SOLAR-B
EIS
Onboard Software Requirements

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Contents

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Change History

V0.4 08-Jun-99
- Axxx: Clarified mission and spacecraft assumed parameters.
- R240: Modified temperature control limits.
- R470: Modified shutter exposure duration precision.

1 INTRODUCTION

1.1 Purpose

The objective of this document is to specify complete, structured and coherent requirements for the onboard software for the EIS instrument onboard the Solar-B spacecraft.

It is intended that the requirements presented here will be sufficiently explicit and quantitative to allow software design and development.

1.2 Limitations

This document current represents working level requirements only, and will ultimately benefit from definitive documents for the following major areas :-

1. EIS Science Requirements	Definitive, coherent, explicit requirements which take into account EIS telemetry rate allocations, and storage allocations between telemetry dumps.
2. Solar-B Spacecraft Requirements	Definition of s/c i/f, operational requirements, command and telemetry systems.
3. EIS Instrument Specification	Definitive EIS instrument specification at subsystem level, and subsystem interfaces.

To cope with lack of definitive information of the Solar-B Spacecraft and EIS instrument, this document contains a section on current assumptions which should be checked for accuracy by the reader.

Where knowledge requirements is known to be limited or absent the following acronyms have been placed in the text :-

(TBD) - To Be Defined
(TBC) - To Be Confirmed

All these unknowns must be resolved in time to complete the final flight code.

1.3 Organisation of Requirements

The following major categorization of requirements is adopted which is felt appropriate to scientific instruments in space. The sub-categories follow the comprehensive list provided in the ESA PSS05 documentation [ref.1], and have been adopted here to help ensure that no major types of requirements have been omitted.

- General
  - Document
  - Management
  - Test
  - Maintainability & Testability
  - Portability
  - Quality
  - Reliability
  - Security
  - Resources
- Operational (How software looks to external user)
- Functional (What software has to be do, incorporating performance requirements)
  - Control -- Control (commanding) reqs of instrument subsystems and modes.
  - Science -- To support science (modes)
  - Engineering -- To support instrument health, diagnostics, corrections.
- Safety - Human, Instrument & Spacecraft.
- Interface - Information across interfaces

Performance requirements (e.g. throughput & response times) are incorporated naturally in the other categories, as they are often specific to particular functional, operational or interface items.

Constraints are handled here as requirements (e.g."Commanding must conform to Solar-B packet structure, protocol and frequency requirements ")

1.4 Glossary, Acronyms & Abbreviations

(a) Glossary

Exposure Duration that CCD accumulates data between shutter being opened and closed.

Cadence Time between successive exposures.

E.g. $T_{cadence} = T_{shutter(open)} + T_{exposure} + T_{shutter(close)} + T_{readout} + T_{latency}$

where :-

$T_{cadence}$ is the cadence time,

$T_{shutter(open)}$ is the time taken to open the shutter prior to the exposure,

T_{expose} is the exposure time,

$T_{shutter(close)}$ is the time taken to close the shutter after to the exposure,

$T_{readout}$ is time taken to read data out of ccd, and

	$T_{latency}$	is other time taken by system such as time to configure ccd camera for exposure, and any other processing pipeline delays.

Raster A complete sequence of mirror positions necessary to scan a desired FOV area of the sun. This is used for imaging larger areas of the sun than a single slit or slot can provide. Repeated rasters will be necessary to determine time behaviour over the image.

Mode A defined subset of instrument activities over a period of time.
Scientific modes often consist of specified evolving configurations and repeated sequences of exposures. Configurations may evolve because of solar tracking. Example scientific modes are Spectra, Imaging, Movie and Calibration.

Observation A mode operated over a specified period of time.

Flare Trigger A ‘Flare Trigger Signal’ is a signal which is generated when a flare onset has been detected. It will be expected to be distributed in real-time and provide the location of the flare region.
Detection of the onset of a flare will be made by some ‘Flare Trigger Sensor’ mechanism, whether detector or data based.
Pre-flare trigger data may be collected, and also post-flare trigger data.

(b) Acronyms & Abbreviations

AEC	Automatic Exposure Control
CCD	Charge Coupled Device
CFT	Comprehensive Functional Test
CPT	Comprehensive Performance Test
EIS	E-UV Imaging Spectrometer
exps	Experiments
fov	Field Of View
HK	HouseKeeping (parameters)
hrs	Hours (time)
kbps	kilo (~10^3) bits per second
mbps	mega (~10^6) bits per second
MDP	Mission Data Processor (spacecraft)
min	minute (time or angle, depending on context)
ms	millsecond
reqs	Requirements
Sci	Science
sec	Second (in time)
SFT	Short Functional Test
Stim	Stimulation
TBC	To Be Confirmed
TBD	To Be Defined
UV	Ultra Violet (light)
XRT	X-Ray Telescope

1.3 References

[1] EIS-sys-eng-userneed-1 : "User Needs and Constraints", draft 1, 03-Jul-98.
[2] EIS-sys-eng-sysreq-1 : "System Requirements", draft 1, 03-July-1998.
[3] ESA PSS-05-0 : Issue 2 Feb 1991. "ESA Software Engineering Standards".
[4] AO 98-OSS-05 : Office of Space Science NASA Announcements of Opportunity "Announcement Of Opportunity For U.S. Participation In The Japanese Solar-B Mission",1998.
[5] Ko/m/5 : "Solar-B Telemetry & Commands", T.Sakao(NAOJ), from 8/12-Mar-1999 meeting in Japan.
[6] Private communications : Chris McFee, MSSL, April/June-99.
[7] : "Working discussion: Implementation of on-chip functionality", Chris McFee, MSSL, 23-Apr-99.
[8] Private communication : Loiuse Harra-Murnion, MSSL, 27-May-99.
[9] Private communication : Matthew Wyndham, MSSL, 26-May-99.

2 ASSUMPTIONS

The following parameters are assumed :-

2.1 Mission & Spacecraft Parameters

A010	Orbital Period	:	???	(~90 minutes (TBD/TBC))
A020	Telemetry storage	:	3 Gbits	(For all Solar-B [ref.4,table 5.1])
A030	Telemetry allocation	:	48 Mbytes for EIS	(~1/8 total s/c ~384 Mbits [ref.1,p9])
A040	Contact periods	:	4x24 hours	([ref.1,p8] ~1 every 4 orbits). (=>~18 kbps sustained average telemetry data collection rate for EIS.)
A050	Telemetry rates			(EIS data from MDP->DHU)
	- Nominal	:	64 kbps	[ref 4, table 5.1 & 5.3] (~1.7 hrs storage capacity without comp).
	- Max	:	0.6 Mbps	(sustained ???)
	- Min	:	???	(sustained)
A060	Command rate	:	~4kbps	(uncertain) for whole spacecraft [ref.5])

Assuming 1/6 for EIS => 83 bytes/sec.
Assuming 10 mins commanding contact => 50kbytes/contact.

A070 MDP-EIS I/f :
- 2 cables - command line and telemetry line (sci & hk) (TBC).
- 1 or 2 Mb/s UART max data transfer rate EIS<->MDP (TBC).
- min data transfer rate ?
- Packet based, 16 bit words, CCSDS (TBC).
- min/max packet size ?
- min/max wait between packets to be telemetered/received.

2.2 EIS Parameters

(a) Telescope

A100 FOV : Depends on elements selected in slit exchange mechanism [ref.2.p6]
Also can extend above instantaneous fov by scanning mirror.

A110 Sensitivity : Is wavelength dependent
- min count rate ? (quite sun ?)
- max count rate ? (flare?)

(b) Slit Exchange Mechanism (TBD)

(No longer dumbbell concept but a perforated disc which can be rotated to selected element position. Exposures to be made with disc static.(TBC).

A200 Slit element : 1 arc sec [ref.8] x4 arc min [ref.2.p6]
A210 Slot element : 4x4 arc min (TBC) [ref.2.p6]
A220 Other elements : ???
A230 Blocked element : ???
A240 Element acquisition time : ??? [Time to move disc to new element]

(c) Mirror

A300 Move speed : ≤10ms/step (to achieve fast cadences ~1 sec)
A310 Step size : < pixel size (to avoid jumpy movies when solar feature tracking)
A320 Scan range : 4 arc min [ref.2,p6]
[for 1" slit =>240 mirror raster positions.
=> 240x10ms/strp =>2.4 secs max for full high resolution raster]

(d) Shutter (TBC)

A400 Exposure durations : 10 msec to 10 sec (TBC)

(e) CCD Camera

A500 Diode : Calibration light source (TBC)
A510 Fe^{55} source : Calibration (TBC)
A520 CCD's : 2 by 2048x512 pixels (TBC)
A530 Max area used : 2048x120 pixels (TBC) **Full image = 0.5 Mbytes**
(2048x120 => 245,760 pixels
=> 491,520 bytes @ 2 bytes/pixel)
A540 Bits per pixel : 12 (≤14) (TBC)
A550 Pixel size : 21 mÅ in wavelength direction (x) (RAH assume)
13.5μm in spatial direction (y) (TBC) [ref.6].
A560 Readout windows : ≤~20 rectangular, same height & non-ovelapping per exposure (TBC). Can be different heights for different exposures. (Readout selected parts of CCD allows fast cadences)
A570 Readout rate : ~ 0.1 to 0.5 Mpixel/s (TBC) variable correlated double sampling time per window or pixel [ref.7].

- **Fastest Time to readout full image = 0.5 secs** (for full image of 0.25 Mpixels).
- **Compression required = 125** to fit into nominal 64 kbits/s (0.5 Mpixels.s^{-1} => 8 Mbits.s^{-1} / 64 kbits.s^{-1} = 125)

A580 On-chip binning : nxm for n,m in range [1,6]. (TBC) [ref.7]
(perhaps to increase cadence rate by ~x10. (P.Cargill req?)

3 EIS ONBOARD SOFTWARE REQUIREMENTS

This section itemizes explicit requirements.

3.1 General Requirements

R010 Documents

The following software documents shall be generated, and put under configuration control :-

(a) Onboard Software Requirements : This document.
(b) Onboard Software Architecture : General and detailed.
(c) Onboard Software Commanding : General and specific structures and use.
(d) Onboard Software Telemetry : General and specific structures
(e) Onboard Software Test : Test classes and definitions
(f) Onboard Software Transfer : Software versions, supported functionality, outstanding NCRs, ECRs, and how to build software for each release.

(The project manager shall specify a schedule for milestone document releases)

R020 Management

Onboard Software Development Schedules shall be produced periodically as required by the project manager, but not more frequently than once a week.

R030 Test

(a) Identify detailed tests for the following categories on the software (TBC) :-
(Test definitions to be incorporated in Software Test document as above)
- SFT - Short Functional Tests (to establish all instrument subsystems are functional)
- CFT - Comprehensive Functional Tests (establish full functional capability)
- CPT - Comprehensive Performance Tests (establish full performance capability, including soak tests)

(b) Identify tests to be performed at unit, system, and spacecraft level (TBC).
(unit level is prior to EIS subsystem integration)
(c) Perform unit testing and provide reports (TBC/TBD).
(d) Perform and support other defined tests as required (TBC/TBD).

R040 Maintainability & Testability

Coding shall follow specified standards (TBD), which shall at least specify that :-

(a) The generated code shall be modular and commented.
(b) Each program shall have a version number of the form a.b where a is an integer which specifies a major release, and b an integer that specifies a minor release. The numbers will start at 1 and increment with each release.
(c) Each module shall have a header section which identifies the title of the module,

version, author and date of each version, including the latest.
No changes may be made to a module, whether code or documentary without updating this header.
(d) A common format for header sections shall be applied to all onboard software modules.
(See also Engineering Requirements - memory downlink & uplink)

R050 Portability
The software shall be implemented in ‘C’ or ‘C++’ (TBC) high level language wherever possible, and only resort to assembler language for items requiring fast response or throughput not otherwise achievable.
(To help ensure portability of code items to future software projects)

---- Quality (To ensure software is fit for its purpose)
None identified - other than already incorporated in other items, such as test, reliability, maintainability, and safety.)

---- Reliability
None identified - other than test, maintainability & testability, and security.

R080 Security
(a) Code and documentation under development shall be backed up regularly, at least once a week.
(b) Released code and associated documents shall be placed under configuration control, be backed up, and made secure against fire, theft, and hacking whether external or internal.
(This is to protect the integrity of software which must not be changed once released.)
(An acceptable method would be to make multiple CD-ROM copies at release time which are distributed geographically.)

R090 Resources
(a) The software shall reside within (TBD) memory.
(b) The software shall be implemented upon (TBD) processors, running at (TBD) Mhz and operating with (TBD) memory wait states.

3.2 Operational Requirements

R200 Accept command control from MDP.
Must conform to Solar-B command packet structure, protocol, and frequency requirements for EIS (TBD).
(e.g. reception, validation, acknowledgement (TBD).)

R210 Accept spacecraft time information from MDP (TBC).
(For assigning times to science data and other events.)

R200 Provide telemetry data to MDP.
Must conform to Solar-B telemetry packet structure, protocol, and frequency requirements for EIS (TBD).
Telemetry packets will be divided into Science and Housekeeping packets (TBC).

R230 EIS Science data packets should be sufficiently self contained that :-
(a) Scientific data analysis can be performed without normally requiring access to HK packets.
(b) Data corruption or loss of a single packet results in loss of ability to scientific analysis to no more than a single exposure.
(It must not result in loss of complete observation).

R240 Provide following science modes to operate one at a time :-
Spectra, Imaging, Calibration, and Movie. (TBC).

R250 Provide real-time mode of operation.

R260 Provide time-tagged operational capability for up to 64 modes for up 24 hours.
(I.e. requires timetable of mode definitions to be stored onboard EIS.)
(Since will be limited ground command opportunities, perhaps only twice a day.)
(Also allows synoptic studies such as overview obs at same time each day (TBD.)

R270 Allow commanded changes to time-tabled mode definitions.
(To minimise number of uplinked commands).

R280 Provide as fast as possible (≤1sec, (TBC)) commanded transition from time-tagged operations to real-time operational mode.
(E.g. to allow immediate transition to observe active region identified by XRT.)
Abort current ccd exposure if active.

R290 Allow resumption of timed operations with commanded delay in range 1 minute to 10 hours (TBC).

R300 Should the EIS generate data faster than it can be passed to the MDP, then the EIS will not commence another exposure until there is room to store its data.
Note:
(i) This may arise under normal operating conditions if more data is collected between telemetry dumps than expected, because of e.g.unexpected active region exposures have to be performed, or lower data compression efficiency than expected.
This could mean last programmed observations before telemetry dump to ground may be lost because of lack of spacecraft telemetry storage space.)
(ii) It is a ground responsibility to ensure that the EIS does not generate telemetry data faster than the MDP can accept it. (i.e. the EIS should be commanded into a suitable

mode.)

R310 The EIS should ensure that it does not have to delay exposures simply because of nominal fluctuations in MDP data taking.
I.e. EIS should be able to cope with MDP maximum nominal delay in taking data packets from EIS.

3.3 Functional Requirements

3.3.1 Control Requirements

R400 Provide Power Switching Control to EIS Telescope and CCD camera subsystems (TBD)
Ensure conformance with power sequencing requirements, keeping transient currents within specified limits, and providing sufficient time delays before powered-on subsystems are used (TBD).
(a) Must be able to completely power off CCD camera.

R410 Provide Instrument Structure Temperature Control. (TBC) [ref.9]
(For optical alignment stability if structure not carbon fibre).
(a) Provide heater power control - (on/off/power level in control range [?,?]Watts (TBC))
(b) Provide temperature control - (enabled/disabled, power level, specified temperature) as follows :-
Acquire specified instrument structure temperature within control range [?,?]˚C using specified heater power in control range [?,?]Watts, and maintain temperature to precision ±0.2˚C (TBC).
Ensure that rate of change of instrument structure temperature is kept < 1˚C/minute (TBC).

R420 Provide CCD Temperature Control [ref.6]
(a) For calibration stability of the scientific data (TBC).
(Calibration dependency on temperature may be performed by taking flat field exposures.)
Acquire specified temperature of CCDs within control range [-30,-100]˚C using specified heater power in control range [?,?]Watts, and maintain temperature to precision ±1˚C (TBC).
Ensure that rate of change of CCD structure temperature is kept < 1˚C/minute (TBC).
(b) For CCD annealing (TBC).
Acquire specified temperature of CCDs within control range [+20,+100]˚C using specified heater power in control range [?,?]Watts, and maintain temperature to precision ±2˚C (TBC).
Ensure that rate of change of CCD structure temperature is kept < 1˚C/minute (TBC).

R430 Provide Telescope Door Mechanism Control (open, shut) (TBC/TBD).

R440 Provide Grating Focus Mechanism Control. (TBD).

R450 Provide Slit Exchange Mechanism Control.
To select e.g.slit, slot, slit/slot, blocked, etc. (TBD).

R460 Provide Mirror Control.
Move mirror to set tilt levels. Number of steps (TBC).
(Mirror does not have both tilt and tip control now.)

R470 Provide Shutter Control (TBD).
To control CCD camera exposure durations from 10 msecs to 10 secs, to 1% precision [ref.6] (TBC).

R480 Provide CCD Camera Control, as follows :-

(a) Window selections	- Single exposure up to 20 same height, non-overlapping rectangular windows. CCD id [0,1]. Height specified to pixels resolution in range [1,512]. Width specified to pixel resolution in range [1,2048].
(b) Full CCD image readout	- i.e. 512x20248 for engineering purposes (TBD)
(c) On-chip binning	- (NxM) ccd pixels for N,M in range [1,6] (TBC).
(d) Stim pattern	- On/Off (TBC)
(e) Flushing	- To remove accumulated dark current before exposure via e.g. dummy readout into dump drain. (TBC/TBD)
(f) Overscan clocking	- To be able to clock out extra pixels not in image i.e. outside normal 2048 pixels (TBD).
(g) Readout port selection	- A&B, or A, or B (TBC).
(h) Diode light source	- On/off (TBC) (For flat field calibration).
(i) Fe^{55} source control	- Shutter open/closed (TBC)
(j) CCD voltage parameters	- Parameters & adjustment levels (TBD).
• Clocking rates	- Pixel readout speed.
• Rise time of clock pulse	- Charge transfer efficiency/noise.
• Correlated sampling time	- Readout noise/sensitivity [per window (TBC)]
• Dither clocking	- Internal pixel charge movement control during exposure /noise (TBC)
• Pixel image shifting	- Whole ccd image position shift control by half pixel for an exposure (TBC/TBD)
• Readout amplifier gain	- (desirable) (TBC)

3.3.2 Science Requirements

Note: Unless otherwise specified full range of controls as in control requirements is assumed.

R500 Provide Spectra Mode for continuous monitoring of specified lines at set cadences as follows :-

(a) Be able to specify start and end time for mode, in range [1 minute to 10 hours] to 1 minute resolution (TBD).

(b) Consist of a repeated sequence of exposures until end time, or aborted.

(c) Be able to specify single aperture setting for all exposures in mode (as in R440) (TBC).

(d) Be able to specify an initial mirror setting which will be used for all exposures in mode when solar feature tracking is not required.

(e) Be able to specify a repeated sequence of up to 4 (TBC) exposures with each exposure having independent exposure and CCD camera controls [R460 & R470 (a) to (d)]. (E.g. allow short exposure of a strong line, followed by a long exposure of a weak line before moving the mirror.)

(f) Be able to specify 'Solar Feature Tracking'.
This will control the mirror position after each sequence of exposures [item (e)], so as to compensate for solar surface rotation to keep a static solar feature in the fov (TBC).

(g) Be able to specify fixed exposure duration, or controlled by AEC (Automatic Exposure Control) whereby exposure time for next exposure is determined by data from previous exposure to expected specified total counts in particular window region.

(h) Successive exposures should begin as soon as possible, so processor latency <0.1 sec)
I.e. exposure cadence should be as short as possible, where :-
Cadence time = Shutter open time + Exposure time + Shutter close time + Readout time + Processing Latency
where Processing Latency is time for processor to setup and initiate the next exposure.
(Note: Next exposures can be held up if processing time is long or MDP cannot take data quick enough so telemetry buffer becomes full. It is expected that processing of the data and MDP data taking can take place concurrently to exposing and readout.)

(i) Be able to specify processing required on the data, such as time or spatial integration for individual windows data. (TBD/TBC)
(E.g. so can integrate data for weaker lines taken in exposures).

(j) Be able to specify data compression method for collected scientific data as follows :-
  (i) No compression at all (for diagnostic purposes)
  (ii) Compression schemes to be performed by MDP (TBD).
  (iii) Other methods (TBD).

(k) Perform all exposures as specified above, in response to start mode command or from timetabled program, determining the start time for each exposure (to millisec precision, TBD).

(l) For each exposure, packetise the science data, the exposure start time, and all control parameters specific to the exposure.

(m) Pass each packet to the MDP for any specified science data compression and for subsequent storage.

R510 Provide Imaging Mode of specified lines and areas at set cadences as follows :-
(a) As for Spectra Mode, plus :-
(b) To be able to specify an initial mirror position and increment, which changes after each exposure sequence of up to 4 exposures.
The mirror position to be set as in R450, and an increment to be an integer number of steps in the range [0, maximum number of steps in mirror movement].
When the maximum mirror position is reached the next position is set at the original position, and so on. (TBC).

R520 Provide Movie Mode (TBC) to allow high time resolution spectra or imaging with variable lossy compression to achieve fixed cadences (TBC) as follows :-
(To allow a complete morphology of fast occurring e.g. flare development to be observed.
(I.e. high imaging refresh, but with limited detail of spectra or imaging resolution.)
(Con: uncertainty capacity to perform detailed scientific analysis on the compressed data.)
(Question: Is this as useful now that 2-d imaging is not possible with only a tilt mirror ?)
(a) As for Spectra or Imaging Mode, except that fixed cadence will be implemented.
Fixed cadence mode will require controlling data rate to MDP to be within specified upper limit. How this is to be achieved is TBD.
(It could be by autonomous control of various data compression factors.)
(b) Be able to specify whether onboard despiking is to be performed prior to data compression (TBC/TBD) ??

R530 Provide Flare Mode for real-time response primarily to active regions discovered by the XRT, as follows :-
(a) Allow commanding specification of and to Flare Mode at any time suitable for scientific operations, including interruption of pre-programmed scientific observations.
(b) Allow as fast as possible (≤1sec, TBC) configuration to and commencement of operation of Flare Mode.
(c) Flare Mode will operate as for any Spectra, Imaging or Movie mode.
(d) Allow termination of Flare Mode by real-time command, and also resumption of pre-programmed operations as for R290.

R540 Provide Calibration Mode(s) (TBC) for approximately once a week operation (less frequent than once a day) exposures as follows :-
(a) Flat field - Grating defocus control with shutter open
- Shutter closed and diode on
(b) Overscan - Allow zero exposure duration.
(c) Dark current - Shutter closed.
And for each mode :-
- Other controls to be as for Spectra Mode, and specifically to allow access to full physical CCD image (2048x512).

- Determine start time for exposure, and collect, process and packetise the generated data, as for Spectra mode, and send packets to MDP.

(Question: What about need for repeated exposures to examine flushing requirements and effectiveness ?).

3.3.3 Engineering Requirements

R600 Instrument Health Reporting

(a) Perform regular collection of HK data from instrument subsystems, packetise it and output to MDP.

(b) Allow collection and reporting frequency to be specified in range [1,3600] secs, in 1 sec steps, default = 8 secs (TBD/TBC).

(c) Collect following HK data from instrument subsystems :-
(Voltages, currents, temperatures, software status parameters, etc..) (TBD)
Parameters will represent instrument status at time of collection.

• CCD CAMERA PARAMETERS (TBD)

• ONBOARD SOFTWARE PARAMETERS (TBC/TBD)

- Onboard time of start of collection of HK data set
- Software version numbers
- Packet numbers of last HK and science packets entered into EIS telemetry buffer.
- Operating mode
- Software error status
- Memory checksums (TBD/TBC)

R610 Instrument Health Maintenance

(a) Perform onboard health & safety checks on specified critical HK parameters (TBC/TBD).
Selected parameters to be specified prior to launch. (TBC).
(May be required as EIS will be out of ground contact for long periods.)

(b) Perform specified action on parameters determined to be out of specification (TBC/TBD).
(E.g. turn-off malfunctioning subsystems.)

(c) Allow collection frequency of specified critical parameters to be set in range [1,3600] secs, in 1 sec steps. (TBC/TBD)

R620 Memory Downlink

(To provide ability on ground to determine code and memory state in space - for e.g. confirmation of code, commanded state such as data tables and parameters, and allow debugging of problems encountered post launch.)

(a) Provide ability to downlink any onboard memory areas from ground command.

(b) Packetise downloaded areas together with sufficient information to identify areas on ground.

R630 Memory Uplink
(Allow data and code changes which either cannot be changed by normal commands, or upgraded software to be uplinked or bug fixes.)
Provide ability to uplink data to any writeable onboard memory area, so that :-
(a) Data values can be changed.
(b) Code can be changed.
If possible, provide ability to minimise amount of memory that requires code change uplink (TBC).
(c) All code and data value areas to be uplinked with associated checksums, which are to be stored onboard (to allow later confirmation that contents have not been corrupted.)

R640 Memory Checksumming (TBC).
(Allow general confidence in memory areas to be determined on a regular basis without requiring large downlink capacity. Provides memory error detection such as SEU's, and other hardware or software faults.)
(a) Memory checksums to be determined onboard for all telemetry packets, and placed at end of packet to allow correct transmission checking.
(Note: will be possible to perform checksum tests on ground for packet data that MDP has compressed - unless MDP updates checksum - TBD.)
(b) Memory checksum to be generated for any specified onboard code or static memory areas by command and to be telemetered down.
(c) Memory checksum to be generated for any specified onboard code or static memory areas by command, be compared to stored memory checksum, and discrepancy or otherwise reported to ground by special telemetry packet.
(d) Memory checksums to be generated periodically for specified onboard code or static memory areas; be compared periodically to stored memory checksum; and results reported in HK.
Cycle iteration count of test to be incremented and reported in HK in range [0,15] (TBC).
Specified areas for tests determined prior to launch, and not commandable. (TBC).
This activity to be performed at low priority, but at least every 1 hour. (TBC).

R650 Watchdog Support
(To provide protection against software hangs).
Ensure hardware register is updated regularly every 3 secs or less, otherwise hardware watchdog circuity will assume software system has hung and cause a reboot (TBC/TBD).
(Subsequent activities upon reboot ,TBD).

R660 Software Error Detection
(a) Detect software exceptions (software errors for which there is no explicit code checks, such as array out of limits or unexpected divide by zero.)
(b) Report first 4 detections of each type of exception in hk and special telemetry packets. (Allow more than one as type may occur in e.g. different location.)

(c) For subsequent same type exceptions, report only an updated count of instances in hk until an explicit 'error reset' command is received.
Max count of exceptions to be 255 after which is maintained at 255 until reset to zero, (TBC/TBD).
(c) Perform appropriate remedial action for each instance (such as reboot, and system restart).

3.4 Safety Requirements

These relate to any safety requirements to either persons or the instrument.

R600 Ensure the EIS instrument is either made safe or performs special (e.g. calibration) operations during radiation belt passage (TBC/TBD).

This could mean various possibilities :-
(i) Completely power off the CCD camera at any time to prevent damage caused by radiation flux effects (not simply high count rates which would just cause saturation), by e.g. :-
  (a) Accepting real-time command (e.g. normal power off command) from spacecraft.
  (b) As a pre-planned time-table activity, designated by absolute times not delayable by insertion of e.g. real-time flare mode operation.
  (c) Autonomously respond to onboard monitoring of radiation levels.
(ii) Set the instrument into a special calibration mode.
(iii) Set the CCD camera into a radiation safe mode.
(iv) Set the instrument into a special radiation monitoring mode.
(E.g. to characterize the radiation belts.)

R610 Ensure that the EIS can be commanded into a safe state by a single command packet received at any time from the spacecraft (TBC/TBD)
(This may be required if e.g. for radiation belt passage as above, or spacecraft anomaly in e.g. power loss situation.)

3.5 Interface Requirements

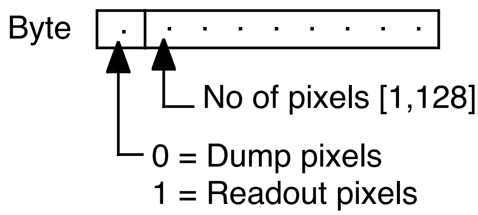
The interface requirements here are limited to specification of the information that has to flow across interfaces external to the software.

It assumes that hardware aspects of these interfaces is specified elsewhere, such as cable, connector, power and low level hardware protocols.

Also, please note that what follows here is very preliminary.

3.5.1 Processor <-> CCD Camera

R700 Processor -> CCD Camera
- (a) Setup Exposure
  - Exposure duration (millisecs)
  - On-chip binning (n by m where n,m are in range 1,6])
  - Flushing (tbc/tbd)
  - Readout windows (window height in [1,120] pixels (tbc), pixels for readout, as e.g. pixel row table~80 bytes to specify up to 32 windows for 2048 pixels.)



- (b) Start Exposure (send after setup)
- (c) Request CCD stim pattern(tbc/tbd)
- (d) Request Status (unless updated automatically)(tbd/tbc)

R710 CCD Camera -> Processor
- (a) Readout Data (to mass memory, 16-bit words)
- (b) EOS (End Of Exposure: send after readout complete)
- (c) Status (of ccd camera, settings etc...)(tbc/tbd)

3.5.2 Processor <-> Telescope

R730 Processor -> Telescope
- (a) Aperture selection (e.g. narrow slit, slot, slit/slot)

R740 Telescope -> Processor
- (a) Status (tbc/tbd)

3.5.3 Processor <-> MDP

R750 Processor -> MDP
- (a) HK telemetry (regular periodic hk reports)

(b) Science telemetry (science data/memory dumps)
(c) Special status reports (e.g. command reception acknowledgment)

R760 MDP -> Processor
(a) Commands (all types)
(b) Time