VIRMOS

MASK MANUFACTURING UNIT

Global Description

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EVOLUTION PAGE

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ACRONYMS

IC : Instrument Cabinet
ICD : Interface Control Document
ICT : Instrument Cabinet Table
IFCTR : Istituto di Fisica Cosmica G. Occhialini
FORS2 : Focal Reducer Spectrograph 2
MDJ : Mask Discard Job
MDR : Mask Discard Report
MDT : Mask Discard Termination
MHCU : Mask Handling Control Unit
MHS : Mask Handling System
MIJ : Mask Insert Job
MIR : Mask Insert Report
MIT : Mask Insert Termination
MMCU : Mask Manufacturing Machine Control Unit
MMJ : Mask Manufacturing Job
MMR : Mask Manufacturing Report
MMT : Mask Manufacturing Termination
MMU : Mask Manufacturing Machine
MSF : Machine Slit File
NIRMOS : Near InfraRed MultiObject Spectrograph
nmmcs : NIRMOS mask conversion software
OHS : Observation Handling Software
OS : Observation Software
PC : Personal Computer
SC : Storage Cabinet
SCT : Storage Cabinet Table
VIMOS : Visible MultiObject Spectrograph
VIRMOS : Visual InfraRed MultiObject Spectrographs
vmmcs : VIMOS mask conversion software
WB : WasteBasket

1.INTRODUCTION

This document gives a global and general description of the VIRMOS Mask Manufacturing Unit (MMU). It is by no means a Users', Operator's or Maintenance Manual, which are issued separately, but rather it is intended to describe the Unit components and their functional relationships.

The function of the MMU is to perform an off-line, remotely controlled, mask cutting and identification, followed by mask storage and filling of the instrument cabinets (IC) with the mask sets requested for the following night(s) telescope observations. The MMU was built by the VIRMOS Consortium to serve both VIMOS and NIRMOS, and it will also be used to manufacture FORS2 masks.

2.INVAR SHEET SUPPLY

Masks are cut out of 0.2x340x450 mm Invar sheets. Invar is an iron-nickel alloy produced by Krupp VDM GmbH, Werdhol, Germany. The Invar is then black coated, de-stressed, cut to size, protected with a low adhesion plastic sheet and packed in folders of 20 sheets by CEM Lavorazioni Elettromeccaniche s.r.l., Milano, Italy.

The reflectance of the coated Invar sheets has been measured by the ESO Optical Lab. It has been found that the specular reflectance is 0.04% at 633 and 1150 nm (twice that of black paper), and that the diffuse reflectance is 4.7% at 633 nm and 3.7% at 1150 nm (equal or slightly better than that of black paper).

A supply of about 4000 sheets (200 folders) is being delivered to Paranal together with the MMU.

3.MMU COMPONENTS

The MMU has several components:

- The **laser cutting machine** with its associated control electronics cabinet, compressed air pressure doubling unit and filters, water cooling system, exhauster and a dedicated PC controlling the cutting process (MMCU);
- The **VIMOS Storage Cabinet** and a Datalogic bar code reader (shared with NIRMOS SC);
- The **NIRMOS Storage Cabinet** and bar code reader (shared with VIMOS SC). This SC will be delivered together with NIRMOS;
- The **MHS Robot** and mask identification system;
- A second PC (**MHCU**) controlling the conversion of the Machine Slit Files into files of cutting instructions, the mask Storage, the Unloading and Loading of the Instrument Cabinets, the mask Discarding from the SCs;
- A **Wastebasket**;

- The **roughness-meter** and its associated computer (which is also a spare);
- Spare parts and LRUs.

3.1 THE LASER CUTTING MACHINE

The **laser cutting machine** is an industrial product manufactured by LPKF Laser & Electronics AG, Garbsen, Germany.

The *laser beam* is focalized onto a *working platform (XY stage)* where the invar sheets are fixed, and which is displaced in X and Y. The laser beam and the working platform are mounted on a granite structure. The metal cutting process occurs under a jet of compressed air at 15-16 bars conveyed onto the area to be cut by a nozzle. For our application, the *pulsed Nd :YAG laser* is operated at approximately 16 W and 1200 Hz, with a pulse length of 0.19 msec ; from the point of view of safety, it is a class 1 laser when the machine is in operation. The *spot of the laser beam* has a size of 40 µm and its centering in the nozzle can be viewed through an eyepiece. The *X and Y displacements* of the working platform are obtained on 4 air cushions working at a pressure of 5 bars.

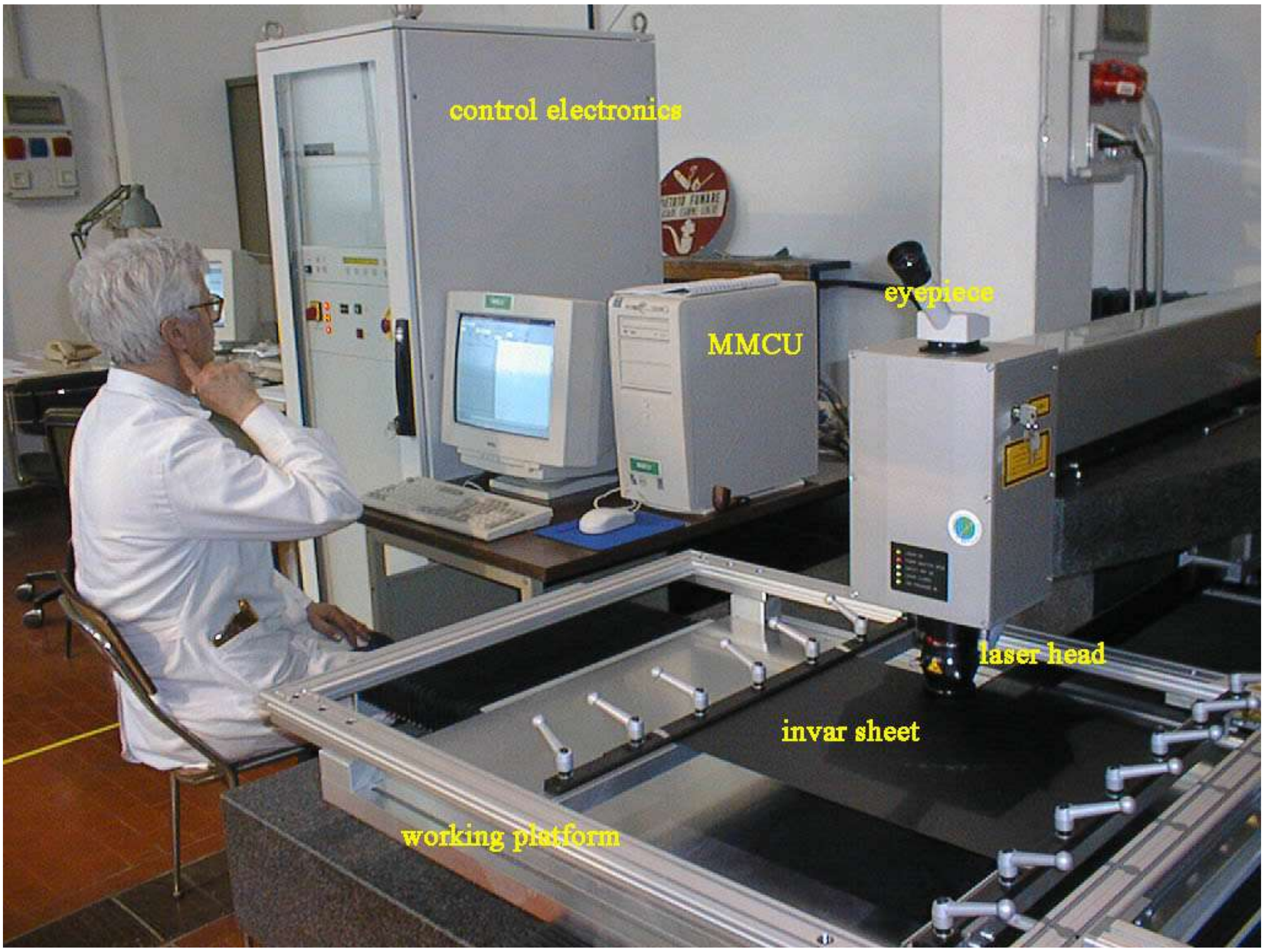


Figure 1 : Close-up view of the laser cutting machine, the MMCU and the control electronics

To operate, the laser cutting machine needs a supply of compressed air at 15-16 bars. This is obtained by a **pressure doubling unit**, which brings the input compressed air from 8 to 16 bars. Since there are strict specifications on the quality of the compressed air, **two filtering systems** are provided : the first one to filter out dust particles and oil from the input 8 bars compressed air flow and the second one to obtain dry compressed air (the most critical item) at the output of the pressure doubling unit. The laser machine has an inbuilt *pressure reducer* to bring the compressed air to the 5 bars needed to displace the working platform on the air cushions.

Cooling of the laser is obtained by a **closed circuit water cooling unit**, using bi-distilled water, located outside the MMU room together with the pressure doubling unit and the exhauster.

The **exhauster** has the function of removing the fumes and particles produced during the cutting process. Its switch is located on the laser cutting machine together with a light signalling when its filter must be cleaned.

The laser machine **control electronics** is housed in a standard rack, which includes a second stage laser cooling system, using de-ionized water. On the front panel, the *on/off switch* and *panic button* are located, together with a LED *display* showing the machine status.

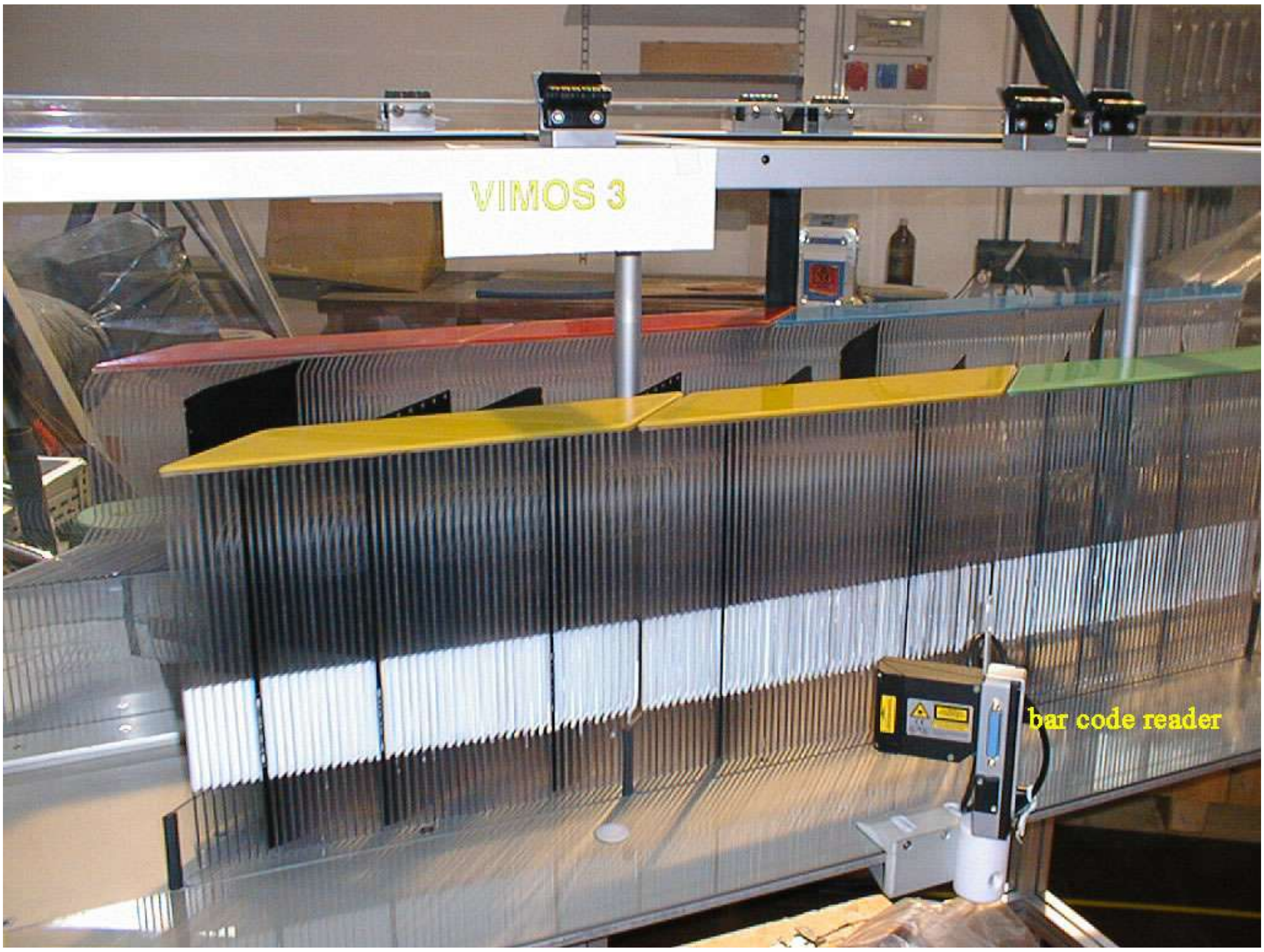


Figure 2 : Close-up view of the VIMOS Storage Cabinet and bar code reader

The cutting process is controlled by the **MMCU**, a Dell PC running under Windows NT. The laser cutting machine is controlled by an LPKF supplied program called *StencilLaser*, running under our CUT MANAGER software. The input to *StencilLaser* is a *.lmd file* containing the machine instructions and produced by the LPKF supplied program *CircuitCam*, running on the MHCU, to which the MMCU is connected through the LAN.

3.2THE STORAGE CABINETS

The Storage Cabinets have been built in the IFCTR workshop.

There are **two Storage Cabinets** : one for VIMOS masks and the other for NIRMOS masks. They share the same **bar code reader**, which can be attached to the SC of the instrument for which masks have to be loaded in the Instrument Cabinets.

The SCs are mounted on wheels and moved where the bar code reader is located when needed. The Storage Cabinets have each a capacity of 400 masks (100 masks per quadrant, two quadrants per side) : once manufactured, masks are vertically stored in the *slots of the proper quadrant (color coded)* of the respective Cabinets. Storage of the masks is driven by an MHCU function which requires the operator to identify the mask to be stored on the *MHS robot mask stand* and place it in any free slot of the proper quadrant. In the SCs, masks are searched by moving the bar code reader along the proper quadrant slots until an audible bip-bip signals that the mask has been located. This is one of the tasks driven by the LOAD MHCU function and by the DISCARD function.

3.3THE MHS ROBOT

The **MHS robot** is a specific industrial product manufactured by ANTIL, San Giuliano Milanese, Italy. Its purpose is to allow the removal and insertion of the masks from/in the Instrument Cabinets, as instructed by the MHCU IC PREPARATION program.

The MHS robot has four component parts :

1. The Z displacement system ;
2. The control electronics ;
3. The IC box (manufactured in the IFCTR workshop);
4. The mask stand, with associated bar code reader and mask clamp (manufactured in the IFCTR workshop).

The **Z displacement system** moves the IC box up and down of pre-determined quantities with an accuracy better than 0.1 mm in order to place an IC slot at the same level of the *mask stand* so that the *mask clamp* can either remove or insert the mask. It is equipped with *limit switches* and a *safety sensor* which sees whether a mask is not fully extracted or inserted inhibiting any displacement in such a case.

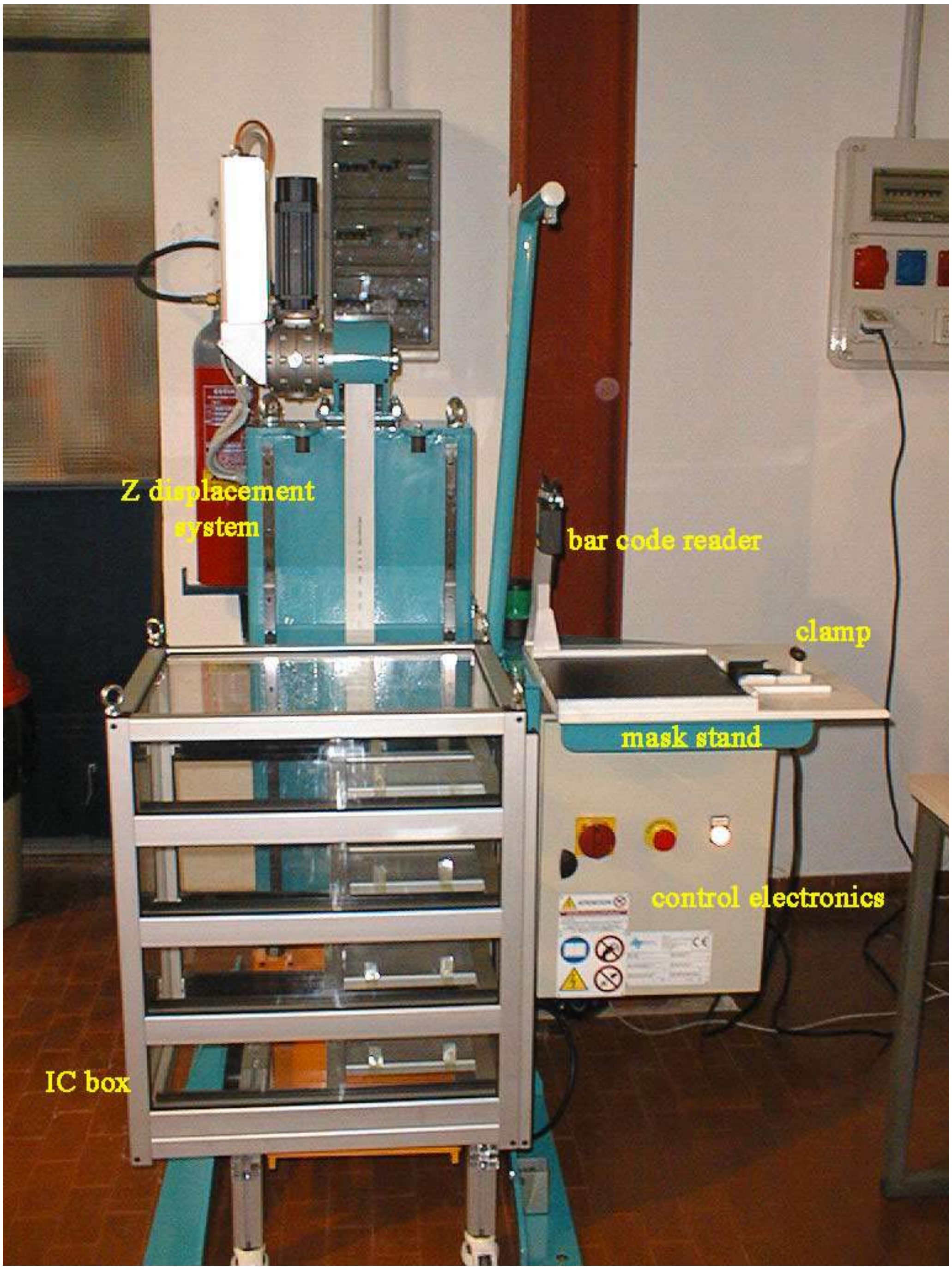


Figure 3 : The complete MHS, with the IC box and the mask stand. The IC box is also used for transportation of the ICs to the telescope

The **control electronics** includes an *on/off switch* and a *panic button*. The *control software* is embedded in the MHCU IC PREPARATION program.

The **IC box** is a four drawer box mounted on wheels. Each *drawer* holds one and only one IC[1]. It is mounted and fixed on the Z displacement platform when masks have to be loaded or unloaded in/from the ICs, and used for the transportation of the ICs to/from the telescope dome. It weighs

[1] ICs are parts of the VIMOS and NIRMOS instrument and are not delivered with the MMU

about 100 kg (inclusive of ICs and masks) . The ICs are removed from the IC box only when they must be mounted on the instrument.

The **mask stand** is at a fixed, ergonomic position in the Z displacement system. It consists of a *plastic stand* where masks are horizontally placed, a *bar code reader* of the same type as the one used on the SCs, and a *manually operated clamp* with two positions : one to insert the mask in the IC slot placed in front of the stand by the Z displacement system, and the second one to clamp the mask and extract it from the IC slot placing it on the stand.

3.4THE MHCU

The **MHCU** is a Dell PC with Windows NT operating system. All the programs used to operate the MMU, but the one controlling the cutting process, reside and are executed from it.

The vmmcs ftps the Orders (Manufacturing, Insert and Discard) and MSFs into its vimos staging area. Similarly, nmmcs will ftp the Orders and MSFs into its nirmos staging area.

Apart from *CircuitCam*, an LPKF program translating Gerber files into cutting machine instructions (.lmd files), several other programs, developed under VisualBasic at IFCTR, run on the MHCU as part of MHS :

- CONVERT transforms the MSFs into Gerber format, and ultimately into lmd format via *CircuitCam*. These Gerber files also contain the description of the contour of the mask, the reference and handling holes and the bar code. Items in the Gerber files are grouped into layers : *CircuitCam* associates to each layer a different logical tool (laser power, voltage, frequency, pulse length, cutting speed)
- STORE reads the id code of the newly manufactured mask placed on the MHS mask stand and tells the operator in which quadrant of the SC the mask must be stored, updating the SC table content
- IC PREPARATION :
  - UNLOAD moves the Z displacement system to the position of the mask to be unloaded from the IC, reads and checks the mask id once extracted and tells the operator in which quadrant of the SC the mask must be stored, updates the SC and IC table contents
  - LOAD activates the SC bar code reader issuing an audible signal when the mask to be loaded is found, checks the id of the mask once it is placed on the MHS mask stand and moves the Z displacement system to the position of the IC slot where it must be inserted, updates the IC and SC table content
- DISCARD activates the SC bar code reader issuing an audible signal when the mask to be discarded is found, updates the SC table content
- RECOVERY is a set of programs to be used in case of faults in the operation of the unit.

3.5 THE WASTEBASKET

The wastebasket is what its name says : a place where to put the left over metal after mask manufacturing and the discarded masks.

3.6 THE ROUGHNESS METER

The **roughness meter** is an industrial product made by Taylor Hobson Ltd., Leicester, England and contributed to the VIRMOS project on Italian funds. It is a measuring machine allowing to verify the *edge roughness* of samples cut under the same conditions as the mask slits. It is connected to a third Dell PC where all measurements carried out during the lifetime of the MMU can be organized in a database. It is periodically used to check the *laser cutting machine performance*.

Figure 4 : The roughness meter while measuring a sample roughness

3.7SPARE PARTS AND LRUS

The spares going along with the MMU are the following :

1. The **LPKF spare parts kit** containing, among other replaceable parts needed for ordinary maintenance, two *laser lamps* (the laser lamp must be replaced after 300-400 hours of operation, when a warning appears on the MMCU screen)
2. The **Dell PC** usually attached to the roughness meter can replace either the MMCU or the MHCU, being configured in exactly the same way. Thus, we consider it a LRU.
3. Another LRU is a third **bar code reader**, which can replace either of the on-line ones.

4.MMU OPERATION CONCEPTS

The entire MMU system allows to perform the following operations necessary for the execution of VIMOS and NIRMOS observations :

- To manufacture the masks requested by vmmcs (nmmcs) on the laser machine via a Mask Manufacturing Job order (MMJ), and to store the manufactured masks in the SC
- To load the masks requested by vmmcs (nmmcs) via a Mask Insert Job order (MIJ) into the ICs
- To get rid of masks and related files no longer needed as requested by vmmcs (nmmcs) via a Mask Discard Job order (MDJ)
- To manage and recover contingency conditions which may occur during the above tasks.

In all operations the MMU will only know masks by their individual six-digit mask id (which is also engraved on the actual masks in the form of a bar code), and will normally handle entire mask sets. A mask set is defined as a set of four masks (with the same last 5 digits in the id) used for the same observation in the 4 VIMOS or NIRMOS quadrants.

4.1EXCHANGE OF INFORMATION BETWEEN VMMCS (NMMCS) AND MHCU

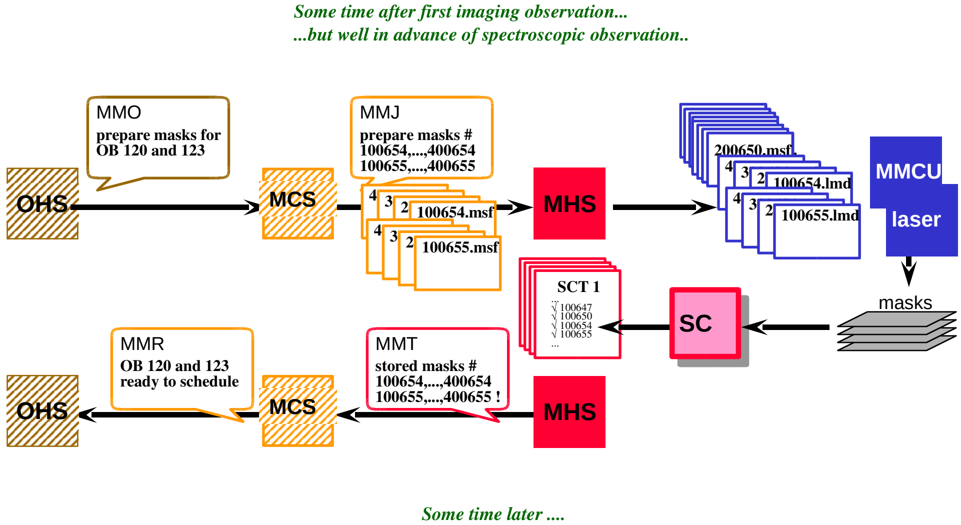
The exchange of information between vmmcs (nmmcs) and the MHCU is regulated by the ICD VLT-ICD-ESO-17240-19200. All operations (except contingency recovery and maintenance operations managed autonomously by the MMU operator) are executed after receipt of a job order from vmmcs (nmmcs) in the form of a file transferred into a staging area of the MHCU, and terminate upon placing a termination report in the same staging area of the MHCU, to be retrieved by vmmcs (nmmcs). vmmcs (nmmcs) has also access to the tables describing the current content of the SC (SCT) and of the ICs (ICT).

4.2MASK MANUFACTURING AND STORAGE

This is a 4-step operation.

1. The operator first runs on the MHCU the function CONVERT, which transforms all MSFs in a MMJ in Gerber format and invokes *CircuitCam*.
2. Next, the operator uses the program *CircuitCam*, which transforms the Gerber files into machine instructions (*.lmd files*).
3. Then, the operator, after having placed an invar sheet on the working platform of the laser machine and having removed the plastic protection, runs the function CUT MANAGER on the MMCU, which gives him access to *StencilLaser*. The masks are manufactured in two phases : in the first (CuttingSide) slits are cut, in the second (Outline) the mask contour is cut, allowing the mask to be removed from the machine.
4. At the same time, the operator runs the function STORE on the MHCU, which leads him to place the newly manufactured mask on the MHS mask stand where the mask bar code will be read indicating in which quadrant section of the SC the mask must be placed. Acknowledgement of these successive operations will automatically update the SC table and write the MMT (Mask Manufacturing Termination) which will eventually be retrieved by the vmmcs (nmmcs).

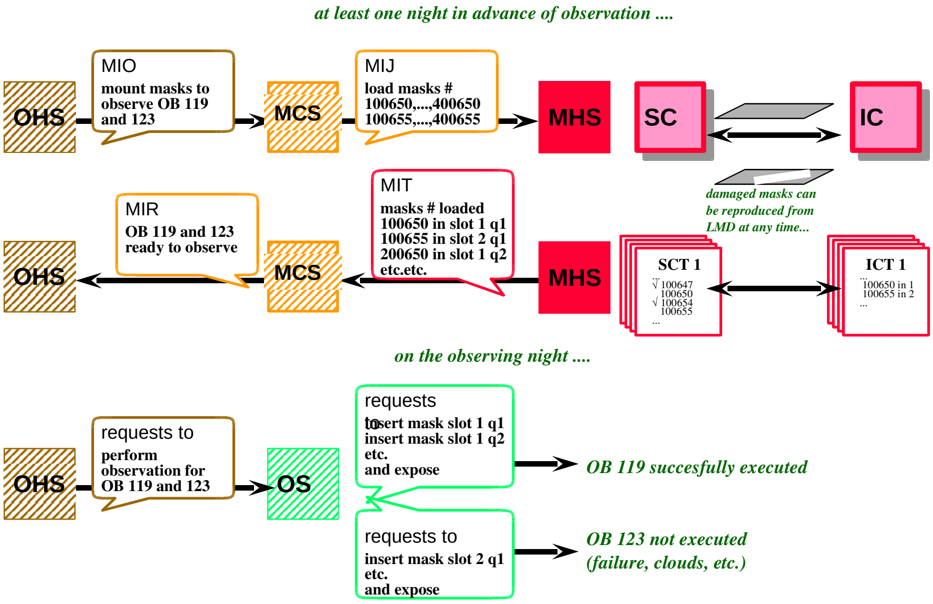
Mask Manufacturing Cycle



4.3INSTRUMENT CABINETS LOADING

When the ICs must be loaded with a new set of masks, the operator will find a MIJ on the MHCU. The IC box shall then be placed on the MHS and the operator will enter the IC PREPARATION function on the MHCU. Loading the ICs is a 2 step process : first, the masks which are in the ICs and will not be used in the following observing run must be removed and then the new mask set must be loaded.

Mask Insertion (and observation) Cycle



The IC PREPARATION software compares the MIJ with the IC table content and determines which masks are no longer needed.

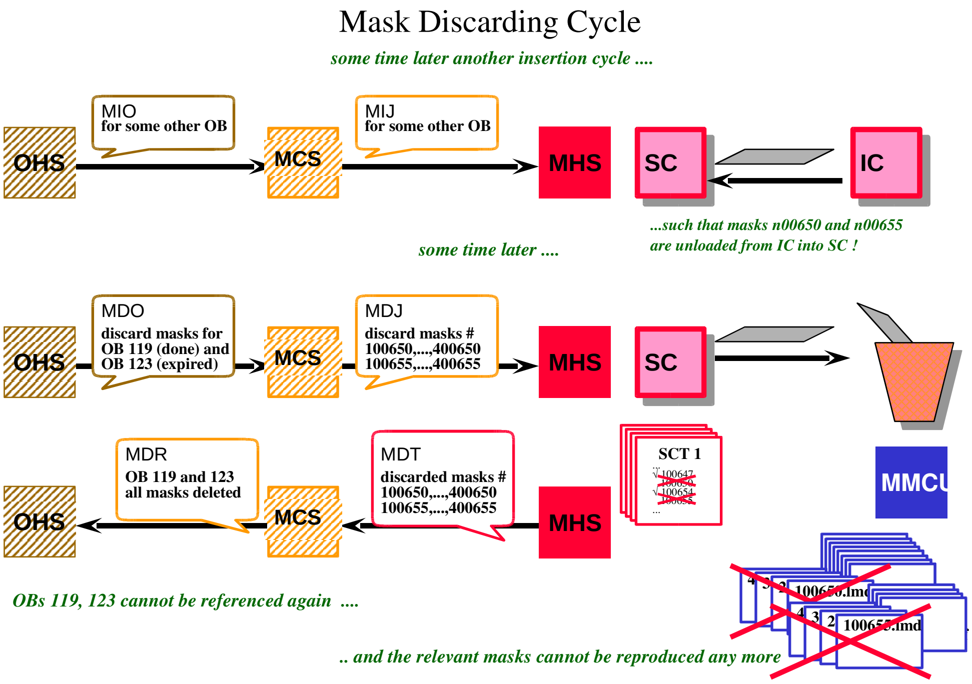
Then the UNLOAD (sub)function is run : this places the IC slot where the mask to be unloaded is found in correspondence with the MHS clamp. The operator extracts the mask which is placed on the stand, its id is checked by means of the bar code reader and the operator is told in which quadrant sector of the SC the mask must be placed. This operation is performed quadrant by quadrant. As a result both the IC and SC tables are updated.

The final step is to run the LOAD (sub)function. The operator must search the masks to be loaded in the ICs by means of the SC bar code reader and when he has identified the mask, he must place it on the MHS stand. Here the mask id is read, the Z displacement system moves the IC of the correct quadrant in correspondence with a free slot and the operator can insert the mask. Also this operation is performed quadrant by quadrant. As a result both the IC and SC tables are updated.

A report (MIT) is written and placed in the staging area where the vmmcs (nmmcs) can retrieve it.

4.4 MASK DISCARDING

The SCs have a limited capacity and must be periodically emptied to leave room for newly manufactured masks.



When a MDJ is present in the MHCU directory, this operation should normally have the priority with respect to any other. The operator runs the DISCARD function on the MHCU. This activates the SC bar code reader and allows the operator to search for the masks to be discarded. Once found, the masks must be removed from the SC and thrown into the wastebasket. The SC table is updated and, at the end, a MDT is issued.

4.5RECOVERY FUNCTIONS

4.5.1storage cabinet rescan

This function allows to reconstruct/verify the SC table, whenever there is a reason to believe that it is not aligned with the actual mask content.

4.5.2instrument cabinet rescan

This function allows to reconstruct/verify the IC table, whenever there is a reason to believe that it is not aligned with the actual mask content.

4.5.3off-line single mask storage (insert)

This function can be used to store masks in the SCs without a MMJ. It also verifies that the id of the mask is a valid one for the currently selected instrument.

4.5.4off-line single mask discarding (remove)

This function can be used to discard masks from the SCs without a MDJ. It also verifies that the id of the mask is a valid one for the currently selected instrument.

4.5.5searching a mask in the sc

This a typical maintenance function : it allows to verify that a given mask is in the SC, without removing it. It does not need any kind of Order. It also verifies that the id of the mask is a valid one for the currently selected instrument.

4.5.6mask identification

Another maintenance function, allowing to identify a mask outside the normal operations. It also verifies that the id of the mask is a valid one for the currently selected instrument.

4.5.7ic box unloading

A function allowing to bring the IC box mounted on the Z displacement system to the unloading position.

4.5.8emptying of the ic

A function allowing to run the IC PREPARATION task, which will execute a permanent MIJ called *null*. It is used when the ICs must be emptied of the mask content.