Solar B - EIS

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EIS SYSTEM DEFINITION

Document Number: MSSL/SLB-EIS/SP011.03 15 April 2003

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Authorised By	A. James	Date:	15 April 2003
Distributed:	A. James	Date:	15 April 2003

Distribution:

EIS Science	✓
EIS Tech	✓

CHANGE RECORD

ISSUE	DATE	PAGES CHANGED	COMMENTS
01	29 June 2000	All new	
02	17 July 2002	ALL	Updated to present status
03	15 April 2003		Updated to present status

CONTENTS

1. INTRODUCTION

Solar-B will study the connections between fine magnetic field elements in the photosphere and the structure and dynamics of the entire solar atmosphere.
The mission will perform three basic types of observation with high spatial, spectral and temporal resolution :

Determination of the photospheric magnetic vector and velocity fields.
Observation of the properties of the resulting plasma structures in the transition region and corona.
Measurement of the detailed density, temperature and velocity of these structures.

The EUV imaging spectrometer (EIS) will obtain plasma velocities to an accuracy of <= 10 km s^{-1} along with temperatures and densities in the transition region and corona at <2 arc sec resolution.

2. SCOPE

The purpose of this document is to reflect the design of the EIS instrument that will satisfy the requirements, as stated in Section 4.

3. DOCUMENTS, GLOSSARY AND ACRONYMS

3.1 Applicable Documents

AD 1	MSSL/SLB-EIS/SP007	EIS Science Requirements
AD 2	MSSL/SLB-EIS/SP003	EIS Interface Control Document (ICD)

3.2 Reference Documents

RD 1

3.3 Glossary and Acronyms

AD	Applicable Document
Bfn	Baffles
BU	Birmingham University
CAM	Camera
CCD	Charge Coupled Device
CLM	Clamshell
CUB	Alignment Cube
EEPROM	Electrically Erasable PROM
EIS	E-UV Imaging Spectrometer
ENC	Enclosure
EUV	Extreme Ultra-Violet
EW	East West
FFA	Front Filter Assembly
FOV	Field Of View
FPA	Focal Plane Assembly
FPF	Focal Plane Filter assembly
GRA	Grating assembly
GSE	Ground Support Equipment
ICD	Interface Control Document
ICU	Instrument Control Unit

ISAS	Institute of Space and Astronautical Science (Japan)
LOK	Launch Lock
MHC	Mechanisms and Heater Controller
MIR	Mirror assembly
MLI	Multilayer Insulation
MSSL	Mullard Space Science Laboratory
NAOJ	National Astronomy Observatory, Japan
NRL	National Research Laboratory, USA
NS	North South
PROM	Programmable Read Only Memory
PUR	Instrument Purge harness
QCM	Quartz Control Monitor
RAD	Radiator
RAL	Rutherford Appleton Laboratory, U.K.
RAM	Random Access Memory
RD	Reference Document
RMS	Root Mean Square
ROE	Readout Electronics
SHT	Shutter assembly
SLA	Slit assembly
SLB	Solar-B
STR	Spectrometer
S-PUR	Spacecraft purge harness
S-WIR	Spacecraft wiring harness
TBC	To Be Confirmed
TBD	To Be Defined
VAC	Instrument Vacuum harness
IHR	Instrument Internal Wiring harness
WIR	Instrument Wiring harness
XRT	X-Ray Telescope (instrument on Solar-B)

4. INSTRUMENT REQUIREMENTS

4.1 Science Requirements
These are defined in AD1.

4.2 Performance requirements
The performance requirements for EIS are summarized in the following table:

Requirement	Value
Effective Area	0.42 cm^2 @ 270 Å
Wavelength ranges	250 - 290 Å
	170 - 210 Å
Spatial Resolution on sun	2 arc secs
Equivalent Spectral resolution	20 km/s
Systematic measurement error	<1%
Field of View	4 arc minutes
Scan Range	4 x 2 arc minute
Maximum misalignment	+/- 1 arc minute
Observing Modes	
Primary	Slit spectroscopy with line selection
Secondary	Monochromatic imaging
Data Rate	64 kbps max
Data Volume	384 Mbits/orbit
Mass	<63.43 kg
Power	<55.6 Watts
1st Resonance Frequency	>70 Hz

4.3 Interface Requirements
Spacecraft interface details are specified in the EIS ICD (AD 2).

5. SYSTEM BREAKDOWN

A block diagram of the instrument is shown in Appendix A.
A list of the system hardware is shown below and references are made to the system software which will be described in separate documents.

5.1 Flight Equipment

5.1.1 Spectrometer

ENC	Enclosure
BFn	Baffles
LOK	Launch lock
CLM	Clamshell
FFA	Front filter assembly
MIR	Mirror assembly
SLA	Slit assembly
FPF	Focal plane filter assembly
GRA	Grating assembly
SHT	Shutter assembly
CUB	Alignment cube
CAM	Camera
FPA	Focal plane assembly
ROE	Readout electronics
QCM	Quartz control monitor
MHC	Mechanisms and heater controller
IHR	Instrument internal wiring harness
WIR	Instrument external wiring harness
PUR	Instrument purge harness
MLI	Multilayer insulation

5.1.2 Instrument Control Unit

The ICU is sited on the spacecraft bus and interfaces with the MDP on the spacecraft and the ROE and MHC on the Spectrometer.

5.1.3 Spacecraft Harnesses

S-WIR	Spacecraft wiring harness (ICU to spacecraft and ICU to Spectrometer)
S-PUR	Spacecraft purge harness (clean dry nitrogen line for purging the Spectrometer)

5.2 Non-flight hardware

These items may be installed in the instrument during integration and test, but must be removed before launch. Typically they would consist of such things as:

Contamination witness plates
Aperture cover
Test interface connectors
Connector savers

Lifting attachments
Installation jigs
Shims
Alignment mirrors

5.3 Ground Support Equipment (GSE)

The following GSE would be provided:

Purge gas supply
Vacuum pump and accessories
Alignment jigs, light sources, targets etc
Electrical GSE
Quick-look data analysis workstations
Operational data center workstations

5.4 Logistics Elements

For logistical support, the following will be required:

Shipping containers
Support frames
Clean tents
Toolkits
Material supplies

6. SYSTEM DETAILS

6.1 Spectrometer General

EIS consists of a multi-layer coated single mirror telescope, and a stigmatic imaging spectrometer incorporating a multilayer coated diffraction grating. The image produced by the primary mirror is imaged onto an entrance slit/slot and the light which passes through this spectrometer aperture is dispersed and re-imaged in the focal plane of the CCD camera. The spectra will be focused on two CCD detectors.

There are two reflections in the system and the two wavelength bands are:

170-210Å and 250-290Å, as limited by the grating

180-204Å and 250-290Å useful ranges, as limited by the multilayer coatings

6.2 Field of View (FOV)

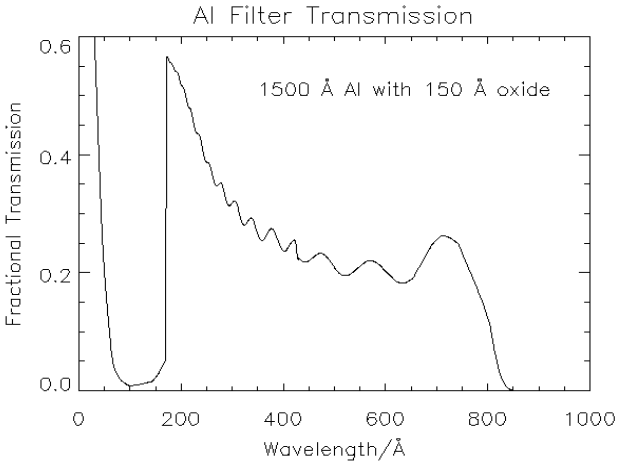
Extent of EW FOV	1840" on sun, given by sum of coarse (±800") and fine telescope positioning (see below)
Max EW scan range, fine only	±120"
Max extent of NS FOV	512" (defined by ROE hardware window)
Spectral scale	0.0223Å per pixel
Spectral resolution	f(wavelength, slit size, field angle) ≈4μm @ 190Å, ≈5μm @ 270Å
Spatial scale	1 arcsec per pixel
Spatial resolution	f(wavelength, slit size, field angle) ≈15μm @ 190Å, ≈11μm @ 270Å
Effective area	see section 7.1
Scattered light	

6.3 Filters

The primary incidence filter is an aluminium foil on a support mesh and fitted into a quadrant frame. The material for the focal plane filter is the same.

Transmission f(wavelength)

Data provided by John Seely (25 Oct 1999), file EIS_FFATrans.001



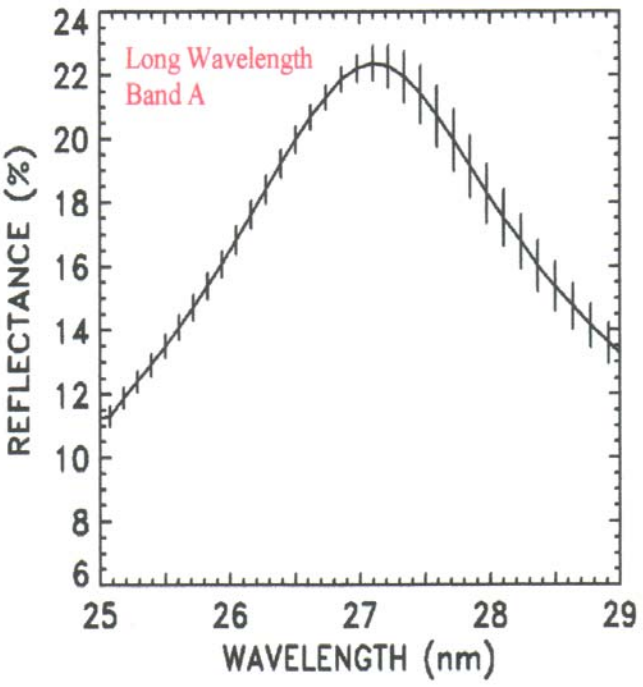
Stray light throughput

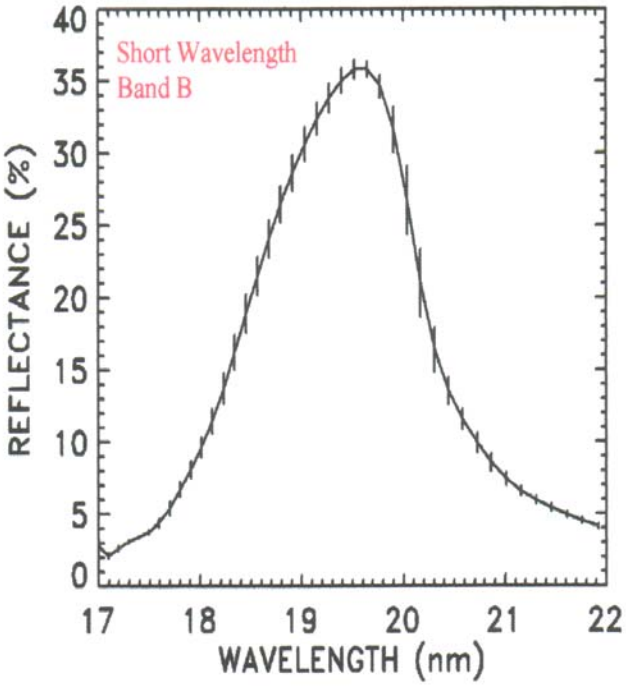
Obscuration

6.4 Telescope Mirror

Type	Off-axis paraboloid
Aperture	15 cm clear
Area	88.4 cm^2 per band
Focal length	1934 mm
Off-axis distance	70 mm
Plate scale at focus (slit)	9.37 microns/arcsec
Multilayer coating	Mo/Si
Number of coats	20
Layer period, short wavelength	105 Å
Layer period, long wavelength	145 Å
Coarse position method	Stepper motor
Range	±800 arcsec solar image motion
Precision	
Repeatability	
Speed	
Fine position method	Piezo electric actuator
Range	±120 arcsec solar image motion
Precision	1/3 arcsec per step
Repeatability	
Speed	

Measured reflectances from M1 mirrors:





6.5 Slits (SLA)

Number	4
Sizes 1	1”
2	2”
3	40”
4	250”
Slit change time	19s to move between positions (90°)
Slit change order	2” ⇒ 40” ⇒ 1” ⇒ 250” ⇒ 2” etc.
Alignment	During integration
Exchange mechanism step size	15 arcmin
Tolerance perpendic. to optical axis	1 micron
Tolerance parallel to optical axis	13 microns

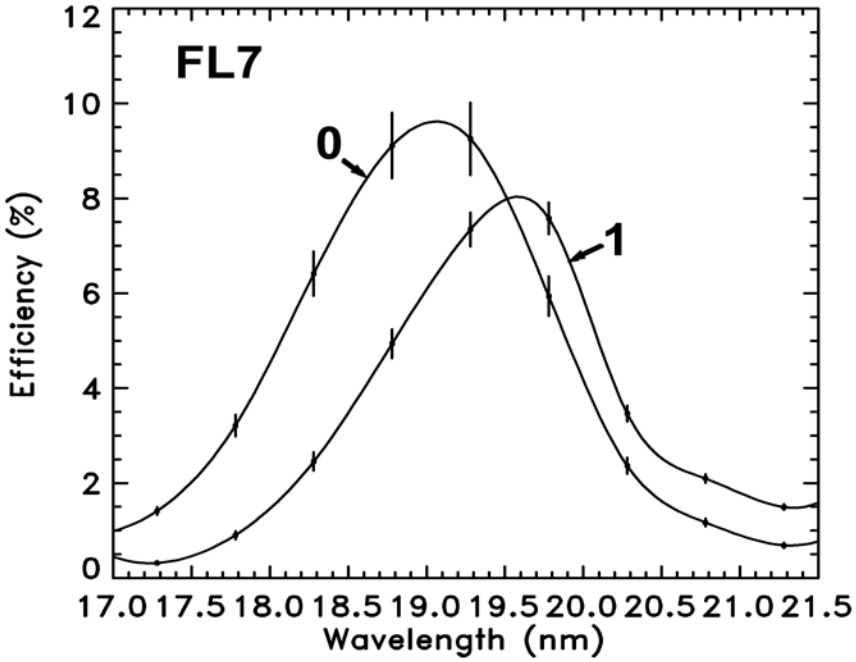
6.6 Shutter (SHT)

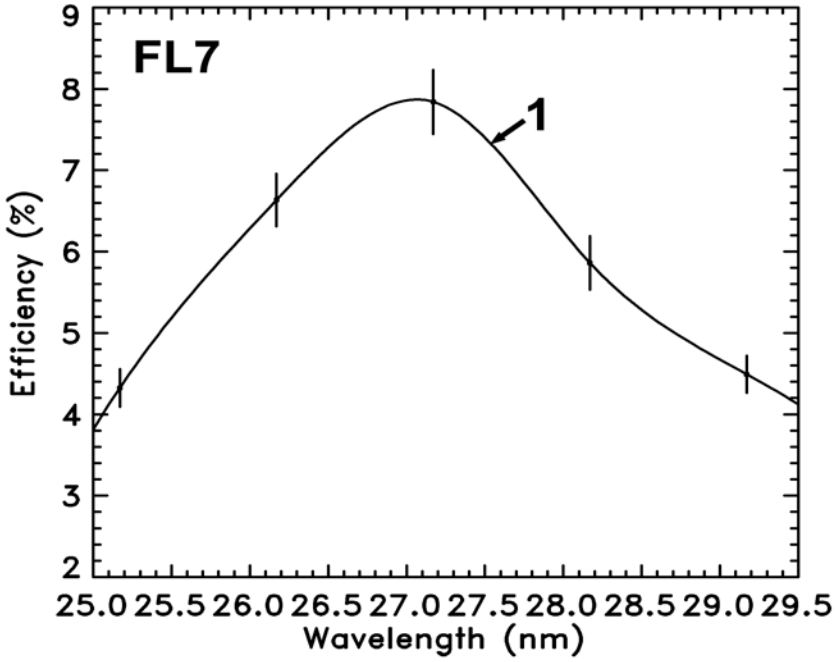
Type	Rotary vane
Position in optical system	Adjacent to slits
Maximum exposure time	655s (2^{16}-1 × 10ms)
Minimum exposure time	50ms
Resolution of exposure time	10ms
Repeatability of exposure time	5% of minimum
Lifetime	$6x10^7$ operations

6.7 Grating (GRA)

Mount	Magnifying
Slit distance	1m
Detector distance	1.4m
Diameter of optic	100mm
Figure	Toroid
Radius in Saggital	1182.940mm
Radius in Tangential	1178.280mm
Substrate surface roughness	5Å RMS
Ruling density	4200 lines/mm
Ruling type	Holographic with straight laminar grooves, uniform line spacing
Groove depth	58Å
Multilayer	Mo/Si
Number of coats	20
Layer period, short wavelength	105Å
Layer period, long wavelength	145Å

Measured efficiencies of the FL7 grating:





6.8 Focal Plane Assembly (FPA)

Number of detectors	2
Detector technology	Back-illuminated CCD
Manufacturer	E2V Technology (Marconi Applied Technology)
Type	CCD-42-20
Format - columns (spectral)	2048
Format - rows (spatial)	1024
Orientation of readout register	Parallel to rows
Image mode	Full frame, not frame transfer
Pixel size	13.5 microns
Minimum read noise	5 electrons
Maximum binned capacity	>500,000 electrons
Full well capacity - image	90,000 electrons
Full well capacity - image	5,000 photons (190Å)
Full well capacity - image	6,570 photons (250Å)
Anti-blooming structures	None
Quantum Efficiency	0.8
Hot pixels	<100
Column defects	0
Operating temperature	-55 C
Position resolution FWHM	16 microns
Dark Current	0.1 electron/pixel @ -55 C
Electrons per photon @ 190Å	18
Electrons per photon @ 250Å	13.7
Shielding	15 mm Al equivalent

6.9 Read-out Electronics (ROE)

Digitisation Level	14 bits
Gain	>5.5 electrons/DN
Number of readout ports	2 per CCD
Read-out time	Variable (but always less than 1 second)
Number of ADC-chains	4
Simultaneous CCD operation	Yes
Output links to ICU	2
Number of windows	2 per CCD
Restrictions of windows	Same height and width on each CCD and symmetrical about centre line.

6.10 Mechanism and Heater controller (MHC)

6.10.1 MHC Hardware

This is described in a separate document

6.10.2 MHC Software

This is described in a separate document

6.11 Instrument Control Unit (ICU)

6.11.1 ICU Hardware

CPU	Temic TSC21020F
CPU speed	20 MHz
Instruction per cycle	1
Instruction word length	48 bits
SEU rate:	
1 PROM - fixed program and boot	LET > 100MeV
2 EEPROM - re-writable program	TBD
3 RAM for running program	SEU immune
4 RAM data memory	SEU = 1.1×10^{-8} error bit^{-1} day^{-1}
5 ACTELS	LET > 43MeV
6 TEMIC	SEU > 50MeV

6.11.2 ICU Software

This is described in a separate document

6.12 EIS Internal Electrical Interfaces

6.12.1 High Speed Link
6.12.2 Control Link

7 System Optical Performance

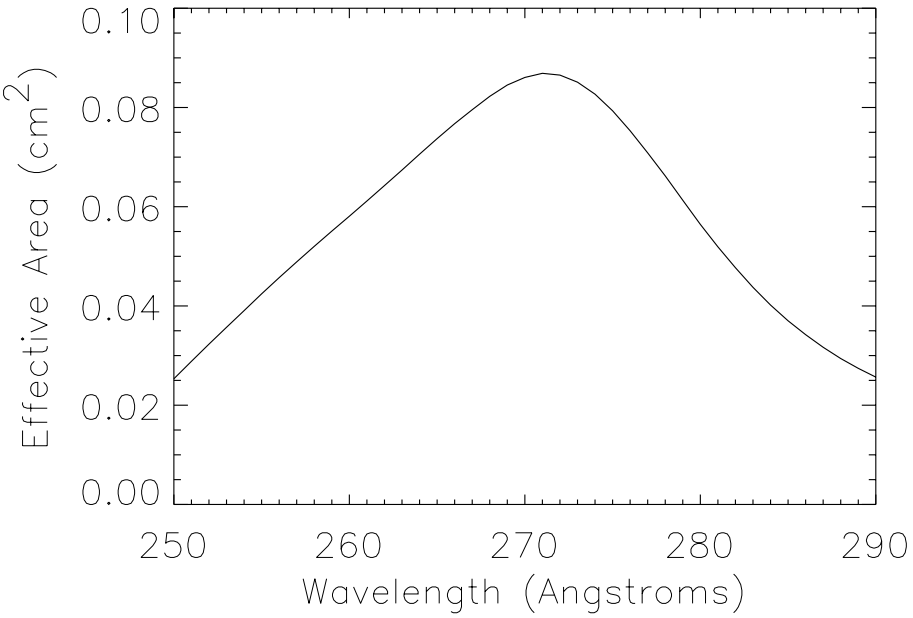
7.1 Effective area curves

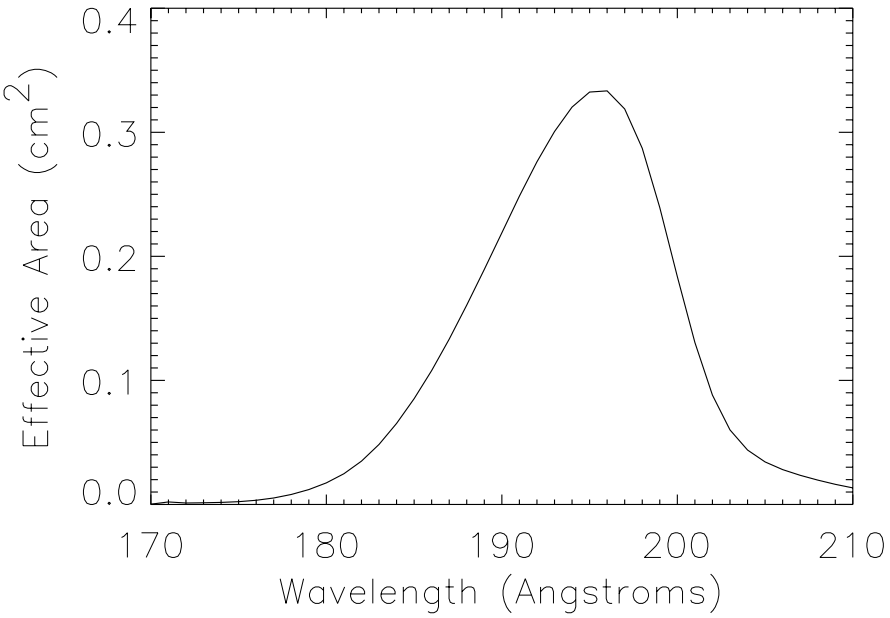
These effective area curves are produced by John Mariska at NRL and a current version maintained in the Solar B EIS branch of the Solarsoft libraries. The plots below are the latest versions but accurate curves should be obtained from the Solarsoft routines.

All data files used to compute the effective area are in the EIS SolarSoft directory $SSW_EIS/response
–All data files are text, with #-delimited comments at beginning
–Read using data = rd_tfile(file, /nocom, /auto, /conv)
–Each data file has a three digit extension—higher numbers are newer, so highest number of each file should be considered current

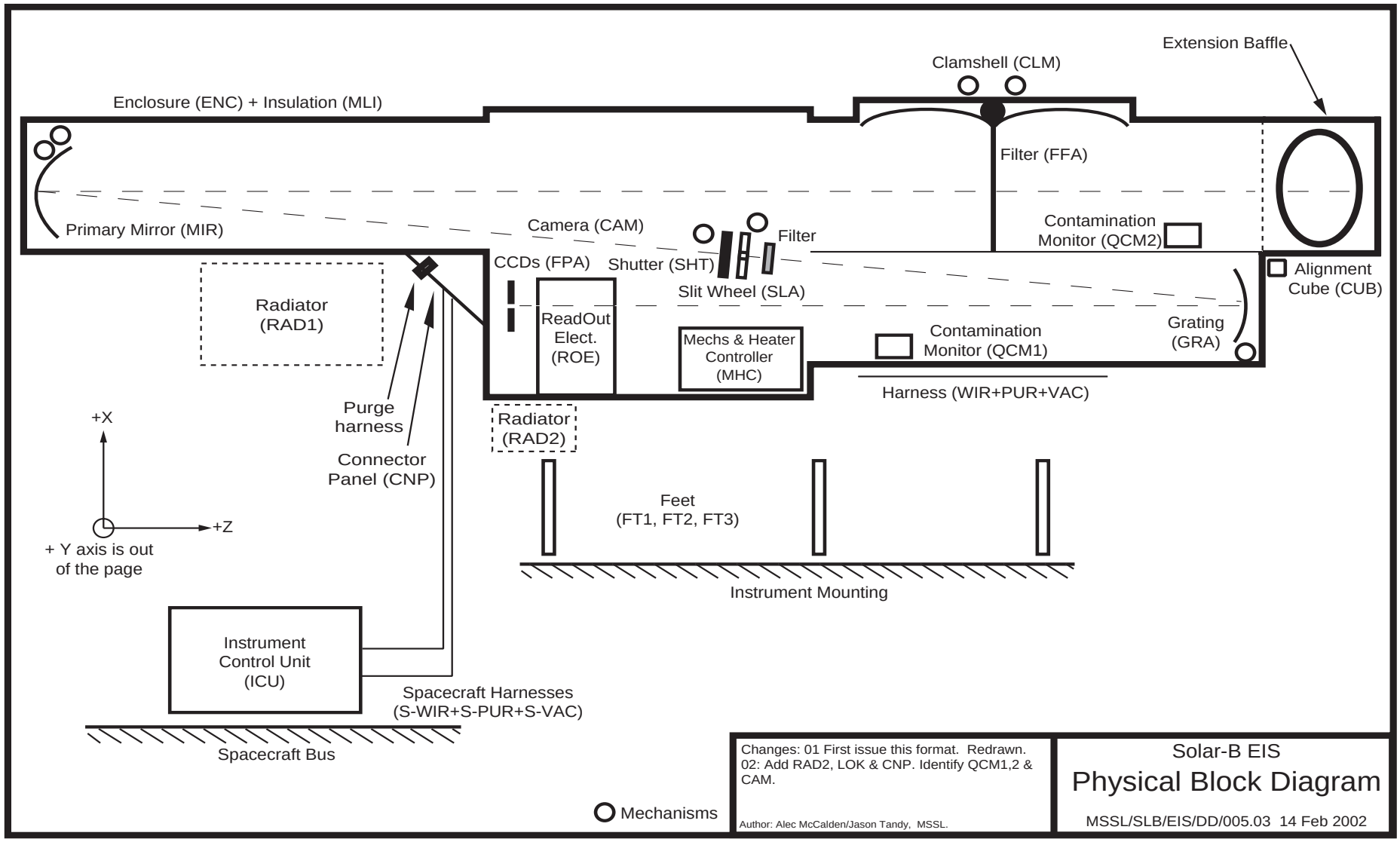
Key files are
–EIS_EffArea_A.001 and EIS_EffArea_B.001
–Procedure for reading effective area files will be placed in $SSW_EIS/idl/cal and will default to taking highest version number of area files
–For now, have not placed procedure for making effective area files into SSW

Effective areas computed using:
–Measured M 1 reflectivities (see section 6.4)
–Measured FL 7 efficiencies (see section 6.7, a combination of reflectivity and groove efficiency)
–Modelled Al filter transmission from John Seely (25 Oct 1999), file EIS_FFATrans.001 (see section 6.3)
–Al filter mesh transmission factor of 0.85
–Spider transmission factor of 0.80
–CCD QE of 0.80
–Mirror area of 0.5*88.4


0.10
0.08
0.06
0.04
0.02
0.00
Effective Area (cm2)
250
260
270
280
290
Wavelength (Angstroms)


0.4
0.3
0.2
0.1
0.0
Effective Area (cm2)
170
180
190
200
210
Wavelength (Angstroms)

Appendix A


Extension Baffle
Clamshell (CLM)
Enclosure (ENC) + Insulation (MLI)
Filter (FFA)
Primary Mirror (MIR)
Camera (CAM)
Filter
Contamination Monitor (QCM2)
CCDs (FPA)
Shutter (SHT)
Alignment Cube (CUB)
Slit Wheel (SLA)
Radiator (RAD1)
ReadOut Elect. (ROE)
Mechs & Heater Controller (MHC)
Contamination Monitor (QCM1)
Grating (GRA)
Harness (WIR+PUR+VAC)
Purge harness
Radiator (RAD2)
+X
Connector Panel (CNP)
+Z
Feet (FT1, FT2, FT3)
+ Y axis is out of the page
Instrument Mounting
Instrument Control Unit (ICU)
Spacecraft Harnesses (S-WIR+S-PUR+S-VAC)
Spacecraft Bus
Mechanisms
Changes: 01 First issue this format. Redrawn.
02: Add RAD2, LOK & CNP. Identify QCM1,2 & CAM.
Author: Alec McCalden/Jason Tandy, MSSL.
Solar-B EIS
Physical Block Diagram
MSSL/SLB/EIS/DD/005.03 14 Feb 2002

Appendix B