**UCL DEPARTMENT OF SPACE AND CLIMATE PHYSICS**
MULLARD SPACE SCIENCE LABORATORY

**Project: Hinode EIS**

# TITLE: EIS post launch regular calibration plan

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## 1 Scope

The purpose of this calibration plan is to detail the calibration activities for EIS during the 90 day science plan and normal operations.
This document describes the data that will be acquired and the analysis tools used for each individual calibration study. This will require a number of different approaches, including obtaining flat field and background data, observing different regions of the Sun using EIS and cross-checking with images from XRT and SOT. All of the calibration studies will be tested (at MSSL, using the flight spare system) prior to being run on orbit.
The calibration studies listed in this plan are primarily based on the studies run during the commissioning phase (COMCAL). Many of these studies are no longer required as calibration studies can now be designed and run through the planning tool (which was not available during the commissioning phase) – these studies have been listed as 'if required'.

## 2 Abbreviations

| | |
|---|---|
| ADC | Analogue to Digital Converter |
| AR | Active Region |
| CCD | Charge-Coupled Device |
| CDS | Coronal Diagnostics Spectrometer |
| COMCAL | Commissioning-Calibration |
| CTE | Charge Transfer Efficiency |
| EIS | Extreme ultraviolet Imaging Spectrometer |
| EUNIS | Extreme Ultraviolet Normal Incidence Spectrometer |
| EUV | Extreme Ultra-Violet |
| FOV | Field Of View |
| GSFC | Goddard Space Flight Centre |
| HLZ | High Latitude Zone |
| IDL | Interactive Data Language |
| ISAS | Institute of Space and Astronautical Science |
| LED | Light Emitting Diode |
| MSSL | Mullard Space Science Laboratory |
| PCA | Polar Cap Absorption |
| PR | Photo response |
| PRNU | Photo response non uniformity |
| PZT | Piezo-electric Transducer |
| QE | Quantum Efficiency |
| QL | Quick-Look (IDL software program) |
| QS | Quiet Sun |
| RAL | Rutherford Appleton Laboratory |
| REGCAL | Regular-Calibration |
| SAA | South Atlantic Anomaly |
| S/C | Spacecraft |
| Si | Silicon |
| SOHO | Solar and Heliospheric Observatory |
| SOT | Solar Optical Telescope |
| TBC | To be confirmed |
| TBD | To be determined |
| Vod | Output drain voltage |
| Vrd | Reset drain voltage |
| Vss | Substrate voltage |
| XRT | X-Ray Telescope |

## 3 Referenced documents

RD1 Wavelength Dispersion Calibration for EIS, C.M. Brown, NRL, 3 August 2006

RD2 EIS Instrument Notes, John Mariska, NRL, Version 0.85, 31 January 2005

RD3 C. M. Brown, various email communications, July/August 2006

RD4 Solar-B EIS Internal Molecular Contamination Analysis, Version 4, Tim Gordon, Swales Aerospace, 28 June 2003

RD5 The radiation damage performance of e2v CCDs (Technical Note), Doc no. S&C 906/424, Issue 1a, 17 February 2000

RD6 Dr Dave Walton, private communication, August 2006

RD7 The EUV Imaging Spectrometer for Solar-B, J.L. Culhane et al (in preparation)

RD8 C. M. Korendyke, email communication, September 2006

## 4 EIS instrument description

The telescope is an off-axis paraboloid with focal length 1.9 m and mirror diameter 15 cm. The two halves of the mirror are coated with multilayers optimised for the wavelength ranges 170-210 Å and 250-290 Å. A toroidal laminar grating, with matching multilayer coatings, disperses the spectrum onto two back-illuminated CCD detectors each covering a 40 Å passband. The optical design sets the 2" angular resolution while the CCD has 1" pixels.

A slit/slot interchange mechanism provides four positions with different slit and slot widths: 1" and 2" slits, 40" and 266" slots. Both slits and slots are 512" in height. The chosen width in the dispersion direction allows emphasis on either spectroscopy or imaging. The best spectral resolution (19 mÅ rms) is achieved using the 1" slit while for studies of lower brightness targets e.g. coronal holes, spectral resolution may be traded for throughput by using the 2" slit. Selection of the 40" wide slot allows imaging in each wavelength range with five strong lines that do not overlap in the dispersion plane. The largest slot - 266" wide, will be used in a sit-and-stare mode to detect transient events. Following detection, the instrument can select a spectroscopy slit under autonomous software control and raster over the brightest region identified in the slot. A raster scan range of 6' in the dispersion direction sets the overall field of view as 6' x 8.5'. In addition there is a coarse motion mechanism that allows the field of view to be offset by up to ± 15' in the E-W direction.

For ≥ 100 photons detected in a line, typically achieved in active region observations of ~ 3 sec duration, the spectral resolution will permit values ≥ 3km/s to be measured for Doppler velocities in active region plasma. Non-thermal or turbulent velocity estimates ≥ 10km/s will be made in similar observation times. Time resolution for spectroscopy, set by the CCD readout, will be 1.2 s for bright transient events. In imaging mode, images of an active region (~ 4' x 8') may be obtained in ~ 3 sec while with the narrower 40" slot, EIS will provide monochromatic images of the transition region and corona at high cadence. High spectral resolution images can be obtained by rastering with a slit in place. EIS will be able to respond autonomously to flare trigger signals from XRT. In addition it will have internal triggers - a flare trigger and a bright point trigger. Exposure duration will be controlled automatically on-board.

The complete EIS instrument is more than 3m in length and weighs 60 kg. Following the SOHO CDS spectrometer, EIS will provide the next steps in EUV spectral imaging of the solar corona and upper transition region. Thus it will have approximately a factor 10 enhancement in effective area due to the use of multilayer coated optics and back-illuminated CCDs. Spectral resolution is improved by a factor 10 in the wavelength ranges being observed which have been chosen to cover a broad range of plasma temperature. The 2" spatial resolution is ~ 50% better than that of the CDS. Although still a rastering instrument, the ability of EIS to image along the slit and to scan more rapidly due to its increased sensitivity will lead to a considerably enhanced performance over that of CDS. Like CDS, the EIS instrument throughput has been absolutely calibrated with a precision of ± 25%.

## 5 The calibration of EIS

Calibration of the EIS instrument is maintained on two different bases. These are:
- *relative* calibration; that may change pre-launch or in-orbit and must be tracked continually to enable effective analysis of EIS data.
- *absolute* or *radiometric* calibration; which was established before launch and will be re-measured during the mission using a NASA rocket-borne spectrometer (EUNIS).

The instrument response is defined by the product of a number of terms that specify filter transmissions, mirror and grating reflection efficiencies and CCD quantum efficiency. Corrections have been applied for the transmission of the front filter support mesh and must be applied for a variation in effective area with coarse motion position due to vignetting by the solid elements of the filter holder and the shutter housing. All of these terms have been measured individually before launch while the product of all such factors has been determined in the end-to-end calibration at RAL. Subsequent to the final RAL calibration, some parameters, particularly the CCD efficiency or the optics reflectivities, may be subject to change either before launch or in orbit due to e.g. contamination, radiation damage. It is therefore essential that any *relative* changes in effective area during the mission be identified quickly and monitored as well as possible by observation of quasi-stable regions on the Sun.

Spectral resolution must be monitored continually as must the on-going performance of the scanning, shutter and slit interchange mechanisms. Operation of the on-board electronics and software will be checked to ensure that sequence run timing and exposure duration continue to respond correctly to commands.

### 5.1 Throughput model maintenance

A model of instrument throughput that includes all the material factors that establish instrument efficiency will be maintained at MSSL. This will be updated throughout the mission. Observations of quiet regions of the Sun will be used to keep track of the instrument's *relative* calibration.

### 5.2 CCD performance checking

During commissioning, understanding CCD Camera operation will require obtaining flat field and background data around the orbit along with calibration data from quiet Sun observing sequences. Continuing calibration measurements will be needed to establish the level of any contamination and to allow a CCD bake-out schedule to be developed should it be found necessary. Maintenance of the relative calibration will require the use of specially designed observing sequences for quiet Sun, active region and coronal hole studies. Evaluation of any long-term emerging blemishes on the CCDs and their corrective removal will almost certainly be necessary during the mission. Any developing visible light leaks will require specific observations and the ongoing deployment of corrective algorithms.

### 5.3 Spectral Calibration

The spectral response of EIS, e.g. wavelength scale, resolution and dispersion, will be tracked throughout the mission by periodic spectral atlas observations. It will be particularly important to identify emission lines from coronal plasma at rest so that a reliable velocity scale may be established. Validated spectral response data for EIS will be used periodically to update the instrument calibration files and will be made available to RAL to assist with the second part of their radiometric calibration task.

### 5.4 Pointing and Alignment Calibration

Maintaining knowledge of the relative alignment of EIS with the spacecraft and with the other instruments is of the utmost importance for a successful scientific outcome of the mission. EIS pointing information will therefore be tracked throughout the mission and any trends identified and measured. Alignment with the spacecraft boresight and with the other two instrument axes will be periodically measured. This will be especially necessary during and following the eclipse seasons when alignments are likely to be affected by thermally induced changes. Where possible, it will be important to compare the results of EIS observations with those of XRT and SOT. Observations of coronal structures with both EIS and XRT will be compared to check the plasma differential emission measure as distributions that are deduced from both sets of data. This will allow on-going comparison of the relative instrument calibrations. While EIS and SOT will be unable to directly detect the same coronal features, their limb and chromospheric network detections will also be compared. The data to be handled will include correlation of EIS coronal line rasters with XRT filtergrams and correlation of EIS He rasters with XRT G filter and SOT G filter observations. The work will require the design and execution of special observing sequences and the implementation of specific spacecraft orientations e.g. towards the solar limb. EIS will also drift somewhat between the acquisition of these pointing data sets. The various components of the drift need to be isolated and understood and if possible removed from the raster data sets. A standard set of algorithms will be developed for this.

### 5.5 Radiometric Calibration

The end-to-end calibration of EIS was completed in August, 2004. It was carried out on an *absolute* or *radiometric* basis using a standard source that had in turn been calibrated at the BESSY I synchrotron in Berlin. The instrument was then shipped to ISAS in Japan for integration with the spacecraft. Thus it has spent approximately two years at ISAS before being taken to Kagoshima for the launch campaign (launched 23 September 2006). Although strict measures are in force to avoid contamination, the instrument and the spacecraft will have been subjected to a range of different environments before and during launch. It is therefore planned to verify the instrument's *radiometric* calibration during the mission with data obtained simultaneously with EIS by the GSFC EUNIS sounding rocket spectrometer. To be flown in the period 2007/08, the rocket instrument, which will itself have been radiometrically calibrated at RAL using the same standard source, will observe an agreed range of solar features simultaneously with EIS.
(EUNIS successfully flown on 6 November 2007)

The on-going monitoring of the radiometric calibration will be performed using EIS observations. This is achieved by using branching ratios and electron density and temperature insensitive line ratios. Also, inter-calibration of EIS with SOHO CDS by making joint observations will be done, in addition to the EUNIS work.

### 5.6 CCD Bake-out

Although exceptional precautions have been taken to avoid contamination of the EIS instrument, contaminants are expected to emerge as the spacecraft outgases. The CCD front surface, which will run at colder than -50$^{o}$C (predicted temperature, actual on-orbit temperatures are higher, so far a range of -36$^{o}$C to -50$^{o}$C has been measured), is the most vulnerable part of the EIS response chain. For this reason the CCD has been equipped with bake-out heaters. Previous experience of CCD operation in missions such as Yohkoh suggests that a monthly bake-out cycle may be required. It will therefore be necessary to prepare commands for and monitor CCD bake-out operations, partly in real-time through the Kagoshima ground station. Following bake-out, changes in response to solar emission will need to be verified and a modified bake-out schedule devised should this be necessary.
*As of 20 May 2008 no CCD bake-out has been required. The instrument throughput is being monitored by a synoptic study which will indicate when a CCD bake-out is required, along with QCM measurements which are taken weekly. Data from flat field images (using the EIS LEDs) are also plotted to monitor any degradation in the intensity levels observed on the CCDs.

## 6 Calibration during the 90 day science plan and normal operations

The table below lists the calibration activities to be performed during the 90 day science plan and normal operations. Each activity has been assigned a unique study id, e.g. REGCAL000. This table provides a description of each calibration study and how often it will be run (this may change over the course of the mission as instrument characteristics are better understood).
The REGCAL studies highlighted in yellow are run on a routine basis, the remainder are 'if required' as most of these studies are now included in science studies (using the planning tool).

| Study id | Test description | Pointing | Slit/slot | Shutter exp times (seconds) | Frequency |
|---|---|---|---|---|---|
| REGCAL000 | Wavelength calibration Observe full spectral scans – compare with ground calibration | QS | 1" slit | 10, 20, 40, 80, 160, 600 | If required |
| REGCAL001 | Wavelength calibration – bottom half of CCD | QS | 1" slit | 10, 20, 40, 80, 160, 600 | If required |
| REGCAL002 | Wavelength calibration – top half of CCD | QS | 1" slit | 10, 20, 40, 80, 160, 600 | If required |
| REGCAL003 | Wavelength calibration | QS | 2" slit | 10, 20, 40, 80, 160, 600 | If required |
| REGCAL004 | Wavelength calibration | QS | 40" slot | 10, 20, 40, 80, 160, 600 | If required |
| REGCAL005 | Wavelength calibration | QS | 266" slot | 10, 20, 40, 80, 160, 600 | If required |
| REGCAL006 | Wavelength calibration | AR | 1" slit | 0.25, 0.5, 1, 2, 4, 8, 16 | If required |
| REGCAL007 | Wavelength calibration | AR | 2" slit | 0.25, 0.5, 1, 2, 4, 8, 16 | If required |
| REGCAL008 | Wavelength calibration | AR | 40" slot | 0.25, 0.5, 1, 2, 4, 8, 16 | If required |
| REGCAL009 | Wavelength calibration | AR | 266" slot | 0.25, 0.5, 1, 2, 4, 8, 16 | If required |
| REGCAL010 | Wavelength calibration | AR | 1" slit | 32, 64, 128 | If required |
| REGCAL011 | Wavelength calibration | AR | 2" slit | 32, 64, 128 | If required |
| REGCAL012 | Wavelength calibration | AR | 40" slit | 32, 64, 128 | If required |
| REGCAL013 | Wavelength calibration | AR | 266" slit | 32, 64, 128 | If required |
| REGCAL014 | ADC offset | N/A - shutter closed | N/A | 0 | If required |
| REGCAL015 | CCD dark current, hot pixels and column defects | N/A - shutter closed | N/A | 1,1, 10, 10, 30, 30, 60, 60 | If required |
| REGCAL016 | CCD dark current, hot pixels and column defects | N/A - shutter closed | N/A | 100, 100, 150, 150, 300, 300, 600, 600 | If required |

| **Study id** | **Test description** | **Pointing** | **Slit/slot** | **Shutter exp times (seconds)** | **Frequency** |
|---|---|---|---|---|---|
| REGCAL017 | Flat-fields using EIS LEDs<br>To determine detector characteristics | N/A – uses the EIS LEDs | N/A | 1<br><br>(LED on times: 0, 0, 10, 10, 20, 20, 40, 40ms) | If required |
| REGCAL018 | Flat-fields using EIS LEDs<br>To determine detector characteristics | N/A – uses the EIS LEDs | N/A | 1<br><br>(LED on times: 60, 60, 80, 80, 100, 100, 120, 120ms) | If required |
| REGCAL019 | Intensity calibration<br>Near Sun centre QS observations to determine detector efficiency – compare with ground calibration | Quiet Sun | 1” slit | 100 | If required (superseded by synoptic study) |
| REGCAL020 | Pointing and alignment – take simultaneous limb observations with the 3 instruments and also measure EIS’ co-alignment with the S/C boresight. | East limb<br>+<br>North Pole | 266” slot | 20, 120 and 200 for the first 3 orbits. For the 4th orbit 20 sec exposures 1 minute cadence | If required (superseded by synoptic study) |
| REGCAL022 | Pointing and alignment | Active region | 266” slot | 20, 120 and 200 for the first 3 orbits. For the 4th orbit 20 sec exposures 1 minute cadence | If required (superseded by synoptic study) |
| REGCAL032 | Stray light<br>Test for bright source off axis contamination | North pole | 2” slit | 10, 20, 40, 80 and 160 | If required |
| REGCAL033 | Stray light<br>Test for bright source off axis contamination | North pole | 40” slot | 10, 20, 40, 80 and 160 | If required |
| REGCAL034 | Stray light<br>Test for bright source off axis contamination | West limb | 2” slit raster | 10, 20, 40, 80 and 160 | If required |
| REGCAL035 | Cosmic rays<br>Determine the frequency of these throughout the orbit | N/A | N/A | Use dark current exposures (REGCAL015 and REGCAL016) | N/A |
| REGCAL036 | Slit/slot studies<br>(to help determine how line widths change with slit/slot selection, repeatability and how position varies over orbit) | QS | 1” slit raster | 200 | If required (now included in science studies) |
| REGCAL037 | Slit/slot studies | QS | 2” slit raster | 200 | If required (now included in science studies) |

| Study id | Test description | Pointing | Slit/slot | Shutter exp times (seconds) | Frequency |
|---|---|---|---|---|---|
| REGCAL038 | Slit/slot studies | AR | 1” slit raster | 20, 120 | If required (now included in science studies) |
| REGCAL039 | Slit/slot studies | AR | 2” slit raster | 20, 120 | If required (now included in science studies) |
| REGCAL040 | Slit/slot studies | QS | 40” slot | 200 (centre of EIS FOV) | If required (now included in science studies) |
| REGCAL041 | Slit/slot studies | QS | 40” slot | 200 (position +180” within the EIS FOV) | If required (now included in science studies) |
| REGCAL042 | Slit/slot studies | QS | 40” slot | 200 (position -180” within the EIS FOV) | If required (now included in science studies) |
| REGCAL043 | Slit/slot studies | QS | 266” slot | 200 (centre of EIS FOV) | If required (now included in science studies) |
| REGCAL044 | Slit/slot studies | QS | 266” slot | 200 (position +180” within the EIS FOV) | If required (now included in science studies) |
| REGCAL045 | Slit/slot studies | QS | 266” slot | 200 (position -180” within the EIS FOV) | If required (now included in science studies) |
| REGCAL046 | Slit/slot studies | AR | 40” slot | 20, 120 (centre of EIS FOV) | If required (now included in science studies) |
| REGCAL047 | Slit/slot studies | AR | 40” slot | 20, 120 (position +180” within the EIS FOV) | If required (now included in science studies) |
| REGCAL048 | Slit/slot studies | AR | 40” slot | 20, 120 (position -180” within the EIS FOV) | If required (now included in science studies) |
| REGCAL049 | Slit/slot studies | AR | 266” slot | 20, 120 (centre of EIS FOV) | If required (now included in science studies) |
| REGCAL050 | Slit/slot studies | AR | 266” slot | 20, 120 (position +180” within the EIS FOV) | If required (now included in science studies) |
| REGCAL051 | Slit/slot studies | AR | 266” slot | 20, 120 (position -180” within the EIS FOV) | If required (now included in science studies) |
| REGCAL052 | Optical verification (to determine any changes to the optical set-up) | N/A | N/A | Use wavelength calibration observations | If required (now included in science studies) |

| **Study id** | **Test description** | **Pointing** | **Slit/slot** | **Shutter exp times (seconds)** | **Frequency** |
|---|---|---|---|---|---|
| REGCAL053 | CCD bake-out (to remove any molecular contamination) | N/A | N/A | N/A | If required |
| REGCAL054 | CCD bake-out efficiency test Two exposures taken before and after bake-out to determine any changes to the image quality | QS | 266” | 50 | Before and after all CCD bake-outs |
| REGCAL055 | CCD flush test To determine the amount of CCD flushes required before an exposure | N/A - uses the EIS LEDs | N/A | 0 | If required |
| REGCAL056 | Grating movement (to determine best focus) | AR | All | 3, 100 | If required |
| REGCAL057 | PZT/fine mirror motion Calibrate PZT motion nonlinearity, direction and reproducibility | North pole | 266” slot raster over full range | 120, 200 | If required |
| REGCAL058 | Coarse mirror Calibrate coarse mirror motion step size, hysteresis and direction sequence | East limb | 266” slot | 120, 200 | If required |
| REGCAL059 | Software window and compression settings | QS | 1” slit | 10, 20, 40, 80, 160 | If required |
| REGCAL060 | Software window and compression settings | QS | 2” slit | 10, 20, 40, 80, 160 | If required |
| REGCAL061 | Software window and compression settings | QS | 40” slot | 10, 20, 40, 80, 160 | If required |
| REGCAL062 | Software window and compression settings | QS | 266” slot | 10, 20, 40, 80, 160 | If required |
| REGCAL063 | Software window and compression settings | AR | 1” slit | 10, 20, 40, 80, 160 | If required |
| REGCAL064 | Software window and compression settings | AR | 2” slit | 10, 20, 40, 80, 160 | If required |
| REGCAL065 | Software window and compression settings | AR | 40” slot | 10, 20, 40, 80, 160 | If required |
| REGCAL066 | Software window and compression settings | AR | 266” slot | 10, 20, 40, 80, 160 | If required |
| REGCAL067 | EUV flat field with moving slot image | QS | 40” + 266” slots | 120, raster | After all CCD bake-outs or at least once a month |
| REGCAL068 | EUV flat field with moving slot image | AR | 40” + 266” slots | 20, raster | After all CCD bake-outs or at least once a month |
| REGCAL069 | Co-alignment of EIS with FPP FOV | East limb | 266” slot | 120, 200 | If required (now included in science studies) |

| Study id | Test description | Pointing | Slit/slot | Shutter exp times (seconds) | Frequency |
|---|---|---|---|---|---|
| REGCAL070 | Flat field including overscan pixels (2 exposures) | N/A - uses the EIS LEDs | N/A | 1<br><br>(LED on time 100ms) | Once a month |
| REGCAL071 | Two dark exposures, bottom rows of CCDs | N/A – shutter is closed | N/A | 100 | Once a week |
| REGCAL072 | Two dark exposures, top rows of CCDs | N/A – shutter is closed | N/A | 100 | Once a week |
| REGCAL073 | CCD dark current, hot pixels and column defects | N/A - shutter closed | N/A | 100, 100, 150, 150 | If required |
| REGCAL074 | Two dark exposures including prescan pixels | N/A - shutter closed | N/A | 100 | When required |
| REGCAL075 | 0 and 100 second dark exposures | N/A - shutter closed | N/A | 0, 0, 100, 100 | Replaced by REGCAL071, 072, 078 and 079 (full CCD height studies) |
| REGCAL076 | Flat field using EIS LEDs (CCD left windows only, 1 exp) | N/A - shutter closed | N/A | 1<br><br>(LED on time 100ms) | Once a month |
| REGCAL077 | Flat field using EIS LEDs (full CCD readout, 2 exps) | N/A - shutter closed | N/A | 1<br><br>(LED on time 80ms) | Once a month |
| REGCAL078 | Two dark exposures, bottom rows of CCDs | N/A - shutter closed | N/A | 0 | Once every 3 months |
| REGCAL079 | Two dark exposures, top rows of CCDs | N/A - shutter closed | N/A | 0 | Once every 3 months |

Table 1: Summary of regular calibration (REGCAL) studies

Unless otherwise noted the PZT and coarse mirror will set to the nominal position for all REGCAL studies. The REGCAL studies will use the hardware window position as defined during the commissioning calibration. The REGCAL studies will use the Quiet Sun and Active Region line lists as defined in Appendix 1 and 2.

The following section gives further details regarding the REGCAL studies listed in the previous table:

**REGCAL000**

*Wavelength calibration*
Quiet Sun and Active Region full spectral scan observations will be made at all of the slit/slot positions. Due to software limitations these observations will be split into fourteen studies (REGCAL000 to REGCAL013). This study (REGCAL000) will take full CCD exposures (using the 'best' 512 rows of the CCDs as defined during COMCAL) of the **QS** using the **1" slit** at exposure times of 10, 20, 40, 80, 160 and 600 seconds. This data will be compared with ground calibration. These studies will be run three or four times consecutively so that data is obtained throughout a complete orbit.
The data will be analysed using IDL, G-fit and MS Excel software. Results will be compared to those obtained from the wavelength calibration performed at RAL (see RD1).
The data obtained from the wavelength calibration studies (REGCAL000 to REGCAL013) will also be used to characterise nominal count rates and shutter transfer curve, identify any vignetting or particles and verify the spatial and spectral resolution.

**REGCAL001**

*Wavelength calibration*
This study will take a full CCD exposure (using the bottom 512 rows of the CCDs) of the **QS** using the **1" slit** at exposure times of 10, 20, 40, 80, 160 and 600 seconds.
This study will only be run if required as the hardware window position will have been defined during COMCAL and should not change.

**REGCAL002**

*Wavelength calibration*
This study will take a full CCD exposure (using the top 512 rows of the CCDs) of the **QS** using the **1" slit** at exposure times of 10, 20, 40, 80, 160 and 600 seconds.
This study will only be run if required as the hardware window position will have been defined during COMCAL and should not change.

**REGCAL003**

*Wavelength calibration*
This study will take a full CCD exposure of the **QS** using the **2" slit** at exposure times of 10, 20, 40, 80, 160 and 600 seconds.

**REGCAL004**

*Wavelength calibration*
This study will take a full CCD exposure of the **QS** using the **40" slot** at exposure times of 10, 20, 40, 80, 160 and 600 seconds.

**REGCAL005**

*Wavelength calibration*
This study will take a full CCD exposure of the **QS** using the **266" slot** at exposure times of 10, 20, 40, 80, 160 and 600 seconds.

**REGCAL006**

*Wavelength calibration*
This study will take a full CCD exposure pointing at an **active region** using the **1" slit** at exposure times of 0.25, 0.5, 1, 2, 4, 8 and 16 seconds.

**REGCAL007**

*Wavelength calibration*
This study will take a full CCD exposure pointing at an **active region** using the **2” slit** at exposure times of 0.25, 0.5, 1, 2, 4, 8 and 16 seconds.

**REGCAL008**

*Wavelength calibration*
This study will take a full CCD exposure pointing at an **active region** using the **40” slot** at exposure times of 0.25, 0.5, 1, 2, 4, 8 and 16 seconds.

**REGCAL009**

*Wavelength calibration*
This study will take a full CCD exposure pointing at an **active region** using the **266” slot** at exposure times of 0.25, 0.5, 1, 2, 4, 8 and 16 seconds.

**REGCAL010**

*Wavelength calibration*
This study will take a full CCD exposure pointing at an **active region** using the **1” slit** at exposure times of 32, 64 and 128 seconds.

**REGCAL011**

*Wavelength calibration*
This study will take a full CCD exposure pointing at an **active region** using the **2” slit** at exposure times of 32, 64 and 128 seconds.

**REGCAL012**

*Wavelength calibration*
This study will take a full CCD exposure pointing at an **active region** using the **40” slot** at exposure times of 32, 64 and 128 seconds.

**REGCAL013**

*Wavelength calibration*
This study will take a full CCD exposure pointing at an **active region** using the **266” slot** at exposure times of 32, 64 and 128 seconds.

**REGCAL014**

*ADC offset*
A zero second full CCD exposure with the shutter closed will be acquired to determine the ADC offset.
The data will be analysed using QL and IDL software.
*Please note that this study has been replaced by REGCAL074 which takes two dark exposures including the overscan pixels. Using the overscan pixels will allow a more accurate ADC offset value to be measured (13 June 2007).

**REGCAL015**

*Dark current, hot pixels and column defects*
The dark current level will be measured by acquiring full CCD exposures with 1, 10, 30, 60, 100, 150, 300 and 600 seconds integration times with the shutter closed. These integration times have been chosen to reflect a typical range of science observations, the maximum exposure time being 10 minutes. To eliminate cosmic rays two frames will be recorded at each integration time. These will be compared pixel-by-pixel and the lowest value used in each case. As two frames are required at each integration time this study will be split into two as software limits 8 integration times per study. This study (REGCAL015) will acquire the following exposures: 1, 1, 10, 10, 30, 30, 60 and 60 seconds.
The data will be analysed using IDL programs eis_fit.pro and eis_dkm.pro.

**REGCAL016**

*Dark current, hot pixels and column defects*
Following on from REGCAL015 this study will acquire full CCD dark exposures with the following integration times: 100, 100, 150, 150, 300, 300, 600 and 600 seconds.

**REGCAL017**

*Flat-fields*
Data will be taken at various EIS LED on times (Off, 10, 20, 40, 60, 80, 100 and 120ms) and full CCD exposures acquired. Two frames are required at each LED on time to allow for pixel-by-pixel comparison. This study will be split into two due to software limitations (8 exposures per study).The first exposures in this study will be two dark frames (LED off, shutter closed, 1 second exposure) followed by 1 second CCD exposures with LED on times of 10, 10, 20, 20, 40 and 40ms.

**REGCAL018**

*Flat-fields*
Following on from REGCAL017 this study will acquire 1 second full CCD exposures with LED on times of 60, 60, 80, 80, 100, 100, 120 and120ms.

Flat field data will be used to measure detector responsivity/gain, linearity and full well:

- Responsivity/gain analysis will be performed using IDL program eis_ltc.pro.
- Linearity analysis will be performed using IDL program eis_lin.pro.
- Full well analysis will be performed using IDL program eis_wel.pro.
  The initial full well measurement will indicate whether ADC full scale is reached before CCD full well (if ADC full scale is reached first then the CCD full well measurement cannot be made).
- Flat field data will also be used to identify dark pixels and to show the variation in PRNU (Photo Response Non Uniformity). Analysis will be performed using IDL program eis_prm.pro.

**REGCAL019**

*Intensity calibration*
A near Sun centre QS observation will be acquired to determine detector efficiency.
A full CCD exposure will be acquired using the 1” slit with an integration time of 100 seconds.

**REGCAL020**

*Pointing and alignment*
With the 266” slot in place point to the east limb and acquire 20, 120 and 200 second exposures continuously throughout three orbits. For the fourth orbit acquire 20 second exposures at one minute cadence. Look for systemic variations, deconvolve instrument from spacecraft and compare to XRT and SOT data. Observe the QS line list (includes core line list) – see Appendix 2.
Repeat this study with a North Pole pointing.

**REGCAL022**

*Pointing and alignment*
As REGCAL020 but use an AR pointing and observe the AR line list (includes the core line list) – see Appendix 1.

**REGCAL032**

*Stray light*
EIS off limb stray light measurements
Point observatory to the north pole, install the 2" slit and take exposure sequence 10, 20, 40, 80 and 160 seconds. Repeat this 3 times.
Observe the QS line list (includes core line list) – see Appendix 2.

**REGCAL033**

*Stray light*
As REGCAL032 above but use the 40" slot, take same exposure sequence.

**REGCAL034**

*Stray light*
Point observatory to west limb, install the 2" slit and acquire a raster with step positions of 10, 20, 30, 40, 60, 80, 100, 120 and 140 above the limb. Take exposure sequence (10, 20, 40, 80 and 160 seconds) 3 times at each raster position. The starting position for the raster is the limb which should be near the spacecraft pointing position.
Observe the QS line list (includes core line list) – see Appendix 2.

**REGCAL035**

*Cosmic rays*
These will be monitored by using dark exposures made at various positions throughout the orbit. Full frame, long (e.g. 600 seconds, to improve cosmic ray statistics) exposures will be acquired, as many as the data rate will allow (dark exposures from REGCAL015 and REGCAL016 will be used, integration times of 1, 10, 30, 60, 100, 150, 300 and 600 seconds).
The analysis will involve using QL and IDL software programs.
Area of particular interest will be the SAA and PCA.

**REGCAL036**

*Slit/slots*
This study will determine how line widths change with slit/slot selection, their repeatability and how position varies over orbit. For this study (REGCAL036) a **QS raster** will be acquired scanning the **1" slit** at positions -20, -15, -10, -5, 0, +5, +10, +15, +20, +180 and -180" across the EIS FOV. 200 second exposures will be acquired at each position. This will be repeated using all slit/slots and for both QS and an AR (near the centre of EIS FOV) - see following studies. This study will be run as many times as possible throughout the orbit to determine orbital variations (care will be taken when planning to avoid the HLZ and SAA).
This study will observe the QS line list (includes core line list) – see Appendix 2.

**REGCAL037**

*Slit/slots*
This study will acquire a **QS raster** scanning the 2**" slit** at positions -20, -15, -10, -5, 0, +5, +10, +15 +20, +180 and -180" across the EIS FOV. 200 second exposures will be acquired at each position.
Observe the QS line list (includes core line list) – see Appendix 2.

**REGCAL038**

*Slit/slots*
This study will acquire an **AR raster** scanning the 1**” slit** at positions -20, -15 -10, -5, 0, +5, +10, +15 +20, +180 and -180” across the EIS FOV. 20 and 120 second exposures will be acquired at each position.
Observe the AR line list (includes the core line list) – see Appendix 1.

**REGCAL039**

*Slit/slots*
This study will acquire an **AR raster** scanning the 2**” slit** at positions -20, -15, -10, -5, 0, +5, +10, +15 +20, +180 and -180” across the EIS FOV. 20 and 120 second exposures will be acquired at each position.
Observe the AR line list (includes the core line list) – see Appendix 1.

**REGCAL040**

*Slit/slots*
This study will acquire two **QS exposures** using the **40” slot** with exposure times of 200 seconds, pointing at the **centre** of the EIS FOV.
Observe the QS line list (includes core line list) – see Appendix 2.

**REGCAL041**

*Slit/slots*
This study will acquire two **QS exposures** using the **40” slot** with exposure times of 200 seconds, pointing at position **+180”** within the EIS FOV.
Observe the QS line list (includes core line list) – see Appendix 2.

**REGCAL042**

*Slit/slots*
This study will acquire two **QS exposures** using the **40” slot** with exposure times of 200 seconds, pointing at position **-180”** within the EIS FOV.
Observe the QS line list (includes core line list) – see Appendix 2.

**REGCAL043**

*Slit/slots*
This study will acquire two **QS exposures** using the **266” slot** with exposure times of 200 seconds, pointing at the **centre** of the EIS FOV.
Observe the QS line list (includes core line list) – see Appendix 2.

**REGCAL044**

*Slit/slots*
This study will acquire two **QS exposures** using the **266” slot** with exposure times of 200 seconds, pointing at position **+180”** within the EIS FOV.
Observe the QS line list (includes core line list) – see Appendix 2.

**REGCAL045**

*Slit/slots*
This study will acquire two **QS exposures** using the **266” slot** with exposure times of 200 seconds, pointing at position **-180”** within the EIS FOV.
Observe the QS line list (includes core line list) – see Appendix 2.

**REGCAL046**

*Slit/slots*
This study will acquire two **AR exposures** using the **40” slot** with exposure times of 20 and 120 seconds, pointing at the **centre** of the EIS FOV.
Observe the AR line list (includes the core line list) – see Appendix 1.

**REGCAL047**

*Slit/slots*
This study will acquire two **AR exposures** using the **40” slot** with exposure times of 20 and 120 seconds, pointing at position **+180”** within the EIS FOV.
Observe the AR line list (includes the core line list) – see Appendix 1.

**REGCAL048**

*Slit/slots*
This study will acquire two **AR exposures** using the **40” slot** with exposure times of 20 and 120 seconds, pointing at position **-180”** within the EIS FOV.
Observe the AR line list (includes the core line list) – see Appendix 1.

**REGCAL049**

*Slit/slots*
This study will acquire two **AR exposures** using the **266” slot** with exposure times of 20 and 120 seconds, pointing at the **centre** of the EIS FOV.
Observe the AR line list (includes the core line list) – see Appendix 1.

**REGCAL050**

*Slit/slots*
This study will acquire two **AR exposures** using the **266” slot** with exposure times of 20 and 120 seconds, pointing at position **+180”** within the EIS FOV.
Observe the AR line list (includes the core line list) – see Appendix 1.

**REGCAL051**

*Slit/slots*
This study will acquire two **AR exposures** using the **266” slot** with exposure times of 20 and 120 seconds, pointing at position **-180”** within the EIS FOV.
Observe the AR line list (includes the core line list) – see Appendix 1.

**REGCAL052**

*Optical verification*
These studies will be performed to determine any changes to the optical set-up.
The full spectral scan observations acquired for wavelength calibration (REGCAL000 to REGCAL013) will be used.

The parameters to be verified are:

1. Slit tilt
2. Slit curvature
3. Dispersion
4. Plate scale
5. Magnification vs Wavelength

- *Slit tilt*
  Slit tilt has been detailed in a J.T. Mariska report (RD2) where results from the ground calibration have shown the tilt to be of the order of approximately one pixel in 200 rows.
- *Slit curvature*
  Analysis performed on the ground calibration data has shown this to be virtually none. The ray trace shows it to be ~0.04 pixel (RD3).
- *Dispersion*
  The linear term is expected to remain the same after launch, but a slight change in $\lambda_0$ is expected ($\lambda_0$ is defined as the wavelength at the edge of column zero for each detector). This change is anticipated since the grating and detectors might move slightly due to launch vibrations. $\lambda_0$ will change slightly as the change is made from the 1" to 2" slit since the slits could not be placed in exactly the same location within the SLA (RD1)
  $\lambda_0$ will also change slightly with N-S location on the detector since the slit is slightly tilted with respect to the CCD columns (see slit tilt above)
- *Plate scale*
  The plate scale at the slit is 1 arc sec/pixel (as measured from the optical model, RD3).
- *Magnification vs Wavelength*
  This is estimated to be ~0.03% (as designed, RD3).

**REGCAL053**

*CCD bake-out*
A CCD bake-out will be performed only when absolutely necessary. Since launch a CCD bake-out has not been required, this will be reviewed after the 90 day science plan.

Directly before and after every CCD bake-out the following studies will be performed:
1. Acquire two exposures of a stable part of the Sun, see REGCAL054 below.
2. Dark exposures (use REGCAL015 and REGCAL016)
3. Flat fields (use REGCAL017 and REGCAL018)
4. EUV flat field (see REGCAL072 below, perform after every CCD bake-out)

**REGCAL054**

*CCD bake-out efficiency test*
Acquire two exposures of a stable part of the Sun (patch of QS), using the 266" slot with a 50 second exposure time (or less if required to avoid saturation).
Observe the QS line list (includes core line list) – see Appendix 2.

**REGCAL055**

*CCD flush*
This study will determine the number of CCD flushes required to ensure a 'clean' CCD before acquiring an exposure. Once the amount of flushes required has been determined during the commissioning calibration phase subsequent studies will use this parameter. The number of flushes will only need to be increased if degradation is observed in the CCD CTE measurements (due to radiation damage). In this case a number of studies will be run to determine the new number of CCD flushes required. These studies will include the following:
1. Flush the CCDs five times
2. EIS LEDs on and saturate CCDs (~250 ms)
3. Flush CCDs using a flush sequence command (flush as many times as required, maximum 255)
4. Run raster with zero second exposure time, full CCD dump (2048*512)
In each frame check first row, middle row and last row (use QL row cut).

**REGCAL056**

*Grating movement*

Once best focus has been determined during the commissioning calibration phase it is envisaged that it will not be changed throughout the remainder of the mission, unless there is movement of the optical components, caused by for example, the instrument structure losing moisture and contracting.

The following will be performed to determine the EIS image quality and the requirement for optimisation:

- Assess present image quality, if spectra show spatial structures between 2 and 4 pixels wide and line widths commensurate with thermal broadening and laboratory measurements, then delay any grating movement until after the 90 day science plan (at this point, issue should be revisited and may need additional adjustment due to shrinkage in structure as moisture is lost).

- Focus instrument as follows:
    - Point to active region (use AR line list – see Appendix 1)
    - Take reference images in all slits and slots over entire CCD, use long (100s) and short (3s) exposures
    - Move grating 20 steps (use real-time commanding based on COMENG008), repeat exposures, compare to previous
    - Final optimisation with 10 step grating moves. The likely outcome will be to compromise between spatial and spectral focus. If large spatial/spectral difference is identified, could try and adjust step position of the paddle wheel. Direction of correction may be determined by trial and error.
      Note: 20 steps should give some change in spatial focus but only a modest change (factor of 2 less) in spectral focus (RD8)

**REGCAL057**

*PZT/fine mirror motion*
Calibrate PZT motion nonlinearity (DAC set versus offset), direction and reproducibility
Point to north pole, install the 266" slot, operate PZT over 20 equally spaced positions over full range (600") taking images synchronously, repeat three times. Use exposure times of 120 and 200 seconds.
Observe the QS line list (includes core line list) – see Appendix 2.

**REGCAL058**

*Coarse mirror*
Calibrate coarse mirror motion step size, hysteresis and direction sequence. Measure attitude control disturbance.
Point to east limb, install the 266” slot, acquire 3 images at the nominal position, move +100 steps, acquire 3 images 10s apart, move –200 steps, acquire 3 images 10s apart at this position, move back to nominal +100 steps, acquire 3 images 10s apart. Move back to nominal. A small range should suffice for this study as gearbox/screw performance should be very linear. Use exposure times of 120 and 200 seconds and observe the QS line list (includes core line list) – see Appendix 2.
Repeat study three times.
**Note: Require spacecraft coordination and permission to move coarse mirror.**
Wait a few seconds to allow spacecraft pointing to settle prior to taking images, e.g. 10 seconds as above.
Calibrate initially and then only if there is a problem.

**REGCAL059**

*Software window and compression settings*
These studies will test REGCAL window and compression settings and will also be used to define windows for slit spectroscopy and both slots. Set-up and test several CCD window selections and repeat with lossy compression as desired.
Several studies will be required to allow for various slit/slot positions and QS/AR pointings.
This study (REGCAL059) requires a quiet sun pointing using the 1” slit and will acquire exposures of 10, 20, 40, 80 and 160 seconds. Observe the QS line list (includes core line list) – see Appendix 2.

**REGCAL060**

*Software window and compression settings*
Point to the quiet sun and acquire exposures of 10, 20, 40, 80 and 160 seconds using the 2” slit. Observe the QS line list (includes core line list) – see Appendix 2.

**REGCAL061**

*Software window and compression settings*
Point to the quiet sun and acquire exposures of 10, 20, 40, 80 and 160 seconds using the 40” slot. Observe the QS line list (includes core line list) – see Appendix 2.

**REGCAL062**

*Software window and compression settings*
Point to the quiet sun and acquire exposures of 10, 20, 40, 80 and 160 seconds using the 266” slot. Observe the QS line list (includes core line list) – see Appendix 2.

**REGCAL063**

*Software window and compression settings*
Point to an active region and acquire exposures of 2, 4, 8, 16, 32, 64 and 128 seconds using the 1” slit. Observe the AR line list (includes the core line list) – see Appendix 1.

**REGCAL064**

*Software window and compression settings*
Point to an active region and acquire exposures of 2, 4, 8, 16, 32, 64 and 128 seconds using the 2” slit. Observe the AR line list (includes the core line list) – see Appendix 1.

**REGCAL065**

*Software window and compression settings*
Point to an active region and acquire exposures of 2, 4, 8, 16, 32, 64 and 128 seconds using the 40" slot.
Observe the AR line list (includes the core line list) – see Appendix 1.

**REGCAL066**

*Software window and compression settings*
Point to an active region and acquire exposures of 2, 4, 8, 16, 32, 64 and 128 seconds using the 266" slot.
Observe the AR line list (includes the core line list) – see Appendix 1.

**REGCAL067**

*EUV flat field with moving slot image*
Using the 40" slot acquire a raster with 10" steps across the entire EIS FOV, pointing at the QS. Acquire a 120 second full CCD exposure at each position.
Using the 266" slot acquire a raster with 59" steps across the entire EIS FOV, pointing at the QS. Acquire a 120 second full CCD exposure at each position.
Perform every month during the first year and after each CCD bake-out.
Observe the QS line list (includes the core line list) – see Appendix 2.

**REGCAL068**

*EUV flat field with moving slot image*
Using the 40" slot acquire a raster with 10" steps across the entire EIS FOV, pointing at an AR. Acquire a 20 second full CCD exposure at each position.
Using the 266" slot acquire a raster with 59" steps across the entire EIS FOV, pointing at an AR. Acquire a 20 second full CCD exposure at each position.
Perform every month during the first year and after each CCD bake-out.

**REGCAL069**

*Co-alignment of EIS FOV with FPP FOV*
Point to the east limb and take a 266" slot image, exposure time of 120 seconds. Compare with the FPP field of view. Calculate coarse motion required to centre EIS FOV on FPP field of view. Re-centre EIS FOV with coarse motion. Take slot image as before. Compare with FPP field of view to verify correction. 30 steps (~10" is the smallest correction worth making). Need to determine centre of PZT field of view prior to running this test procedure. Observe the QS line list (includes core line list) – see Appendix 2.

**REGCAL070**

*Flat field including overscan pixels*
This study will be used to calculate CCD CTE. For the CTE method used overscan pixels are required.
This study will take 2 full CCD images using an LED on time of 100ms. The top 512 rows of the CCDs will be used.
In the readout the 50 overscan pixels (left and right) and 8 overscan pixels at the top will be included.
CTE analysis will be performed using IDL program eis_cte.pro (this program calculates serial and parallel CTE using the overscan pixel method).

**REGCAL071**

*Dark exposures using bottom rows of CCDs*
This study will be used to monitor the dark current, hot pixels and warm pixels across the full height of the CCDs (along with REGCAL072).
Take 2 full CCD 100 second exposures (two exposures are required to allow for pixel-by-pixel comparison).
*The exposure time was increased from 60 seconds to 100 seconds on 22 November 2007.

**REGCAL072**

*Dark exposures using top rows of CCDs*
This study will be used to monitor the dark current, hot pixels and warm pixels across the full height of the CCDs (along with REGCAL071).
Take 2 full CCD 100 second exposures (two exposures are required to allow for pixel-by-pixel comparison).
*The exposure time was increased from 60 seconds to 100 seconds on 22 November 2007.

**REGCAL073**

*Dark current, hot pixels and column defects*
This study is a copy of REGCAL016 but with the longer exposures (300 and 600 seconds) removed. It will be run weekly in place of REGCAL016 (REGCAL016 will be run once a month).
This study (REGCAL073) will acquire four full CCD exposures with the following exposure times: 100, 100, 150 and 150 seconds.
The data will be analysed using IDL program eis_fit.pro and eis_dkm.pro.

**REGCAL074**

*Dark exposures including prescan pixels*
This study will be used to calculate the ADC offset.
This study will take 2 full CCD 100 second exposures. In the readout the 50 prescan pixels will be included. The top 512 rows of the CCDs will be used.

**REGCAL075**

*Dark exposures (0 and 100 seconds)*
This study will be run daily and the data used to identify warm pixels.
Two 0 second exposures and two 100 second exposures will be taken with the shutter in the closed position.

**REGCAL076**

*Flat-fields*
A one second exposure will be taken with an EIS LED on time of 100ms. The readout will include the CCD left windows only.
Data from this study will be used to monitor the intensity levels using the EIS LEDs.

**REGCAL077**

*Flat-fields*
Two one second exposures will be taken with an EIS LED on time of 80ms. The full CCD windows will be used.
Data from this study will be used to monitor the PRNU and PR defects.

**REGCAL078**

*Dark exposures using bottom rows of CCDs (0 seconds)*
This study will be used to monitor background levels across the full height of the CCDs (along with REGCAL079).
This study will be run once every three months.
Two 0 second exposures will be taken with the shutter in the closed position.

**REGCAL079**

*Dark exposures using top rows of CCDs (0 seconds)*
This study will be used to monitor background levels across the full height of the CCDs (along with REGCAL078).
This study will be run once every three months.
Two 0 second exposures will be taken with the shutter in the closed position.

# 7 Additional notes

## 7.1 Monitoring of EIS mechanisms

The on-going performance of EIS mechanisms will be monitored continually, registered in housekeeping and usage time recorded. Operation of the on-board electronics and software will be checked to ensure that sequence run timing and exposure duration continue to respond correctly to commands.

## 7.2 Radiation damage to the EIS CCDs

In the event of radiation damage occurring we would expect to see a decrease in measured CTE and a smearing effect in images. If/when this occurs a corrective method will be implemented depending on the radiation effect (RD6).
The two radiation effects that can reduce CTE and their corrective methods are:

1. Flat-band shifts caused by charge build-up in the CCD insulator layers from ionising radiation. This would probably produce reduced parallel CTE in the middle columns of the CCD, where the clocking waveforms are “softer” due to the filtering effect of the electrode distributed resistance and capacitance. This can be corrected by increasing Vss, Vrd and Vod. A CCD bake-out may also help: if Vss, Vrd and Vod have been increased then they could be adjusted back to their nominal values following a bake-out to determine whether the bake-out has helped. In the case of changing Vss, Vrd, Vod a partial re-calibration (e.g. dark current, flat field studies) would be required as the CCD set-up will have changed.

2. Traps in the Si caused by lattice damage from non-ionising radiation. This would affect CTE in all columns and can only be treated by the LED approach (this entails using the LEDs to saturate the CCDs, flush the CCDs and then perform a normal exposure and readout (similar to REGCAL055).

The radiation damage performance of e2v CCDs has been reported in an e2v technical note – see RD5.

## 8 Appendix 1 – Active Region line list (including the core line list)

SW band:

Fe XI 188.2
Ca XVII 192.8
Fe XII 195.1
Fe XIII 202.0
Fe XIII 203.8

LW band:

Fe XXIV 255.1 (will only be seen in flares)
He II 256.3
Fe XVI 263.0
Fe XIV 270.5
Fe XIV 274.2
Fe XV 284.1 (will only be seen in active regions and bright points)

## 9 Appendix 2 – Quiet Sun line list (including the core line list)

SW band:

Fe XI 188.2
Fe XXIV 192.0
Ca XVII 192.8
Fe XII 195.1
Fe XIII 202.0
Fe XIII 203.8 (1” slit studies only)

LW band:

Fe XXIV 255.1 (2” slit studies only)
Fe XVI 263.0
Fe XIV 274.2
Fe XV 284.1 (will only be seen in active regions and bright points)