MULLARD SPACE SCIENCE LABORATORY
UNIVERSITY COLLEGE LONDON **Authors: K. Al-Janabi**

EIS sequence structure overview

Document Number: MSSL/SLB-EIS/TN014.06

Distribution:

Author	K. Al-Janabi	Date:	12/07/2005
Authorised By	A. James	Date:	12/07/2005
Distributed	A. Spencer	Date:	12/07/2005

EIS-Science	✓
EIS-Tech	✓

CHANGE RECORD

ISSUE	DATE	PAGES CHANGED	COMMENTS
01	December 2001	All new	First release
02	July 2002		Add Sequence and raster repeats, as per January 2002 science meeting request - NRL. Also modified run raster command as needed for the camera operations. General clarifications on issues rose.
03	December 2002	6 7 9 14	Modified raster structure Clarified Sequence header and control Added science operations control parameter Added line list structure
04	December 2003	6	Science operations control parameters are controlled on raster by raster base, rather on a sequences base. Also restricted the maximum number of exposures per raster position to 8 [4].
05	04/08/2004	4 6	New number of EIS sequences = 128 Specified FMIR scan range and step size
06	08/07/2005	Various	Clarified raised issues

List Of Contents:

2.0 Solar-B time tagged command store 4
3.0 EIS modes of operation 5
4.0 EIS simple Raster 6
5.0 EIS sequence structure 9
5.1 Sequence loops 11
5.2 Sequence "chaining" 12
6.0 EIS coordinate structure 13
6.1 EIS CCDs naming convention 14
6.2 Line list structure 17

Applicable References (appears in [] within this technical note):

1 – MSSL/SLB-EIS/SP007.07: EIS Science requirements
2 – NAO/SLB-EIS/SP/MDP3.4: MDP-ICU Electrical Interface
3 – MSSL/SLB-EIS/SP016.06: EIS Telecommanding Structure
4 – Action item, EIS science meeting, RAL 2003.
5 – Scale Factors for MIR Motion: C. Brown, C. Korendyke, and J. Shea
6 – MSSL/SLB-EIS/SP018.06: EIS Mission data Structure

1.0 Introduction

This technical note deals with EIS sequence structure and addresses the following issues:

1 – How EIS sequence interpreter operates in conjunction with Solar-B operation requirements

2 – Sequence and line list structures

2.0 Solar-B time tagged command store

As Solar-B spends most of its time out of ground contact, a time tag command store was provided for its subsystems and payload use. The J-side terminology for time tagged commands is called OP (Operational command store) and OG (Organized Group command store). A simplified structure of Solar-B time tagged command store is shown below:

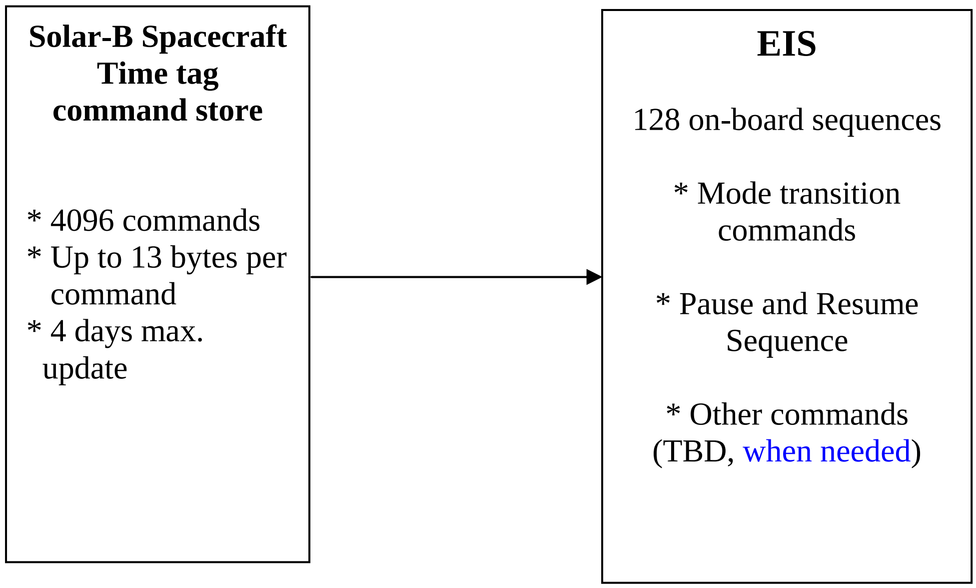
TIME	COMMAND
T1	Command
T2	Command
T3	Command
-----	-----

Note that the following restrictions applies to all time tagged store users:

1) The maximum size of a time tagged commands is 13 bytes.
2) The maximum time tag store update is 4 days, i.e. T can be up to 4 days in seconds from the time of the uplink. The 4 days time is related to the longest holiday in Japan, during which it is expected that the spacecraft will operate autonomously.

It is not envisaged that these restrictions will have any impact on EIS operations for the following reasons:

1) Key time tagged commands needed by EIS are select sequence and change mode commands. Each command is 2 bytes long.
2) An EIS sequence can be operated recursively or sequences can be chained together to minimize reliance on time tagged commanding, when needed.

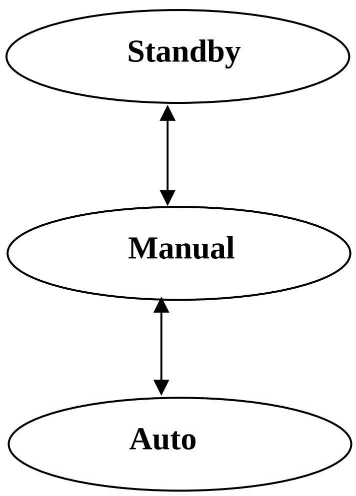


Solar-B EIS Time tagged commanding

Note that time tag commands are shared between all Solar-B subsystems and payloads.

3.0 EIS modes of operation

The following diagram shows EIS key modes (engineering modes, e.g. CCD bake-out mode are excluded from the diagram to avoid over-complicating the science operations). However, the description of EIS modes is available in MSSL/SLB-EIS/SP0013.02.



Standby Mode: This is the first mode entered after operational code invoke. In this mode both the Camera and the MHC defaults to OFF (safe and minimum power consumption mode).

Manual Mode: In this mode both the Camera and the MHC are ON. At this point EIS is ready for science and engineering operations.

Auto Mode: Starts executing a pre-selected sequence.

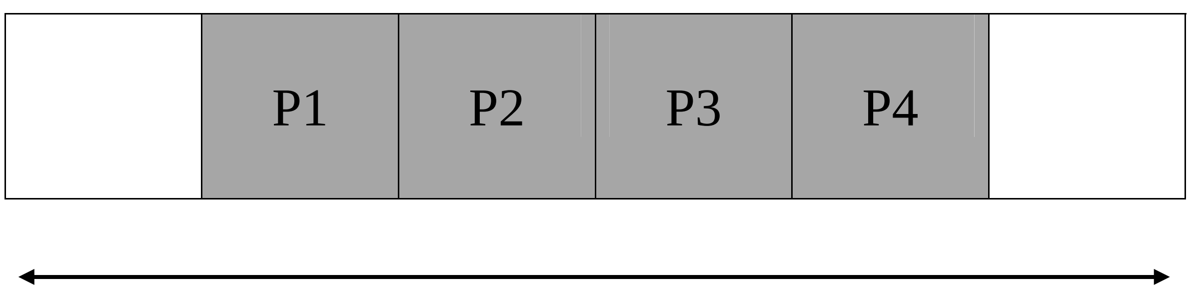
The Science operational procedure, which is unified for all Solar-B instruments, is as follows:

1 – From **Manual mode**, select a sequence to run.
2 – Change mode to **Auto**. The selected sequence in point 1 starts running.

Items 1 and 2 commands can be issued either from the ground or from the time tagged command store.

4.0 EIS simple Raster

A Raster is a basic unit of science operations, which consists of a set of exposures performed at different mirror positions, except for sit and stare rasters whereby exposures are performed at the same fine mirror position, as illustrated below:



EIS Field Of View

The Fine Mirror Initial Position (MIP), i.e. P1, can be any where within the field of view. Subsequent exposures are performed at uniform mirror positions, known as step size (P2, P3 and P4), assuming that the mirror steps should not extend beyond the mirror end stop. Note that the fine mirror scan range is from 0 to 2400 steps. Each mirror step size is 0.12299 ". This gives a 295" MHC scan range which corresponds to a solar X-FOV of ~600"[5].

A run raster command consists of the following parameters, as shown below:

<table>
<tr><td colspan="3">Bit 0</td><td colspan="2" align="right">Bit 15</td></tr>
<tr><td colspan="5">Raster ID</td></tr>
<tr><td colspan="5">Fine Mirror Initial Position</td></tr>
<tr><td colspan="5">Loop Counter (Min. = 1)</td></tr>
<tr><td colspan="5">Data Compression Parameters</td></tr>
<tr><td colspan="4">OCB-X</td><td>OCB-Y</td></tr>
<tr><td colspan="4">CAM CSG Flush Sequence ID</td><td>Number of CCD Flushes</td></tr>
<tr><td>4 Spare bits</td><td colspan="3">No. Of exp. per raster position</td><td>ASRC control parameters</td></tr>
<tr><td colspan="2">R/O nodes</td><td colspan="3">Number of raster repeats (Min. = 1)</td></tr>
<tr><td colspan="4">ASRC Skip</td><td>CAM CSG R/O sequence ID</td></tr>
<tr><td colspan="5">Mirror step size</td></tr>
<tr><td colspan="3">Line list</td><td colspan="2">Science operations control</td></tr>
</table>

The Raster ID is the raster identifier, which is a unique number to identify a specific science operation.

Fine Mirror Initial Position (MIP) is the raster starting position within the field of view (range 0 to 2400) steps. Note that at the start of a raster, the ICU moves the fine mirror to its home position (position 0) first, then to the specified mirror initial position. Each move requires 700 ms. For example, to run a raster at FMIR positions P1 (MIP), P2 and P3 the following is performed:

1) Move the fine mirror to its home position (Position 0).
2) Move the fine mirror to MIP (P1) and perform an exposure
3) Move the fine mirror to P2 and perform an exposure
4) Move the fine mirror to P3 and perform an exposure
5) Go to 1 if raster repeats are required.

Note that MIP is the FMIR position in steps (range 0 to 2400 steps), where the first exposure is performed. In order to perform the other exposures, the FMIR is advanced by the raster step size. The raster step size range is from 0 to 2400 steps.

Loop counter is a reference to the number of loops to be performed within a raster (exposures loop). The loop field could be anywhere between the end of run raster parameters and **loop back** command. This parameter range is 1 to 65535.

Data compression parameter specifies the type of compression required for the raster [2]. A value of 0 indicates that no data compression is required.

OCB X and Y are flags to be set in the MD packets. Note that when OCB is used, an appropriate read-out CSG sequence ID and line list must be used.

CAM CSG flush sequence ID and CAM CSG R/O sequence ID identify the clocking sequences required to perform flushing and CCDs read-out, respectively.

The number of exposure times per raster, i.e. exposures per raster position should have the value of 1 if only one exposure time is needed. However, if more than one exposure per raster position is required then this parameter is set to the required number of exposures. The maximum number of exposures per raster position is 8 [4], hence this parameter has range of 1 to 8. The exposure time(s) should be included within the raster loop (sequence start exposure command parameter).

ASRC defines the Anti Solar Rotation Compensation operations. This parameter consists of two fields:

Bit 0 (MSB): Compensation direction
0 = forward
1 = backward

Bits 1 to 7: The compensation number of fine mirror steps required.

ASRC value of 0 means ASRC is disabled.

ASRC Skip defines the frequency of the fine mirror compensation. A value of 1 implies that compensation is performed every raster. However, a value of 2 implies that compensation is performed every other raster. This is to allow for short duration rasters compensation.

When Anti Solar Rotation Compensation is required, neither ASRC nor ASRC Skip should have a value of 0.

Mirror step size defines the fine mirror step size, in steps. Note that for sit and stare rasters, this parameter should be set to 0 thus all the exposures are performed at the initial mirror position, except when ASRC is enabled. Also note that the fine mirror is moved while the CCDs are read-out in order to absorb the fine mirror step time latency. The FMIR step time is 700 ms. Note that the FMIR step time latency will only impact rasters with a read-out time of less than 700 ms (the nominal read-out time of 1024*512 pixels is ~1.2 seconds). When more than one exposure time per raster position are required, the mirror will be moved at the end of the exposures “set”. For example if three exposures are required, then the mirror is moved after the completion of the third exposure.

R/O nodes is a 4-bit parameter that defines the CCDs read-out nodes (1 = enabled), which are as follows:

Bit 0: CCDB L R/O chain enable
Bit 1: CCDB R R/O chain enable
Bit 2: CCDA L R/O chain enable
Bit 3: CCDA R R/O chain enable

Note that the read-out nodes setting is for the ICU CAM control board, which needs to route incoming data to the CCD buffer segments, according to the CCD read-out nodes. The setting here should match that of the CAM Control Reg. 2 (see CAM command BC1 = 0x45 [3]).

Number of raster repeats defines the number of raster runs required (4095 repeats). When a raster set of exposures is completed, this parameter is decremented by 1 and if the raster repeats is not equal to 0, then a new jump to run raster command is initiated; otherwise, the next sequence command following the loop back command is executed. This parameter range is 1 to 4095.

The Science operations control parameter, which controls a specific science operation, is as follows:

Bit No.	0	1	2	3	4	5	6	7
Control	Unused		XRT FLARE TRIGGER	EIS AEC	EIS EVENT TRIGGER	EIS FLARE TRIGGER	Unused	

1 = ENABLE
0 = DISABLE

Note that only one flag enabling per raster is allowed, except for the AEC and XRT flare trigger flags, which can be enabled together as there is no conflict of operations and resources.

Please note that bits 3 to 5 are used in conjunction with line list **window headers**. For example, enabling EIS AEC (bit 3) requires setting a flag bit in one of the window headers to “mark” the line selected for AEC operations (see section 6).

5.0 EIS sequence structure

A sequence is defined as a collection of commands and parameters. Sequence commands are executed sequentially. Currently, the following memory space is allocated:

1) 128 sequences, each 128 bytes long
2) 48 line lists, each 164 bytes long. Each line list is capable of containing up to 25 lines, i.e. software windows

EIS sequences consists of 3 basic components, as illustrated below:

1) Sequence header
2) Sequence and subsystems commands
3) Sequence control parameters

Mandatory Sequence Header
Length, study ID and number of sequence repeat

CAM & MHC Set-up commands
Mandatory Raster Definition command
Start Exposure command

CAM & MHC Set-up commands
Raster Definition command
Start Exposure command

Mandatory Sequence Control
Terminate or Call another sequence
Sequence Checksum

BASIC SEQUENCE STRUCTURE

Note1 - Sequence length:

The sequence length is the total number of the sequence parameters, including the length field and checksum, in bytes. For example, if a sequence contain 4 parameters (P1 to P4), then:

Sequence Length = 6 = length field + P1 + P2 + P3 + P4 + checksum

Note2 - Sequence checksum:

The sequence checksum is the **XOR** value of all the sequence parameters, excluding the checksum of course. For example:

Checksum = Sequence Length **XOR** P1 **XOR** P2 **XOR** P3 **XOR** P4

The **mandatory sequence header** consists of the following parameters:

PARAMETER	LENGTH	SEQUENCE INDEX
Sequence length	8-bit	0
Study ID	16-bit	1 and 2
Sequence repeat **(Min. = 1)**	8-bit	3

The **mandatory sequence control** (the last sequence command) must be either terminate sequence or call another sequence [3].

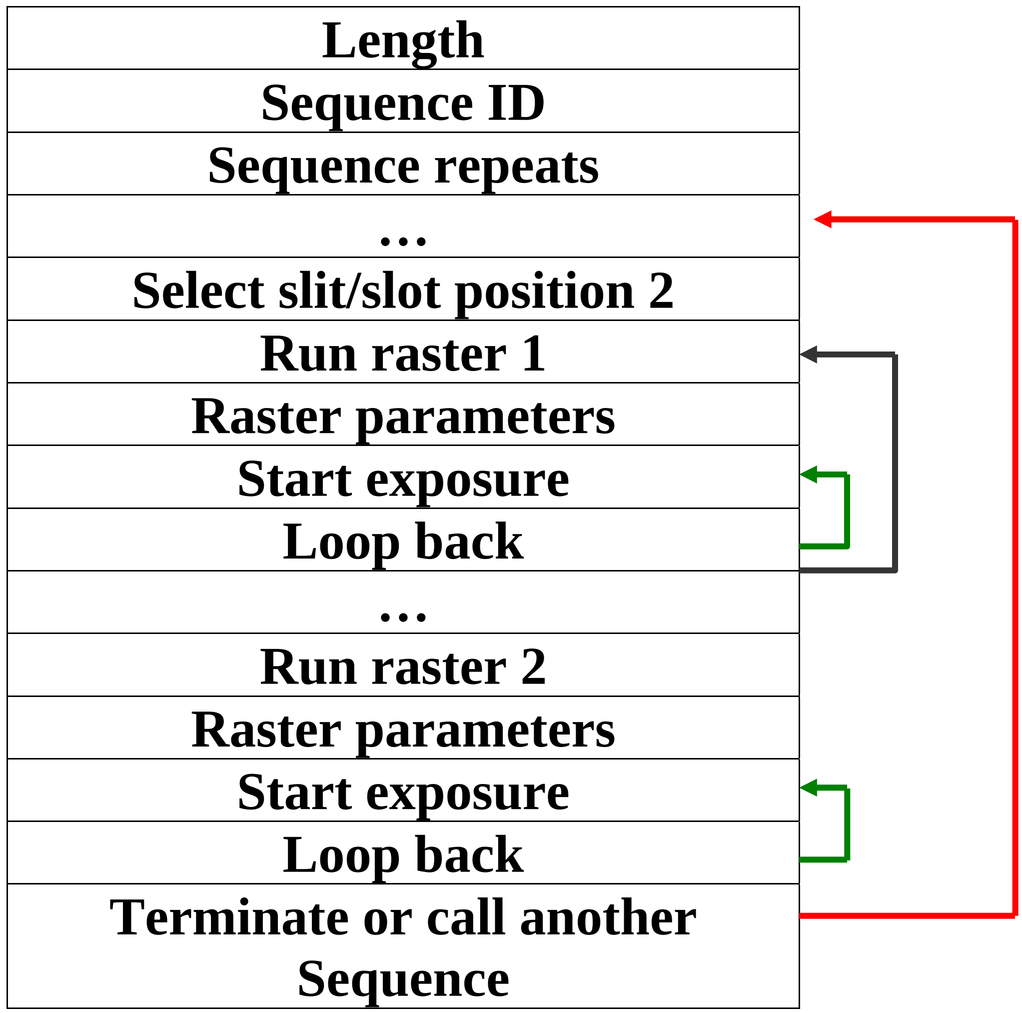
5.1 Sequence loops

Within a sequence, there are three types of nested loops, as illustrated in the diagram below:

Exposures loop (green) is controlled by the raster loop counter parameter. Loop back command parameter determines the jump location [3].

Raster repeats loop (dark grey) is controlled by the raster repeat parameter. A raster repeat initiates a jump to run raster command (internal software control).

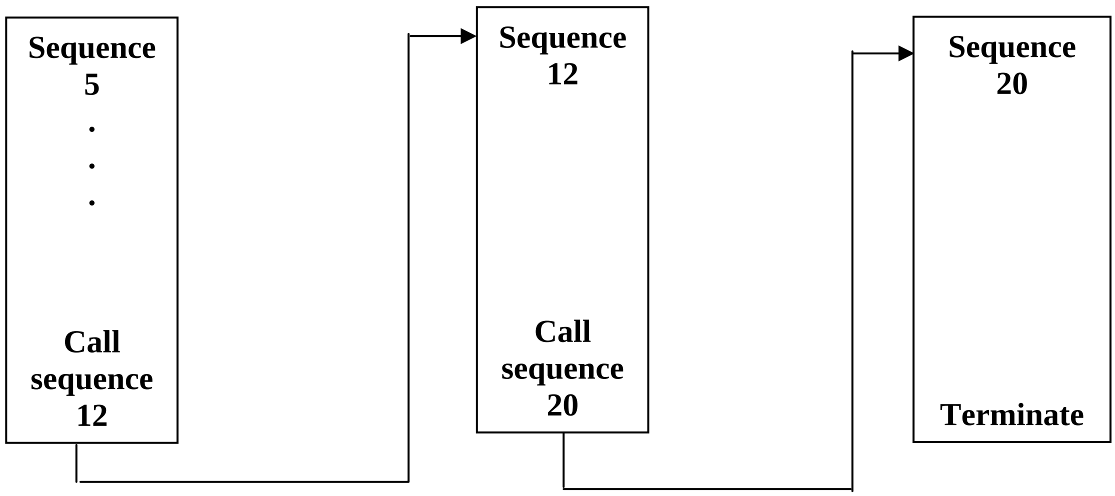
Sequence repeats loop (red) is controlled by the sequence repeat parameter. A sequence repeat initiates a jump to the sequence location following the sequence repeat parameter (internal software control).



Simple Raster/Sequence Repeats

5.2 Sequence "chaining"

In order to minimize the reliance on time tag commands, particularly in the event of prolonged no update periods, EIS sequences can be chained such that a sequence can call another sequence when completed, as shown below:

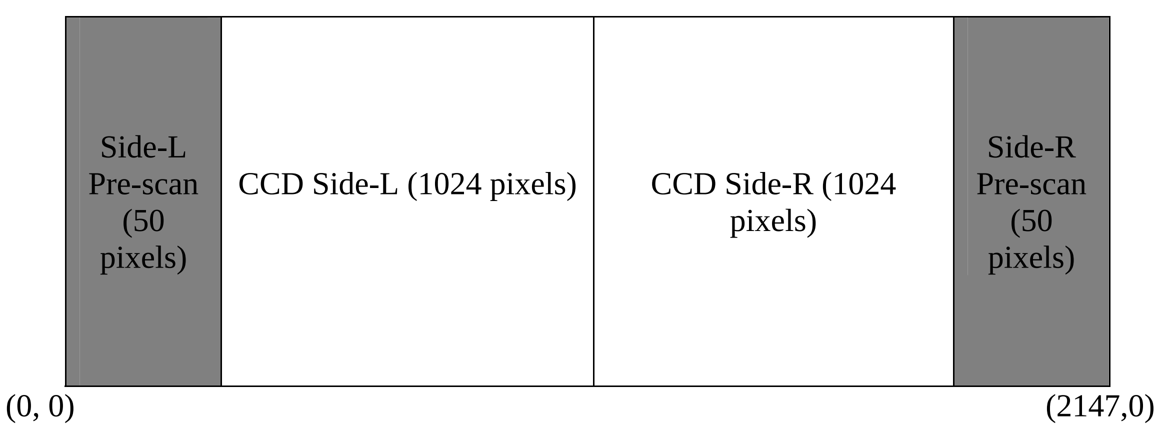


In this example only 3 sequences are chained together. However, there are no restrictions on the number of sequences that can be chained together. Also note that in this example, only sequence 5 is called from time tagged command store or the ground.

Each sequence can be repeated N number of times when required. A call to another sequence can be initiated after the sequence repeats are completed. This also can be used in conjunction with raster repeats to gain EIS autonomous science operations for long periods of time. Also note that “infinite” run time operations can be achieved when sequence recursion is used (in this example, sequence 20 would call sequence 5 rather then terminate).

6.0 EIS coordinate structure

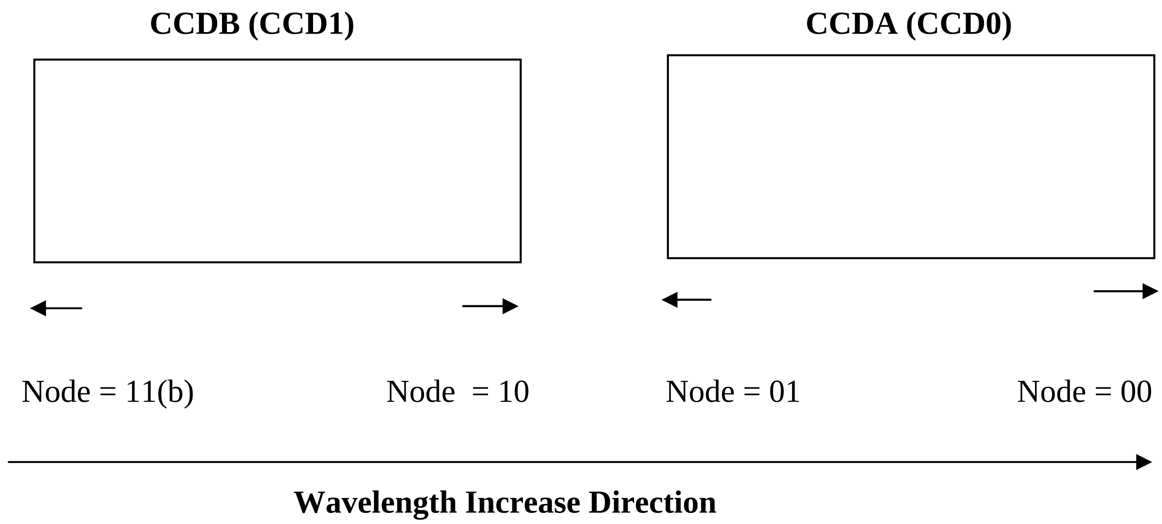
Although the specified CCDs length is 2048 pixels, however, the actual length is 2148 pixels when the pre and over-scan pixels are included, as shown below:



EIS CCDs STRUCTURE

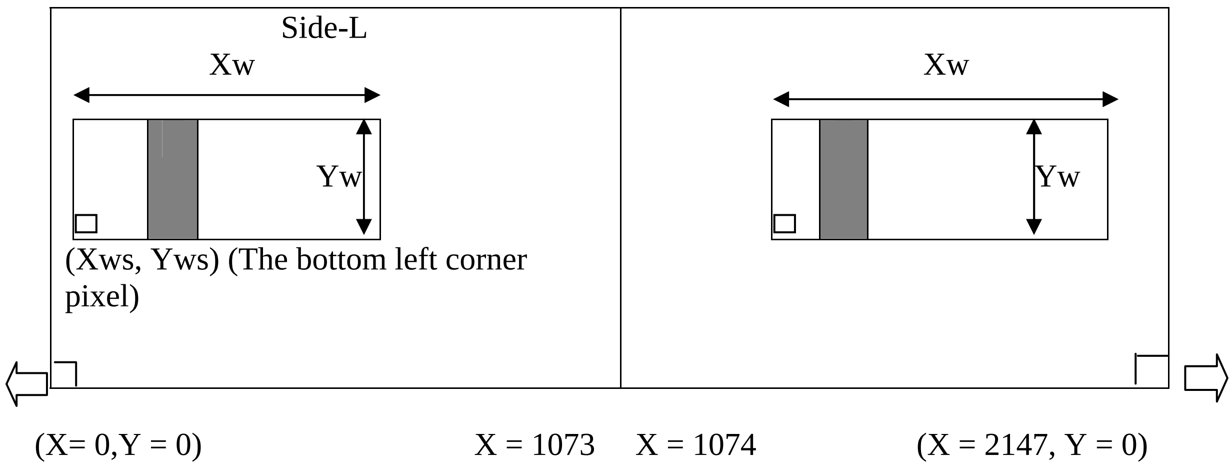
Note that the pre-scan and over-scan pixels are used for CCDs calibration, i.e. charge transfer efficiency measurements and 0 pixel level determination (background noise). Also note that when reading from one node (e.g. Side-L), then the first 50 pixels are the pre-scan pixels and the last 50 pixels of the row (side-R in this example) are the over-scan pixels. Note that the scan pixels are an extension to the CCD read-out registers (bottom row), and the above schematic diagram is for illustration.

6.1 EIS CCDs naming convention



Note that incoming pixels are tagged by the CAM hardware by adding a 2 bits node ID to the 14-bit energy. The node ID specifies the CCD and the read-out side. For example:

Node = 10b means CCD 1 (CCD-B), read-out side 0 (right side). The Node ID is used for extracting window pixels from the CCD BUF.

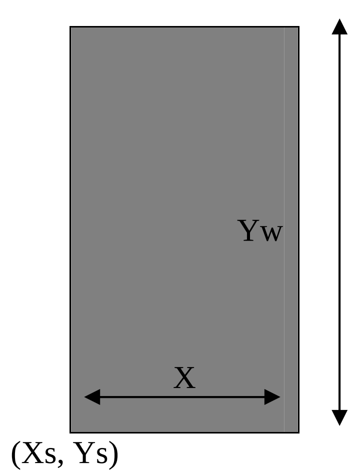


CCD Coordinate system

For the Camera hardware window, the following terminology applies:

Xws: CAM Window X-start
Yws: CAM window Y-start
Xw: CAM window X-length
Yw: CAM window Y-length

Within a hardware window, an N number of software windows (up to 25 windows in total [1]) can be selected (the shaded areas in the diagram above). Each window is defined by the following parameters, as shown below:



Xs: Software window X-start
X: Software window X length

Note that all the software windows have the same height and their height should be the same as that of the hardware window (Yw). The same applies for the window Y start.

All the coordinates are (**absolute**) CCD coordinates, referenced to the CCD left hand bottom corner (X = 0, Y = 0).

6.2 Line list structure

A memory space for 48 line lists is allocated. Each list is 164 bytes long. Also each list can accommodate up to 25 software windows [3]. Note that the line list length definition and checksum follow the same rules as that of sequences (see section 5). Also note that the checksum is embedded in the line list in order to achieve 32-bit word alignment.

Byte	Byte	Byte	Byte
Length	**Reserved**	**No. Of SW Win.**	**Checksum**
CCD Length		**Xws**	
Xw		**Yws**	
Yw		**SW1 Header**	
SW1 Xs		**SW1 X**	
Other software windows, if required			
		SW25 Header	
SW25 Xs		**SW25 X**	

Note that the minimum number of SW windows is 1 and the maximum is 25 [1]. Also note that the line list X and Y coordinates ranges are available in [6].

The structure of SW Headers, which controls a specific science operations and window data extractions, is as follows:

Bit No.	0 to 10	11*	12*	13*	14 to 15
Function	Reserved	EIS AEC LINE	EIS EVENT LINE	EIS FLARE LINE	NODE

*** 1 = Selected**

When making a line list, it is recommended to list the windows starting from Node 11b and so forth (short wavelength CCD, left sport). This ensures that lines are extracted in ascending order (in the increased wavelength direction).