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CHANGE RECORD

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Applicable references:

These references appear in [] brackets in this document.
1 – EIS Science requirements: MSSL/SLB-EIS/SP007.07
2 – Position of Flare in EIS FOV, calculated from information from XRT, V2 by H. Hara.
3 – MDP ICU interface document: NAO/SLB-EIS/SP/MDP3.4
4 - EIS Telecommanding Structure: MSSL/SLB-EIS/SP016.03
5 - EIS sequence structure overview: MSSL/SLB-EIS/TN014.03
6 – EIS Status: MSSL/SLB-EIS/SP017.06
7 – Use of two line lists, two exposure times for XRT flare response as requested by H. Hara.

Glossary and Convention:

α	Flare angle
BC	Block Command, Solar-B Command parameter
CAM	EIS Camera
CMIR	EIS Coarse Mirror
EGSE	Ground Support Equipment
EIS	Extreme ultraviolet Imaging Spectrometer
FMIR	EIS Fine Mirror
FOV	Field Of View
FT	Flare Trigger
H	XRT Horizontal coordinate
Hc	XRT Horizontal flare position
HK	Housekeeping (status)
Fs	Follow on Sequence
LL	Line List
MHC	Mechanism and Heater controller
MIP	EIS fine Mirror Initial Position
NA	Not Applicable
OCB	On Chip Binning (CAM function)
SIB	Satellite information database
θ	EIS/XRT angular alignment error
V	XRT Vertical coordinate
Vc	XRT Vertical flare position
X	EIS X coordinate
X1	EIS FOV centre in the X-direction
X_0	EIS/XRT linear alignment error in the X-direction
X_f	EIS flare position in arcseconds (relative to X-FOV)
Y	EIS Y coordinate
Y1	EIS FOV centre in the Y-direction
Y_0	EIS/XRT linear alignment error in the Y-direction
Y_f	EIS flare position in arcseconds (relative to Y-FOV)

1.0 Introduction

The task of responding to an XRT flare trigger was undertaken in response to the following EIS science requirement:

"To respond or not to XRT flare trigger by moving to the flare location and starting a new observation sequence or staying in the same location and change the study. Only respond if the flare is within EIS FOV"

However, an option has been added whereby the EIS may respond to an XRT flare even if the flare is outside the EIS FOV as there is some scientific merit to this (e.g. to study solar waves or turbulences around a flare region). Such a response study can be undertaken if an "active region" with the potential for flaring is close to the EIS FOV, but not within it. This option can be enabled via a command.

Note that within the following text, XRT flare coordinates are referred to as Hc and Vc, i.e. Horizontal and Vertical coordinates respectively, while EIS coordinates are referred to as X and Y.

2.0 XRT flare coordinates system

The XRT camera acquires two images, in parallel; these images are in 1x1 to 8x8 OCBs. The 8x8 OCB image is used for XRT flare detection. The primary purpose of using 8x8 OCB is to reduce the XRT on-board data processing load.

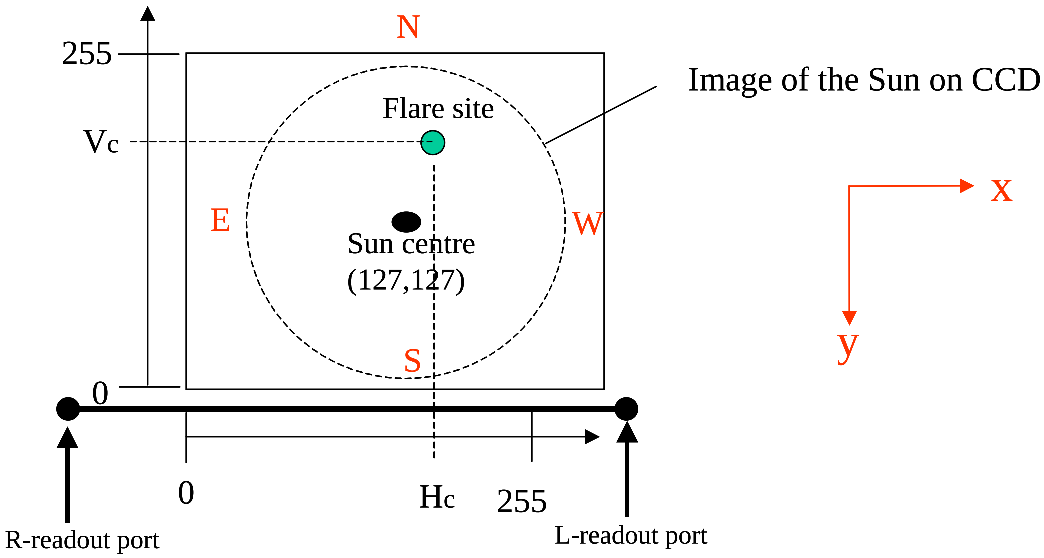
As part of the MDP nominal operations [3], the MDP transmits XRT flare status parameters, (flare/no flare) flag and the flare coordinates, for every status (HK) or memory dump request, at 0.5-second intervals. The structure of these messages is as shown below:

Command format for transfer from MDP to ICU

CMD ID	Command Parameters			
Command ID	Time Indicator	Flare Flag	XRT Flare Location H	XRT Flare Location V
8bits	32 bits	8 bits	8 bits	8 bits

Command ID: 01, 02, 03 or 04
Time Indicator: Copy of satellite on-board time.
Flare Flag: 0: no flare, 1: flare
XRT (Hc, Vc) Flare Location: Range 0–255 that reflects XRT CCD image size in 8x8 OCB i.e. (2048/8, 2048,2048/8).

The flare coordinates are in **XRT CCD coordinates** and these need to be translated to the EIS FOV location.



XRT Flare positions, (Hc) Horizontal and (Vc) Vertical positions

Note that there is 10 seconds minimum latency (nominal 30 seconds) between XRT detecting a flare and the MDP transmitting the flare information to the EIS.

3.0 XRT flare coordinates to EIS FOV translation

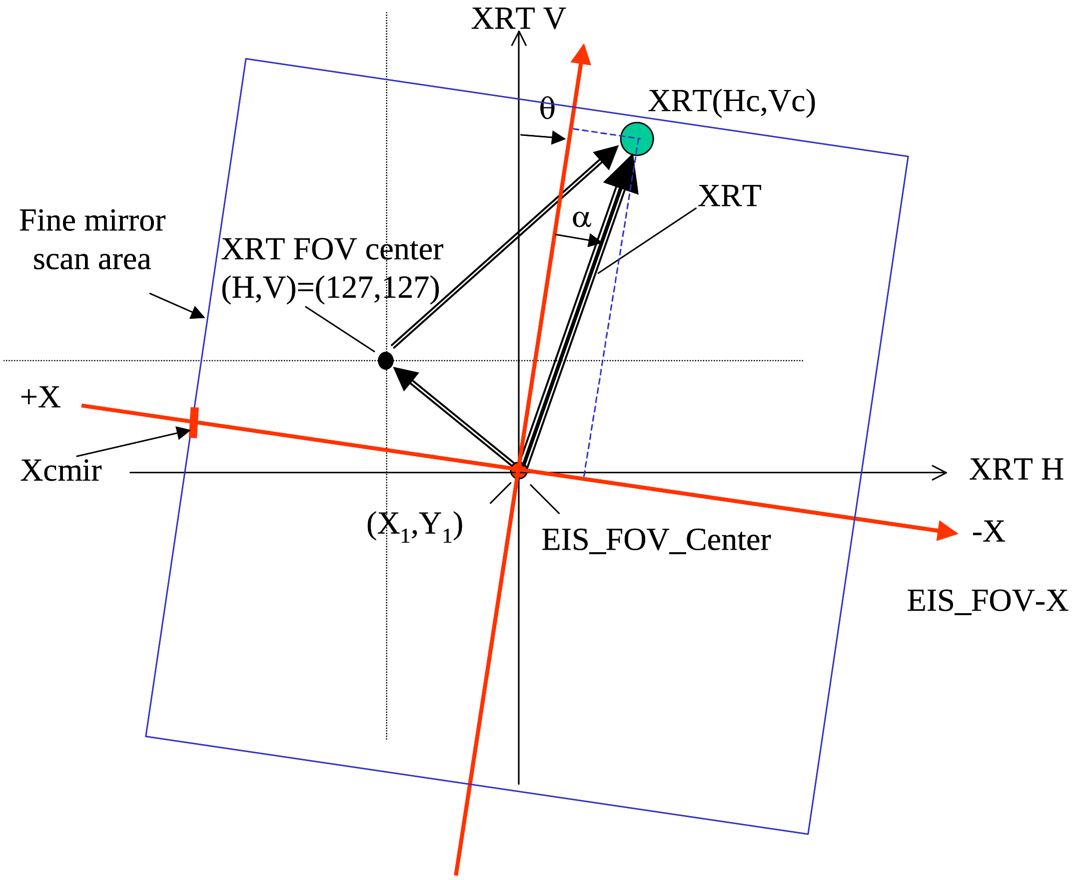
In order to determine the flare position relative to the EIS FOV, XRT flare **CCD coordinates** (Hc and Vc) are translated to EIS positions (X_f" and Y_f") in arcseconds.

The diagram below shows an XRT flare at coordinates (Hc, Vc), and a flare angle of α. X1 and Y1 are the EIS FOV centre position, which is determined by the coarse mirror position (Xcmir), i.e.:

$X_1 = X_0 + (Xcmir + 295") * \cos\theta$
$Y_1 = Y_0 - (Xcmir + 295") * \sin\theta$

Where:

X_0 and Y_0 are the linear alignment errors and θ is the angular alignment error between the EIS and XRT telescopes. The alignment errors are up-linkable parameters and are to be determined post-launch. The 295" is the EIS FOV image centre.



XRT flare position with respect to EIS FOV

$\tan(\alpha + \theta) = (Hc - X_1) / (Vc - Y_1)$

$A = \sqrt{([Hc-X_1]^2 + [Vc-Y_1]^2)}$

The EIS flare position, in arcseconds, is determined as follows:

$Xf'' = -A \sin \alpha$

$Yf'' = +A \cos \alpha$

A flare is declared to be within the EIS FOV if:

1) Xf" is between 0 and 590" (EIS image X-FOV) and
2) Yf" is between 0 to 512" (EIS image Y-FOV)

4.0 XRT flare trigger control parameters

In addition to enabling the raster XRT flare trigger flag [5], the following XRT flare trigger control parameters must be loaded into the EIS observation table prior to undertaking XRT flare trigger operations:

Bit 0 **Bit 31**

<table>
<tr><td colspan="2">Sequence no.</td><td colspan="6">Raster ID</td><td colspan="2">Control flags</td></tr>
<tr><td colspan="10">Y start address</td></tr>
<tr><td colspan="10">Y height address</td></tr>
<tr><td colspan="4">X0</td><td colspan="3">Y0</td><td colspan="3">Filler sequence no.</td></tr>
<tr><td>θ</td><td colspan="2">XRT OCB</td><td colspan="2">XRT P-Size</td><td>FS enable</td><td colspan="3">EIS FOV flag</td><td>Spare bit</td></tr>
</table>

Where:

Sequence no.: Is an 8 bit parameter which specifies the EIS XRT flare trigger response sequence number (study). This sequence will run when an XRT flare is triggered. This sequence should have its raster(s) XRT flare trigger flag disabled, as a flare response is already active when the response study invoked. The response sequence (study) may be chained to other sequences (see section 7.3).

Raster ID: Is a 16-bit parameter, which specifies the response raster identifier. Raster parameters are used for EIS autonomous re-pointing, if required. The raster ID shall be <u>present in the sequence number parameter described above (**Sequence no.)**</u>. The raster ID **must not** be 0 or 0xFFFF otherwise it will be considered on-board as an un-initialised parameter error.

Note that it is possible to have more than 1 raster in an XRT flare response study (e.g. a background noise measurement raster and a main raster). However, X or Y re-pointing, if required, <u>can only be performed on a single raster</u> (the main response raster which is marked by this parameter). Nevertheless and due to the high response speed required, similar operations can be performed from a "filler sequence" which may be run after an XRT flare response is terminated (to acquire noise measurements for example).

Control flags: These 1-bit flags are as follows:
<u>Verify FOV</u>: When set, the ICU software verifies whether the flare is within the EIS FOV prior to starting a response study.
<u>Adjust Y</u>: When set, a re-pointing in the Y-direction is performed, via reducing the number of CCD rows read out to speed up the cadence. The read-out portion is centred around Yf". Obviously, the response raster line list Y-height parameter must be less than 512 pixels.
<u>Adjust X</u>: When set, a re-pointing in the X-direction is performed, via the fine mirror. Obviously, the response raster X-FOV FMIR scans must be less than 259".

Note that Adjust X and or Y must be accompanied by Verify FOV flag setting, as it is not possible to re-point if the flare is outside the EIS FOV. Also re-pointing in the X-

direction can only be performed using the FMIR, as the use of the CMIR is restricted for EIS due to a high level of disturbances.

X0 sign: EIS/XRT alignment error sign in the X direction (dispersion). Setting the flag to 1 indicates a –X0 alignment error.
Y0 sign: EIS/XRT alignment error sign in the Y direction (spatial). Setting the flag to 1 indicates a –Y0 alignment error.
θ Sign: EIS XRT angular alignment error sign. Setting the flag to 1 indicate a –θ alignment error.
X Conversion: EIS/XRT X-direction optical orientation. Setting the flag to 1 indicates –X conversion (inversion). This flag shall be set to 1 as EIS/XRT images are inverted in the X direction, relative to each other.
Y Conversion: EIS/XRT Y-direction optical orientation. Setting the flag to 1 indicates –Y conversion (inversion). This flag shall be set to 0, as EIS/XRT images have the same orientation in the Y direction.

Y Start Address: The camera read-out sequence Y start address memory location, which is a 32-bit parameter. The address is generated by the CSG compiler and should be treated as a constant, as long as the CAM read-out sequence is not changed. For example, using the FM CAM RROM CODE, CSD-ID 4, this parameter has the value 0x04000C00.

This parameter **must not** be set to 0 0r 0xFFFFFFFF otherwise it will be considered on-board as an un-initialised parameter error.

Y height Address: The Camera read-out sequence Y height address memory location, which is a 32-bit parameter. The address is generated by the CSG complier and should be treated as a constant, as long as the CAM read-out sequence is not changed. For example, using the FM CAM RROM CODE, CSD-ID 4, this parameter has the value 0x04001400.

This parameter **must not** be set to 0 0r 0xFFFFFFFF otherwise it will be considered on-board as an un-initialised parameter error.

X0: Is a 12-bit parameter that specifies the EIS/XRT linear alignment error in the X-direction, in arcseconds. The alignment sign is set to +/- using the X0 sign control flag (see control flags).

Y0: Is a 12-bit parameter that specifies the EIS/XRT linear alignment error in the Y-direction, in arcseconds. The alignment sign is set to +/- using the Y0 sign control flag (see control flags).

Filler sequence number: If the flare flag is resets by XRT (flare end) **or** a response sequence terminated, a follow on “filler sequence” can be run to fill the time gap until a next sequence is run via the Solar-B deferred command store, i.e. the OP/OG command store. This is an 8-bit parameter (range 0 to 127). This parameter is used if the **FS enable flag is set.**

θ: Is a 16-bit parameter (range 0 to 65535) that specifies the EIS/XRT angular alignment error, in arcseconds. The alignment sign is set to +/- using the θ sign control flag (see control flags).

XRT OCB: The XRT flare detection algorithm OCB. This parameter shall be set to 8. However, in the unlikely event of XRT changing their OCB factor, EIS can respond by changing this parameter. This is a 4-bit parameter (range 1 to 15).

XRT P-Size: This is an 8-bit parameter that specifies the XRT CCD pixel size, in arcseconds. A scale factor of 100 is applied to this parameter. For example, if the XRT pixel size is 1.1", then this parameter is set to 110.

FS enable: This is a 1-bit flag, which enables the running of a "filler sequence", when set to 1. See Filler sequence number parameter.

EIS FOV flag: This is a 2-bit parameter that holds the EIS FOV centre in the wavelength direction. The EIS X-FOV is obtained from the coarse mirror position, as reported in the MHC HK. Prior to EIS integration, this parameter could have one of the following values:

01b = Coarse mirror position" + (X-FOV / 2)"
02b = Coarse mirror position" - (X-FOV / 2)"
03b = Coarse mirror position"

This parameter **must** be set to 01b.

Spare bit: Reserved for internal use. This **must** be set to 0.

4.1 XRT commanding verifications

Following XRT flare trigger enabling [5] and XRT flare detection, the ICU prior to responding performs the following checks:

1 – Verify that the raster ID, CAM Y-start and Y-height addresses are neither 0's nor F's or they will be considered as un-initialised or illegal values. This indicates that the XRT flare control parameters in the EIS OBS table are not loaded on-board.

2 – Verify that the response sequence number in the XRT control parameters table is within range (0 to 127) and contains a valid checksum.

3 – Verify the presence of the raster ID (XRT control table parameter) in the response sequence. Matching three consecutive bytes performs this check. These bytes are the run raster command BC1, the raster ID most significant byte and the raster ID least significant byte.

4 – Verify that the raster ID line list is in range (0 to 47) and contains a valid checksum.

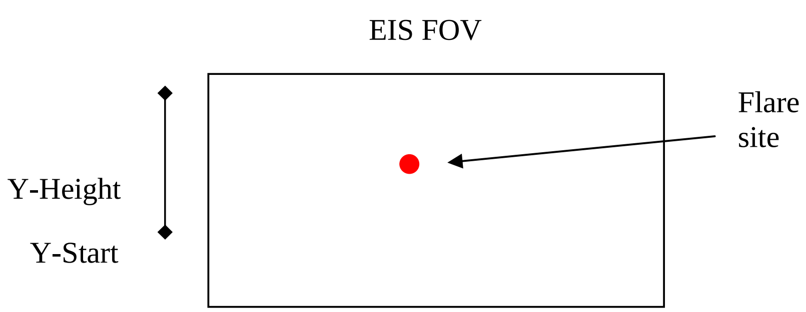
If any of the above checks is failed, the ICU software autonomously disables EIS XRT flare trigger flag, as a response is not possible. The offending error is reported in the EIS HK, i.e. status type 1 [6], XRT_ERROR parameter.

4.2 EIS X and Y flare location re-pointing

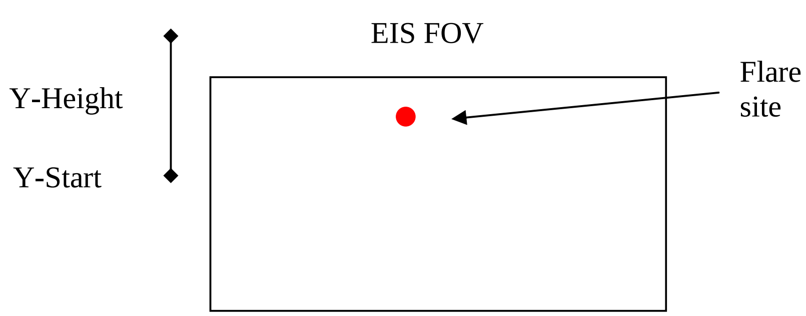
When Verify FOV is set in conjunction with the adjust X and adjust Y flags (see section 3), a re-pointing operation(s) will be undertaken in response to an XRT flare. Re-pointing implies zooming in on the flare site with reduced FOV to speed up the cadence. The reduction in the FOV is pre-selected by the user.

4.2.1 Option 1: Y adjust (re-pointing in the Y-direction)

Reducing the number of rows clocked out of the CCD performs this operation. The number of rows clocked (Y-height) is as specified in the response raster line list. However, the flare Y-start (first row to be read) is determined from the flare Y position (Y_f) such that the flare is positioned at the centre of the Y-height, as illustrated below:

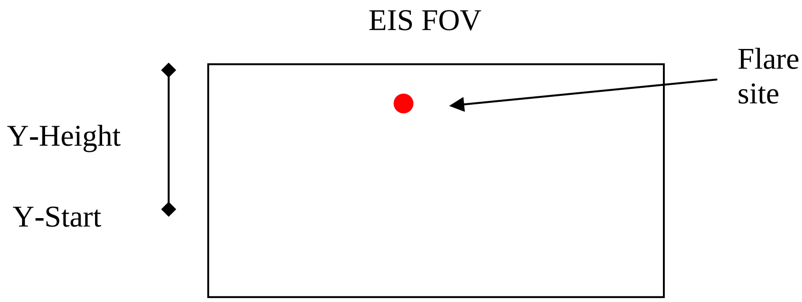


Note that if the flare site is near the edge of the field of view and it is not possible to encapsulate the flare site and remain within the Y-FOV, then the read-out section is re-adjusted, as illustrated below:



Y re-pointing error

Re-adjusted:



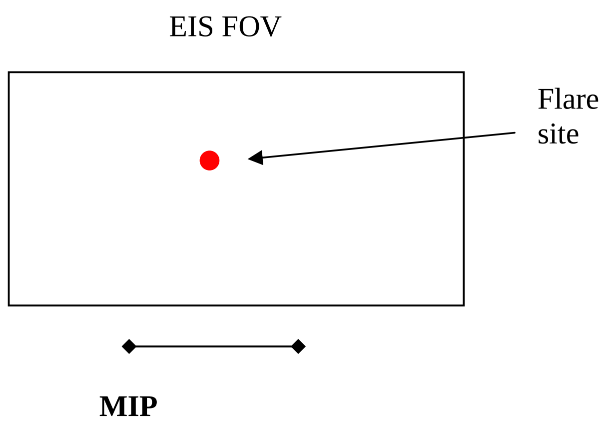
Y adjustment is performed via re-programming the CAM, on the fly, and modifying the response line list Y-start.

4.2.2 Option 2: X adjust (re-pointing in the X-direction)

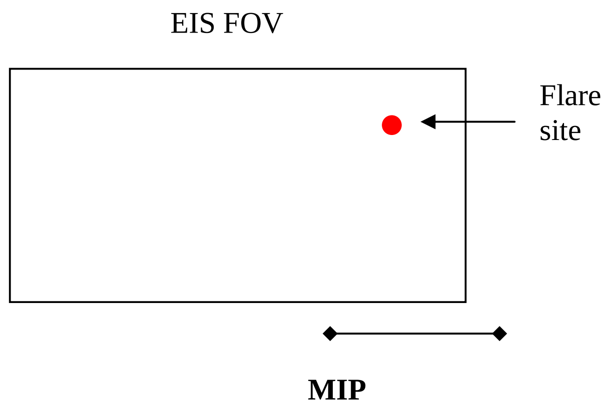
Re-pointing is achieved by moving the fine mirror to the flare site, such that the flare is positioned at the centre of the raster scan. For sit and stare rasters, the fine mirror is position at the flare site (Xf). Note that the flare response raster scan size (pre-determined) is acquired from the response raster, as marked by the response raster ID, using the exposure loop and FMIR mirror step size parameters [5], as follows:

Raster scan size" = (exposure loop – 1) * step size

The raster FMIR initial position (MIP) is modified on the fly prior to running the response sequence (study), as illustrated below:

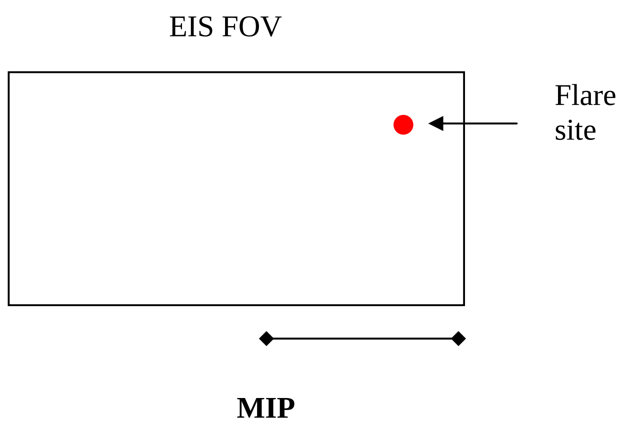


Note that if the flare site is near the edge of the field of view and it is not possible to encapsulate the flare site and remain within the X-FOV, then the read-out section is re-adjusted, as illustrated bellow:



X re-pointing error

Re-adjusted as illustrated below:



4.3 Post flare operations

Note that once an XRT flare trigger response is active (response study is running and the XRT flare flag is ON), the ICU stops processing incoming XRT flare coordinates, as this is unnecessary processing load and of no use.

Also it should be noted that once a response is active the ICU **disables** mode transitions, autonomously. This is to inhibit the Solar-B OP/OG command store from accidentally aborting the response study when the next time line commands are due (timeline commands and flares are asynchronous). Once the response is finished (stopped or aborted) or the XRT flare flag turned OFF, the ICU **re-enables** the mode transitions, autonomously and starts accepting OP/OG commands.

5.0 XRT FT response termination and Filler sequencing

EIS response to an XRT flare can be terminated in any of the following ways:

1 – Flare end by XRT. A “filler sequence” can be activated, until a new OP/OG command is received.

2 – Response sequence end (stop, i.e. execute terminate sequence command). A “filler sequence” can be activated, until a new OP/OG command is received.

3 – Abort the running sequence from the ground by going to MANUAL mode (this requires an enable mode transition command first). This will stop everything including any filler sequence activation. Control is handed over to the ground.

6.0 EIS observation table management

As a requirement for Solar-B operations, an identical copy of the EIS OBS table on-board shall be made available to ISAS EGSE, for memory management purposes. However, when re-pointing operations are undertaken, both the response sequence and the main response raster line list may be modified on-board. In order to maintain similarity, the XRT flare trigger software task creates local copies of the response sequence and the line list, prior to modifying them. Once an XRT flare trigger response is terminated (see section 5), the local copies are re-copied to the EIS OBS table, such that the OBS table maintained in it original form.

7.0 XRT FT examples

The XRT flare trigger response was tested at MSSL during the course of the ICU on-board software development, and at ISAS. The MSSL and ISAS tests were performed independently. However, it must be noted here that the ultimate testing will be performed in orbit. Nevertheless, the ground testing goes a long way in verifying the correctness of the operations and performance of the on-board software.

This sections deals with the testing at MSSL. These tests consist of 3 parts:

1 – Verify the XRT flare location with respect to the EIS FOV. This is critical to verifying XRT flare coordinates to EIS FOV translation, as described in section 3.

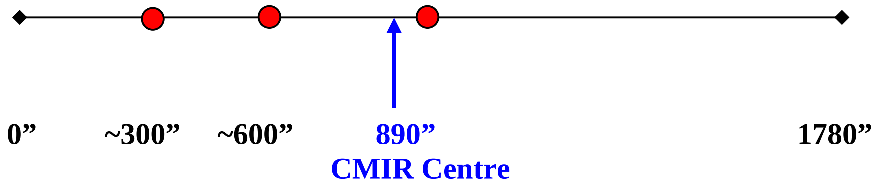
2 – Verify X and Y re-pointing operations.

3 – Acquire some reasonable figures for EIS response time.

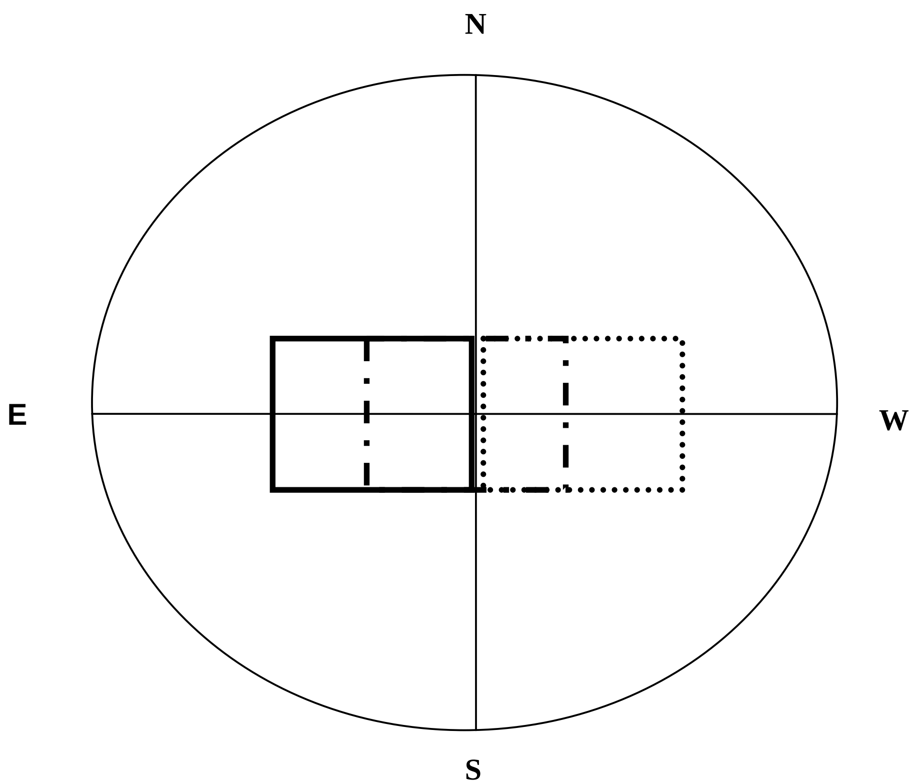
As the XRT flare position with respect to the EIS FOV depends on EIS pointing via the CMIR, these tests have been performed in the following positions:

CMIR = ~ 300”

CMIR = ~ 600”
CMIR = ~ 900” (CMIR centre is at 890”)



EIS CMIR Range



EIS FOV with respect to CMIR position

The following is an example of Sit and Stare response rasters with re-pointing in both the X and Y directions. The FMIR is positioned at the flare location.

CMIR POINTING	**XRT (H_C, V_C)**	**EIS (X_F, Y_F)”**	**LOCATION (FOV)**	**FMIR (SET POINT)**
607”	(64,128)	(793,263)”	OUT	N.A.
=	(160,128)	(25,264)”	IN	701
309”	(64,128)	(495,263)”	IN	2612
=	(160,128)	(-273,264)”	OUT	N.A.
908”	(127,128)	(591,263)”	OUT	N.A.
=	(130,128)	(566,264)”	IN	2900

N.A. = Not applicable (no FMIR re-pointing is possible as the flare is outside EIS FOV)

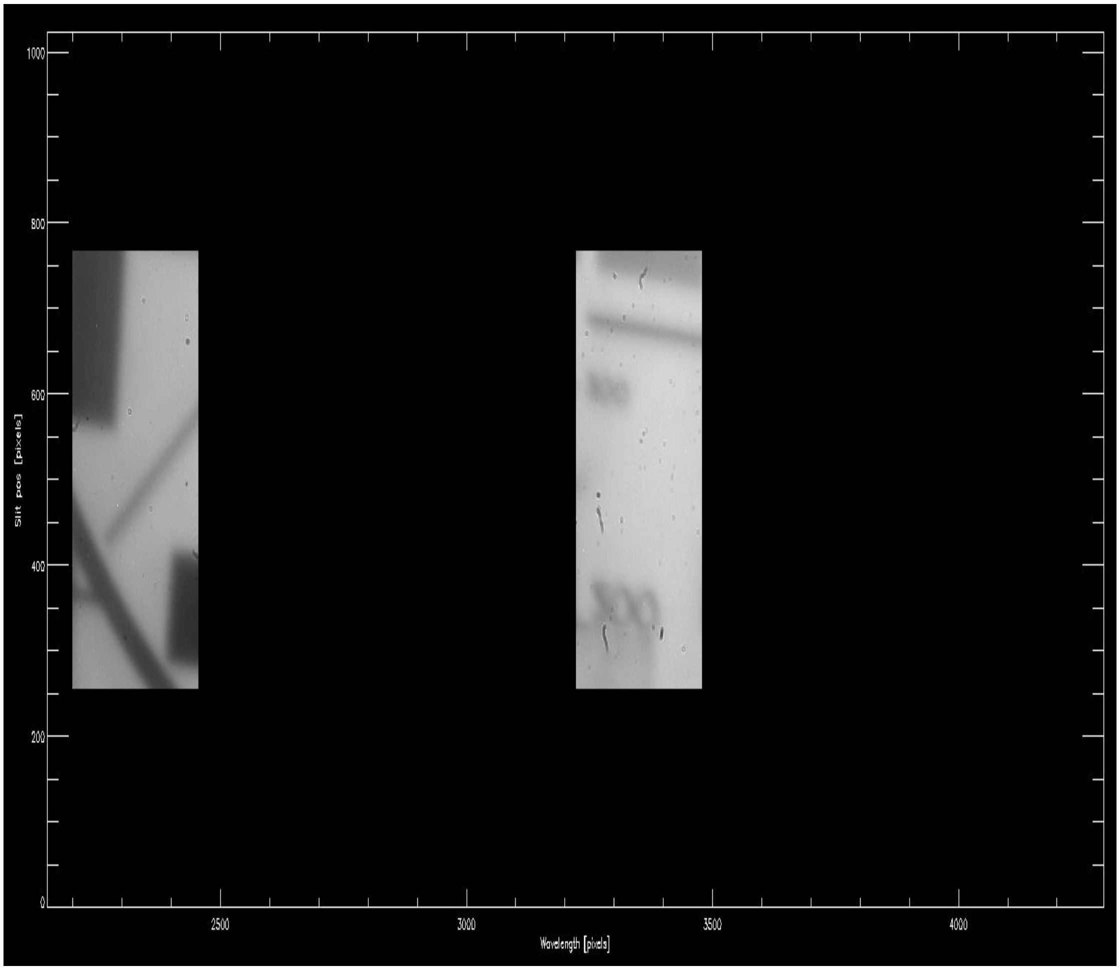
Note: X_F and Y_F are relative to the EIS FOV

And a raster response (3 Exposures response raster, FMIR steps = 50):

CMIR	**XRT (H_C, V_C)**	**EIS (X_F, Y_F)”**	**LOCATION (FOV)**	**FMIR (SET POINT)**
908”	(130,128)	(566,264)”	IN	Flare at 2900 Raster at: P1 = 2850 P2 = 2900 P3 = 2950

Note: X_F and Y_F are relative to EIS FOV.

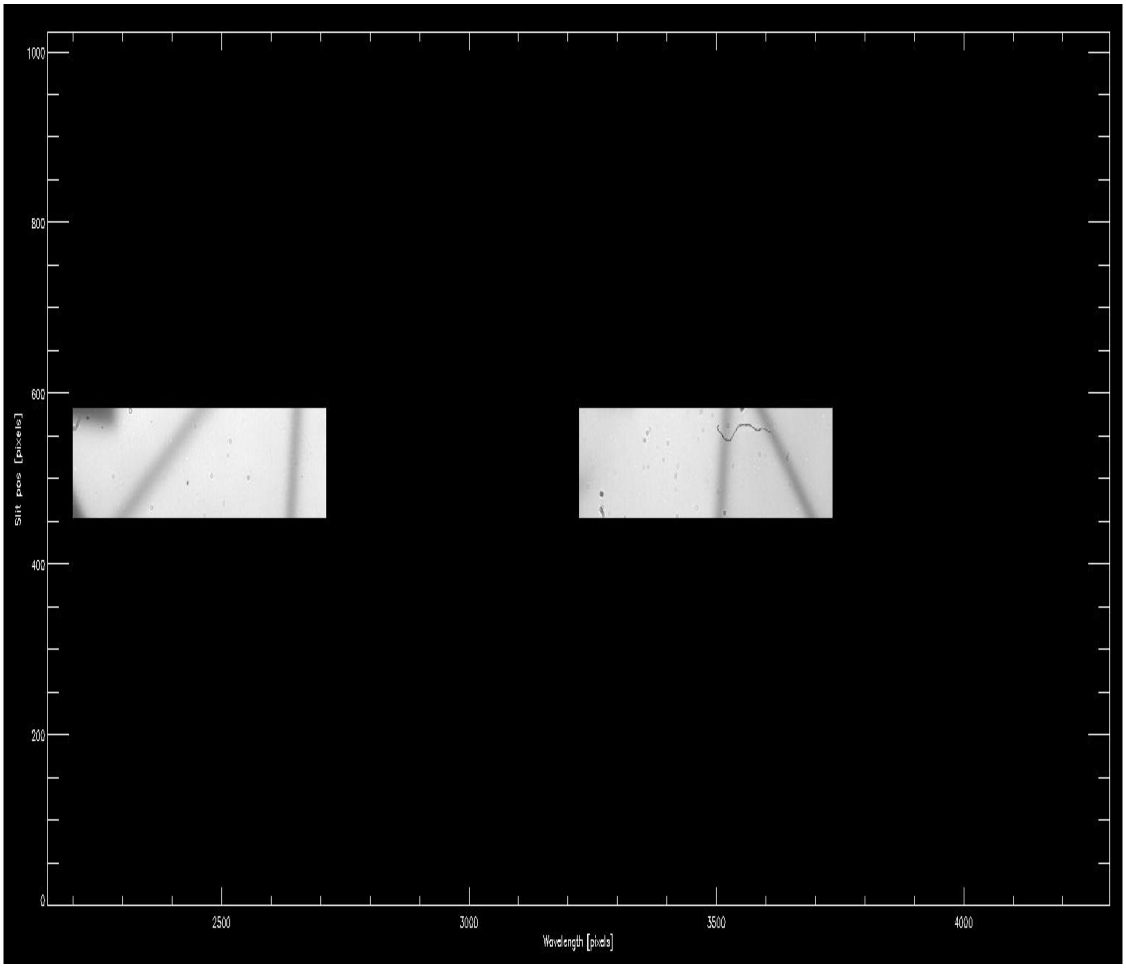
The following two figures show a pre and a post flare image acquired using the EIS Development model “pin hole” camera.



Pre-flare study

Y-height = 512
Y-start = 255
X-length= 256

And a flare response:



Post-flare study (response)

Y-height = 128 (pre-determined from the ground)
* Y-start = 455 = 255 (Slit Y start) + 245 (Y_f relative to Y-FOV) – 64 (128/2)
Line width = 512 (pre-determined from the ground). Note that the line width setting here is unrealistic for "science type" operations, however it is useful for identifying the CCD image features.

* EIS CAM is re-programmed to clock 128 rows starting from row 455 (increased cadence).

7.1 Response time verifications

The following measurements of 10 flares were taken by monitoring the EIS HK which is updated every 2 seconds. A response time is measured as the time between sending XRT flare coordinates to EIS via the EIS MSSL-EGSE and the HK reporting that the flare response study is running.

Typical time: 2 seconds
Maximum time: 4 seconds

These figures should be treated as a guideline for XRT flare trigger response.

8.0 XRT FT modes of operation summary

There are three key modes for operating the XRT flare trigger, as listed below:

8.1 Normal mode of operation

The response study consists of a single sequence (study). When the EIS FOV is verified, re-pointing in both the X and Y directions can be undertaken (optional). This kind of study is useful for high cadence operations.

8.2 Unconditional response

In this case no FOV verification is commanded and the response study will run when an XRT flare is triggered. The study will run unchanged (no re-pointing is possible). Such a response study is useful if “the active region” is not within the EIS FOV, but not far from it (e.g. solar turbulence/waves near a flare region studies).

8.3 Two line lists and two exposure times response

In this case the verification of the FOV is optional and the response study consists of a large number of rasters (a chained sequences). The rasters use different line lists (strong and weak lines) and run with short and long exposure times [7]. Such a response is of low cadence and runs unchanged on-board. It is not possible to re-point in the X or Y directions, as this requires modifications of a large number of rasters and line lists (the flare response is a study with very long chain of sequences). Also such a chain can run recursively, i.e. the last observing sequence calls the first sequence in the chain. **All the chained sequences are considered as part of the same response study and no processing of XRT coordinates is undertaken or OP/OG commanding is accepted.**

Such a study can be terminated by any of the method described in section 5.