SOLAR-B

EIS Design Guide

Edited: Alec McCalden MSSL-UCL
Revision: 29 Jan 99

....a evolving guide to the technology of the EIS instrument on Solar-B.

Functional Requirements

Alec McCalden & Matt Whyndham MSSL-UCL 2 Dec 98

EIS-sys-des-functreqs-0.1

1.0 Introduction

This is a list of the functional requirements of the EIS instrument.

1.1 Manage ccd imaging

Aquire ccd data
Store ccd frames
Shutter
Monitor ccd temperature
Technology management
Automatic exposure control
Instrument temperature monitor
Optical mechanisms
Clock drivers

1.2 Manage readout of ccd

Subtract dark level
Buffer ccd data
Maintain list of windows - deal with creation, verification, execution
Analogue to digital conversion
Science data flow

1.3 Image processing

Selection
Labelling
De-spiking
Compression
Binning
Projection
Parameterisation (eg line width)

1.4 Table management

Creation - upload
Execution
Verification

1.5 Co-operate with other instruments

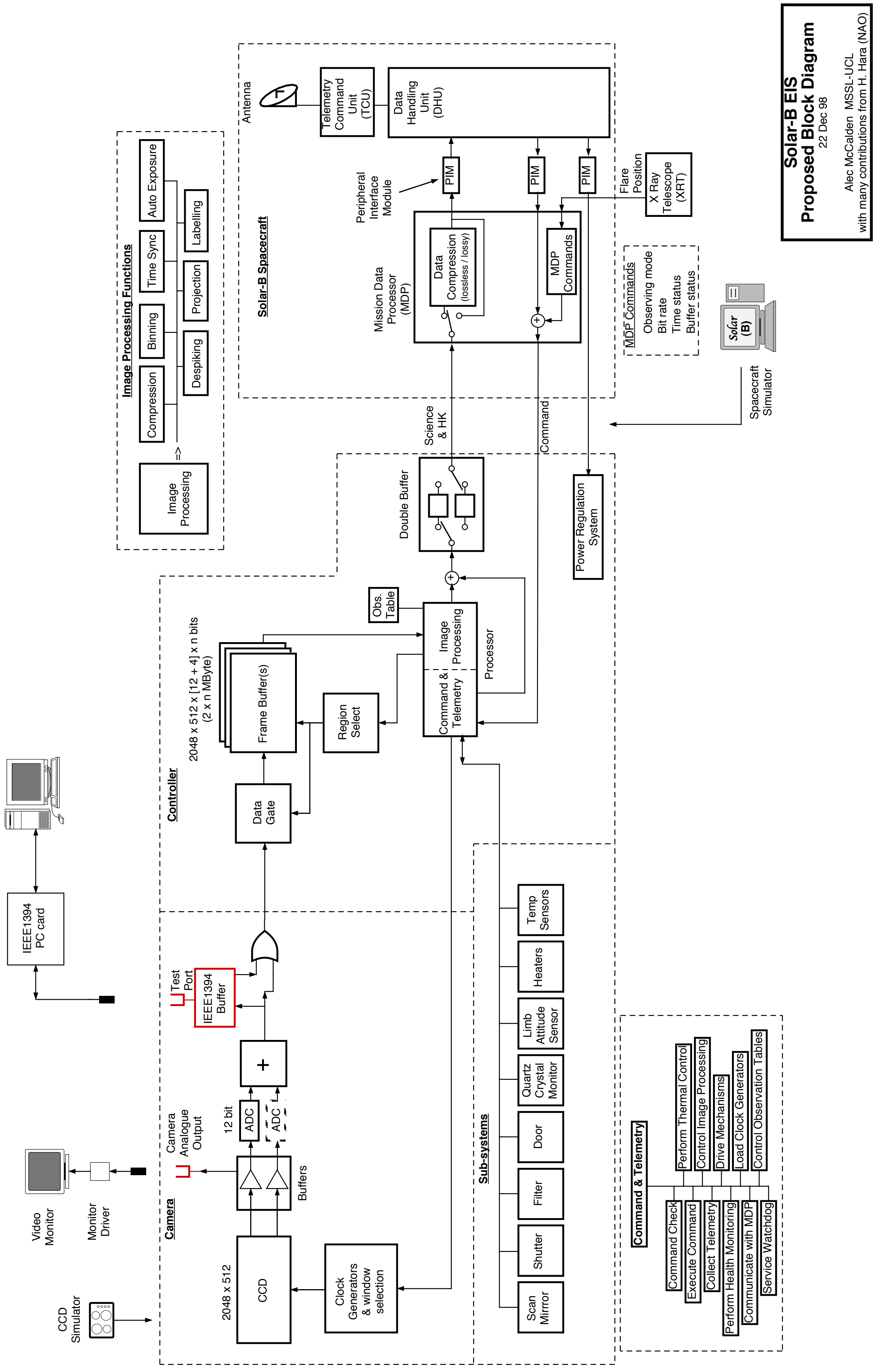
1.6 General behaviour

1.7 Communicate with MDP

Receive commands (check, execute)
Report faults
Health monitors
Collect and assemble telemetry

1.8 Thermal control of optical bench and possibly others

1.9 Mode control - off, standby, on


Solar-B EIS
Proposed Block Diagram
22 Dec 98
Alec McCalden MSSL-UCL
with many contributions from H. Hara (NAO)
Camera
CCD
2048 x 512
Clock Generators & window selection
Buffers
Camera Analogue Output
12 bit
ADC
ADC
+
IEEE1394 Buffer
Test Port
Controller
Data Gate
Frame Buffer(s)
2048 x 512 x [12 + 4] x n bits (2 x n MByte)
Region Select
Command & Telemetry
Image Processing
Processor
Obs. Table
Double Buffer
Power Regulation System
Sub-systems
Scan Mirror
Shutter
Filter
Door
Quartz Crystal Monitor
Limb Attitude Sensor
Heaters
Temp Sensors
Command & Telemetry
Command Check
Execute Command
Collect Telemetry
Perform Health Monitoring
Communicate with MDP
Service Watchdog
Perform Thermal Control
Control Image Processing
Drive Mechanisms
Load Clock Generators
Control Observation Tables
Image Processing Functions
Image Processing
=>
Compression
Binning
Time Sync
Auto Exposure
Despiking
Projection
Labelling
Solar-B Spacecraft
Antenna
Telemetry Command Unit (TCU)
Data Handling Unit (DHU)
Peripheral Interface Module
PIM
PIM
PIM
Mission Data Processor (MDP)
Data Compression (lossless / lossy)
MDP Commands
Science & HK
Command
Flare Position
X Ray Telescope (XRT)
MDP Commands
Observing mode
Bit rate
Time status
Buffer status
Spacecraft Simulator
Video Monitor
Monitor Driver
CCD Simulator
IEEE1394 PC card

Can Electronic Processing Replace a Tip-Tilt Mirror Mechanism?

Alec McCalden 25 June 98

Discussion

The tip-tilt mechanism allows the EIS telescope optics to compensate for vibration caused by other mechanisms on the spacecraft. This vibration may have a spectrum extending to 100Hz.(?). A single frame image may be captured over a period of several seconds. This implies that vibration compensation must take place whilst a single frame is being acquired.

Commercial camcorders have anti-vibration systems which are believed to work by electronically shifting the image on the ccd. The noise spectrum probably only extends to say 10Hz assuming that the mechanism is simply trying to compensate for hand-induced movements, whilst the frame rate is at least 25Hz. Therefore the camcorder needs only to correct for movement between frames.

Therefor for EIS to compensate for vibration electronically it requires that the image being built on the ccd can be moved around whilst the exposure is happening. This must be possible, but there is probably little experience in the ccd world of achieving this. New algorithms for clocking the ccd would have to be derived.

Any electronic compensation requires a ccd that is larger than the required active area in order for the image to be moved around. The size of the spare ccd area would obviously depend on the amplitude of the vibration.
EIS also needs to track the movement of solar features for which a mirror mechanism may be the only realistic answer. The extent of the movement required may imply a large area of wasted ccd if corrections were carried out electronically..

Spacecraft Interface Specification

Alec McCalden MSSL-UCL 19 Nov 98

EIS-sys-des-scifspec-0.1

1.0 Introduction

This document is a set of suggestions for forming the EIS interface to the spacecraft. It covers some aspects of the electrical interface but makes no attempt yet to look at thermal or mechanical details.

It is presented as an aid to discussion about and evolution of a functional interface.

2.0 Data Uploads to EIS

2.1 Use USB standard?

2.2 Connector

2.3 Electrical Characteristics

Differential 5V signals

Serial data and frame with embedded clock

Impedance

2.4 Data Structure

Variable length packets (0 -> 1024 bytes?)

2.5 Timings and Protocols

2.6 Virtual Channels

2.6.1 Commands

2.6.2 On board time

2.6.3 Telemetry Frame Synchronisation

2.6.4 Broadcast data sent to all experiments

2.7 Error Protection

Implement as part of operator console to instrument link

3.0 Data Downloads from EIS

(Use same physical connector as the data uploads, and use bi-directional signals?)

3.1 Use USB standard?

3.2 Connector

3.3 Electrical Signals

3.4 Data Structure

3.5 Timings and Protocols

3.6 Virtual Channels

3.6.1 Science data

3.6.2 Engineering Data

3.7 Error Protection

Use spacecraft system

4.0 Power - Main Bus

4.1 Voltage

4.2 Current

4.3 Connector

4.4 Overload Protection

4.5 Isolation

The instrument will be electically isolated with a switched mode power converter.

4.6 Converter Frequency

About 500kHz, synchronisation signal not required.

4.7 EMC

5.0 Power - Keep Alive

5.1 Voltage

12V

5.2 Current

10mA maximum

5.3 Connector

5.4 Overload Protection

5.5 EMC

6.0 High Power Commands

(Pulse commands for driving latching relays directly)

7.0 Systems Powered by the Spacecraft

7.1 Temperature monitors

Driven by spacecraft telemetry system

7.2 Standby Heaters

These heaters are used with the instrument powered off to prevent excessively low temperatures.

8.0 Redundancy

Use full redundancy for each electrical interface with individual switching.
Use separate connectors for prime and redundant interfaces.

9.0 EMC

Overall points to consider.

10.0 Data Structure

10.1 Science Data Packet Structure

Science packet identification
Time tag
Packet count
Packet length
Mirror position
Exposure duration
Automatic exposure control value
Calibration lamp on flag
Number of packets in data set
Packet position in data set
Single image or movie flag
Movie frame number
Movie key frame identification
Science data
Packet checksum

10.2 Packet Grouping

Image sizes may vary from near zero to much greater than the maximum packet size.

If an image plus the header is equal to or less than the maximum packet size, then the packet size is set to efficiently include no more than the image plus header.

If the image plus header is larger than the maximum packet size, then the image is spread over more than one packet as appropriate. Each packet would contain the same header information except for an incrementing 'packet position in data set' value.

EIS Specification

29 Jan 99
Duncan Self & Alec McCalden

1.0 CCD and Driver Electronics

1.1 CCD: Nominal 2048 x 512 pixel (2^{20}) from EEV.

1.2 12 bit digitisation

1.3 Readout time dependant on readout noise requirement -

- 1.3.1 1MHz => 1s EEV hint on maximum speed
- 1.3.2 100kHz => 10s HK study 1994
- 1.3.3 20kHz => 50s Using CCD spec from EEV

1.4 Full frame or frame transfer?

1.5 Question of cost of a large CCD - but need to trade off against the cost and reliability of a shutter mechanism

1.6 Does CCD need cooling?

1.7 Interlaced readout scheme / dithering technique? (HK)

1.8 Is a zero order detector required?

1.9 Is hot pixel rejection required?

2.0 Analogue to Digital Conversion

2.1 Number of electrons equivalent noise.

2.2 Random noise.

2.3 Systematic noise.

3.0 Digital Image Store

3.1 Depends on CCD; default implies 2MByte per full frame image, with 4 bits per pixel available for flags.

3.2 Use one frame store as dark current reference store.

4.0 Command and Telemetry

4.1 Use same processor (DSP) as for image processing

4.2 - one learning curve, one development environment, one set of pitfalls

- easier procurement
- similar circuit design

4.3 Housekeeping, engineering info.

4.4 Auto exposure control - to trap overexposure of CCD

4.5 Health and safety of instrument

5.0 Image Processing

5.1 Correction for spacecraft drift

5.2 Provide low and high thresholds for pixel values

5.3 Use dedicated DSP

5.4 Rejection of data spikes expected from radiation induced events in the CCD.

5.5 Data compression

6.0 Spacecraft Interface

6.1 64k - IM bit/s to spacecraft (MDP)

7.0 Mass

In June 98 the mass budget was 60kg.

8.0 Power

8.1 About 20W bus power excluding heaters

8.2 Post regulation of supply rails close to point of use - particularly for camera head.

8.3 Independent switching of power rails and sub-systems.

8.4 Sub-system level monitoring of currents.

9.0 Radiation

9.1 Speculate 20k rad or better for procurement

10.0 Size

11.0 Thermal Requirements

Operation:-20 -> +40 C
Survive switch on: -30 -> +50 C
Non-operation: -35 -> +55 C

12.0 Vibration

13.0 EMC

Meet MIL-STD 461 or better?

14.0 Procurement Standard

Speculate MIL-STD 883B or equivalent

15.0 Calibration

15.1 On board - flat field?

15.2 Ground based

16.0 EGSE

16.1 Stimulus of CCD - does it need UV source in vacuum?

16.2 Is CCD sensitive to daylight - Yes?

16.3 Built in stimulus generator - eg 1 dot in corner

16.4 Real time test ports on camera head - analogue and digital

16.5 Investigate idea of CCD simulator due to cost of CCD

17.0 MGSE

18.0 General

18.1 Camera head (in particular) must be capable of stand-alone operation - treat it as a sub-system itself.

18.2 System construction must be designed for debugging - all cards accessible whilst connected. In particular applies to fully integrated instrument on spacecraft.

18.3 Design to minimise harnessing.

19.0 Operations

19.1 Typical exposure time 8s.

19.2 Time between exposures?

19.3 What size is data store on spacecraft?

EIS to MDP Communication

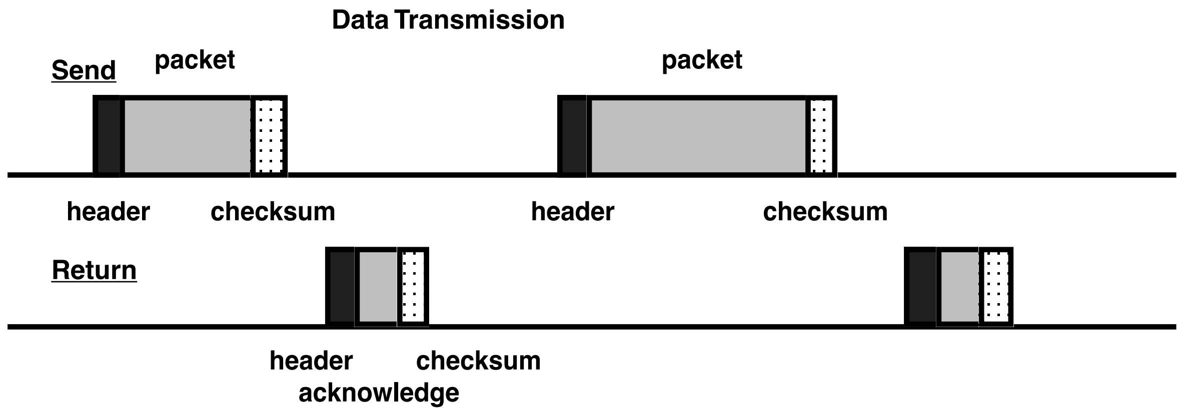
18 Jan 99

1.0 Introduction

This note describes a possible protocol between the EIS and MDP units.

2.0 Details

We propose a protocol that is based on variable length data packets with a return acknowledge packet for every data packet sent. No hardware handshake would be required.



In this example, a packet header is sent, followed by the packet data and a terminating checksum. The receiver reads the packet and replies with a minimal acknowledge packet. The next data packet is then sent. No acknowledge causes the data to pause until a system time-out. Information in the acknowledge could be used to request data retransmission in the event that the data checksum is incorrect.

Data packets pass in the opposite direction in exactly the same manner.

The EIS and MDP would probably each implement a dual buffer for the data packets to allow one buffer to be sent whilst the other is building the following packet. The contents of the received acknowledge packet determine which part of the buffer is used next. If the reception was good, the new data is used; if not, the original is re-sent.

3.0 Extensions

This approach could be taken further and used as the data exchange on an industry standard Universal Serial Bus (USB) link between EIS and MDP. Silicon parts are readily available and standard personal computers could be used as support equipment.

Correspondence on Instrument Design

8 October 98 Alec McCalden to Hiro Hara: System Design Concepts

A 2048 x 512 pixel CCD is the nominal choice.

The read out is shown from two corners with an ADC at each corner for increased speed.

The test port allows high speed CCD data with possibly a control connection also.

The clock generators are programmable to allow window selection on CCD.

The selected and digitised CCD image is fed to one or more Frame Buffers each capable of holding a full CCD image. The 'data gate' and 'region select' functions allow flexibility in mapping the CCD data across the image store. Multiple buffers allow the option of compressing data across several images.

The Observation Table function holds the uploaded exposure sequences.

The processor deals with camera control, spacecraft communication, and image processing. The image processing function could be implemented separately as a digital signal processor (DSP) machine.

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4 Nov 98 Alec McCalden to Hiro Hara

Block Diagram

We are keen on the idea of an EIS that is a capable of operation by itself as much as possible. Although this will mean more work in the early stages of the mission, we feel sure that in the later integration and test phases that the benefits will show in reduced time, rework and travel. We see it important to keep the interface - software, electrical, mechanical, thermal - between EIS and the spacecraft as simple as possible to minimise the number of possible errors. We expect this to have a very beneficial effect on the costs.

Data size and Rate

We anticipate the following worst case situation of a CCD full frame download with no compression or selection:

Expected EIS to spacecraft data rate:64kbit/s (2^16 bit/s)
Probable CCD size:2^20 pixels (1024 x 512)

Data set size, assuming 12 bit data + 4 bit (2^4) info per pixel:
2^20 pixel => 2^24 bit

Download time:2^(24-16) = 256s => 4min 16s

Any selection or compression of data will reduce this figure. For the required temporal resolution, significant reduction will be necessary.

Frame Buffers

We saw the operation as one of accumulate the image, digitise and transfer it to a digital store (frame buffer), and then apply image processing and data compression techniques to it before making it available for transmission. It may be possible to start the accumulation of the next image on the CCD whilst this digital processing is in progress.

Smarter compression schemes could be used with this approach. For example, the CCD could be clocked to send just a small window at a high repetition rate. The frame buffer would be set to store a large set of these images, and then image processing applied to transmit just the differences between subsequent images. The result is a data set with a very high temporal resolution but compact in size.

If several frame buffers were available, this technique could be applied across larger imgaes. The limit on size would be set by the available mass and power.

Bit Compression

We're uncertain what you define as "bit compression". Please could you clarify this.

Packet Communication

We are also assuming packet communication.

Nov 29, 1998 Typical Data Size/Rate of EIS Observations

H. Hara (NAO)

<Abstract>

This document describes the typical data size created by EIS. The data size is determined by what kind of observations are going to be done by EIS. Although the value discussed here is almost TBD (to be determined), the authur believes that it will help the discussion when we design the EIS systems.

<Assumptions>

For discussing the size of EIS data, many items have to be assumed. Reasonable values are shown here. As for the items 4, 7, 8 shown below, the values are expected ones.

```
  1. Format of CCD;                         2048 x 512 pixels (TBD)
```

2. Full-frame (2048 x 512 pixel) data will be used for the purpose of calibration. Therefore a high-cadence acquisition will not be necessary for the full-frame observations. EIS high-cadence observations are done in the partial-frame data acquisition.

```
  4. time required to set up the exposures; t_set = 0.5 sec (TBD)
  5. readout speed of CCD;                  512 kpixel/sec    (TBD)
  6. region size to be readout from CCD;    2048 x 128 pixels (TBD)
     readout time for this data;            t_read = 0.5 sec
  7. time for extracting the region of emission lines:
                                            t_extract = 0.1 sec (TBD)
  8. time for bit compression from 12 to 8 bits.
                                            t_bit = 0.2 sec  (TBD)
  9. EIS-E - MDP data transfer speed:       r_trans = 1 Mbps (TBD)
```

<Observing Mode>

Three EIS observing mode defined by the EIS observing table will be considered (TBD).

1. Active Region (AR) 2. Quiet Sun (QS) 3. Flare (FL)

<Slit & Slot>

The typical number of pixels along the slit or slot (N_pos) in the data is assumed to be 128. The typical number of pixels in the spectral direction (N_wave) is 24 (TBD; +/- 250 km/s in velocity scale at 270 A) in the AR or QS observations and 64 (TBD; +/- 670 km/s in velocity scale at 270 A) in the FL observations.

<Number of Emission Lines; N_lines>

Regions of emission lines are extracted from the data of 2048 x 128 pixels. The author assumes that observing wavelength are 170-196 A and 250-290 A. The number of photons in a unit time observed with EIS was calculated in "Sensitivity of EIS (Rev. 2.0: Aug 15, 1998)". Judging from the result of this document, the number of emission lines
used in the typical observations will be 12 (TBD) in the AR/QS observationand 8 (TBD) in the flare observation.

<Exposure Durations; t_exp>

Judging from the result of "Sensitivity of EIS (Rev. 2.0: Aug 15, 1998)", the typical exposure duration will be determined as follows:

1. 1.0 sec (TBD) for AR observations
2. 10.0 sec (TBD) for QS observations
3. 0.1 sec (TBD) for FL observations
   (Exposure duration for flares depends on the flare brightness.)

<Data Size in EIS>

	t_exp (sec)	data size (kbits)	Freq. of Expos.(s)	data rate (kbps)	Number of scan	Cadence for a set of data
1. AR-slit	1.0	295	2.6	113	128	2.6(s)x128= 5.5 min
2. AR-slot	1.0	786	3.1	254	2	3.1(s)x 2= 6.2 sec
3. QS-slit	10.0	295	11.6	25.4	64	11.6(s)x 64= 12.4 min
4. QS-slit	10.0	786	12.1	65.0	1	12.1(s)x 1= 12.1 sec
5. FL-slit	0.1	524	1.9	276	64	1.9(s)x 64= 2.0 min
6. FL-slit	0.1	524	1.9	276	1	1.9(s)x 1= 1.9 sec

	DR recording rate (kbps)
1. AR-slit	113 * 0.5 = 56.5
2. AR-slot	254 * 0.5 = 127
3. QS-slit	25.4* 0.5 = 12.7
4. QS-slit	65 * 0.5 = 32.5
5. FL-slit	276 * 0.5 = 138
6. FL-slit	276 * 0.5 = 138

<< Note >>

* "data size" is calculated by (N_wave) x (N_pos) x (N_lines) x 8 bits.
  In case 1 and 3, 24 (pix) x 128 (pix) x 12 (lines) x 8 bits = 295 kbits.
  In case 2 and 4, 64 (pix) x 128 (pix) x 12 (lines) x 8 bits = 786 kbits.
  In case 5 and 6, 64 (pix) x 128 (pix) x 8 (lines) x 8 bits = 524 kbits.

* Frequency of exposures t_sum is defined by the summation of times required to finish a single exposure and its corresponding data transfer to MDP:

$$t_{sum} = t_{set} + t_{exp} + t_{read} + t_{ext} + t_{bit} + (\text{data size})/r_{trans}$$
$$= 0.5(s) + t_{exp} + 0.5(s) + 0.1(s) + 0.2(s) + (\text{data size})/(1\ \text{Mbps})$$

In this calculation the next exposure setup starts after the data obtained by the previous exposure are completely transferred to MDP. The time for the compression by MDP is not consdered here.

* "data rate" is defined by "data size"/t_sum . When the exposure duration becomes longer, the data rate becomes small.

* 0.5 in "DR (data recorder) recording rate" is an assumed compression factor by the loss-less compression in MDP.

* Some cases in cases 1 to 6 show a higher DR recording rate than 64 kbps. This problem will be cleared by changing the cadence longer in principle. A higher rate in some EIS special observations by changing the size of data allocation is being requested at present, though it may not be accepted.

* Here the transfer rate of 1 Mbps from EIS to MDP was assumed. However, the time for the transmission is small. In the case 1 above, for example, the time for the transmission is 295 (kbits)/1 Mbps = 0.3 sec, and this corresponds to 11 percent of the frequency of exposures. Therefore, the trans-

mission rate may be smaller.

* The case of lossy compression is not considered here. This is because the data size becomes smaller than the case of loss-less compression.

* The author thinks that the function of bit compression from 12 to 8 bits should be necessary for reducing the size of data from EIS to MDP.

*** The discussion above will be applicable for both so-called Plan-B and Plan-C by H. Hara.

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12 Dec 98 Hiro Hara to Matt Whyndham et al.

Rev. 1.0 12-Dec-1998

EIS-MDP I/F Plan

H. Hara (NAO)

EIS-MDP I/F Plan is in a primitive stage at present. This document describes a plan (the so-called plan-C) that do not restrict any other possibilities.

	master CPU	slave CPU	EIS t table	PFI selection
plan-A	MDP	EIS-S	MDP	MDP
plan-B	MDP	EIS-S	MDP	EIS-S
x plan-C	EIS-S	MDP	EIS-S	EIS-S

EIS-E: EIS electronics
EIS-S: EIS sensor
EIS-M: EIS mechanism
XRT : X-ray telescope

HK: house keeping unit
DHU: data handling unit
MDP: mission data processor
TCU: telemetry command unit
PCU: power control unit

```
                                                                 _
                                                        antenna  V
 +EIS-M                                                          |
 |   | analog HK data                        _____________       |
 |   |      ________        ______          |             |    __|__
 |  +----->|   HK   |-------| PIM  |--------|     DHU     |--| TCU |
 |   |     |________|       |______|        |             |  |_____|
 | EIS-S     |                              |_^___|_|_____|
 |   +       | analog HK data                 |   | |
 |   |       | (temp. etc)                    |  _|_|____
 |   |       |                                | | | | PIM|
 |   |       |                                | |_|_|____|
 |   |       |                                |   | |
 |   |     __|________                       _|___|_|_____ MDP
 |   |    |           |                     | |   | |     |
 +---+---->|  EIS-E   ----------------------->(A)  | |     | (A): image
 digital  |           |    Science data     |     | |     |  compression
 status   |  EIS obs. |                     |     | |     |
          |  table   <-- EIS command(DC/BC) ------+ |     |
          |           |                     |       |     |
          | EIS-soft.<-----  RAM patch  ------------+     |
          |           |                     |             |   _____
          |          <-----------------------  flare pos.<---| XRT |
          |           |                     |             |  |_____|
          |          <--- observing mode -----            |
          |           |    and/or bit rate  |             |
to        |           |                     |             |
 EIS-M    |          <----- inf. of time -----            |
 |        |           |                     |             |
 | to     |          <--- status of buffer ---            |
 |  EIS-S |___________|                     |_____________|
 |   |        |
 |   |        |
 |   |     ____|____
 |   +-----|regulator|
 +---------|_________|         EIS powers
             ___|___    _____    ON/OFF
           |  PCU  |---| PIM |-------- to DHU
           |_______|   |_____|
```

<Science data line> four kinds of data will be transferred.

- (1) automatic operation : header + science data
- (2) RAM read 1 in manual operation : EIS observing talbe
- (3) RAM read 2 in manual operation : EIS onboard software
- (4) buffer dump in manual operation : header + science data

1. transfer speed: 1 Mbps (this is a baseline speed, but not determined yet)
2. Header includes the EIS status, size of image data, and how the data should be compressed.
3. [How to transfer the science data]

   a) length of header: fixed length
   b) Information of (1) science data transfer (2) dummy data transfer must be informed to MDP.

```
        EIS     ---------- time ----------->     MDP
               +-+-------------------+-------+
               |d|   science data     |header |
               | |    (variable)      |(fixed)|
               +-+-------------------+-------+
                d: dummy data

     [information from EIS to MDP]
        1       ______________________________
               |  transferred data window     |
        0 -----+                              +------- dummy
```

The line informing the kind of data is necessary, and this will have to be informed from EIS.

c) Buffer in MDP receives the data consisting of header, science data, and small-size dummy data.

d) After MDP reads the header in its ownbuffer, MDP knows the real size of data (header + science data), the compression scheme, and other EIS status data.

Therefore the size of EIS buffer in MDP is defined by the maximum size of single data unit. Although the maximum image size is the full-frame CCD data, the data may be considered as a collection of a unit of partial-frame data.

<RAM patch>

The onboard softwares and EIS observing table should be changed by the RAM patch functions.

<buffer status>

This should be informed from MDP to EIS-S to judge how to control EIS exposures and the data transfer.

<flare position>

The flare location is informed from XRT. The XRT-CCD coordinates will be directly informed to EIS-S. Therefore EIS needs a function of calculating EIS-M coordinates from XRT-CCD coordinates.

<observing mode, bit rate, and time >

These are used for changing the EIS sub-table from one to another according to the EIS table. See `EIS Observing Table (02-Dec-1998)' by Hara.

<DHU: Data Handling Unit>

DHU collects the data from all the common/scientific instruments and make the telemetry format from the data. This plays almost the same role as DP of Yohkoh.

<PIM: Peripheral Interface Module>

This is a standard command interface unit between DHU and other users. There is a discussion that the EIS command and RAM patch functions should be realized by the connection of DHU - PIM - EIS. The system design is still in a primitive stage.

<Power control> TBD.

Comments on EIS-MDP I/F Plan (H.Hara) Rev 1.0

Alec McCalden 22 Dec 98

1. EIS as master

If Solar-B carries three instruments, and the Mission Data Processor (MDP) is common to all of them, then it seems that the MDP should be the master and the instruments should be the slaves. Any other arrangement will I think lead to difficulties with the communication protocols.

If the concept is for a separate MDP per instrument, then this concern does not apply.

2. Block Diagram

Please look at the 'Solar-B EIS Proposed Block Diagram'. I've taken the latest ideas from Hara san and tried to merge them with the block diagram that we generated a few weeks ago. An important aim has been to keep interfaces as simple as possible. The points to note are:

1. A lot of detail of the possible EIS configuration is shown.

2. The Housekeeping (hk) information flow is shown as processed by the EIS first before being passed to the MDP, whereas the EIS-MDP plan of Hara san shows it processed by the Data Handling Unit (DHU). This change allows the data interface from EIS to be completely digital, rather than mixed with analogue data. This will help ensure a robust interface. It also allows the EIS to act in an autonomous manner upon the hk data as it is also able to read it.

3. All data flow is assumed to use a variable length packet structure.

4. Combined science and hk streams are shown, in order to keep the physical interface as simple as possible. The MDP data compression block shows a bypass path for data not requiring compression in the MDP, such as hk, memory downloads and science data already compressed.

5. Information from the MDP such as time status or observing mode is shown combined with the EIS ground commands before being passed to the EIS.

6. Matt and I tried to think of the information that might be required in each science packet. This is the list:

Header
Science packet identification
Time tag
Packet count
Packet length
Compression scheme
Mirror position
Exposure duration
Automatic exposure control value
Calibration lamp on flag
Number of packets in data set
Packet position in data set
Single image or movie flag
Movie frame number
Movie key frame identification
Science data
Packet checksum

7. 1 Mbps (I presume this means about 125k byte per sec) sounds a good transfer speed. Is it worth considering using Universal Serial Bus (USB), borrowed from the computer world, as an interface standard? This is good for 12Mbps, will make testing of individual units easier, and is low power and inexpensive. I do not know about the availability of radiation tolerant parts.

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12 Jan 99: Hirohisa Hara to Matt Whyndham..

Didn't you receive a document "Typical Data Size/Rate of EIS Observations" ? This is also important for considering the data flow in EIS system. If you did not read it, I will send it again.
.....<edit>.........
2-7. Transfer speed

1 Mbps is the default transfer speed. As I wrote in the document "Typical Data Size/Rate of EIS Observations (29-Nov-1998)", this rate may be able to be reduced for the EIS observation in my mind.

The parallel transfer by 8 lines is considered for the science data line. The transfer rate of each line is reduced by a factor of eight in this case. I assume that the data from EIS to MDP are 8 bits data which are made from 12 bits data by bit compression within EIS.

From Alec McCalden to Hiro Hara 13 Jan 99

Thank you for your comments on the block diagram. The following are my thoughts on what you said and are agreed by Matt and Rob.

1. I completely agree with the concept of MDP as master.

2-1. Movie Mode: I guess this is a topic for a consortium meeting. Judging though by the use made of movies on SOHO, I believe it would be a useful addition to the instrument capabilities. It will have no impact on the MDP interface or design.

2-2. We are planning to digitise *all* the hk.

2-3. I understood a packet to imply just what you said - variable length data with a fixed length header. I'd plan only to use the CCSDS standards as guides, *not* as requirements.

2-4. With the limited power and mass budgets, I'm keen to minimise electrical buffers and connector pins. They are also critical nodes in failure analyses. I'd recommend the adoption of one physical data line with differential signalling carrying both science and hk.

2-5. I'm sure we can achieve a high enough signalling rate on the command line to ensure that delays in passing buffer status messages as well as ground commands are trivial.

2-6. The list of header info is likely to be updated!

2-7. I would urge that we use a serial rather than parallel interface for the science (+ hk) data. It gives advantages of reliability, power consumption, mass (of connectors and cable), and reduction of clock and data skew problems. MSSL is wired with 100s of metres of UTP for ethernet at 100Mbit/s with few problems - I'm sure we can achieve ~1Mbit/s over maybe three metres of high quality cable on Solar-B.

We have thought a lot about data compression techniques, and I feel that whilst maybe we should retain a 12 to 8 bit compression scheme for Yohkoh compatibility we would be making a mistake not to look at modern schemes such as Discrete Wavelet Transform as well. Schemes such as this would probably benefit from a 16 bit interface from the EIS to MDP rather than the 8 bit interface proposed.

I've some comments on the 'Typical Data Size' document to add in the near future. Further explanation of the section on protocol will also follow later.

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20 Jan 99 From: "Hirohisa Hara"

I would like to ask you why you prefer a single serial differential line to single-end parallel lines (8 lines) for the data line from EIS to MDP. Is it related to the bit compression (from 12 bits to 8 bits) in EIS-E, which I have in mind ?

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22 Jan 99 From Alec McCalden

Data Lines - your note of 20 Jan 99

My preference is not related to bit compression, but to ease of implementation and reliability of the link between the EIS and MDP.

Let me try to reply to your points first.

1-1 Number of circuits

As you say, serial to parallel transformation is a trivial matter.

1-2 Number of physical lines

I think the point at issue here is that I would propose we use a data packet handshake, with start and stop bits to frame the data. In detail:

8-bit parallel transfer takes 11 physical circuits, including handshake.

The worst case data rate on any line numerically equals the number of bytes per second.

Using a single ended method takes 12 wires including a common signal return. Some people would advocate a return for every signal but the data rate in this case probably does not justify it.

Using a differential method would take 22 wires.

16 bit transfer involves an unrealistic number of wires.

....

8-bit serial transfer takes 2 physical circuits. One of those circuits can be the link carrying commands to the EIS from the MDP if the handshake is included as a data packet.

The worst case data rate on any line is numerically 10 times the number of bytes per second allowing for one start and one stop bit.

Using a single ended method takes 3 wires, 1 of which also carries the MDP - EIS commands and another is a common return. A single ended approach would be unwise at the expected data rate.

Using a differential method would take 4 wires, 2 of which also carry the MDP to EIS commands.

16 bit transfer uses the same cable and has almost the same worst case data rate.

I think it is fair to say that only two wires are needed to carry the data.

2 Power Consumption

Compare the single ended parallel approach with the differential serial approach:

Parallel:11 wires at 1 times the nominal byte-per-sec rate.

Serial:2 wires at 10 times the nominal byte-per-sec rate.

If you assume that the current consumption of the interface is proportional to the data rate, then the parallel appears to consume 11 units compared to the serial at 20 units. Define this as dynamic current.

In practice, there is always some quiescent current in an interface driver:

Parallel:11 x ((1 x dynamic) + quiescent)

Serial:2 x ((10 x dynamic) + quiescent)

The much greater quiescent current in the parallel example will tend to balance the greater dynamic current taken by the serial interface, and both interfaces will have comparable current consumption overall.

3 Weight

A parallel cable will have greater mass than a serial cable, be less flexible, and need larger connectors too.

4 Noise Immunity

A differential interface will have much better common mode noise rejection than a single ended interface. A differential serial interface is easy to implement, whilst a differential parallel interface takes a large number of wires.

There's two other features as well:

5 Data Skew

With parallel data you have an extra task of ensuring there is no variation, or skew, in the propagation of the data on one wire compared to another. Too great a skew will mean that the data is misread or unreliable. Skew can be caused by ageing of transmit buffers or receivers.

With serial data this problem does not exist.

6 Reliability

An interface requires all circuits working for the overall interface to function. There are at least six times more circuits for a parallel interface than for a serial. This makes the parallel interface six times more prone to failure than the serial, given the same technology for the implementation.

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I've tried to argue this through with myself as I've written it, and I find that my original intuitive response seems well backed by a logical argument. Please tell me if you think I've omitted something important. Otherwise, I feel that the case for a serial interface using a data packet acknowledge seems good both from the ease (and cost) of implementation and from a reliability viewpoint. The common mode noise rejection is also improved.

CCD Notes

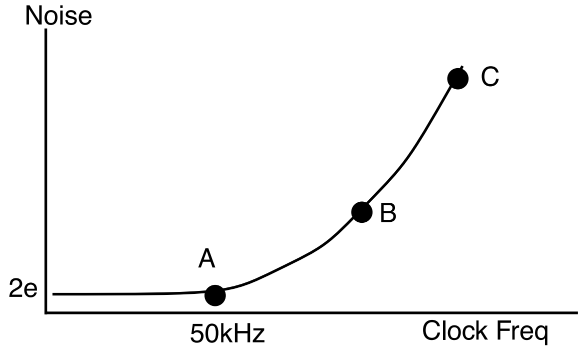
Alec McCalden 27 Jan 99

1.0 Introduction

This is a miscellaneous set of notes on the use of a CCD in EIS.

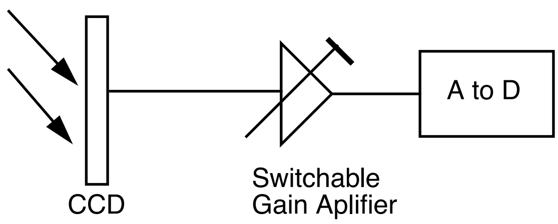
2.0 Readout Frequency vs Noise

Readout frequency verses noise is a compromise, with a typical plateau of 2 electrons equivalent noise at up to 50kHz for the EEV CCDs likely to be used. One plan for dealing with the question of where to put the working point along that graph is to engineer the means to select one of two or three of those points. 'A' would be used for best noise performance, whilst 'C' might be more useful for best time resolution.



3.0 Dynamic Range

EEV devices have full well counts of about 10^5 electrons and best dark count of about 2 electrons, giving a dynamic range of 5×10^4. This implies digitisation to 16 bits to represent all possible data. This is likely to be impractical for available A to D converters, particularly when space flight qualification is required. A probable solution is to use a 12 bit converter and switch the gain of the amplifier stage before it.



This implies operating the CCD either in a 'bright' or 'cloudy' mode. In the former, the CCD will not saturate but very dim lines may not be seen; in the latter, full use will be made of the CCD sensitivity but smearing may occur at the points of maximum intensity.

Use of variable gain implies careful tagging of the data stream to indicate the gain setting, or compensating the data in the EIS and telemetering a 16 bit corrrected value.

An alternative solution might be the use of a quasi-log amplifier to reduce a 5×10^4 dynamic range to 8×10^3, suitable for 12 bit digitisation.

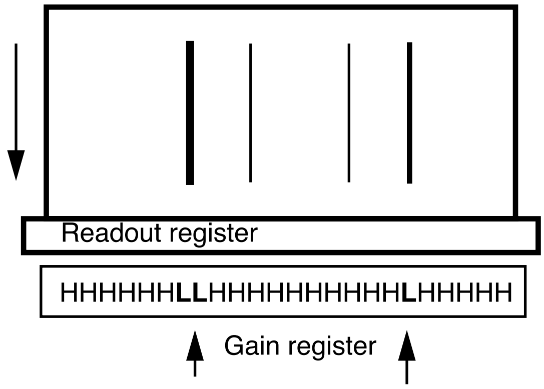
4.0 Frame Transfer or Full Frame CCD

4.1 Frame transfer implies use of a CCD with an real area of twice the illuminated area whilst full frame mode requires a shutter in the light path.

4.2 Frame transfer may give smearing of bright points of the image. A full frame device with a shutter has no such problem.

4.3 Frame transfer allows a new image to be collected whilst the previous one is being read out, giving a maximum duty cycle of almost 100% for the CCD. A full frame device will give a best duty cycle of somewhere around 50% to maybe 90% depending on the size of the CCD window to be read out.

5.0 Orientation & Windowing



A CCD conventionally is read out by shifting cell charge into a register along the bottom of the columns. This gives a problem if the dynamic range of the CCD is greater than the A to D converter, as will probably be the case for EIS. The ratio between two lines may mean that either the bright line saturates or the faint line is buried in noise. There are two ways of dealing with this. The gain of the preamplifier can be defined for every column, or the CCD can be turned though 90° and a whole spectral line read out at a time. The gain is then changed for the next line, and so on. A new window would in practice be created for each spectral line with a gain value attached to it.

Re-orienting the CCD through 90° from normal would not allow charge addition or binning in the readout register, and so is probably not a good choice. The preferred method of maintaining the full CCD dynamic range remains conventional readout with a gain register implemented in the readout electronics.

6.0 Charge Transfer Efficiency & Calibration

Charge transfer effiviency from one cell to the next may be as good as 0.99999 - i.e. one part in 10^5 is lost. A readout from the opposite corner of a CCD involves rippling through many cells. For example, a 2048 x 512 array will lose $1 - 0.99999^{(2048 + 512)} = .025$, or 2.5%. Radiation damage and other ageing factors may make this worse. In practice, the column and row transfer efficiencies may be different and a two corner (or more) readout will ease the problem, but calibration in flight needs to be considered.

A light source or sources could be used and itself require calibration before launch, or an Fe 55 source will give an inherent calibration.

7.0 Resolution Increase

There is a technique for increasing the apparent resolution of a CCD by dithering the readout sequence. More investigation needs to be done! - ref Hajime.

Yohkoh SXT 12 to 8 bit compression

Alec McCalden 11 Dec 98

The Yohkoh SXTinstrument uses a fixed data compression scheme to reduce the 12 bit CCD data to 8 bits for transmission. The algorithm (Morrison / Acton Jan 1993) is:-

For DataIn value 0 to 64:

$$DataOut = DataIn$$

For DataIn values 65 to 4095:

$$dataout = 0.5 + [59.249 + \sqrt{[3510.39 - 9.5 \times (431.14 - datain)]}]$$

This is the transfer characteristic:-

SXT 12 to 8 bit compression