FLAMINGOS Mosplates:

Notes on Maskdesign,

World Coordinate Systems,

Mos Plate Loading Orientation vs. Position Angle,

and

Instructions for Loading Mosplates into the Dewar

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1. Introduction

Mosplate masks produced at UF with our design software and laser have 4 holes for mounting the mask, and two smaller alignment holes. Two of the mounting holes and one of the alignment holes lie at each narrow end of the mask. One of the alignment holes lies along the long axis of the mosplate, while the other is off center from the long axis; both alignment holes are covered by the mask mounting frame when the masks are installed in the mos wheel. See *Figure 1* for an example mosplate from the KPNO *4-m*; one of the mounting holes and the offcenter hole are labeled. The face of the mask has been labeled with a Sharpie marker with the name of the telescope *(4-m)* and mask field name *(q1451),* the position angle (*PA*; shown as *PA90*) and a small compass indicated by *N* and *E*.

This small compass has what I call *Sky parity*, *i.e. East* is counter clockwise with respect to *North* as it would be if you were looking up at the sky; conversely, if *East* is clockwise with respect to *North* it would have what I call *Earth parity*, as it would be if you were looking down at a map of the Earth. **A raw FLAMINGOS image taken at Kitt Peak or the MMT has *Earth* parity[1].**

The offcenter hole on the mask in *Figure 1* has an arrow and the word *HUB* written next to it to indicate how this particular mosplate should be installed into the Mos wheel. This hole is meant to be an indicator key, or *keyhole*, for inserting the mask in a consistent way every time. *However, only using the keyhole for mask installation assumes that everyone designs mosplates every single time from images that have the same parity*. If someone does not follow whatever the present convention might be, and/or the pipeline reduction and maskdesign software somehow change the image parity, then the keyhole orientation will change and it will no longer be a good guide for mosplate installation.

Figure 1. Example 4-m Mosplate with Labels - q1451. I usually write on the face of the mosplate with a Sharpie marker, as seen here. Note the *N-E* compass has *sky* parity. This is the side of the mosplate that you see when loading it into the Mos wheel.

Since the Gemini run last year I've been concerned that there was such a change. I do not know if the problems I had loading mosplates happened because I wrongly instructed the mask designers, or if there truly was a change in the net result from the pipeline and mask design software. At the time, I certainly thought that mosplates were arriving to me with the alignment

1 It has sky parity on any of the Gemini ISS Sideports, and earth parity only on the uplooking port.

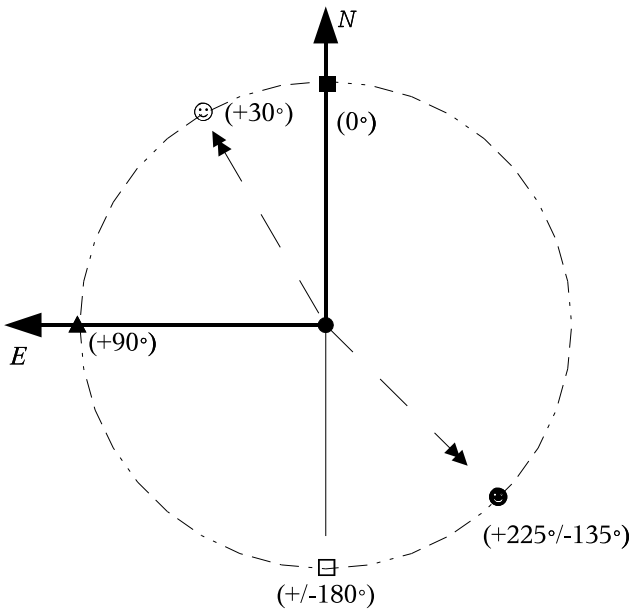

Figure 2. PA Illustration. Several sources are shown arrayed in a circle around the central point, •, along with the *N-E* compass arrows. The vector from the center to ■ lies at *PA = 0◦*, while the vector to ☺ is at *PA = 30◦*, the vector to ▲ is at *PA = 90◦*, and the vector to □ is at *PA = 180◦*. Finally, the vector to ☻ is at *PA = +225◦ or -135◦*.

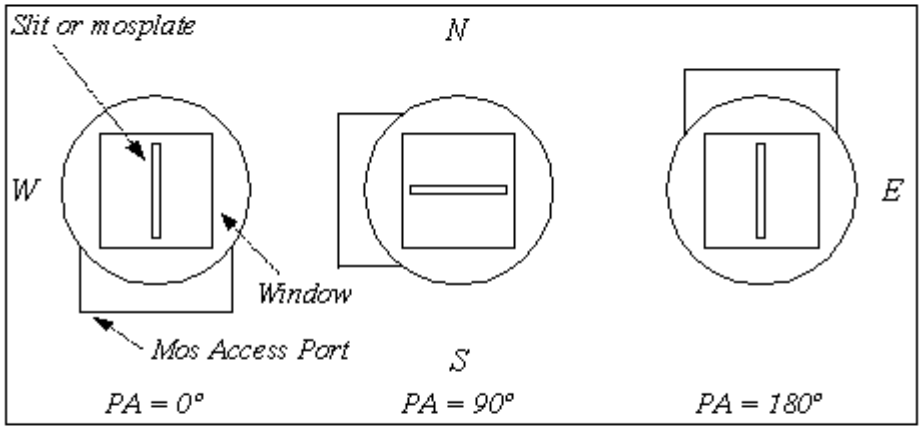

Figure 3. Orientation of the Mos Dewar for Various PA Values. The viewpoint is as if looking down at the Earth, and is correct for FLAMINGOS mounted in an uplooking configuration *(i.e.* as it normally is at the KPNO *2.1-m* and *4-m* telescopes, but not when on an ISS sideports at Gemini South). Nothing is to scale.

hole in the wrong location. Therefore, on the January - March KPNO *4-m* and MMT observing runs I decided to try to diagram the mosplate orientations that I knew worked, and then see if I could explain it to everyone else.

The goal of this document is to explain to everyone how to install a mosplate with only the mosplate and the design image, as long as it has a valid World Coordinate System (*WCS*) to indicate its parity. The mask keyhole still should be useful if everyone is consistent in their design, however using the *WCS* and design image plus `ds9 reg` file should be sufficient and completely accurate.

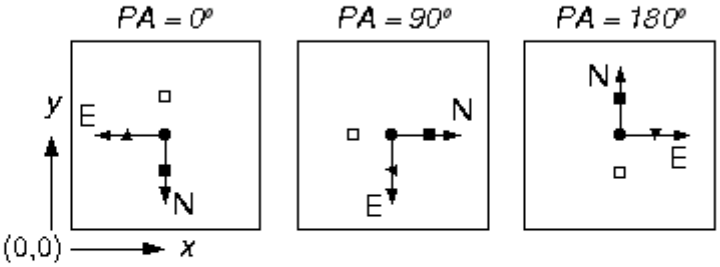

Figure 4. Orientation of WCS in Raw Image. The orientation of the *Earth*-parity *WCS* compass in a raw image is shown for various common *PA* values at the *4-m* (note *PA = 0˚* is valid for the *2.1-m*, too). These orientations are valid if the `(0,0)` pixel is in the lower left corner, and the `(x,y)` axes are oriented as indicated; this is the normal state in `ds9` if `Align to WCS` is off, and there are no applied flips or rotations.

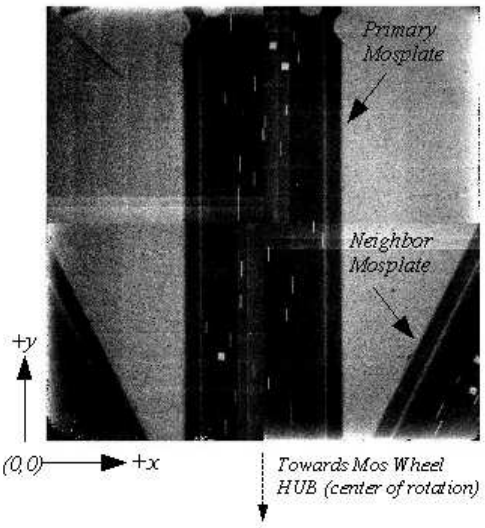

Figure 5. K-band Image of a Lynx Mosplate. This raw FLAMINGOS image shows the back of the Mos wheel, with it positioned at a mosplate (the vertical dark band with slitlets and alignment boxes, *cf. Figure 1*); the masks are less emissive than the black-painted Mos wheel, and that is why the mosplate is the darkest part of the image.

Two neighboring mosplates are visible at the bottom left and right of the image, as well as the frames that hold them into the Mos wheel. These mosplates are baffled by the corrsponding Mos aperture on the Decker wheel.

The image in this figure appears as it would without any flips or rotations in `ds9`. The center of rotation of the Mos wheel lies approximately at `(1162, -1868)`, off the bottom of the image in the direction indicated.

N.B. *The instructions here are always valid for observing at the KPNO 2.1-m and 4-m telescopes*[2]*. They are valid for FLAMINGOS at Gemini South if we are mounted on port 1, which is uplooking, and they are valid for some orientations at the MMT. The MMT is treated as a separate case in the appendices.*

Before you get deeply involved with picking objects on the design image for the mosplate, you should look at the design image and decide what mask orientation angle will acquire the most objects, *i.e.*, the highest density of slitlets[3]. Even if you use the default plate orientation, you need to understand what *PA* this corresponds to, and indicate it on the actual mask. If the person installing the mask at the telescope is armed with this information they will have no problem installing it correctly for your observing run.

In the next section I give an illustration of the definition of *PA*; I also show the the

2 As long, of course, that it always is installed on the telescopes in the same orientation.

3 See Matthew's web pages, `Design Ethos` and `Advanced Methods-Rotation` at `www.flamingos.astro.ufl.edu/maskdesign/maskhelp.html`.

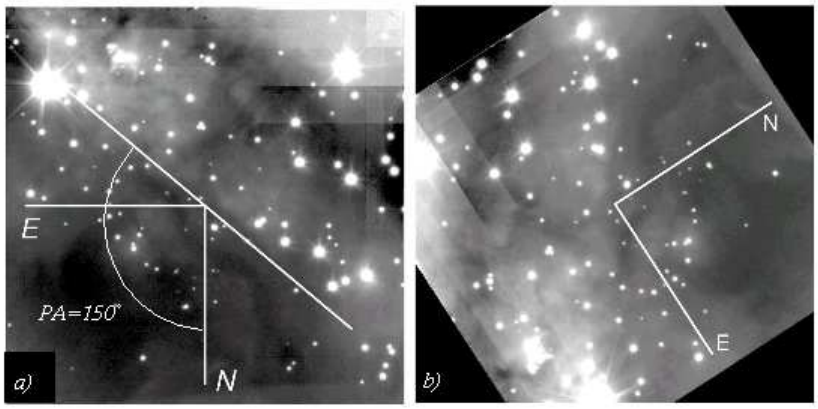

Figure 6. Selection of a new PA for NGC2024. The original pipeline reduced image from Gemini South appears on Matthew's web page, where it is oriented with *North* up and has sky parity.

a) That image was flipped to correspond to what would be obtained if it had been observed at the *4-m* with *PA = 0º*. A line has been drawn over the image, indicating a good orientation for a mosplate; the *PA* of this line is 150º. Note that you could describe the line as having *PA* = -30º, but this *PA* is not obtainable at the *4-m*.

b) This shows the orientation of the image after using the `IRAF` task `rotate` (in the `imgeom` package), with the rotation angle set to the position angle, 150º.

corresponding orientation of FLAMINGOS at the *4-m* for *PA = 0, 90,* and *180* degrees. Following that, I show the orientation of the *WCS* on a raw image and its correspondence on the face of a mosplate for a few values of *PA*; I also show the orientation of the mosplate when it is installed in the Mos wheel. I give a check list for designing a mosplate. Finally, I end with a rudimentary set of instructions for actually thermally cycling the Mos dewar in order to install the mosplates. The appendices include a complete listing of the FITS header keywords required to describe the *WCS*.

2. Illustration of Position Angle, *PA* and Dewar Orientation

The vector from point *A* to point *B* on an image can be decomposed into the distance from *A* to *B*, and an angle, called the Position Angle, where *PA* is measured from *North* into *East* until reaching point *B*. Hence, it is normally defined to cover the range {0, 360} degrees, however, you sometimes see negative values, where the range is defined over {-180, +180} degrees. See *Figure 2* for several examples.

FLAMINGOS is attached to the KPNO *4-m* such that the instrument rotator angle matches the position angle of the long slits and mos plates. Thus, in *Figure 3* we see the orientation of the Mos dewar with respect to the cardinal directions for *PA = 0, 90,* and *180* degrees; the viewpoint is as if you are looking down at the Earth. If you stand in the Cassegrain cage at the *4-m*, you can look at the location of the Mos access port and quickly tell the approximate position angle of the slits. This will match the rotator angle on the Telescope Control System *(TCS)* video display unit (*VDU*) in the control room. *Note well*, at the *4-m* the maximum range of PAs, and

corresponding instrument rotator angles, is `(-0.6, +180)` degrees. At the *2.1-m* there is no rotator, and the *PA* is fixed at `0` degrees.

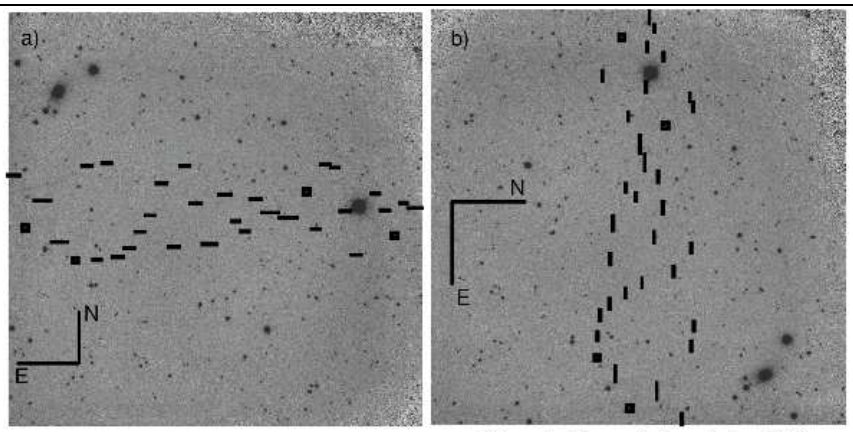

Figure 7. q1451 Design Image & Reg File. a) The design image and reg file for the mask in *Figure 1* were loaded into `ds9`, and `Align to` *`WCS`* was turned on; all other flips and rotations are off, resulting in the image being displayed with *Sky parity* and *North* at the top of the image. Note that the reg file looks exactly like the mosplate in *Figure 1.* b) Now the image is displayed without any flips and rotations, as it looked when running `Maskdesign.C`; this orientation agrees with the fact that the data were taken with *PA* set to *90* degrees. The slits at the bottom of the image go closest to the Mos wheel hub; *cf.* with *Figures 1* and *7.*

3. Determine *PA* from `ds9` and the *WCS*

Raw images generated by FLAMINGOS have a set of keywords in their headers that define a rudimentary *WCS* solution for the mapping from pixel space to *(α, δ)* coordinates. It has two purposes: (1) it allows `ds9` to show the orientation of the *N-E* compass on a raw image, and (2) it gives you a starting point for obtaining an astrometric *WCS* solution in the final pipeline image. If the pipeline image that you are working with shows a messed up *N-E* compass (*e.g.*, the arrows are on top of one another), then you should try to fix it using `wcsedit` or `hedit` in `IRAF`. You should fix it ***before*** you do any image rotations to increase the slitlet density. Please refer to the appendices for a complete listing of the FITS header *WCS* parameters if you need to change it.

Once you have a valid *WCS* you can determine the appropriate *PA* for your mosplate. *Figure 4* shows the orientation of the *WCS* for *PA* values of `0`, `90`, and `180 degrees`. The lower left corner of the image is the `(0,0)` location in pixel space. If a raw image is displayed in `ds9` with `Align to WCS` off and no flips or rotations applied, then the *WCS* compass will appear in the `ds9 panner` to have the same orientations illustrated here, with *Earth* parity.

Figure 5 shows a raw image (taken at K-band) of a Lynx mosplate. The Mos wheel is oriented in the dewar such that the mosplates run vertically in a raw image, *i.e.* the long axis is parallel to the `y`-axis of the image. This is relevant, as our program for designing mosplates, `Maskdesign.C`, assumes that the mosplate-shaped selection window overlayed on the design image also runs vertically, parallel to the `y`-axis. It is possible, however, to shift the center of the selection window along the `x`-axis if the cataloged targets are not in the center of the design image. It is not completely obvious from the stretch in this figure, but you can also see the mosplate mounting frame along the sides, and at the top, but not the bottom, of the mosplate. This shows that the detector is slightly vignettted across the top of the image (~50 pixels, I think); you do not need to worry about this vignetting when running `Maskdesign.C`, as it knows about it and will not let you put alignment star boxes or slits within the vignetted region.

Figure 6a shows an image that is best rotated before designing a mosplate. If you were to run `Maskdesign.C` on this image, without rotating it first, the mosplate would be oriented at *PA=0* , along a *N-S* axis, and not many slitlets would be on the mask. If you draw a ruler on the image with `ds9`, double clicking on the ruler will cause a window to pop up with information about it. One piece of information is the angle of the line, with respect to the `x`-axis. You can quickly determine the *PA* that corresponds to the ruler angle if the *WCS* compass is displayed in the `ds9` panner. Use the `IRAF` task rotate, and rotate the image by the *PA*. This generates the image in *Figure 6b*, where the targets now run up and down the image at a constant `x`-value.

Figure 8. Example Mosframe and Mosplate. The q1451 mosplate from *Figure 1* is shown in between the mosframe. To assemble, the mosplate is sandwiched between the top and bottom frame pieces; four flat head screws are inserted through the frame top and mask, and screwed to the frame bottom. The assembly is mounted to the Mos wheel with three larger flat head screws through the thre tabs, on the frame top. The lower end of the mosplate was labeled with the word *HUB* (*cf. Figure 1)*; this end must be placed at the end of the frame which has the single central tab.

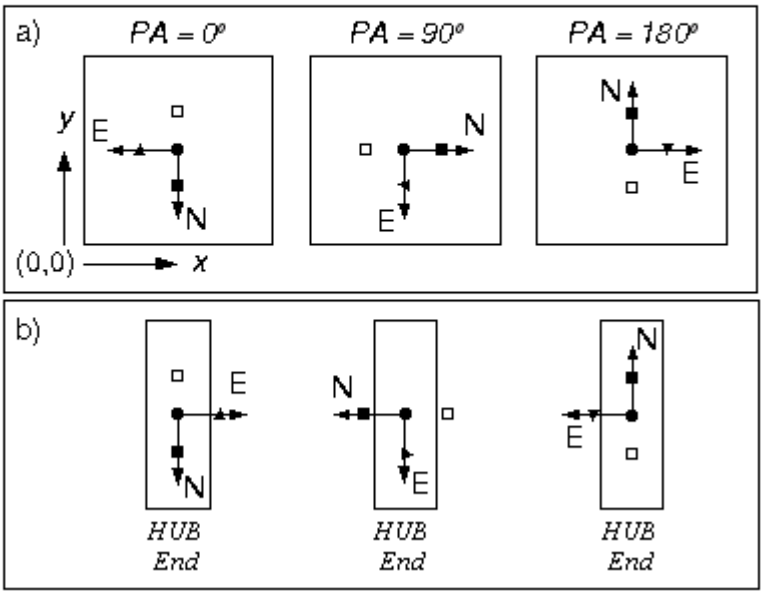

Figure 9. Correspondence Between Orientation of Raw Image and Mosplate WCSs for Common Position Angles. a) The orientation of the *WCS* is shown as it appears on a raw FLAMINGOS image, with Align to WCS off and no additional flips or rotations applied. The (0, 0) pixel is in the lower left corner. b) The corresponding orientation of the face of the mosplate is shown as it appears as it is loaded into the mosframe.

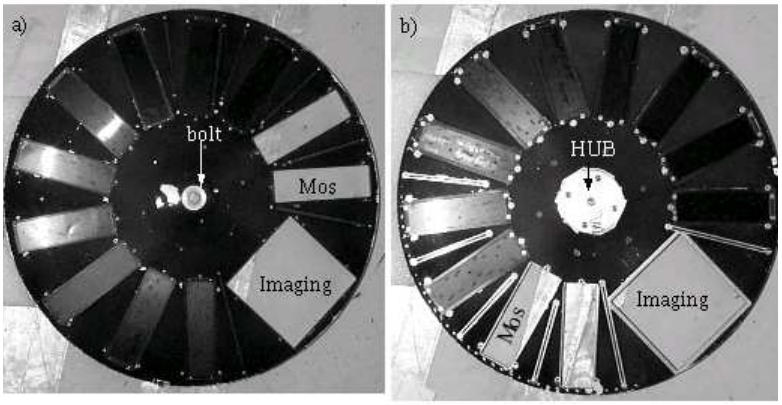

Figure 10. Mos Wheel Sides. Both sides of the Mos wheel are shown; the skyward side of the Mos wheel is shown in (a), and the mosplate loading side is shown in (b). Nine of the eleven mosplate positions are occupied, and one of the unoccupied mosplate positions is labeled in each view, as is the imaging aperture. Each mosplate mounting frame sits in a pocket on the loading side of the wheel, and is bolted to the wheel with three flat head screws, one at each outer corner, and one in the middle of the frame at the end closest to the center of the wheel. The Mos wheel's mounting bolt is visible in the skyward side, and the unpainted region where the Mos wheel mates with the drive *HUB* is indicated on the loading side. *Note all mosplate positions should be occupied by some sort of mask when in use, for baffling.*

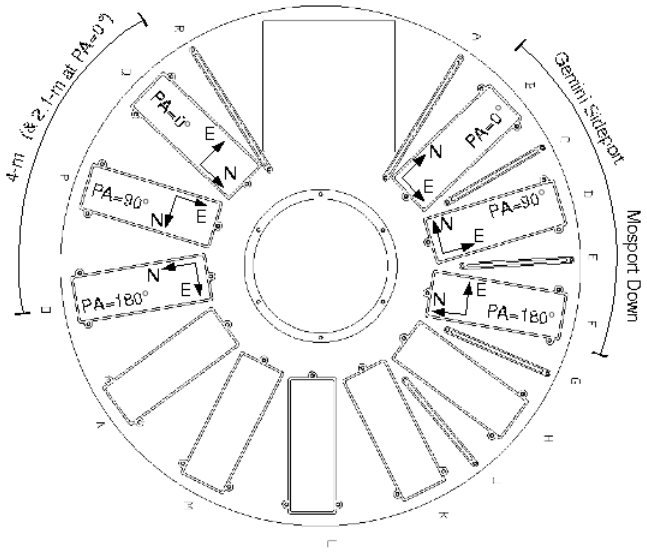

Figure 11. Mosplate Orientations on the Mos Wheel. The MOSLABLS.eps printout is shown here; several mosplate positions are labeled with common values of *PA* used at the KPNO *2.1-m* and *4-m* telescopes. The orientation of the *WCS* is also indicated, just as it should appear on the face of a mosplate when the Mos wheel is viewed from the loading side. Note, the orientation for *PA = 0°* is the same at the *4-m* and *2.1-m* telescopes. The orientations for FLAMINGOS mounted on a Gemini ISS sideport, with the Mos access port downwards, are also indicated for reference.

4. *'We've cut a Mosplate. Now What?', or Labeling a Mosplate*

You've just cut a stack of mosplates, and perhaps you've labeled them with their target names. But have you labeled them on the correct side, and have you indicated how they should be loaded into the Mos wheel and at what *PA* they should be observed ?

Here's what to do to label the mosplate:

- Dislay the design image and reg file in `ds9` with `Align to WCS` on, and no flips or rotations applied. The *WCS* compass in the panner window should have *North* up and *East* to the left.
- Hold up the mosplate next to the monitor, and flip it around until it matches the appearance of the reg file slitlets. The side of the plate you see is the side that gets labeled. Compare *Figure 1* with *Figure 7a* for an example. The mosplate for q1451 appears in *Figure 1*, with labels written on its face, and the design image and reg file for this mask are displayed in *Figure 7a*; note the slitlets in this orientation match the face of the mosplate.
- Label the face of the mask with the target name.
- Label the face of the mask with a *North-East* compass that matches the image in `ds9`. Note it should have *Sky parity*.
- Label the face of the mask with the *PA*. For this mask, the slitlets run *East-West*, and it was designed for the *4-m*, so the *PA* is `90` degrees. If you had to rotate the design image before running `Maskdesign.C`, the *PA* is whatever you rotated the original image by (see back to §3).
- Now display the design image to match the orientation of a raw image, *i.e*. *Earth parity* (try turning off `Align to WCS`) with a rotation. The slitlets should run vertically in the image. Verify that the *WCS* compass in the `ds9` panner is oriented in a valid manner for the telescope (*cf. Figure 4).* Once this is set up properly, then the slitlets at the bottom of the image are the ones closest to the Mos wheel *HUB*, or center of rotation. Hold up the mosplate next to the screen so that you're looking at the back of the mask in order to check this. Then, flip it along its long axis and label the face of the mosplate at the bottom end with the word *HUB.* Compare *Figures 1* and *7b* for examples with the q1451 mosplate.

5. *'We've received a box of mosplates. Now What?', or Loading a Mosplate into a Mosframe and the Mos Wheel.*

You've just received a box of mosplates, and will need to install them in a few days. This section will describe how to correctly load a mosplate into a frame and into the Mos wheel, while a different section will detail the actual procedure for thermally cycling the Mos dewar in order to obtain access to the Mos wheel itself.

Here's how to load the mosplates:

- Find the box of traveling mosplates, spare mosplate frames, mounting screws and allen

wrenches. There should be at least 11 spare mosplate frames, enough for a complete wheel reload.

- Download the design images and reg files from `/astro/data/flamingos/flamingos/public_html/mosplates/` to the flamingos computer that you are taking data on. A directory should also exist for these. Note, gzipped images will transfer more quickly.
- Select the mosplates from the new batch that have the highest priority for loading.
- Refer to *Figures 8 & 9*. The mosplate and mosframe pieces are shown in *Figure 8*.
  - Place the mosplate on top of the frame bottom, with the plate labels facing up and *HUB* end at the lower edge of the frame. The *WCS* compass should have *Sky parity*.
  - Double check that the end of the mosplate that goes towards the Mos wheel *HUB* agrees with the indication in *Figure 9*.
  - If the *PA* is not equal to 0, 90, or 180 degrees, *North* should be on the left hand side of the mosplate as you look at it with the *HUB* end at the bottom. The indicated *PA* should be within the range from 0 to 180 degrees.
- Place the frame top on the mosplate, with the central tab at the bottom.
- Screw the pieces together with 4 small flat head screws. Turn the screws until they are snug, and then back them out about 1 – 2 turns. It will be easier to insert the mosplate sandwich into the Mos wheel pockets if the screws are loose; you will have to tighten them after the sandwich is installed.

Loading the mosplates into the Mos wheel is now pretty straight forward. Both sides of the Mos wheel are shown in *Figure 10*, with several of the mosplates removed. Each plate sits in a pocket, and is bolted to the wheel with three flat head screws. To load a new set of mosplates:

- Find a large roll of tape that fits over the mounting bolt (see *Figure 10a*), and lay the Mos wheel on the tape with the loading side up. If you cannot find a large roll of tape, place some books on either side of the bolt, so that the Mos wheel is flat and stable.
- Remove the 3 mounting screws from the mosplates that you will be removing.
- Gently push on the mosplate frame (*not the mask)* from the bottom, to get the mosplate sandwich out of the wheel. If it will not pop out, loosen the 4 screws that hold the sandwiches together and try again. Once it is out, place it to the side (away from the the new mosplates), to disassemble later.
- Insert all of the new mosplate sandwiches. Screw them in with the flathead mounting screws.
- Snug up the 4 screws that hold each mosplate together. *Do not forget to do this.*
- Grab a MOSLABLS.eps printout from the FLAMINGOS binder (or print more; transfer the file from the flamingos user directory to an observatory computer in order to print it). On the printout, label the positions of all the mosplates for later reference. Be sure to

include the *PA* along with the mask name and *WCS* orientation; the slit width is nice, too.

- Verify the orientations of the *WCS* compass and the listed *PA* values agree with the examples shown in *Figures 9 & 11*.

6. *Thermally Cycling the Mos Dewar*

If you are the designated plate loader at the mountain, you will need to get onto a day schedule. If the observers turn on the Mos dewar heater at the end of the night, you can load the new mosplates by lunchtime, and then pump and recool the dewar so that it is ready to use by dark. If you have never used the heater or the vacuum pumps, make plans in advance with KPNO mountain staff or NOAO Friends of FLAMINGOS for them to train you in their usage.

Here's a checklist for this procedure:

- *Pick up plates in the afternooon*.
- *Download design images and reg files in the afternoon*. Gzipped design images will transfer more quickly, but the transfer still shouldn't be done while observing.
- *Load the highest priority masks into the secondary set of mosplate sandwich frames*. You can do this in the afternoon or evening before you will change plates.
- *Go to bed early.* You can be at the telescope by 9:30 am the next morning for a full day's work.
- *Have the observers park the Decker and Mos wheels at imaging at the end of the night's observing.*
- *Have the observers start the Mos dewar warm-up heater no later than 6:30 am.* You have to get the Mos dewar to ambient temperature; this takes ~4-5 hours during the morning hours..The heater is the silver box in the computer rack, near the bottom. It has a power switch in the back, on the right hand side, and a key switch on the front. The power cable is the orange extension cord coiled on the back of the computer rack. It should be plugged into *dirty* power; at the *4-m* this is the plug above the doorway to the cage, while at the *2.1-m* this is a plug on the telescope structure. If you are unsure what power recepticle to use, have a KPNO staff member show you in the afternoon. Plugging the heater into the wrong outlet can have disasstrous consequences if the heater throws a breaker to a circuit powering a computer.
- *Poison the Mos dewar vacuum if the Mos dewar temperature is ~255 K.* Bring the pressure to about `1 Torr` with the N_2 gas line and oil filter. This should be done between 9:00 – 9:30 am.
- *Wait a while more, for the dewar to warm the rest of the way.* You want the temperature to be about the same as the ambient temperature in the dome, usually ~283 K. It should be about 11 am.

Figure 12. Useful Tools for Loading Mosplates. The hex wrench and handle have been replaced by a tool that does not come apart; it is used to take out the screws holding on the Mos access port cover. The Allen wrenches have been replaced by hex wrenches, one for each of the two sizes of screws for instert mosplates and frames; the wrenches are kept in the sack of screws. The Aluminum tape is used to hold the cold baffle on over the Mos wheel. The long-handled wrench and pick tool are used to remove and re-insert the Mos wheel. A flashlight is useful for seeing in to the Mos wheel mounting bolt.

Figure 13. Open Mos Access Port. The Mos wheel and gear train are visible in the middle of the access port.

- *Vent Mos dewar with Nitrogen gas.* You should hear it when the dewar is at atmospheric pressure, as the pop off valve will hiss. Leave the purge on low while you work.
- *Now remove the Mos access port vacuum cover; then remove the Aluminum tape along the top of the cold baffle, and let it fold towards you.* See *Figure 12* for an illustration of all the tools required, and *Figure 13* for an example of how it should look once the port cover is open, but the Mos wheel is still inside of the dewar. I usually remove the top, central screw last. Place the cover somewhere to the side, with the o-ring facing up, but where no dirt or hairs will fall onto it.
- *Remove Mos wheel.* Use the long-handled wrench to loosen the central bolt holding the Mos wheel in place. Once it is no longer snug use the pick tool to grab the edge of the bolt and spin it around. ***The bolt should not come all of the way out!*** *If it does so, it could fall into the dewar and/or onto a lens.* Use the pick tool until you can see that the bolt is loose and wiggly. Note the bolt is a captive bolt – it has a turned down section with no threads such that the Mos wheel is no longer attached, but the bolt cannot come out. If you turn it past this location it will, however come out.
- *Swap old plates for new plates.* See the previous section for details.
- *Reinsert Mos wheel.* Use the pick tool to start the bolt, then gently snug it up with the long-handled wrench. It does not require a lot of torque!
- Reattach cold baffle. Fold it up, so that the face torwards you is straight up and down. Cut a long piece of the Aluminum tape, and use it to hold the baffle in place.
- Reattach the access port vacuum cover. Start by inserting the top central screw, then start all of the other screws. Snug them down from left-to-right, doing the top and bottom rows at the same time. Repeat the snugging about 3 times.
- *Pump out Mos dewar to 0.00 mTorr on the Convectron gauge.* This takes about 1.5 hours; usually you can eat lunch while the dewar is pumping out.
- *Begin cooling the Mos dewar.* If the pump out went well, it should be no later than 2:00 pm. The cooldown usually takes ~2 fills of LN_2, and the dewar must be cold for ~4 hours before you can move the Decker and Mos wheels. Do the first fill until the Mos dewar just starts to spit, then turn it off. Come back about 1.5 hours later and refill the dewar. The next required fill will be at the usual time at the start of the night. If you are doing this at the *4-m* you should make plans in advance with the KPNO mountain staff for assistance and training, as it requires use of the platform lift.

Appendix 1. Listings of Spatial WCS Parameters

The initial spatial *WCS* solution in a raw FLAMINGOS image is described in the header with a deprecated[4] set of header keywords (`CDELT1`, `CDELT2`, and `CROTA1`). The pipeline attempts to rewrite the *WCS* solution in the header in terms of the preferred `CD` matrix (`CD1_1`, `CD2_2`, `CD1_2`, `CD2_1`)[5]. This matrix allows you to convert for skew, in addition to the usual translation, rotation and scale transformations.

Additionally, the pipeline adds the `LD` matrix, which represents the Logical Coordinate System. This specifies the linear transformation in pixel space from the original physical image to the current image. For example, in `ds9` the Physical (`x, y`) values may not be the same as the Image (`x, y`) values, which would indicate that your image has been extracted and/or rotated with respect to the original image.

The following tables list header keywords relevant to the world coordinate system. *Table 1* shows a listing of positional and scale parameters found in a raw image `FITS` header with FLAMINGOS at the *4-m*; *Table 2* lists the corresponding set of deprecated *WCS* keywords and values. Note the *TCS* gives the requested and apparent values of *(*α*,* δ*)*, and the `CRVAL`s are computed from the requested values of *(*α*,* δ*)*. *Table 3* lists the *WCS* keywords and values from *Table 2*, converted in terms of the `CD` matrix. *Table 4* lists the Logical Coordinate System keywords and values that the pipeline might add (these were taken from a mask design image for the *4-m*). Note that the `LTV` values indicate that the image has been shifted, and the `LTM` matrix values imply that the image was magnified by a factor of 2.

Table 1. Some Positional & Scale Parameters Presently in Raw Images – 4m Example

Keyword	*Example Value*	*Comment, with units in []*
`RA`	`'12:14:31.55'`	Telescope RA position; [`HH:MM:SS.SS`]
`DEC`	`'35:34:40.0'`	Telescope DEC position; [`DD:MM:SS.S`]
`RA_APR`	`'12:14:42.12'`	Apparent RA position; [`HH:MM:SS.SS`]
`DEC_APR`	`'35:33:40.3'`	Apparent DEC position; [`DD:MM:SS.S`]
`PIXSCALE`	`0.3165`	Plate scale at detector [`arcsec/pixel`]
`ROT_PA`	`90.00`	Position Angle [`deg`]

Table 2. Example WCS Parameters Using Deprecated CDELT Parameters – 4m Example

Keyword	*Example Value*	*Comment, with units in []*
`CTYPE1`	`'RA--TAN'`	X-axis type

4 Meaning that their usage is highly discouraged.

5 During this summer's engineering block I plan to rewrite the FLAMINGOS perl scripts to use the `CD` matrix by default.

Table 2. Example WCS Parameters Using Deprecated CDELT Parameters – 4m Example		
CTYPE2	'DEC--TAN'	Y-axis type
CRVAL1	183.63125	Reference pixel value; RA in [deg]
CRVAL2	35.57778	Reference pixel value; Dec in [deg]
CRPIX1	1024.5	Reference pixel corresponding to CRVAL1
CRPIX2	1024.5	Reference pixel corresponding to CRVAL2
CDELT1	8.7916E-5	Plate scale along X-axis; [deg/pixel]
CDELT2	8.7916E-5	Plate scale along Y-axis; [deg/pixel]
CROTA1	90.00	Coordinate system rotation; [deg]

Table 3. WCS Parameters Using CD Matrix – 4m Example		
Keyword	*Example Value*	*Comment, with units in []*
WCSDIM	2	Dimensionality of *WCS*
CTYPE1	'RA--TAN'	X-axis type
CTYPE2	'DEC--TAN'	Y-axis type
CRVAL1	183.63125	Reference pixel value; RA in [deg]
CRVAL2	35.57778	Reference pixel value; Dec in [deg]
CRPIX1	1024.5	Reference pixel corresponding to CRVAL1
CRPIX2	1024.5	Reference pixel corresponding to CRVAL2
CD1_1	0.00	1_1 direction/rotation plate scale value; [deg/pixel]
CD2_2	0.00	2_2 direction/rotation plate scale value; [deg/pixel]
CD1_2	-8.7917E-5	1_2 direction/rotation plate scale value; [deg/pixel]
CD2_1	8.7917E-5	2_1 direction/rotation plate scale value; [deg/pixel]

Table 4. Logical Coordinate System Parameters Added by Pipeline		
Keyword	*Example Value*	*Comment, with units in []*
LTV1	-2142.5	Linear translation vector in X; [pixels]
LTV2	-2165.5	Linear translation vector in Y; [pixels]
LTM1_1	2.0000	1_1 direction/rotation plate scale value; [pixel/pixel]
LTM2_2	2.0000	2_2 direction/rotation plate scale value; [pixel/pixel]
LTM1_2	2.6E-5	1_2 direction/rotation plate scale value; [pixel/pixel]
LTM2_1	3.5E-3	2_1 direction/rotation plate scale value; [pixel/pixel]
WAT0_001	'system=image'	
WAT1_001	'wtype=tan axtype=ra'	X axis attributes
WAT2_001	'wtype=tan axtype=dec'	Y axis attibutes

Appendix 2. Calculating the FLAMINGOS CD Matrix for a Raw Image

The CD matrix is computed by scaling the correct version of the standard rotation matrix by the detector plate scale, in degrees per pixel. Thus we get *Table 5,* which shows how to compute the CD matrix for ***raw images*** from FLAMINGOS (when it is mounted in an uplooking configuration). Note that the cosine and sine arguments are a function of the net angle (180 – PA) and not the PA alone, and the particular sign convention for this rotation matrix arise due to the fact that the native raw FLAMINGOS image has *East* clockwise with respect to *North* (*i.e.*, *Earth parity*). The plate scale for raw images is listed in *Table 6*, for completeness; pipeline reduced images have been expanded to twice their normal size, so the plate scale values are a factor of two smaller, of course.

Table 5. CD Matrix as a Function of Plate Scale (degrees per pixel) and Position Angle (degrees)

Keyword	*f(PS, PA)*
CD1_1	PS cos(180 – PA)
CD1_2	–PS sin(180 – PA)
CD2_1	PS sin(180 – PA)
CD2_2	PS cos(180 – PA)

Table 6. FLAMINGOS Plate Scales at Various Telescopes

Telescope	*PS (arcsec/pixel)*	*PS (degrees/pixel)*
KPNO *2.1-m*	0.606	1.683E–4
KPNO *4-m*	0.3165	8.7917E–5
MMT	0.169	4.6944E–5
Gemini South	0.078	2.167E–5

Appendix 3. Mosplate Design Checklist

There is a procedure I think you should follow completely before you design and ship a mask to the mountain:

- *Before running* `maskdesign.C`*, read Matthew's nice web pages at* `www.flamingos.astro.ufl.edu/maskdesign/maskhelp.html`:
  - `First Run`
  - `Design Ethos`
  - `Advanced Methods-Rotation`
- *Make certain the design image has a valid World Coordinate System (WCS) in the header.* This will allow you to see *N-E* compass arrows in the panner, in addition to the orientation (*x-y*) compass.
- *Rotate the mask if necessary.* ***Make certain the WCS is valid before rotating.***
- *Determine the final position angle (PA) of the mask.*
- *Design and cut your mask with the laser.*
- *Label the mask with a Sharpie marker.* Include the mask name, **and the WCS orientation**.
- *Ship new masks by Fed-Ex to the observers.*
- *Gzip the design images.*
- *Post the gzipped design image and ds9 reg files on the flamingos data server at* `/astro/data/flamingos/flamingos/public_html/mosplates/<2meter | 4meter | gemini | mmt >`; make an object directory for your files. Both the regfiles with (`*.reg`) and without (`*.reg_cless.reg`) comments should be uploaded.

The rest of this document will describe these steps in more detail.