Constraints on the OM Window Configuration and Definition of the OM Default Configurations

XMM-PS-TN-26

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Contents

1 Introduction

1.1 Scope

OM offers a high flexibility and dynamic in the instrument setup and in its configuration for an observation. The flexibility is limited by the amount of resources available onboard and by the way an observation/exposure is scheduled at the SOC. Here an overview is provided of the limiting factors and how these factors constrain the instrument configuration.

This note was circulated within the OM consortium and within the XMM-SOC as a draft version, with the intention to receive a confirmation on the validity of the assumptions made and of the constraints. After having received the comments the note was updated, TBDs were removed and the OM default configurations were defined in the last section in detail. This note does not address the scientific aspects of the default configuration, as the scientific aspects are addressed in Tim Sasseen's TN "Suggestions for Survey/Default UV Observing with the Optical/UV Monitor on XMM" (XMM-OM/UCSB/TC/0040).

1.2 Documentation

References

[1] C. Ho S. Horner, J. Klarkowski. XMM-OM/DPU Digital Processing Software Architectural Design Document. XMM-OM/PENN/SP/0003.draft0.7, PENN, February 1996.

[2] D. A. Bone. Software Setup for the Blue Detector Electronics. XMM-OM/MSSL/SP/0077.01, Mullard Space Science Laboratory, March 1995.

[3] M. Cropper. User Requirements Specification for the XMM Optical Monitor. XMM-OM/MSSL/SP/0030.02, Mullard Space Science Laboratory, March 1995.

[4] D. Schink. System Performance Prediction. XM-RP-DOC-0002 Issue 5, Dornier, February 27 1998.

[5] K. Adamson. Proposal Database Parameters and IPPVs. XMM-SOC-TN-0007-SMD Issue 2 Rev 5, MOD-SMD, April 14 1998.

[6] ESA. XMM OM Experiment Interface Document (Part B). RS-PX-0018 Issue 5, ESA/PXP, March 1996.

[7] ESA. XMM RGS Experiment Interface Document (Part B). RS-PX-0019 Issue 5, ESA/PXP, March 1996.

2 Basic Approach

In this technical note each OM exposure is as far as possible treated as an independent unit, i.e. OM is set up to fit into the available resources irrespective of the configuration of previous exposures.

Very often the limits are associated with safety margins, i.e. the resource available for configuration will initially not fully be exploit. It is set to a lower value than the actually available resource. The amount of margin will be conservative at the begin of the mission and will generally decrease with growing experience. A first guess for the margin is provided, where applicable.

3 Limiting Factors of OM Configuration

There are different resources which must be considered when setting up an OM observation. The OM configuration is very often constrained by a combination of various resources and the different resources are not independent. Generally constraints have different origins:

- OM onboard software
- DPU processing power
- Hardware related issues
- S/c resources
- SOC observation scheduling

Note that the different constraints are not always visible to the GO, e.g. the memory window configuration is set up by an PHS-tool.

3.1 Big Word Memory

The big word memory (BWM) is the place where the final image is accumulated. After the accumulation of a tracking frame in the small word memory (SWM) the attitude solution is calculated and the tracking frame is corrected (shifted) for s/c drift and add into the BWM.

In total there are 1048576 BWM words available. 32768 words are reserved for the PROC area (= storage area of data processing parameters), leaving 1015808 words. These

1015808 words available in BWM are divided into two parts, 507904 words each. One part holds the data of the previous, completed exposure, the other part is used to keep the data of the currently ongoing exposure.
No BWM space is required for the actual tracking windows, as they are kept in the SWM. However the number of words (pixels) available to the GO is further reduced by the storage space needed to hold the DD_TRH (tracking history data) and DD_REF data (reference frame data) of the currently ongoing exposures. DD_REF data have a fixed length of 629 words (they are only acquired once at the begin of an exposure), the size of the DD_TRH data depends on the number of tracking frames in an exposure.

$$\text{size(DD\_TRH)} = 53 \cdot \text{frames\_per\_exposure} \quad \text{(in units : words)} \tag{1}$$

The DD_TRH and DD_REF data are written backwards from a point in BWM. Assuming a tracking frame time of 10 sec and the maximum exposure duration of 5 ksec, we obtain a DD_TRH size of 26500 words. Under the assumption that the exposure has 500 tracking frames the constraint is imposed that the sum of all image mode pixel must not exceed 480775 pixels (= 1015808/2-53x500-629).

- **The sum of all image mode pixels for each exposure must not exceed 480775 pixels.**
- The intitally applied safety margin of 10% reduces the number of pixels available to the GO for configuration to 432698 .

Note that two science windows covering an identical patch on the sky (window within window) account twice to the total number of BWM pixels.[1]

3.2 Small Word Memory

A total of 4x1048576 words is available in the Small Word Memory (SWM). The 4 Mega words SWM are allocated in the following way:

- 2M for ping/pong
- 1M for fast mode data
- 1M for compressed science data buffer for downlink

[1]We associate with the science window an area in the BWM, where data (the actual image) of a patch of sky are stored.

3.2.1 Ping/Pong Area

The memory windows are held in the ping/pong area. Memory windows are used to store tracking frames. While the current tracking frame is being accumulated, for example, in the Ping area, the previous tracking frame in the Pong area may be used to determine the s/c drift. The correcting shift is applied to the Image Mode sub-areas before coadding the data into the accumulated image residing in the BWM area. The roles of Ping and Pong areas are reversed after each tracking frame time. Each science windows will fully reside in a memory window. There may be more than one science window associated with a memory window.

The sum of pixels in all memory windows is limited to 1048576 pixels. The number of pixels is reduced by the pixels reserved for tracking windows. Tracking windows are intially set up $\pm$ 16 arcsec around the nominal star position. The number of available SWM is reduced by 40960 pixel ($10x64^2$ pixel).

The SWM allocation must consider the margin around a science window which is required to accomodate the Shift and Add (SAA) process (s/c drift compensation). A margin is required for two reasons.
First, it is needed to make sure that photons at the window edge can be centroided with a good quality. Centroiding of an event requires 3x3 CCD-pixel. The BPE takes care of that boundary at the window edge. The required additional margin of 2 CCD pixels is allocated around the active windows. Events are always centroided correctly even if they are located at the edge of the FOV. This is possible because of the "oversized" CCD.
Second, a margin is required to accomplish SAA during the exposure. The relevant patch of sky should always stay within the defined memory window, resulting in a uniform exposure of the window. If the drift through the exposure is n arcsecs, then a margin should be allocated of n arcsec. An estimation of the required drift margin is made in section 7.1.1. The configurable margin for SAA accomodation will initially be the equivalent of $\pm$ 8 arcsec, which are 16 centroided pixel, on each side of the window.
In principle the drift margin can be considered as a soft constraint as the 'exposure' map can be calculated after the observation to help normalizing the image. However this functionality is not implemented in the first SAS delivery (OM task MKSENS), but it is intend to implement the feature in a later release.

- **The allocated SWM area must include a $\pm$ 16 arcsec margin around each science window. (note that 1 arcsec corresponds 8 pixel with the magnifier).**
- **The sum of all SWM pixels must not exceed 1007616.**
- **Memory windows (kept in SWM) must not overlap.**
  For the case of "a window within a window" only one memory window is allocated.

The sum of SWM pixels can be estimated from the science window configuration according to equation 2. Science windows embedded in another window do not contribute and are not considered in equation 2.

$$\mathrm{SWM-pixels} = \sum_{\mathrm{i=not-embedded-windows}} \frac{(\mathrm{xsize_i} + 2 \cdot \mathrm{margin}) \cdot (\mathrm{ysize_i} + 2 \cdot \mathrm{margin})}{\mathrm{f_{filter}} \cdot (\mathrm{BPE-bin})^2} \tag{2}$$

where

xsize/ysize	is the extent of the science window in x/y direction in units of arcsec
margin	is the memory window margin to accomodate s/c drift, i.e. 8 arcsec
BPE-bin	is 0.5 arcsec (BPE-binning off) or 1.0 arcsec (BPE-binning on)
f_{filter}	pixelsize factor (0.25 for the magnifier otherwise 1)

Although the BPE binning is not available for science exposures defined by a GO, the BPE-binning factor is included for the sake of completeness in equation 2. The parameter BPE-bin will always be equal to 0.5 arcsec for GO specfied exposures.

3.2.2 Fast Mode Area

In the SWM 1048576 small words are reserved for fast mode data. The available SWM-memory is segmented into two parts, with 524288 words each. One segment is used for storing the fast mode data of the current exposure, the other segment keeps the fast mode data of the previous exposure.
The available memory for fast mode data is 524288 words, if one BFAST area (blue module fast mode area) is used, or 262144 words, if both BFAST areas (bluedsp1/2) are used.
Each registered fast mode event requries one word of storage. The fast mode data stream includes a 4 word long marker for each tracking frame crossing. Assuming an exposure with duration T_{exp} the required data volume overhead V_{marker} for holding the frame markes is

$$V_{marker} = \frac{4 \cdot T_{\mathrm{exp}}}{T_{\mathrm{tracking-frametime}}} \quad \text{(in units : words)} \tag{3}$$

The total fast mode data volume is the sum of the tracking frame marker and the actual events. The volume to required to store the events is proportional to the product of exposure duration $\mathrm{T_{exp}}$ an the count rate.
Within the available SWM the fast mode data inclusive the tracking frame markers must be stored.

$$524288 = n_{\mathrm{BFAST}} \cdot (n_{\mathrm{cts}} \cdot T_{\mathrm{exp}} + \frac{T_{\mathrm{exp}}}{T_{\mathrm{tracking-frametime}}} \cdot 4) \tag{4}$$

$$T_{\mathrm{exp}} = \frac{524288}{n_{\mathrm{BFAST}}} \cdot \frac{1}{n_{\mathrm{cts}} + \frac{4}{T_{\mathrm{tracking-frametime}}}}; \tag{5}$$

where

524288	available SWM
n_{BFAST}	number of BFAST areas in use (1 or 2)
T_{exp}	duration of exposure
n_{cts}	count rate
$T_{\mathrm{tracking-frametime}}$	duration of a tracking frame

The memory consumption by fast mode data depend on the average count rate n_{cts} in the fast mode window, which because of the small fast mode window size is dominated by an eventual bright source in the FOV. Assuming that the fast mode window contains one bright source saturating the detector (100cts/sec) and a tracking frametime of 10 sec, the maximum duration of an exposure is calculated with equation 3.2.2 to be 5.2 ksec with one BFAST area and 2.6 ksec with two BFAST areas in use (here it is assumed that both areas contain one bright source saturating the detector). The maximum duration of an exposure will be further reduced by a $\sim$ 15% safety margin, limiting the maximum exposure duration to 4.4 ksec and 2.2 ksec respectively.

- **The maximum length of an exposure is 4.4 ksec with one fast mode area in use and 2.2 ksec with two fast mode areas in use.** Both numbers include a 15 % safety margin.
- These numbers assume one bright source in each BFAST area.

3.3 Processing Power

3.3.1 Shift and Add

The tracking frame time must be long enough to calculate the attitude solution and to complete SAA of the previous tracking frame.

- the processing time required for SAA scales like the number of pixels, if they are all at the same binning factor.
- the scaling factors for 1x1-, 1x2-, 2x2-, ... binning are different.
- the scaling factors are TBD and will be available after DPU benchmark tests.
- the required frame time is additive, after each window is calculated according to its scaling factor (cf. equation 6)
- initially a 20% margin on the frametime will be added.

As a benchmark SAA of 700x700 pixel into 350x350 pixel takes 4.2 sec (TBC). The number for 1x1 and 4x4 binning can be provided after a more detailed benchmarking.

$$T_{\mathrm{frame}} = T_{\mathrm{attitude-calculation}} + \sum_{\mathrm{i=windows}} \frac{\mathrm{xsize_i} \cdot \mathrm{ysize_i}}{\mathrm{f_{filter}} \cdot \mathrm{BPE} - \mathrm{bin}^2} \cdot \mathrm{scaling} - \mathrm{factor_i} \qquad (6)$$

where

xsize/ysize	is the extent of the science window i in x/y direction in units of arcsec
BPE-bin	is 0.5 arcsec (BPE-binning off) or 1.0 arcsec (BPE-binning on)
f_{filter}	pixelsize factor (0.25 for the magnifier otherwise 1)
scaling-factor	is the average SAA-processing time for one pixel with the binning applied as in window i
$\mathrm{T}_{attitude-calculation}$	is the time required to determine the attitude solution and calculate the shift vector. $\mathrm{T}_{attitude-calculation}$ can be assumed to be constant.

3.3.2 Fast mode data processing

The blue fast mode area can be read with a frequency of 64 pixel/ms (TBC). The fast mode sampling time (fast mode time slice) T_{slice}, j of the BFAST area j (j= 1 or 2) is limited for the cases where only small windows are configured to:

$$T_{slice}, j \geq \sum_{i=BFAST\_area,j} pixel_{ij}/64 \tag{7}$$

- **The minimum fast mode time slice duration [in msec] of a BFAST area must be longer than the total number of fast mode pixels in that area divided by 64.**
- **An additional 50% safety margin will be added to the time slice duration.**

Note that the duration of the fast mode time slice is specified in units of CCD frame times. However the CCD frame time is not *exactly* known until the exposure has taken place, because it depends on the position of the tracking windows.

3.4 TM bandwidth

Before exposure n+2 is started the data of exposure n+1 must be fully compressed and the compressed data from exposure n must be fully transmitted. The former is achieved with an IC_FLUSH_CMPRS command issued onboard before commencing a new exposure. From the OM DPU point of view the data downlink constraint is not a very strict limit, because the compressed data buffer can hold much more data than one exposure worth of compressed data. However considering the existance of a TM gap and the fact that there is no monitoring of the compressed data buffer the requirement of data downlinking is needed from the operational point of view.
This requirement introduces an inter-exposure dependence, which can be fulfilled in two ways:

1. exposure n+1 is planned long enough to downlink the data of exposure n

2. after exposure n+1 the instrument set into idle mode until the data are downlinked.[2]

Where possible, the first approach will be adopted. At the proposal enhancement level the expected downlink time of exposure n is calculated and compared to the duration of exposure n+1.

The required time for compressing and downlinking of exposure n can be calculated as follows:

$$T_{downlink} = T_{compression} + (\frac{S_{fast}}{f_{f-comp}} + S_{image} \cdot log_2(k \cdot \sqrt{\frac{N_{image}}{S_{image}}})) \cdot \frac{1 + f_{overhead}}{TM_{bandwidth}} \quad (8)$$

whereby

$T_{downlink}$	is the required time for downlinking the data
$T_{compression}$	is the time required for compressing the data
S_{fast}	total number of fast mode pixel
f_{f-comp}	efficiency of fast mode compression
S_{image}	total number of image mode pixel
N_{image}	average content of image mode pixel
k_{image}	compression characterization constant for image mode data
$f_{overhead}$	data overhead
$TM_{bandwidth}$	allocated OM TM bandwidth

As a working assumption the following values can be used.

$T_{compression}$	100 sec
f_{f-comp}	Depending on source brightness (TBD)
N_{image}	TBD
k_{image}	6
$f_{overhead}$	0.2
$TM_{bandwidth}$	8 kb/sec

The provided numbers are a first guess. Detailed verification of the numbers is TBD and need validation by benchmark testing.

4 Constraints Imposed by Onboard Software and MIC Hardware

4.1 Total number of Memory/Science Windows

The total number of memory windows is constrained to 16. 10 memory windows are reserved to cover the tracking windows. Five memory windows are available to cover the the GO specified science windows. For simplicity it is assumed that each science window corresponds to at least one memory window. This limits the number of science windows available to a GO for configuration to 5.

[2]This constraint may be relaxed once there is a better understanding of the uncertainties of the involved parameters.

- **The GO must not configure more than 5 science windows.**

The memory windows associated with the science windows are calculated on the ground by an PHS tool. For the cases where a window is specified by its center and the size in x- and y-direction, the window position on the detector (defined by the lower left window corner) is calculated by the SGS.

4.2 Detector Windows

The detector windows associated with the memory windows are assigned onboard by an algorithm. It must be ensured on the ground that the memory windows can be covered by the available detector window resources.
The detector window pixels have a one to one correspondence to the memory window pixels. A memory window is comprised of more than one adjoining detector windows, once its size exceeds 512 pixel in one direction.
Beside the detector windows associated with the GO specified science windows, additional detector windows are required to accomodate the tracking windows. Tracking windows are allocated autonomously onboard by the DPU swap task `su_dowindow.c`.

There are several checks to be made on the window configuration in order to ensure that a configuration is valid within the available detector window resources and that the detector window allocation is accomplished onboard without problem:

- **Five detector windows are available to cover the memory windows associated with the GO specified science windows.**
  This is a conservative approach, because some of the tracking windows will already reside in a science window and do not require an independent detector window.
- **The maximum width of a detector window in one direction is limited to 512 centroided pixels.**
  If the width of a memory window exceeds 512 pixels it needs more than one detector window to cover this memory window.
- **The minimum width of a detector window is the equivalent of 4 CCD pixels.**
- **Detector windows must start at an even pixel number in horizontal (x-) direction**
- **Detector windows must start at an odd pixel number in vertical (y-) direction**
- **The detector window sizes and addresses are quantized in units of 2x2 CCD pixels, which are 16x16 centroid pixel.**
- **Detector windows must not overlap.**

An algorithm is needed to validate the OM window configuration with respect to the detector windows (DTW). As there is a 1:1 correspondence between memory and centroided detector window pixels the algorithm can also be applied to memory windows checking the science window configuration.
However In the intial version independent detector window(s) are allocated to the memory window, except for the case of fully embedded science windows (window within window). A more complex algorithm is sketched below, which may be implemented in a later verion of the PHS-tools.

```
C
C Routine to validate DTW equivalent constraint
C
C First make a simple check whether windows can be accomodated
  begin loop over science windows
   Neglect science windows fully embedded within another windows
   Expand size of science window to account for required margin
   Calculated number of DTW equivalents required per expanded window
   Sum DTWs up
  end loop over science window
  If (sum of required DTW equivalents $\le$ 5) then
        set flag ‘configuration valid’
         exit
  endif /* DTW check */

C  For the cases where a detailled calculation is required
C  Loop over science  windows
C  different algorithms are possible
C      from -large to small windows
C           -right to left or vice versa
C           -top to bottom or vice versa
C  here the algorithm large to small is shown

  begin loop over expanded science window
     If (there are still detector windows available)  then begin
       select largest available expanded science window: max(Xsize_i * Ysize_i)
       if (window can be allocate within existing detector window) then begin
          remove window from list
          go to begin of loop
       else
         check number of required detector windows vs available number
         allocate new detector windows
         reduce number of available  detector windows accordingly

         Loop over remaining windows
           if required DTW equivalent of new window is 1 then
              try to allocate window within the already existing windows
              (or by expanding the DTW equivalent to 512)
```

```
            if window can be allocated then
                remove windows from list
                 go to begin loop over remaining windows
             endif
         else if required DTW equivalent is 2 or more  then
            check availability of required DTW equivalents
            expand  DTW equivalents of original window by required number-1
            if window can be allocated then
                allocate new window within the expanded  windows
                remove windows from list
                go to begin loop over remaining windows
            endif
         endif /* required DTW equivalent more than 2 */
       endloop over remaining windows
     endelse /* window not allocated within existing DTWs */
   else /* not enought DTWs available */
     set flag 'configuration valid'
     exit
   endelse /* not enought DTWs available */
endloop over science windows
```

5 Observation Scheduling Constraints

The way proposals are translated into an observation at the SOC complicates the definition of an OM configuration. The roll angle, at which an observation is made, is not defined until the observation is scheduled. The only exceptions are the rare cases, where an explicit position angle constraint is specified in the proposal. However for most observations there will be no constraint on the s/c roll angle and the following sections applies.

5.1 Position Angle Ambiguity

At the time of proposal submission it will be possible to define the science windows either in the celestial coordinate system as pointing direction and window width in x- and y-direction (α, δ , XSIZE, YSIZE), or in the detector coordinate system as the lower left corner of the window and the window width in x- and y-direction (XLOW, YLOW, XSIZE, YSIZE). For the latter case the covered patch of the sky is a strong function of the roll angle.

- the two observations will observe different patches on the sky.
- a part of the sky patch associated with window 4 is no longer within the OM field of view in observation 2.

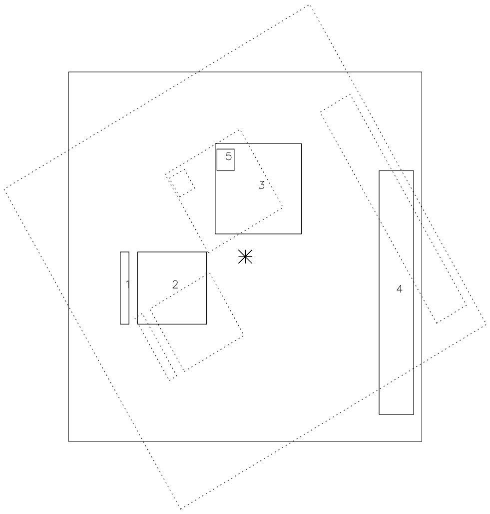

Figure 1: The figure shows a view from the sky onto the OM detector for two observations with different roll angle. The roll center is the OM optical axis. The window configuration is identical in the detector coordinate system for both observations. Different patches of the sky are observed with identical **detector** window configuration due to the roll angle difference.

Fig. 1 shows a view down onto the OM detector for two observations with identical pointing direction but different roll-angle. The roll center is assumed to coincide with the optical axis of the telescope and is marked with an asterisk (*). A sample detector window configuration is indicated (observation 1 solid line, observation 2 dashed line). The detector configurations of both observations are identical in the OM detector coordinate system. It is obvious that different patches of the sky are covered by the OM windows.

Fig. 2 illustrates the case where the window configuration is specified in celestial coordinates. Window configurations are shown for two observations with identical pointing but different roll angle. The rotation center is the OM optical axis and is marked with an asterisk. The center of the detector windows is corrected for the offset introduced by the change in roll-angle. The detector windows are set up with the specified width in x- and y-direction around the corrected window center.

The following problems are immediately evident:

1. window 5 is no longer fully embedded in window 3. The windows only partially overlap.
2. window 4 extends beyond the OM field of view in observation 2

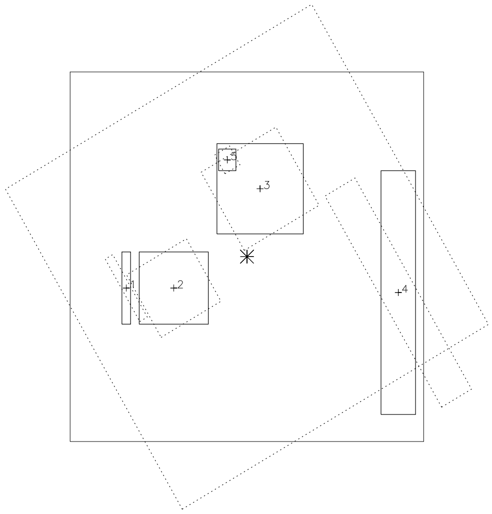

Figure 2: A view from the sky onto the OM detector is shown for two observations with different roll angles. The rotation center is the OM optical axis marked with an asterisk. The center of the detector windows are corrected for the offset introduced by the change in roll angle. The windows are allocated around their central positions with the same width XSIZE, YSIZE for both observations. Different patches of the sky are observed. One window extends beyond the OM FOV.

3. the two observations will not observe the same patches on the sky. The difference in sky coverage of the windows is worse for elongated windows.

In real operation the situation is even more complex, because the roll-center is no longer the optical axis of OM, but the boresight of the prime XMM-instrument. The optical axis of OM and the boresight of any other XMM instrument may be offset up to 1 arcmin, which corresponds to 120 centroided pixel (see below). Fig. 3 illustrates the effects of a rotation around an axis offset to the OM optical axis. The rotation center is indicated by the diamond. The diagram shows the effect of a rotation by 30, 70, 150 and 270 degree (from top left clockwise). For all four roll-angles window 4 falls partially outside the OM field of view. Generally a window definition in celestial coordinates is only possible for areas, which are always contained within the OM FOV, i.e. for all roll angles. The center of the rotation is the boresight of the prime instrument. Figure 4 (left diagram) shows the detector positions for all possible roll angles around a roll center (indicated by the diamond) which is offset from the OM optical axis (indicated by the asterisk). As figure 4 (left diagram) shows, windows can only be defined in a circle around the roll center with a radius equal to the minimum distance from the roll center to the edge of the FOV. Considering the specification of the boresight misalignment of 1 arcmin, the minimum radius is 7.5 arcmin.

However at the time of submission of the GT-programme and the AO1 proposals, the misalignment of the different instruments is not yet known. Therefore the specification has

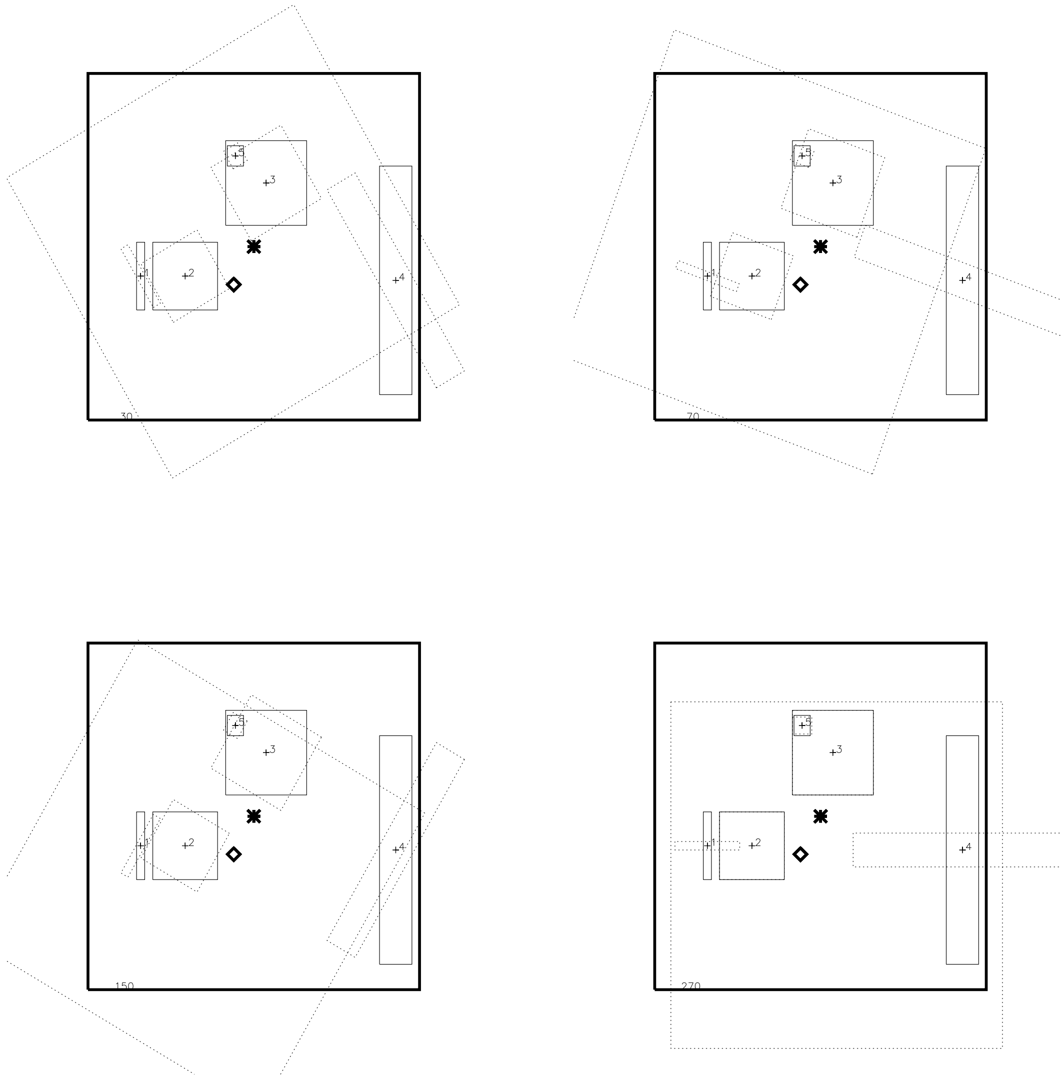

Figure 3: The effect of an rotation is illustrated, when the rotation center is offset from the OM optical axis. The rotation center is indicated by the diamond, the OM optical axis by the asterisk. The rotation angle is (from top left clockwise) 30, 70, 150, 270 degree respectively.

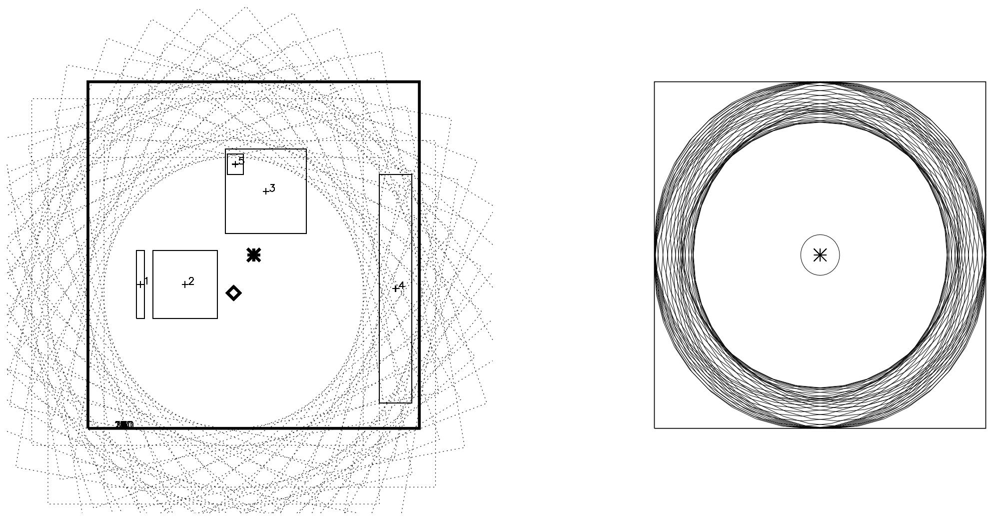

Figure 4: *Left Panel:* The effect of the rotation around one center offset from the OM optical axis. The left panel shows an overlay of all possible detector positions. It can be seen that the windows 3, 4 and 5 of the initial observation (roll angle 0) are defined in an area, which is not for all roll angles contained within the OM FOV. Only detector windows within the circle described by the various detector positions (dotted lines) are available to an GO. *Right Panel:* The effect of the rotation around different center. The inner circles from the left panel are overlayed for all boresight misalignments compatible with the specification (half-cone angle of 1 arcmin). The 1 arcmin half-cone angle is indicated by a solid line (small inner circle). The detector area available for free configuration is a circle around the OM optical axis with 6.5 arcmin radius.

to be used instead, which allows any values of misalignment within a specified half-cone angle. The specification for the misalignment between OM and EPIC is 1 arcmin (cf. [6] section 3.3.1.1). The OM vs. RGS boresight misalignment fulfills the same specification as it applies to OM vs. EPIC, which can be derived (cf. Chr. Erd's email from 3/11/97) from the RGS alignment specification ([7]).

The right panel of figure 4 illustrates the area available for configuration of windows defined in celestial coordinates. It is the circle around the optical OM axis (marked by an asterisk) with radius 6.5 arcmin. According to specification the boresight of the other XMM instruments must lay within a circle of radius 1 arcmin, indicated by the small inner circle.

The constraints for the OM window configuration resulting from the roll angle ambiguity are summarized below. The separation of two non-overlapping windows must be big enough, that they do not overlap for any possible roll angle. This is achieved by:
The separation of the centers of two non-overlapping windows (x_1, y_1) and (x_2, y_2) must be larger than the sum of the radii of their enclosing circles:

$$\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \leq 0.5 \cdot \sqrt{XSIZE_1^2 + YSIZE_1^2} + \sqrt{XSIZE_2^2 + YSIZE_2^2} \quad (9)$$

Embedded windows must stay embedded for any roll-angle:
The distance between the center of an embedded window (x_e, y_e) and the center of the surrounding window (x_s, y_s) must not be larger than r_{max}:

$$r_{max} = 0.5 \cdot min(XSIZE_s, YSIZE_s) - 0.5 \cdot \sqrt{XSIZE_e^2 + YSIZE_e^2} \quad (10)$$

A window of the size XSIZE$_i$ and YSIZE$_i$ and a center (x_i, y_i) must be centered less than a distance D$_i$ away from the optical axis, with

$$D_i \leq 8.5 - \sqrt{XSIZE_i^2 + YSIZE_i^2} \quad (11)$$

It will be possible to relax this requirement, once the misalignment of the boresight of the instruments is known.

Finally the strong change of sky coverage for elongated windows will be treated by recommending the use of square windows and discouraging the use of elongated windows.

6 Summary of OM Window Configuration Constraints

A summary of all constraints is listed in table 1.

origin	constraints	condition
DPU s/w	number of science windows	≤ 5
BWM	sum of science pixels	$\leq$ 432698 BWM-pixel (480775 without 10% margin)
SWM ping/pong area	sum of memory pixels	$\leq$ 1007616 SWM-pixel
DPU SAA s/w	sum of memory pixels	margin required (cf. equ. 2)
DPU s/w	window position	windows must not overlap (except embedded windows)
SWM fast mode area	maximum exposure length	$\leq$ 4.4-TBD % (one BFAST area) $\leq$ 2.2-TBD % (two BFAST area)
DPU processing power	tracking frametime	$\geq T_{frame}$ + TBD% (T_{frame} cf. 6)
DPU processing power	fast mode time slice	$\geq T_{slice}$ + TBD % (T_{slice} cf. 7)
TM bandwith	exposure duration	TBD (equ. 8)
MIC hardware	size and position of windows	$\leq$ 5 detector windows
MIC hardware	detector window size	4 CCD pixel $\leq$ window $\leq$ 512x512 centroided pixel
MIC hardware	detector window position	start position in horizontal (x-)direction even
MIC hardware	detector window	start position in vertical (y-)direction odd
MIC hardware	detector window	window size and addresses quantized in units of 2x2 CCD pixels
MIC hardware	detector window	windows must not overlap
Roll angle ambiguity	window separation	minimum allowed separation of the center of non-overlapping windows (equ. 9)
Roll angle ambiguity	embedded windows	maximum allowed separation of centers of embedded windows (equ. 10)
Roll angle ambiguity	window position	window corners within radius of 6.5 arcmin + TBD % (equ. 11)
Roll angle ambiguity	sky coverage	use of elongated boxes is discouraged

Table 1: Summary of all constraints

7 Default OM Configuration

It is the intention to provide a set of OM default configurations, which cover the needs of most of the scientific issues addressed with OM. When submitting the proposal the GO can select between the different configurations and need not care about the different constraints. The default configurations fulfill the following criteria:

- optimized FOV coverage
- continuous monitoring of the pointing direction of the prime instrument
- optional fast mode window at the pointing direction of the prime instrument

7.1 General Considerations

The following statements can be made about the defined OM default configuration.

- Within the given constraints the OM FOV can almost (~92% level) be covered with a sequence of five exposures.
- The OM FOV is covered by images binned at the DPU 2x2 both in x- and y-direction, which results in image pixels of 1x1 arcsec.
- In all five exposures a second, small science window in image mode at full resolution (i.e. no binning applied) will be located at the boresight of the prime instrument. This small science window (half-width 56 arcsec) ensures a continuous monitoring of the prime target.
- As there is a potential misalignment between the boresight of the different XMM instruments of up to 2 arcmin, there will be one set of OM configurations for each possible combination between OM and any other XMM instrument, i.e. for OM-RGS1, OM-RGS2, OM-EPIC-pn, OM-EPIC-M1, OM-EPIC-M2, OM as prime instrument. These sets of default configurations are in principle identical and differ only in the position of the central small science window. This reflects the different boresight offsets between OM and the various XMM instruments.
  The central small OM science window will initially be located at the center of the OM FOV for all instrument combinations. Once the boresight offset between OM and the other instruments is calibrated, the window position will be adjusted to account for the offset.
- Each default configuration includes an exposure with a central large image mode window, to make the default configuration as far as possible independent from the selection of the prime instrument.
  The location of the central small science window can be moved around within the area of the large image mode window according to the boresight offset and the s/c roll anlge.

- There will be a second default configuration offering in addition to the central image mode window a small fast mode window at the boresight position of the selected prime instrument (where the prime target is supposed to be).
  The position of the fast mode window will be adjusted once the boresight offset is calibrated in the same way as it is done for the central image mode window.

- In order to optimize the FOV coverage within the given constraints, it was decided not to force an overlap between large science windows. Any pointing offset between the five subsequent exposures can be determined using the central, small window, or by making use of the DD_TRH data.

7.1.1 Margin between Science and Memory Window

The margin required between memory and science windows is calculated based on the reference document [4].
The relative OM pointing changes in the course of an exposure are described by a long term drift, namely the absolute pointing drift over 16 h (APD(16h)), and a short term component, the relative pointing drift within 2 min (RPE(2min)). The APD within 16h provides an upper limit to the longterm OM pointing performances. Short term fluctuations are described by the relative pointing error and the RPE(2min) value provides a limit on these fluctuations. The APD(16h) is predicted as 3.7 arcsec for an orbit with ecclipse, which is the case scenario, and the RPE(2min) is predicted as 1.2 arcsec. The sum of both components is $\leq$ 5 arcsec. Adding a safety margin and considering the OM "multiple of 16 pixel address scheme", a drift margin of 16 pixel seems to be adequate for the default configurations. This margins equals 8 arcsec for the "normal" filter elements. For the magnifier a margin of 56 pixel should be adopted. However this can't be implemented into the default configurations.

A margin of 16 centroided pixel is allocated between memory and science windows. This does not include exposures with the magnifier.

Exposures with the magnifier are not covered by the OM default configurations.

Exposures with the magnifier require either the explicit configuration of OM by the GO (using the OM Instrument mode *OM Science User Defined* in the IPPV) or the acquired image may have a nonuniform exposure at the edges.

Once operating in orbit it has to be investigated whether the initially allocated *drift-margin* between the science and the memory window can be decreased or even removed. Note that in the zero-margin option the nonuniform exposure resulting form the s/c drift can in principle be corrected during data analysis. However such a correction is not implemented in the current version of the SAS (task MKSENS). It is intended to implement this feature in a later release.

The OM default configuration listed in section 7.2.1 include a margin of 16 pixel. In section B configurations without margin are provided, which may be implemented later in the mission.

7.1.2 Definition of OM Window Positions

OM window positions can either be defined by the coordinates of the lower left corner and the extent in x- and y-direction (XLOW, YLOW, XSIZE, YSIZE), or by the coordinates of the window center and the extent in x- and y-direction (XCENTER, YCENTER, XSIZE, YSIZE).
The definition of the default configuration is complicated by the fact that the large science windows used for FOV coverage are fixed in detector coordinates and are independent from the XMM pointing direction, while the small central science window is supposed to be aligned with the pointing direction of the prime instrument. As there are very likely boresight offsets between OM and the other XMM instrument, the position of the small window depend on the roll angle. This means, the position of the small central window must be defined by the position of the window center in celestial coordinates (XCENTER, YCENTER). The position of the lower left corner of the central window is calculated once the observation is scheduled and the roll angle is known by the SGS.

For a zero boresight offset the small image mode (and fast mode) window will be centered at pixel (1024,1024) and the lower left corners have coordinates as listed in table 3 to 7.

For normal operation the listed values XLOW and YLOW of window 2 and 3 in table 3 to 7 will be replaced by the window center XCENTER and YCENTER, which is the position of the boresight of the prime instrument in celestial coordinates.

7.2 Definitions of the OM Default Configurations

7.2.1 OM Default Configuration

The initial OM default configurations will be identical for the various combinations between OM and the other XMM instruments. However with increasing knowledge of the boresight offset between OM and the other instruments, the default configurations will be updated to reflect the difference in boresight offset. The update will only affect the central small windows (window ID= 2 and 3).

There are two different instrument configurations for each combination OM-prime instrument, namely OM-XXX Image and OM-XXX Image/Fast. XXX stands for one of the other XMM instruments, namely EPIC M1, EPIC M2, EPIC pn, RGS1, RGS2, OM [5]. These two configurations are identical except that the second configuration includes an additional fast mode window at the position of the boresight of the selected prime instrument.

parameter	value	description
n_dpu_cyle	20000	tracking frame duration in [DPU cycles]
n_frames	500	exposure duration [tracking frames]

Table 2: OM configuration parameters, which are not directly related to the active windows

expos.	window		science window				Parameter		memory window				
ID	ID	mode	xlow	ylow	xsize	ysize	p1	p2	ID	xlow	ylow	xsize	ysize
1	1	Image	528	528	976	960	1	1	1	512	512	1008	992
	2	Image	912[2]	912[2]	224	224	0	0	1	-	-	-	-
2	1	Image	48	16	480	1792	1	1	32	0	1	512	1824
	2	Image	912[2]	912[2]	224	224	0	0	2	896[2]	896[2]	256	256
3	1	Image	224	48	1792	480	1	1	1	208	32	1824	512
	2	Image	912[2]	912[2]	224	224	0	0	2	896[2]	896[2]	256	256
4	1	Image	1504	240	480	1792	1	1	1	1488	224	512	1824
	2	Image	912[2]	912[2]	224	224	0	0	2	896[2]	896[2]	256	256
5	1	Image	16	1488	1792	512	1	1	1	0	1472	1824	512
	2	Image	912[2]	912[2]	224	224	0	0	2	896[2]	896[2]	256	256

[2] position only valid for a zero boresight offset, the window position will be specified by the window center (cf. section 7.1.2)

Table 3: OM default window configuration parametersfor the OM Instrument mode: OM-XXX IMAGE, where XXX stands for one of the other XMM instruments (EPIC M1, EPIC M2, EPIC pn, RGS1, RGS2, OM). A drift margin of 16 centroided pixel is accomodated between science and memory windows. The FOV coverage is 92.0%.

The initial window setting of the OM default configurations are listed in Table 3 and 4. The parameters not related to the window setting are listed in Table 7.2.1, which are the tracking frame time and the exposure duration. The tracking frame time is set to 20sec which should be sufficiently long to complete SAA and the exposure duration is set to 1000 sec (500 * 20sec), which will allow downlinking of the data of the previous OM exposure.

In Figure 5 the window positions of the five exposures in the default configurations are displayed. The OM boresight is indicated by a diamond. The optional fast mode window is not displayed. The boresight offset of the prime instrument was assumed to be zero. The first exposure covers the central area of the OM FOV, while the subsequent four exposure cover the outer FOV area. The small central window is present in all five exposures and continuously monitors the pointing direction of the prime instrument. There is an overlap between the windows of the different exposures. The FOV coverage amounts to 92.0%.

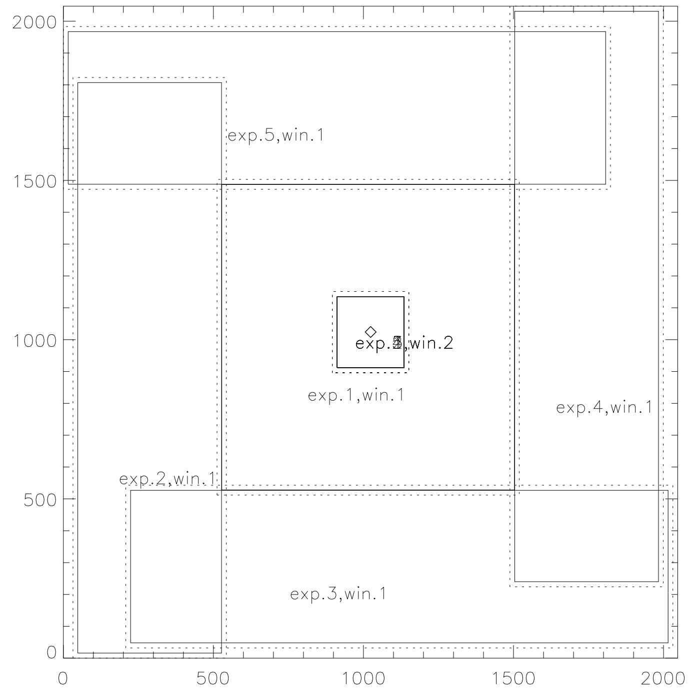

Figure 5: The OM default configuration consisting of a sequence of five exposures. The science windows are indicated by solid lines, the memory windows by dashed lines. A 16 pixel margin is allocated between science and memory windows. The FOV coverage is 92.0%. For the display a zero boresight offset is assumed between OM and the prime instrument. The OM boresight is indicated by the diamond.

expos.	window		science window				Parameter[1]		memory window				
ID	ID	mode	xlow	ylow	xsize	ysize	p1	p2	ID	xlow	ylow	xsize	ysize
1	1	Image	528	528	976	960	1	1	1	512	512	1008	992
	2	Image	912[2]	912[2]	224	224	0	0	1	-	-	-	-
	3	Fast	1014[2]	1013[2]	22	23	8[3]	1	1	-	-	-	-
2	1	Image	48	16	480	1792	1	1	1	32	0	512	1824
	2	Image	912[2]	912[2]	224	224	0	0	2	896[2]	896[2]	256	256
	3	Fast	1014[2]	1013[2]	22	23	8[3]	1	1	-	-	-	-
3	1	Image	224	48	1792	480	1	1	1	208	32	1824	512
	2	Image	912[2]	912[2]	224	224	0	0	2	896[2]	896[2]	256	256
	3	Fast	1014[2]	1013[2]	22	23	8[3]	1	1	-	-	-	-
4	1	Image	1504	240	480	1792	1	1	1	1488	224	512	1824
	2	Image	912[2]	912[2]	224	224	0	0	2	896[2]	896[2]	256	256
	3	Fast	1014[2]	1013[2]	22	23	8[3]	1	1	-	-	-	-
5	1	Image	16	1488	1792	512	1	1	1	0	1472	1824	512
	2	Image	912[2]	912[2]	224	224	0	0	2	896[2]	896[2]	256	256
	3	Fast	1014[2]	1013[2]	22	23	8[3]	1	1	-	-	-	-

[1] Note the different meaning of p1/p2 for image and fast mode windows.
[2] position only valid for a zero boresight offset, window position is specified by window center (cf. section 7.1.2)
[3] (TBC)

Table 4: OM default window configuration parametersfor the OM Instrument mode: OM-XXX IMAGE/FAST, where XXX stands for one of the other XMM instruments (EPIC M1, EPIC M2, EPIC pn, RGS1, RGS2, OM). A drift margin of 16 centroided pixel is accomodated between science and memory windows. The configuration has an additional central fast mode window.

8 Open Issues and Questions

Here is a list of issues which require further attention.

- For calculating the shift vector during SAA is the intial tracking star position read from the DD_REF data or does it require additional storage space.
- confirmation of value for compression efficiency (3.1)
- value for compression time needs settling
- start address of mmw/dtw in respect to even/odd absolute CCD pixel address must be resolved

expos.	window		science window				Parameter		memory window				
ID	ID	mode	xlow	ylow	xsize	ysize	p1	p2	ID	xlow	ylow	xsize	ysize
1	1	Image	560	544	944	992	1	1	1	544	528	976	1024
	2	Image	912[2]	912[2]	224	224	0	0	1	-	-	-	-
2	1	Image	112	64	1808	480	1	1	1	96	48	1840	512
	2	Image	912[2]	912[2]	224	224	0	0	2	896[2]	896[2]	256	256
3	1	Image	112	1536	1808	480	1	1	1	96	1520	1840	512
	2	Image	912[2]	912[2]	224	224	0	0	2	896[2]	896[2]	256	256
4	1	Image	16	544	864	992	1	1	1	0	528	896	1024
	2	Image	912[2]	912[2]	224	224	0	0	2	896[2]	896[2]	256	256
5	1	Image	1168	544	896	1024	1	1	1	1152	528	896	1024
	2	Image	912[2]	912[2]	224	224	0	0	2	896[2]	896[2]	256	256

[2] position only valid for a zero boresight offset, window position is specified by window center (cf. section 7.1.2)

Table 5: OM window configuration parameters for the altnernative OM default configuration with allocated drift margin of 16 centroided pixel. The FOV coverage is 88.7 %.

A Alternative Default Configuration

Table 5 and Figure 6 describe an alternative OM default configuration. However this configuration was not selected as default for two reasons. The large window (win 1) of exposure 4 and exposure 5 are very closely located to the small central window (win 2) of the same exposure. If the misalignment of the different instruments require a change in the location of window 2, a modification of the large window location or size is required either in exposure 4 or exposure 5. This would lead to a differences in the FOV coverage for the different XMM instruments, which is undesirable.
Note that the OM default configuration in section 7.2.1 is rather insensitive against this effect, as there is the central area is covered only by one large window.

B OM Default Configurations without Drift Margin

OM default configuration without *drift-margin* between science and memory window may be implemented at a later stage of the mission, once a better understanding of the XMM pointing performance is available and once the nonuniform exposure map correction is implemented into the SAS. Note that here in the proposed configuration a margin is still accomodated for the small image mode window in the center of the FOV.

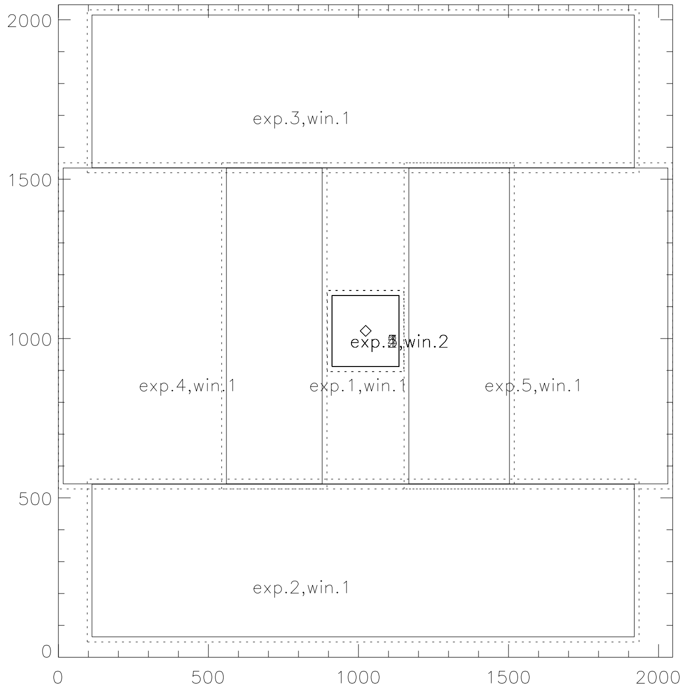

Figure 6: Alternative OM default configuration consisting of a sequence of five exposures. The science windows are indicated by solid lines, the memory windows by dashed lines. A 16 pixel margin is allocated between science and memory windows. The FOV coverage is 88.7 %. For the display a zero boresight offset is assumed between OM and the prime instrument.

expos.	window		science window				Parameter		memory window				
ID	ID	mode	xlow	ylow	xsize	ysize	p1	p2	ID xlow	ylow	xsize	ysize	
1	1	Image	528	512	976	1024	1	1	1	528	512	976	1024
	2	Image	912[2]	912[2]	224	224	0	0	1	-	-	256	256
2	1	Image	16	0	512	1840	1	1	1	16	0	512	1840
	2	Image	912[2]	912[2]	224	224	0	0	2	896[2]	896[2]	256	256
3	1	Image	208	0	1840	512	1	1	1	208	0	1840	512
	2	Image	912[2]	912[2]	224	224	0	0	2	896[2]	896[2]	256	256
4	1	Image	1504	208	512	1840	1	1	1	1504	208	512	1840
	2	Image	912[2]	912[2]	224	224	0	0	2	896[2]	896[2]	256	256
5	1	Image	0	1536	1840	512	1	1	1	0	1536	1840	512
	2	Image	912[2]	912[2]	224	224	0	0	2	896[2]	896[2]	256	256

[2] position only valid for a zero boresight offset, window position is specified by window center (cf. section 7.1.2)

Table 6: OM window configuration parameters for the OM default configuration without allocated drift margin. The FOV coverage is 98.2 %.

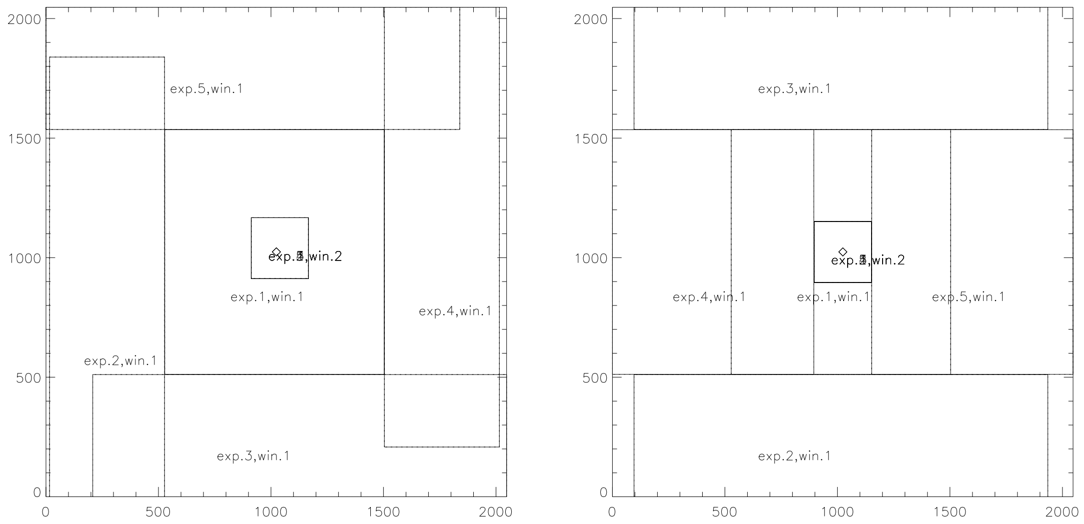

Figure 7: OM default configuration consisting of a sequence of five exposures without drift margin, i.e. there is a no pixel margin left between science and memory windows. For the OM default configuration (section 7.2.1) in the left panel and for the alternative configuration (cf. appendix A) in the right panel the FOV coverage is 98.2 % and 94.9 % respectively. For the display a zero boresight offset is assumed between OM and the prime instrument.

expos.	window		science window				Parameter		memory window				
ID	ID	mode	xlow	ylow	xsize	ysize	p1	p2	ID	xlow	ylow	xsize	ysize
1	1	528	512	976	1024	1	1	1	528	512	976	1024	
	2	912[2]	912[2]	224	224	0	0	1	-	-	-	-	
2	1	96	0	1840	512	1	1	1	96	0	1840	512	
	2	912[2]	912[2]	224	224	0	0	2	896[2]	896[2]	256	256	
3	1	96	1536	1840	512	1	1	1	96	1536	1840	512	
	2	912[2]	912[2]	224	224	0	0	2	896[2]	896[2]	256	256	
4	1	0	512	896	1024	1	1	1	0	512	896	1024	
	2	912[2]	912[2]	224	224	0	0	2	896[2]	896[2]	256	256	
5	1	1152	512	896	1024	1	1	1	1152	512	896	1024	
	2	912[2]	912[2]	224	224	0	0	2	896[2]	896[2]	256	256	

[2] position only valid for a zero boresight offset, window position is specified by window center (cf. section 7.1.2).

Table 7: OM window configuration parameters for the alternative OM configuration (cf. appendix A without allocated drift margin. The FOV coverage is 94.9 %.