manipulator-with-mask and move down)
- ◆ ungrab mask (open manipulator)
- ◆ retract manipulator
- ◆ lock individual mask into position (with electro-magnets, the locking device will be operate later when all 4 masks are inserted)
- ◆ while verifying again the mask id is not required, sensing the correct locking of the mask into position may be necessary, and, if failed, may require a corrective action to re-extract the mask and attempt re-insertion or unload it
- ◆ finally move robotic arm to rest position

12.3.3 unload quadrant to reservoir

The individual *reservoir/quadrant unload* function requires two parameters:

- ◆ the *reservoir* to operate (VIS or NIR)
- ◆ the *quadrant* to operate (which can be top or bottom, or the appropriate quadrant number as given in table in 3.1.5 above). If it is top or bottom the software could compute the quadrant number itself.



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The mask identifier is not required as a parameter. The function will unload whatever mask is currently in the quadrant. Sensing its id is optional. If unload of an empty quadrant is commanded, this shall be sensed and the operation considered successful (with warning).

The function is in turn split in a sequence of low level operations:

- ◆ move (left or right) robotic arm to the “quadrant preloading position” just above the requested quadrant
- ◆ all mask locking devices shall already be in the open position
- ◆ unlock individual mask (with electro-magnets)
- ◆ insert manipulator (this is a tilt empty manipulator and move down)
- ◆ grab mask (i.e. close manipulator)
- ◆ retract manipulator (with mask, so up to the preloading position and then untilt)
- ◆ move robotic arm down (assuming the empty slot where the mask was before in the reservoir is known)
- ◆ insert mask into reservoir slot
- ◆ ungrab mask
- ◆ finally move robotic arm to rest position

12.3.4 move robotic arm to predefined positions

It is expected that each robotic arm will have at least one position (home position) which can be reached autonomously. E.g. this can occur commanding a motion, and let it terminate when the position is sensed by a photo cell, proximity sensor or other device.

It is possible that there are more than one predefined positions, but with the exception of a home position necessary as a starting reference, all other such positions (e.g. top of the quadrants, top of the reservoirs) can be reached commanding a relative movement to a stored y position.

So there will be a single (per arm) **move VISINIR arm to home** lower level function, but whether all other **move VISINIR arm to xxx position** are implemented as autonomous motions or as **move VISINIR arm to y** is left to the implementor. All the autonomous movement functions have no arguments.

12.3.5 move robotic arm to y position

The **move VISINIR arm to y** lower level function requires one argument, which is the y coordinate (units *TBD*) to be reached.

12.3.6 other lower level functions

They will be detailed in a *further stage* but they are mentioned en passant above :

- ◆ fine movement of the manipulators/reader (e.g. go to reservoir slot n or go to reservoir set barcode identifier)
- ◆ finer movements (in terms of YZ or angles *TBD*) of the manipulators
- ◆ open and close manipulator
- ◆ read identifier
- ◆ open and close (or close and lock) mask locking device

12.3.7 emergency stop and reset

It can be presumed (for analogy e.g. with the VIRMOS IC robot) that the robotic system has an hardware



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provision (“red button”) to perform an emergency stop, where all movements shall be stopped immediately at the current position.

In such case an appropriate alarm or status signal shall be raised, and an explicit **reset** command is needed before the issue of any further command is re-enabled.

The Reservoir Presence Sensor supplies an interlock signal which prevents robot motion when no reservoirs are present.

12.3.8 very low level commands

Also for analogy it can be presumed that there will be commands to set **speed** and **acceleration** for each of the robot axes (typically used in initialization).

It is also likely that there will be a **status** command to obtain a number of **status flags** of each robot axes (whether is idle or busy, whether an error was encountered), and all low level commands above the very lowest will for instance test that an axis is not busy or in error before initiating a movement, and test continuously the status before declaring a movement completed.

These statements have been imagined by analogy with the Antil driver used for VIRMOS. The details of the current proprietary protocol have not been disclosed to us yet. *These details or the choice of a common protocol with other devices in DIORAMAS will be dealt with in the next phase.*

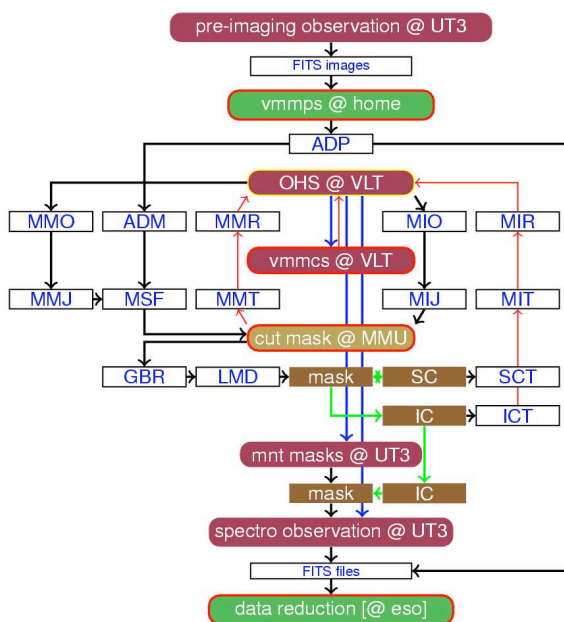
13 Mask flow overview summary

This section compares the proposed DIORAMAS mask-related item flows with the actual VIMOS flow, with the intent to demonstrate a simpler flow can be achieved. The flows are depicted in two figures, while a table compares them step by step.

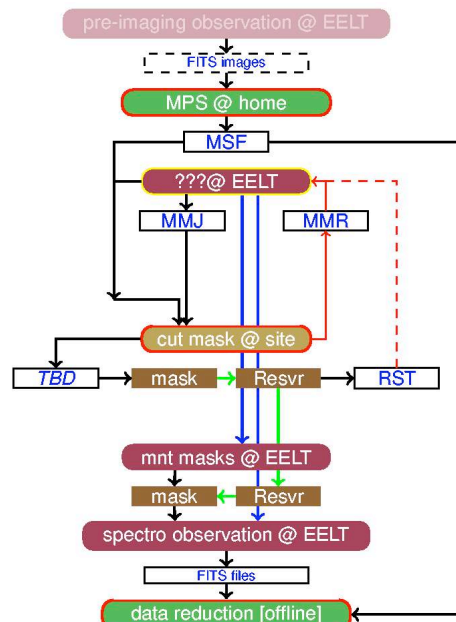
In both figures the following graphical conventions are used:

- ◆ rounded corner boxes indicate (software or functional) modules
- ◆ white rectangles indicate files
- ◆ brown rectangles indicate hardware items
- ◆ violet modules are operated by ESO at the telescope (control) site
- ◆ green modules can be operated by the observer at home
- ◆ the brown module is operated by ESO at base camp or other location
- ◆ modules with a red border are supplied by us
- ◆ black lines and arrows indicate the direct flow of data exchange
- ◆ red lines indicate a reverse (return) flow of data exchange
- ◆ green lines indicate transport or relocation of hardware
- ◆ blue lines (usually in background) indicate some form of control link

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Simplified view of the VIMOS mask flow



View of the DIORAMAS mask flow

| VIMOS case | DIORAMAS case |
|--|--|
| A preimaging observation is always a prerequisite to a MOS observation. Images are stored in the ESO archive. | Pre-imaging observations are the baseline. If performed, the output images <i>are assumed to be stored</i> in some ESO archive |
| As part of P2PP the user retrieves the images and uses them with one's own catalogs to feed the vmmps Mask Preparation Software | The user shall run Mask Preparation Software at home using one's own catalogues (and eventually the preimaging images) |
| vmmps produces the Aperture Definition file in Pixel (ADP) and stores it in an ESO repository | MPS shall produce slit lists (MSF which <i>are assumed to be stored</i> in some ESO repository |
| In parallel an Aperture Definition File in mm (ADM) is produced and stored | Slit lists will contain (column or information) for the conversion to mm |
| ESO Observation Handling Software (OHS) issues a Mask Manufacturing Order (MMO) and fetches from repository and passes the associated ADMs to vmmps, the Mask Conversion Software | A <i>TBD ESO Scheduling software</i> will issue a Mask Manufacturing Job (MMJ) and passes it to MMS together with MSFs fetched from repository |
| vmmps converts MMO and ADMs into MMJ and MSFs and transfers them to MHS, the software system of the cutting machine. In particular vmmps maps observation identifiers to 6-digit mask identifiers. | |
| MHS transforms MSFs into CAD format (Gerber GBR files) required by LPKF CircuitCam | MMS transforms the mm positions derived from (or contained in) MSF into the TBD format required by the laser machine (1 or 2 steps) |
| CircuitCam transforms GBR into proprietary format LMD required by LPKF StencilMaster | |

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| VIMOS case | DIORAMAS case |
|---|--|
| StencilMaster commands the laser machine to cut the masks | The masks are cut |
| The masks are stored in the storage cabinets (SC) and a table (SCT) is updated accordingly care of MHS | |
| MHS returns a termination report (MMT) to vmmcs. In turn vmmcs passes back a report (MMR) to OHS | |
| At a later stage before the observation OHS issues a Mask Insertion Order (MIO) which lists the masks required at the telescope | |
| vmmcs receives the MIO and transforms it into a MIJ which is transferred to MHS | |
| MHS assists the operator in retrieving the masks from the SC and inserting them in the Instrument Cabinets (ICs). A table (ICT) is updated accordingly. | The mask are automatically inserted in the Reservoirs. The RST table is updated accordingly. |
| MHS returns a termination report (MIT) and the ICT to vmmcs. In turn vmmcs returns a report (MIR) to OHS. | MMS issues a termination report (MMR) and returns it to the <i>ESO scheduling software</i> (eventually with a copy of the RST) |
| The ICs are physically transported at the telescope and installed on the instrument | The reservoirs are physically transported at the telescope and installed on the instrument |
| At a later stage OHS requests mask insertion from the ICs into the focal plane, and performs the spectroscopic observation. | Immediately prior to observation, insertion of the mask from reservoirs into the focal plane is commanded to the MEUS via ICS, and the spectroscopic observation is performed. |
| DRS (for the pipeline) or the user (at home) requires the FITS files of the observation which include in their header the info of the ADPs. | DRS (offline) requires the FITS files of the observation and the info on pixel position of slits from the MSFs. |

14 Handling of special masks

The existence of special masks which are used for a-periodic or periodic technical operations, apparently conflicts with the “no reuse of mask policy” (see 6.2 above). We have considered three alternatives to bypass this conflict and recommend one:

14.1 Bypass cut

This solution requires that special mask have dedicated identifiers.

The MMJ shall contain such identifiers *without* attached MSFs.

The MMS shall recognize the special identifiers. The MMUS operator, instead of cutting a new mask, fetches a pre-cut one from some offline repository, and manually inserts it into the reservoirs.

This solution is discouraged because there is no provision for offline storage for other masks, and insertion in reservoirs is foreseen only in a machine-aided mode of which the software should be aware. Also masks are relatively heavy to be handled manually

14.2 Bypass MSF

This solution requires that special mask have dedicated identifiers.



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The MMJ shall contain such identifiers *without* attached MSFs.

The MMS shall recognize the special identifiers, and the software will fetch predefined MSFs stored somewhere on disk, and cut afresh a new special mask, which is then inserted and handled identically as all other masks.

This solution is possible as a fallback if the next simpler one cannot be implemented

14.3 All masks are equal

In this case the MSFs of special masks are stored somewhere in the *ESO TBD scheduling system* which generates MMJs.

Special mask *observations* do not require dedicated identifiers. Each time ESO staff will require a technical observation, they will generate a request making reference to the stored MSFs and assign to it a new identifier.

The MSFs are attached to the MMJ as for normal masks. New special masks are cut afresh, inserted and handled identically as all other masks.

This solution is recommended.

14.4 Dark masks

Dark masks are different from other special masks, since they will be permanent masks, which are ordinarily never removed from the Reservoirs. As such they will require a permanent dedicated identifier which will be known to the single-band observing templates requiring such masks, and will enter the definition of a composite mask set (mixing 2 dark and 2 normal masks).

In the event that a damaged dark mask set will have to be replaced, the old masks have to be manually discarded, and new ones produced according to the rules given above for other special masks. The MSF of a dark mask will be extremely simple (it will list zero slits !).