

SOHO CDS

Operations Manual

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MSSL/UCL

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Additional Information:

This book will replace the current version of the ‘Green Book’. Richard and I will have to ensure that information already in the Green Book, but not mentioned below, is transferred to the ‘Blue Book’.

Detailed sub-headings are required from each author by 25 April. These will then be discussed by the Green Book panel at MSSSL, as well as at RAL, before actual inputs are required.

I have added more subheadings to each item, to try and produce a consistent style for the whole document. Please follow these suggestions if possible.

1. Introduction (KN/PDT)

1.1 Revisions

Issue	Date	Who	Comments
0.0			First Release

1.2 Distribution and Intended Users

1.3 Reference Documents

1.4 Summary and Purpose of Document

2. Instrument Description (DJP/ECS)

2.1 Optical and Mechanical Details

2.1.1 Optical design

Fig 2.1.1.1 shows the optical elements of CDS. The telescope focuses an image of part of the sun onto the slit after a reflection of off the scan mirror. This image can be viewed by either the normal incidence spectrometer (NIS) or the grazing incidence spectrometer (GIS).

The telescope aperture is divided into two, one for each of the spectrometers. Light from the upper aperture passes through the slit and falls onto a pair of toroidal gratings at near normal incidence which focus dispersed spectra back onto a two dimensional detector called the viewfinder detector system or VDS. The gratings are inclined relative to one another such that two spectra fall onto the VDS detector, one above the other. This spectrometer is stigmatic and uses a long thin slit.

Light from the lower aperture passes through the slit and hits a spherical grating at grazing incidence and is then dispersed to four, one dimensional detectors spaced around the Rowland Circle. This spectrometer is astigmatic and uses a pinhole.

Images can be built up by using either the NIS and scanning the scan mirror, or by using the GIS and moving the pinhole and slit in a raster pattern.

The useful field of view of the telescope is 4 arc mins, to cover the whole solar disc and the lower corona the whole instrument can be pointed through an angle of +/- 0.75 degrees.

Optical Characteristics of CDS

The telescope	Outer f-number	9.38
	Eff Focal Length	257.831 cm
	FWHM	<2 arcsec
	Full Geometric Area	289.28cm ²
	Plate Scale at Slit	12.5µm/arcsec
NIS	Telescope Aperture Used	34.3cm ² per grating
	Wavelength Ranges	308 - 381, 513 - 633 Å
	Prime Slits	2 x 240.4 x 240.90 x 240 arcsec
	Grating Ruling	2400 & 4000 lines/mm
	Slit-Grating Dist	736.5mm
	Grating-Detector Dist	744.6mm
GIS	Telescope Aperture Used	47cm ²
	Wavelength Ranges	151 - 221, 256 - 338, 393 - 493, 656 - 785 Å
	Prime Slits	2 x 2, 4 x 4, 8 x 50 arcsec
	Grating Ruling	1000 lines/mm
	Rowland Circle Radius	750mm

2.1.2 Mechanical Design

All the optical components with the exception of the telescope are housed in an enclosed spectrometer for reasons of contamination control, ease of alignment and stray light rejection, see Fig 2.1.2.1. The spectrometer and telescope are mounted in an outer structure consisting of an aluminium alloy framework see Figs 2.1.2.2 & 3. In front of the telescope is the +Z panel which carries the two aperture doors.

The mechanism control electronics together with electronics to service the detector systems are mounted on a platform above the optics bench.

The instrument is mounted on the spacecraft by means of six ball jointed legs, the rear two being linear actuators which allow the necessary pointing.

2.1.3 Mechanisms

2.1.3.1 Aperture door mechanisms

To minimise contamination to the telescope, doors are fitted over both the telescope apertures. These will be closed on launch and opened some time into the mission. After that they can be closed as necessary to avoid contamination during attitude control manoeuvres when the spacecraft thrusters are fired.

The doors are a very simple design. A magnetic latch holds the door closed against a torsion spring. On command a current is passed through a coil around the permanent magnet cancelling the magnetic field allowing the torsion spring to open the door. There are two coils around the magnet for redundancy, one can be controlled by CDS the other by direct spacecraft command. Under normal circumstances the coil operated by CDS will be used, in which case current is applied for a limited time (approximately half a second). In the unlikely event of CDS not being able to open one or both doors by command, a direct spacecraft command will be used to open both doors simultaneously. Commands of this type operate relays, consequently the power would continue to be applied to the coils for some time. To prevent this occurring, the doors operate microswitches as they open cutting off the power to the coils.

Stepper motors are fitted to end of each shaft which allow the doors to be closed independently by command. Magnetic reed switches indicate door open and door closed position for each door.

2.1.3.2 Scan mirror mechanism

The NIS is a stigmatic instrument which uses a long slit. To build up two dimensional pictures, images of the Sun are scanned across the entrance slit, in an east/west or west/east direction by the scan mirror. The scan mirror is mounted in a housing which is supported by a pair of Bendix flex pivots which allow a few degrees of movement. An arm projects out the back of the housing which can be moved by a recirculating ball screw and carriage arrangement to give the necessary angular movement of the mirror and housing. The ballscrew is rotated by a size 13, 200 per rev stepper motor. An absolute optical shaft angle encoder tells the operator unambiguously which step position the motor is at any time. The operating range of the motor is less than one revolution so no full rev indicator is required. Micro switches are fitted to ensure that the carriage does not hit the end stops in the event of a software error.

2.1.3.3 Scan mirror mechanism parameters

Operating Steps	+/-	64 Steps
Raster step size		2.032 arc sec
Raster range	+/-	130 arc sec
Mirror home position		Zero
Step rate		30 Hz

2.1.3.4 Slit drive mechanism

The GIS is an astigmatic instrument and builds up images by scanning a pin hole in a north/south or south/north direction combined with movements of the scan mirror. The slit drive mechanism consists of a 200 step size 13 stepper motor driving a 0.1 inch pitch, recirculating ball screw which is attached to a carriage supported by a pair of cross roller slideways. There are six slits attached to the slideway, their centres being spaced 0.2 inches apart which is two rotations of the ball screw. A coarse linear encoder consisting of an array of LEDs and photodiodes indicated which slit is in the line of sight (slit number) and an optical shaft angle encoder attached to the motor shaft indicates the position of the selected slit (slit position). The linear encoder incorporates limits to prevent accidental operation outside the normal operating range.

2.1.3.5 Slit number parameters

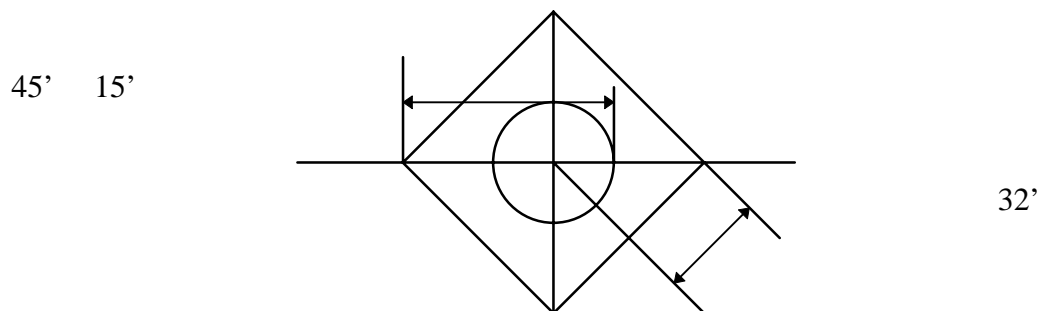
Slit number	Slit size arc sec	Slit size mm
1	2 x 2	25µm x 25µm
2	4 x 4	50µm x 50µm
3	8 x 50	100µm x 0.625mm
4	2 x 240	25µm x 3mm
5	4 x 240	50µm x 3mm
6	90 x 240	125mm x 3mm
Motor step size	1.016 arc sec	12.7µm
Slit home position	00	
Slit range	slit 1	+/- 120 steps
	slit 2	+/- 118 steps
	slit 3	+/- 95 steps
	slit 4 - 6	zero
Step rate	30Hz	

2.1.3.6 Offset pointing mechanism

The CDS instrument is attached to the spacecraft by six ball jointed legs. The rear two legs are linear actuators which allow the whole instrument to be pointed through an angle of approximately +/- 0.75 degrees to cover the whole solar disc, a significant portion of the corona and to allow for some misalignment of the instrument relative to the spacecraft. The actuators consist of 200 step, size 23 hollow shaft stepper motors, driving a plain nut and screw assembly of 1mm pitch. Position readout is provided by a redundant pair of hybrid track potentiometers.

The step increments and the potentiometer digitisation do not match one to one. 5000 motor steps are digitised into 4096 increments by the encoder, consequently one motor step is 1.22 encoder increments.

The drive system incorporates software end stops in addition to microswitches which limit movement in the case of a software error. The actuators are inclined at 45 degrees to the spacecraft platform and to the north/south axis of the Sun. This causes a pointing envelope as shown below.



2.1.3.7 Offset pointing mechanism parameters

Home position 80, 80

2.1.3.7.1 Pointing range set by software end stops

encoder readings	+ 1536 to - 1536
angular position	+/- 45 arc min

Position of Microswitch end stops	LH: + 1620, - 1640
	RH: + 1603, - 1672

Motor step size 0.005mm, approx 1 arc sec

Step rate 14 Hz fixed

2.1.4 Thermal Design

The thermal design of CDS comprises both active and passive components. The temperature of the structure and optics bench are maintained at 20 degrees with a maximum gradient of 2 degrees.

There is 19 watts of solar energy entering CDS1 through the telescope apertures, half of which is absorbed by the gold coated mirrors and radiated back through the apertures to space or conducted through the support to the front bulkhead. From here it is conducted along the forebody and radiated to space through the telescope radiator, an exposed part of the forebody that has a good view to space. The solar energy that is not trapped by the telescope continues into the optics bench where it encounters the first thermal stop which absorbs unwanted components of the beam and thus reduces the flux onto the scan mirror. The scan mirror and its mount absorb up to one watt and reflect the rest onto the second thermal stop which absorbs the remaining unnecessary components of the beam and admits to the slit only about 0.2 watts. Both thermal stops are conductively coupled to a radiator on the side of the instrument.

The VDS CCD is required to operate below -80 degrees. To achieve this it is conductively coupled to a large radiator on the top of the instrument that radiates directly to space.

With the exception of the radiators and telescope apertures the whole instrument is covered by thermal blankets consisting of 22 layers of aluminised Mylar and Kapton separated by Dacron netting. The outer layer is black conductive Kapton.

To prevent unnecessary heat leak into the structure from electronics units, some of the detector electronics (VDS LVPS, VDS MEU and GIS MEU) and the MCU are mounted on a thermally isolated platform above the optics bench where they can radiate heat through holes in the MLI directly to space.

2.1.4.1 Heaters

The prime operational heaters consist of sixteen thermofoil heaters each controlled by an AD590 temperature sensor. The prime heaters can consume 24 watts at full power but are limited to either $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ or full power according to the mode of operation of CDS. The table below shows heater power setting versus mode.

Mode	Power setting
ZZ	Zero (MCU off)
Standby	full
Ready-GIS	full
Ready-VDS	$\frac{1}{2}$
Ready-Both	$\frac{1}{2}$

The redundant operational heaters consist of a separate set of eight thermfoil heaters controlled by eight temperature sensors selected from the same set that control the prime heaters. To provide further redundancy these heaters are controlled by the CDHS although the switching is done by the MCU. The control of these heaters is described in section 6.

In addition to the operational heaters there is a prime and redundant set of non-operational heaters powered directly by the spacecraft for use when CDS is powered off. Either one of these sets of heaters will consume 50 watts when fully powered. The spacecraft can control the power to a fixed percentage of full power, in increments of 5%, or it can use the spacecraft controlled thermistor to control to a fixed temperature.

Tables 2.1.4.1/4 show the position and resistance of each heater.

2.1.4.2 Temperature monitors

There are 32 AD590 temperature monitors distributed on the CDS1 instrument to monitor the temperature of the structure, optics bench and other critical areas. Sixteen of these monitors also control the heaters as mentioned above. Table 2.1.4.5 gives the position and expected temperature range of each temperature monitor.

In addition to the monitors above there is a pair of spacecraft controlled thermistors mounted on the front bulkhead to record the temperature when CDS is powered off.

Table 2.1.4.1 Prime Operational Heaters

Heater	Ohms (Ω)	Location
OPH00	241	Forebody -Z end +X/-Y
OPH01	241	Forebody -Z end +X/Y
OPH02	241	Forebody -Z end +X/Y
OPH03	241	Forebody -Z end +X/Y
OPH04	653	-Y s/f between +X rad feet, +Y face
OPH05	653	+Y s/f between +X rad feet, -Y face
OPH06	653	Bulkhead 3, top, -Y side, -X face
OPH07	653	Bulkhead 3, top, +Y side, -X face
OPH08	1120	Bulkhead 4, top, -Y side, -X face
OPH09	1120	Bulkhead 4, top, +Y side, -X face
OPH10	1120	-Y s/f bottom of -Z diag, +X face
OPH11	1120	+Y s/f bottom of -Z diag, +X face
OPH12	290	GI optics bench +Z end of -X face
OPH13	560	GI optics bench middle of -X face
OPH14	560	GI optics bench -Z end of -X face

OPH15 560 NI optics bench -X face

Table 2.1.4.2 Redundant Operational Heater

Heater	Ohms (Ω)	Location
ORH00	134	Forebody -Z end +X
ORH01	134	Forebody -Z end -Y
ORH02	134	Forebody -Z end +Y
ORH03	290	GI optics bench +Z end of -X face
ORH04	290	GI optics bench -Z end of -X face
ORH05	560	NI optics bench -X face
ORH06	653	-Ys/f vertical of b/h 3, -Z face
ORH07	653	+Ys/f vertical of b/h 3, -Z face

Table 2.1.4.3 Prime Non-Operational Heaters

Heater	Ohms (Ω)	Location
NPH00	70.9	Forebody -Z end -Y
NPH01	70.9	Forebody -Z end +Y
NPH02	146	GI optics bench +Z end on +Y face
NPH03	146	GI optics bench -Z end on -Y face
NPH04	166	Elect platform -X face -Y/+Z
NPH05	166	Elect platform -X face +Y/+Z
NPH06	166	Elect platform -X face -Y/-Z
NPH07	166	Elect platform -X face +Y/-Z

Table 2.1.4.4 Redundant Non-Operational Heaters

Heater	Ohms (Ω)	Location
NRH00	70.9	Forebody -Z end -Y
NRH01	70.9	Forebody -Z end +Y
NRH02	146	GI optics bench +Z end on +Y face
NRH03	146	GI optics bench -Z end on -Y face
NRH04	166	Elect platform -X face -Y/+Z

NRH05	166	Elect platform -X face +Y/+Z
NRH06	166	Elect platform -X face -Y/-Z
NRH07	166	Elect platform -X face +Y/-Z

Table 2.1.4.5 Flight Temperature Sensor Locations

Sensor	Location	Application	Normal Temperature Range
FS00	Front bulkhead, +X _u /-Y _u quadrant	Thermal control	18 to 22
FS01	Front bulkhead, +X _u /+Y _u quadrant	Thermal control	18 to 22
FS02	Front bulkhead, -X _u /-Y _u quadrant	Thermal control	18 to 22
FS03	Front bulkhead, -X _u /+Y _u quadrant	Thermal control	18 to 22
FS04	-Y _u sideframe between +X _u radiator feet	Thermal control	18 to 22
FS05	+Y _u sideframe between +X _u radiator feet	Thermal control	18 to 22
FS06	Bulkhead 3, top, -Y _u side	Thermal control	18 to 22
FS07	Bulkhead 3, top, +Y _u side	Thermal control	18 to 22
FS08	Bulkhead 4, top, -Y _u side	Thermal control	18 to 22
FS09	Bulkhead 4, top, +Y _u side	Thermal control	18 to 22
FS10	-Y _u sideframe, bottom of -Z diagonal	Thermal control	18 to 22
FS11	+Y _u sideframe, bottom of -Z diagonal	Thermal control	18 to 22
FS12	Optical bench, +Z _u end of GI compartment, -X _u side	Thermal control	18 to 22
FS13	Optical bench, middle of GI compartment, -X _u side	Thermal control	18 to 22
FS14	Optical bench, -Z _u end of GI compartment, -X _u side	Thermal control	18 to 22
FS15	Optical bench, NI compartment, -X _u side	Thermal control	18 to 22
FS16	-Y _u radiator between heat straps	Housekeeping	-25 to -105
FS17	VDS low voltage box, middle of +Z _u face	Housekeeping	10 to 20
FS18	Slit motor housing	Housekeeping	20 to 25
FS19	Scan motor housing	Housekeeping	20 to 25
FS20	-Y _u actuator housing near windings	Housekeeping	10 to 30
FS21	+Y _u actuator housing near windings	Housekeeping	10 to 30
FS22	MCU heater drive chip	Housekeeping	20 to 35
FS23	Bulkhead 3, middle of bottom	Housekeeping	18 to 22
FS24	VDS main electronics box, +X _u face under MLI	Housekeeping	8 to 16

FS25	GIS main electronics box, +X _u face under MLI	Housekeeping	8 to 16
FS26	Electronics platform, -Z _u end between GIS and VDS boxes	Housekeeping	12 to 23
FS27	MCU electronics box, middle of +Z _u face	Housekeeping	12 to 23
FS28	STOP1 near interface with heat strap	Housekeeping	-10 to +5
FS29	STOP2 at +X _u end of shaft	Housekeeping	-15 to -5
FS30	Scan mirror housing	Housekeeping	15 to 25
FS31	Telescope mount near baffle interface	Housekeeping	15 to 25
SC00	Front bulkhead	Non-op heaters	15 to 25
SC01	Front bulkhead	Non-op heaters	15 to 25

2.1.5 Mechanical Design

1. Overall layout, etc, a few diagrams , etc

2.1.6 Optical Design

2.1.6.1 General Description

with diagrams

2.1.6.2 Telescope

2.1.6.3 Gratings

2.1.6.4 Scan Mirror

2.1.6.5 Detectors

2.1.7 Mechanisms

2.1.7.1 Slit

2.1.7.2 Mirror

2.1.7.3 Offset Pointing System

2.1.7.4 Doors

2.1.8 Thermal Control System

2.1.8.1 General Description

2.1.8.2 Heaters

2.1.8.2.1 Non-op

2.1.8.2.2 Prime

2.1.8.2.3 Backup

2.1.8.3 Temperature Sensors

2.2 CDS Electrical Architecture

2.2.1 Electrical block diagram - Alecs Picture

2.2.2 Power Switching

2.2.3 Redundancy - SCIF, IMIF, Science interfaces, power

2.3 Operational Concepts

2.3.1 CDS Modes

2.3.1.1 *ZZZ*

2.3.1.2 **SBY**

2.3.1.3 **ESB**

2.3.1.4 **R-GIS**

2.3.1.5 **R-VDS**

2.3.1.6 **R-BOTH**

2.3.2 Observing Sequences

2.3.3 Instrument Health Monitoring

2.3.3.1 **Engineering data**

2.3.3.2 **Housekeeping data**

2.3.3.3 **On-board health checks**

2.3.3.4 **EGSE Alarm Concepts**

2.4 CDS Commanding and Control

2.4.1 Introduction

2.4.2 Types of Command

2.4.2.1 **Direct**

2.4.2.2 **Table load**

2.4.2.3 **Deferred**

2.4.3 Commandable Subsystems

brief description of the function (with reference to commands) of:-

2.4.3.1 **EPS**

- 2.4.3.2 CDHS (hardware)**
- 2.4.3.3 MCU**
- 2.4.3.4 VDS**
- 2.4.3.5 GIS**
- 2.4.3.6 IMIF Support module**
- 2.4.3.7 MCU Backup module**
- 2.4.3.8 Watchdog module**
- 2.4.3.9 Deferred Command module**
- 2.4.3.10 Macro module**
- 2.4.3.11 Science module**
- 2.4.3.12 Data Compression module**
- 2.4.3.13 Primary memory dump module**
- 2.4.3.14 Secondary memory dump module**
- 2.4.3.15 Two Transputer module**
- 2.4.3.16 Engineering Acquisition module**
- 2.4.3.17 CDHS Internal Telemetry module**
- 2.4.3.18 Health module**
- 2.4.4 CDHS Tables**
 - 2.4.4.1 Mode Tables**
 - 2.4.4.2 Sequence Tables**
 - 2.4.4.3 Raster Tables**
 - 2.4.4.4 Data Extraction Tables**

2.4.4.5 VDS Hardware Tables

2.4.4.6 Solar Event Table

2.4.4.7 Deferred Command Store

2.4.5 CDHS Control

3. Instrument Work Station (JP)

3.1 Configuration

3.1.1 What needs to be done (in words)

3.1.2 How to do it (which buttons to press etc.)

3.2 Start Up Procedure

3.2.1 What

3.2.2 How

3.3 Commands

3.3.1 What

3.3.2 How

3.4 Databases

3.4.1 What

3.4.2 How

3.5 Playback

3.5.1 What

3.5.2 How

3.6 Data Monitor

3.6.1 What

3.6.2 How

3.7 Engineering Monitor (EMON)

The procedure EMON is provided as a convenient interface to the information received in the engineering packets of the science telemetry. It can be used interactively or it can be packaged in its batch mode in other procedures to perform monitoring tasks on specific groups of parameters.

The use and maintenance of EMON and the associated databases are described in CDS Software note #26.

3.7.1 Daily tasks performed by EMON

It is expected that during the operations day, selected routines based on EMON will be run on all the telemetry files from the previous day. This will allow monitoring of critical parameters and maintenance of cumulative use statistics for critical mechanisms.

Details of the procedures are TBD.

3.7.2 What do the Engineering packets in the science stream contain?

There are two kinds of engineering packets in the science stream. They are known as Engineering A and B. Each contains a different set of parameters. There are various ways of listing the databases which detail their contents but the easiest, from a non-specialist user point of view, is to look at the file

`$CDS_ENGINEER/new_database.txt`

This file gives the parameter names and a brief description.

3.7.3 Brief overview of what EMON can be used for.

Details of how to use EMON are given in CDS software note #26.

3.7.4 Packaging EMON to perform specific tasks.

Although EMON can work in interactive mode, it can also be packaged to read and monitor selected parameters in batch mode. One example of this is the routine `EMON_ERROR`. This monitors all the parameters in the engineering packets which may show an error status. This routine is set running and it prints on the screen any parameter currently showing an error status. Beware however that depending on the CDS state, an error status on some parameters may not necessarily be a cause for concern.

3.7.4.1 Packaging EMON to perform specific tasks.

Include existing examples.

3.7.4.2 Error monitoring (EMON_ERROR)

4. Observation Planning (CDP)

4.1 Overview of planning

Philosophy of planning in view of need for non-RT observations. Resume of how observations are controlled on board (deferred command list, sequence tables, raster tables etc.) Resume of how complete planning process is supposed to work.

4.1.1 Overview

Apart from two months a year, CDS will be out of ground contact for 16 hours each day. For that time normal operations must occur and therefore must have been planned beforehand and the instructions loaded on board during the realtime contact. CDS has provided software tools in IDL to help observers plan the day's observations. All of the details relating to planning are kept in databases, also controlled by IDL software.

4.1.2 On board control.

On board, a specification for an observation is held in 'tables'. The hierarchy of tables can be viewed as follows:

Data extraction tables - these define which pixels are to be extracted from the detector data and telemetered to ground. For NIS observations there are also associated VDS extraction window tables, but these are created automatically, and transparently to the user. Note that their definition depends not only on the extraction window defined by the user during planning but upon the hardware readout mode currently in use for the VDS. This is specified in the state planning database (see section ??)

Raster tables - these define the instrument setup for the observation. Their contents are fully defined in the document "CDHS Macro Process: Practical Implementation" by K. al-Janabi but contain such user-definable parameters as the detector, slit number, data compression scheme, size and number of mirror/slit steps in a scan, exposure time and a reference to which data extraction table to use.

Series tables - these are created automatically by the Command Preparation Tool (CPT) and the user has no direct control over them. They form the highest level of on board tables and contain instructions for pointing the CDS (TBC), readying the detector and pointers to which rasters to run.

The Deferred Command Store (DCS) on board is also an important planning element. It contains instructions (time-tagged in UT) to start particular series tables running. Note that observations already running are aborted if a new observation is started by an instruction from the DCS.

4.1.3 The ground based planning procedure.

The aim of the planning tools is to take the user requirements and translate them into instructions that can be loaded directly into the on board stores described above.

Again there is a hierarchy of processes, which from the lowest level up is:

MK_RASTER - A raster is a set of exposures which are taken with a particular instrument configuration and possibly at different pointing locations, defined by the mirror and slit positions. At its simplest, a raster definition may reduce to a single exposure. **Mk_raster** selects the parameters needed to define a raster, including the spectral extraction (derived from spectral line lists) to be used.

MK_STUDY - creates studies which are packages of one or more rasters. If appropriate, pointing information can also be associated with each of the rasters making up the study at this stage. A study definition may also specify that each raster is to be repeated a number of times.

MK_PLAN - gives an overview of the complete SOHO planning for a specified time interval and can call **MK_DETAIL** (by entering edit mode) to plan in detail the CDS operations. Previously defined studies are inserted into the time-line in a variety of ways. Any still undefined pointings are supplied at this stage. The basic study definition may be repeated at the same or different locations in order to build a more complete observation.

CPT - takes the information in the detailed planning database (created in **MK_DETAIL**) and forms data files whose contents can be loaded into the tables on board to achieve the required observation. This is a non-interactive process. Details of how to run it are given in CDS software note #25.

Once **CPT** has run, the complete set of on board tables and the contents of the DCS are uplinked by running two Perl scripts from the TCL command line of the EGSE (see sections ?? & ??).

4.2 Planning databases and access to them

Resume of database use (why use them).

Explain distinction between private and project databases. Define controls to be exercised over each of them.

Resume of routines to interact with them ('show' routines). Reference to software note #10

4.2.1 Overview of planning databases.

It is anticipated that many CDS observations will be repeated during the mission, indeed it is planned to run some (eg the Synoptic scans) daily. In order to be able to reuse previously defined observations it was decided that all definitions (from raster to general time-line) would be kept in databases controlled by IDL software (see CDS Software note #10). The contents of these databases will be kept for the duration of the mission and will ensure that definitions are identified uniquely within the databases. Not only does this obviate the need for constant reinventing of definitions, but, since the science FITS files will have the database identifications in their headers, it will always be possible to trace the exact instrument setup used to acquire a dataset.

The databases have been structured to try and keep repetition of information to a minimum. For instance the raster database is divided into fundamental raster parameters and a parameter list which forms variations upon the fundamental raster. A prime example of a variation parameter is the exposure time, which can be expected to vary in an observation much more frequently than the size or number of mirror/slit steps. Redefining the exposure time of an observation therefore only involves defining a new variation on a raster rather than a complete new raster.

4.2.2 Official versus private databases.

The project will keep a set of protected databases which will form the 'official' CDS databases. All users will have read access to these but write access will be restricted. Users are free to have their own copies of databases in order to be able to build up a 'palette' for use in their own observation planning. All the planning tools allow use of either private or official databases. A software tool will be provided by which users can copy their own definitions into the project databases once they have been vetted for use on board.

4.2.3 Controls over access to the databases.

The official databases will be readable by all users so that they can make use of their contents when planning their own observations. Write access to the official databases will be strictly controlled (TBD) and probably only allowed from a single account on the EOF machines.

4.2.4 Accessing database information.

Various IDL routines allow users an overview of the contents of the databases or to extract more explicit data from them. In general routines called '(x)show... ' or 'list...' will give an overview or return general information while routines called 'get_...' will extract detailed information.

Use the procedure `tftd` to see lists of such programs. eg.

```
IDL> tftd, 'show*'
```

will list the following routines relevant to database information

`SHOW_DETAIL` - List salient points of details database.

`SHOW_LINELIST` - To list the contents of the linelist database.

`SHOW_RASTER` - To summarize the descriptions in the raster databases.

`SHOW_SCI_PLAN` - List salient points of SOHO science plan database.

`SHOW_STRUCT` - Display contents and breakdown of an IDL structure.

`SHOW_STUDY` - To summarize the descriptions in the study databases.

while

```
IDL> tftd, 'get_*'
```

will list routines to extract specific information (and a whole lot more!)

4.3 Technical planning (`mk_raster`)

Review of what it's for, what it does.

Mention on-line help.

Reference to software note #24 for user guide.

4.3.1 Technical planning routines.

MK_RASTER is the first stage in observation planning. It is called technical planning because it defines the physical setup of the instrument. Although this is of course designed with a view to the science that is to be done, the scientific aspects do not enter directly at this stage. To run `mk_raster`, simply enter the procedure name in any IDL session that has access to the CDS IDL directories.

When you are just 'playing' or developing a raster without wanting necessarily to interact with any databases, you may make use of the parameter which `mk_raster` can take. Thus, for instance, if `mk_raster` is called with an undefined parameter

```
IDL> mk_raster, raster
```

that parameter will be returned, on exit, as a structure which contains a full raster definition. It need not be complete in the sense that it would not be accepted for insertion to a database but can be used as a temporary storage for your ideas.

Note that the returned structure also contains a number of tags which are only used internally by `mk_raster`. If you call `mk_raster` with a parameter that is already a valid structure variable, the details contained within the structure will be loaded into the `mk_raster` display on startup. There is, furthermore, an exit mode from `mk_raster` which allows the structure to be saved to a file. If that mode is used the file can be restored (you must use the Yohkoh routine `RESTGEN`) for further use.

4.3.2 Obtaining help on the use of `mk_raster`.

CDS software note #24 describes `mk_raster` but note that the main source of helpful information is the on-line help. `Mk_raster` can be switched into a special on-line help mode wherein help on any of the top-level features can be obtained by accessing (clicking on) that feature.

4.4 Science planning

`mk_study`, why and briefly how to use it.

`mk_detail`, ditto

`mk_plan` ditto

Reference to software note #??

4.4.1 Overview of science planning.

Science planning is the stage of planning concerned with putting together the technical aspects (rasters) into a useful package that will perform the observation(s) required to obtain the data to solve the scientific problem that keeps you awake at night.

4.4.2 Creating study definitions.

The first step is to run `MK_STUDY`. Use the on-line help to understand the logic of the program, but a few handy starting tips are:

- 1) Check under the "File" menu that you are accessing the database (private or official) that you require. In order to use a private database, the environment variable `ZDBASE_USER` must point to a directory containing your databases.
- 2) Select a raster (and a variation when the associated list appears)
- 3) ADD it to the study definition

- 4) Repeat steps (2) and (3) for each raster required in the study. 5) Highlight each raster in turn in the study definition window and decide and enter the parameters you want associated with that raster (eg. pointing type (and the position if appropriate) and number of repeats.
- 6) Enter all the descriptions necessary for the study (title, science objective etc.)
- 7) When satisfied with the study definition enter it into the database (under the File menu).
- 8) Fix any problems that the database access routines throw back at you.
- 9) Go to (2)

4.4.3 Entering details into the plan timeline.

Mk_plan (which calls mk_detail) is the planning routine that creates a time line for CDS operations. Again use the online help to understand its logic, but you can get started by following these instructions.

- 1) Under the "File" menu, make sure you are accessing the database (private or official) that you require.
- 2) Call up a study and its variation. The parameters will be loaded into the screen so you can confirm you have what you intended.
- 3) If you want to setup a general science plan for the time period then click on the 'science' button (bottom left). A single layer time plan will appear. The time interval is defined by clicking the left mouse button to define the start time and the right mouse button to define the end time of the period. If you have entered sufficient header information (objectives etc) you may click the ADD button to get your selection entered into the plan.
- 4) To edit the detailed time line you must be in 'details' mode, so click on the 'details' button if not.
- 5) The start time of the study you are about to enter into the plan can be defined either by clicking the mouse button in the time line graph or by typing a time in the "Current time" box.
- 6) Before entering a study into the plan, decide whether it is to be time-tagged (ie start at a specific time) or not (ie will start when the previous study finishes). If a study is not time-tagged and no previous study exists, the new study will start at 00:00 hours UT.
- 7) Also before entering a study into the time line, you must decide if multiple pointing are needed, whether this study is to be repeated more than once and whether the number of repeats of the last raster in the study is as you want it. This latter parameter, together with repeats of the study as a whole can be used to manipulate the total duration of this plan entry.
- 8) Enter any pointing positions that are still not defined (ie were defined as 'deferred at the mk_study stage)
- 9) If you have both entered a start time, recalled a study and supplied all the auxiliary information you may now add it to the plan by clicking on the ADD button.
- 10) Build up the (daily) plan by adding the studies you require.

4.5 Command preparation (CPT)

Review of use.
Reference to software note #25

4.5.1 Command preparation.

The Command Preparation Tool (CPT) is somewhat of a black box for users. It is fully described in CDS Software note #25. It should only be used by operations staff (TBC).

In its simplest form it takes only one parameter, the date for which commands are required. Hence:

```
IDL> cpt, start='1996-2-24'
```

will look up the detailed plan in the database for the 24 hours starting at 1996-2-24 00:00 UT and create the text files with the information needed to be uplinked to the on board tables.

Note that the following environment variables must be defined:

CDS_CP_CVTFILES

CDS_CP_TTCFILES

CDS_CP_LTBFILES

These specify where the various cpt output files will be stored (they may be the same directory).

4.6 Uplinking commands via Perl scripts

---> this should link with other commanding sections.

Once CPT had been run on an appropriate IDL session, it is necessary to uplink both the tables and the DCS contents. That is achieved by running two Perl scripts from the TCL command line of the EGSE. The commands to load the tables and the DCF are respectively:

```
TCL> cpt/PSLOAD 1996-02-24T00:00:00.000Z
```

where the parameter is the file name (.LTB) assumed) created by cpt, and

```
TCL> cpt/DFLOAD 1996-02-24T00:00:00.000Z
```

where the parameter is the file name (.TTC) assumed) created by cpt

4.7 4.7 Real time operations

What you can and can't do

TBD

4.8 Deferred Commands

4.8.1 What

4.8.2 How

5. Data processing

5.1 The science telemetry stream.

The science telemetry is downlinked as a stream of data and normally received at approximately 10 Kbits/sec, although other rates are possible. In this stream the data are divided into packets of 306 bytes. Each packet has a time stamp and an identification byte. The packets may contain science data, engineering data or on board memory dumps. Users and operations staff can monitor the incoming telemetry by running the IDL procedure STM (Science Telemetry Monitor). See CDS Software note #27 for details of that program.

5.2 The telemetry (TM) files.

The EGSE software which receives the telemetry writes it to telemetry (TM) files. A new file is written every hour, on the hour. It is possible to have read access to the file currently being written and this is how STM and other programs access so-called realtime telemetry. Older TM files can be accessed by STM in its 'replay' mode

5.3 The science telemetry monitor (STM)

STM can monitor telemetry data from any IDL session that has read access to the telemetry files (stored in CDS_TM_DATA). It really is a monitor program since it can only display the incoming data parameters (raster header information for example) and display the science data. Very little analysis is possible other than determining some statistics of the data.

Its use is fully described in CDS Software note #27

5.4 FITS files

=====
=====

What are they
How to check things are working OK
How to read a FITS file and display data in IDL
Use of QL programs.
Reference to software notes # 3 and 20 for details.

=====
=====

5.4.1 Contents of FITS files.

The format for the storage and distribution of CDS science data is FITS format. Details of the exact format to be used are given in CDS Software Note #3

5.4.2 Creating FITS files

The FITS files are created by the procedure FITSGEN. The use of this program is for operations staff only and is described in CDS Software note #23

FITSGEN should be started from an IDL session before telemetry reception starts.

5.4.3 Checking contents of FITS files

The operation staff should check that the FITS files are being created correctly by reading and displaying the data from such a file. Use the IDL procedure QL_MENU to start up the Quick Look (QL) software. A manual for that is in CDS Software Note #20

5.5 Archives

=====
Overview of what they will contain
How will they be created?
How to access them.
Distribution of archive CDS data.
=====
See CDS software note #29 (TBC)
=====

6. Basic Functions (DJP)

6.1 Emergency Procedures

6.2 CDS Switch On and Off

6.2.1 Power Configuration

6.2.2 CDHS Configuration

6.3 Power-Up Defaults

6.3.1 Default Mode

6.3.2 Default CDHS Table contents

6.3.3 Default Software Status

6.4 Thermal Control

6.4.1 Non-Operational Heaters (Spacecraft Controlled)

6.4.2 Operational Heaters

6.4.2.1 Main Heaters

6.4.2.2 Backup Heaters

6.5 Modifications to Default Configuration

6.5.1 Mode Tables

6.5.2 System Sequences

6.5.3 Redundant hardware

6.6 System Preparation for Science Observations

6.6.1 Secondary Processor

6.6.2 Optional CDHS Software Modules

6.6.3 Cleaning Up Telemetry Displays

6.6.4 Pointing

6.6.5 CDS Physical Pointing

6.6.6 Pointing Software

6.6.7 Mode Transitions

6.7 Uploading Observing Sequences

6.7.1 Uploads

6.7.2 Upload Validation

6.7.2.1 Engineering data

6.7.2.2 Special telemetry

6.8 Recovery From a Cocked Up Situation

7. Scientific Operations (ERB)

This chapter will detail some of the tasks necessary to perform scientific operations with CDS. It is assumed that the individual detectors have been commissioned and any adjustable parameters noted.

7.1 GIS Operation

The GIS has four XUV detectors which can be independently controlled. Adjustable parameters for each detector include: High Voltage setting; Look up Table parameters; Detector Enable/Disable; Stim pulse generator; etc.

The GIS operates by sending a continuous stream of event positions to the CDHS, where it is histogrammed into a spectrum by the CDHS hardware. Thus the CDHS controls the integration and exposure times for GIS data. It is important to note that the GIS continues to send event positions to the CDHS when the CDHS is not taking GIS exposures; the CDHS just ignores them.

7.1.1 Pre-operational Checks

7.1.1.1 Adjustable Voltages incl. HV

7.1.1.1.1 What

7.1.1.1.2 How

7.1.2 Uploading Tables

7.1.2.1 What

7.1.2.2 How

7.1.3 Selecting and Running Observation Sequences

7.1.3.1 What

7.1.3.2 How

7.1.4 Complete Example

7.1.4.1 What

7.1.4.2 How

7.2 VDS Operation

7.2.1 Pre-operational Checks

7.2.1.1 Exposure Time Increment

7.2.1.1.1 What

7.2.1.1.2 How

7.2.1.2 Adjustable Voltages, inc. HV

7.2.1.2.1 What

7.2.1.2.2 How

7.2.2 Uploading Tables

7.2.2.1 What

7.2.2.2 How

7.2.3 Selecting and Running Observation Sequences

7.2.3.1 What

7.2.3.2 How

7.2.4 Complete Example

7.2.4.1 What

7.2.4.2 How

7.3 Combined Operations

7.3.1 Configuration Commands

7.3.1.1 What

7.3.1.2 How

7.3.2 Upload and Enable

7.3.2.1 What

7.3.2.2 How

7.4 CDS Pointing

7.4.1 Commands

7.4.1.1 What

7.4.1.2 How

7.4.2 Inter-Instrument Data Exchange

7.4.2.1 What

7.4.2.2 How

7.5 Running and Monitoring Observing Sequences

7.5.1 Real-time - with Ground Contact

7.5.2 Playback - Out of Ground Contact

7.6 Recovery from Cocked-Up Situation

7.6.1 Panic

7.6.2 Fix it - don't call me !

7.7 Calibration

7.7.1 What

7.7.2 How

8. Detailed GIS Procedures (ERB/AAB)

8.1 Four Types of data

There are two formats of data which can be obtained from the GIS detectors. These are known as 'raw' and 'science' data.

- Raw data with UV
- Science data with UV
- Raw data with filament
- Science data with filament

8.1.1 Raw data with UV

The raw data for a chosen detector is sent on special request via the GIS engineering stream from the GIS to the CDHS. The CDHS recognises the raw data packets and sends them as special packets in the science stream. The packets consists of the raw co-ordinates of events. The form is 16 bit data made up of the two 8-bit signals (*A* and *B*) from the detector's ADCs. In certain locations in each packet of data are a random selection of values from another ADC which measures the total signal (called *PHA* (Pulse Height Analysis data)) from the detector for events. There are 88 *PHA* values to about 512 event raw data co-ordinates. It is not possible to associate a *PHA* value with any particular event although they are evenly distributed throughout the time taken to fill the raw packet.

From the raw data one therefore obtains *A*, *B* and *PHA*. A header with the detector number, the HV set and measured, front face bias, MCP current, LLD setting and count rates is also included.

The reasons for having this mode of data are:

- a) to allow the setting of the High Voltage for each detector such that the PHD (Pulse Height Distribution) is inside the analogue signal window defined by the lower and upper level discriminators (LLD and ULD). This is the only way to get accurate intensity measurements.
- b) to allow an appropriate look up table (LUT) to be written for that detector.
- c) to allow corrections to be made to the *science* data for any loss of intensity in a particular line through the use of a particular set of LUT parameters. The raw data can be put through any LUT on the ground.

When the GIS is not in raw data mode, one of the GIS engineering parameters is a PHA value from one of the detectors. The detector can be chosen and the PHA values gathered over time to create a histogram which should reflect the PHD during the time the detector was being used. It can also be used to measure the height of the stim signals. Each detector has two stims. The PHA value should read close to zero when the detector is not at HV and the stims are off.

8.1.2 Science Data with UV

In this mode, the signals from the ADCs, (*A* and *B*), are put through a LUT on board. In the LUT each (*A*, *B*) co-ordinate is associated with an *x*-position in the spectrum. All four detectors are used simultaneously in this mode. The data takes the form of a histogrammed spectrum, 4×2048 pixels long. Once on the ground the spectra are put into FITS form. A header with each file gives exposure time, slit and mirror positions *etc.*

The purpose of this mode is to obtain large volumes of data from all four detectors, simultaneously and fast. There is an overhead of ~20 minutes to build the LUTs, but once this is done it takes 13 seconds at 10 kbit s⁻¹, to transmit a whole spectrum of 8192 pixels where each pixel contains up to 65536 (16-bit) events. Thus if the dwell time is greater than 13 s all the data can be telemetered, as long as there is no more than 5000 c s⁻¹ in any pixel (to prevent saturation of the 16-bits). For the raw data on the other hand, with 1 GIS engineering packet every two seconds, 1440 events per minute can be received. To obtain 10,000 events then takes about 7 minutes.

8.1.3 Filament Data

Two tungsten filaments are mounted in front of the four detectors in the optics bench. When a current is put through either of the two filaments, electrons are emitted. The current is programmable.

The detector front face can be biased to ±12 V. The -12 V setting is for normal use with the UV, repelling any background electrons. The +12 V setting may be used to attract the filament electrons to the detectors. (All detectors are switched together).

The purpose of the filaments is to provide a repeatable and quick view across the detector active area. They illuminate the whole of the front face, unlike a UV spectrum. If the filament setting and detector settings are repeated identically after periods of use, changes in the detector performance can be monitored. This assumes the filament output does not change at all.

8.2 Obtaining the best science data

Figure 1 illustrates the procedure, which must be done for each detector. Start by setting the LLDs to zero. Then for each detector in turn, point at an area of the Sun giving typical count rates for the experiment to be done, and change to the appropriate slit. Then:

1. Set the HV until the ratio of ULD to processed counts, displayed on the EGSE, is in the ratio 1:10. Care must be taken in taking the detectors up to HV. Safety checks are included in the GIS software; a HV upper limit—commanding HV above this will result in the limit only being reached; a MCP current limit—if the current is exceeded the HV will be switched off to this detector. Both limits are commandable.
2. Take a raw data file of about 10,000 events (200 packets). Record the name of the raw data file chosen by the EGSE STM.
3. Use the IDL program *read_raw_gis* on the raw data file obtained to split the data into two separate files, one containing the raw data co-ordinates (*.raw), the other the PHA data (*.pha). It is helpful to name the files with the detector number, filament number, HV setting and date and time. This program draws a PHD—a histogram of the PHA data.
4. Check that the HV setting is appropriate by examining the PHD drawn. If another drawing is required, *plotpha.pro* draws the histogram again from the PHA data file. The data starts at the left hand side of the plot at the LLD. The ULD is not so obvious though. It is at channel 196–204. Table 1 records the discriminator levels in terms of electrons and in terms of PHA channels. The PHD should form a peak at about channel 110 ($\sim 4 \times 10^7$ electrons), inside this window. (e.g. see figure 2). Channel 255 corresponds to 1×10^8 electrons.
5. If the PHD is satisfactory, take a large raw file of about TBD events (TBD packets?) for error analysis and meanwhile analyse (see point 6.) the small raw data file already taken, for LUT parameters. If the PHD is not satisfactory, repeat from 2., changing the HV setting by 20 V each time until the PHD is good. However, look at the later notes on count rate dependent Gain Depression.

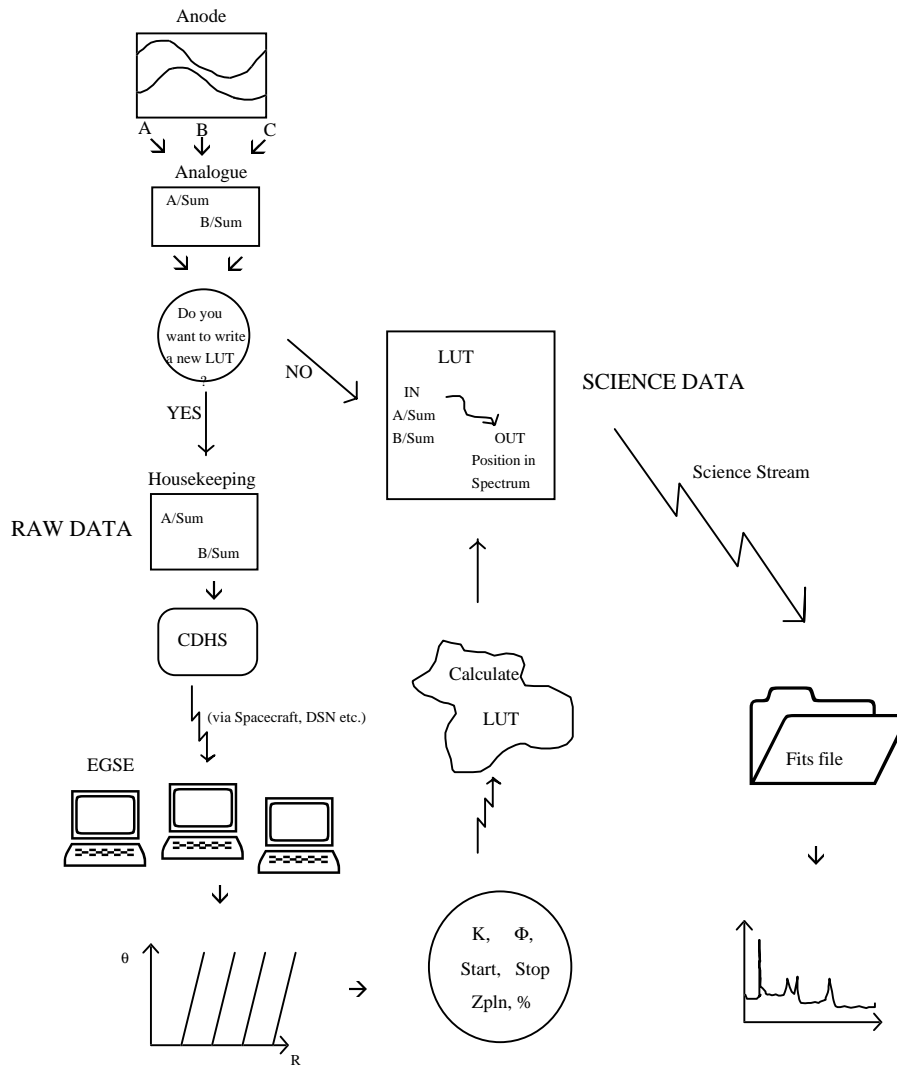


Figure 1. Flow diagram to illustrate setting up of detectors for science data

6. Use the program *vrawnall.pro* to look at the raw data taken with a good HV setting.

- Plot the raw data in polar co-ordinates. The raw data should form a series of parallel straight lines; spiral arms.
- Change gain and sum (sometimes called *zpln*) settings until the polar plot arms are as straight as possible.
- Plot in intensity co-ordinates.
- Change *k* and ϕ until the over-plotted straight lines follow the centre of the data arms.
- Choose *start* and *stop* until the over-plotted lines only follow the data arms—or just the part of the spectrum of interest. Selecting part of the spectrum in this way will invalidate any automatic wavelength calibration, but may be useful for reducing fixed patterning.
- Choose *percent* to bound the data in each arm to prevent ghosts (see later). Set this as high as possible for intensity measurements.

- Output the parameters. The LUT parameters to be uploaded are listed in order. A check on the LUT and a first view of the spectrum can be obtained by writing a LUT in IDL using *mylut.pro*. The raw file can be put through the LUT using *uselut.pro*.

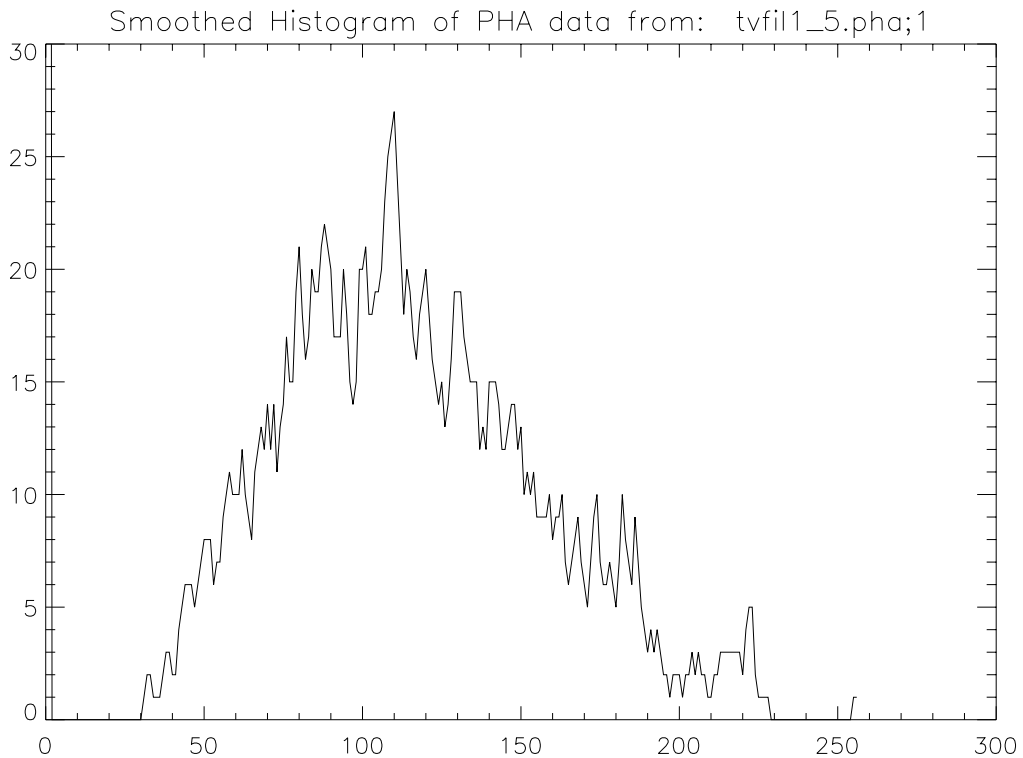


Figure 2. A typical Pulse Height Distribution showing the peak at channel 120.

	Detector 1		Detector 2		Detector 3		Detector 4	
	Electrons	Channels	Electrons	Channels	Electrons	Channels	Electrons	Channels
LLD0	1.35 e7	34	1.47 e7	38	1.27 e7	32	1.35 e7	34
LLD1	1.42 e7	36	1.55 e7	40	1.37 e7	35	1.45 e7	37
LLD2	1.65 e7	42	1.78 e7	45	1.60 e7	41	1.70 e7	43
LLD3	1.78 e7	45	1.91 e7	49	1.73 e7	44	1.85 e7	47
LLD4	2.11 e7	54	2.29 e7	58	2.11 e7	54	2.24 e7	57
LLD5	2.34 e7	60	2.54 e7	65	2.29 e7	58	2.44 e7	62
LLD6	3.05 e7	78	3.23 e7	82	3.00 e7	76	3.15 e7	80
LLD7	3.30 e7	84	3.56 e7	91	3.20 e7	82	3.43 e7	87

ULD	7.70 e7	196	8.00 e7	204	8.00 e7	204	7.75 e7	198
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Table 1. Calibration points of lower and upper level discriminators.

Repeat 1.–6. for all four detectors. Then:

7. Upload the LUT parameters to the spacecraft and start to rebuild—one detector at a time because the parameters are shared.
8. Now science data may be collected, keeping the HV settings the same as the reference raw files.

VRAW intensity and r,theta plot: d2_ne_s2_vbf_1

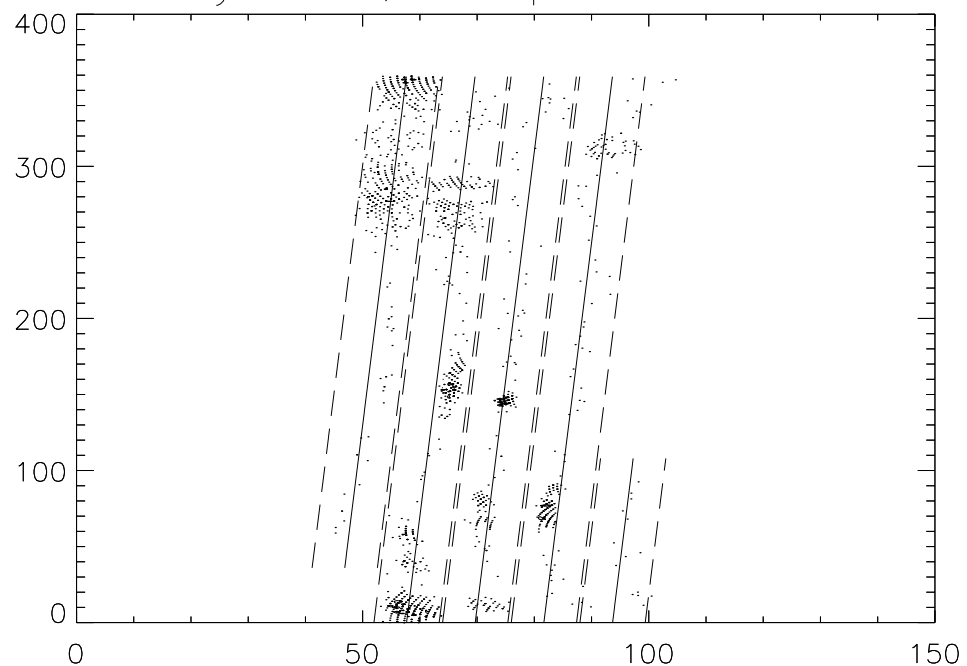


Figure 3. Showing a raw data file fitted to LUT parameters

8.3 Pre-processing corrections to the FITs science data

8.3.1 Electronic Dead times

There are two electronic dead times. One is associated with the analogue electronics for each detector standing alone. The other is associated with combining the data from the four detectors into one stream and the limited rate of data flow to the CDHS.

After the arrival and detection of a photon there follows a finite time before a new event can be detected, within which any new events will be discarded by the electronics pile up discrimination. This limits the rate at which events may be detected and results in a non-linear relationship between the input and output count rates. The reduction of the *global* count rate of the detector can be calculated and therefore compensated for. Provided there is no rapid change in the input image, this dead time does not alter the distribution of detected events in the output image. Every ‘pixel’ is available to detect a new photon within the same time period—the length of the period is reduced by dead time by the same amount for each pixel. *i.e.* the detection of a photon depends only on its arrival time, not on its position. The theoretical output rate follows the law:

$$R_o = R_i \cdot e^{(-R_i \cdot T_d)}$$

where R_i is the input rate, R_o is the output rate and T_d is the dead time, which is $2.6 \mu\text{s}$. This relationship is plotted in figure 4.

In fact the count rate is limited ultimately, by the rate at which information can be sent to the CDHS from the GIS box, which is $8.9 \times 10^4 \text{ c s}^{-1}$. A FIFO buffer, 512 events deep, is used to store bursts of events closer together, allowing short bursts of events at a higher count rate. At total (sum of all four detectors) count rates near to this value it may be possible to reduce the number of detectors being used. If the count rate from just one detector is still too high, the intensities must be treated with caution. Very short exposure times could be used.

The events from the four detectors are combined into one stream on a first come first served basis. The detector to detector dead time is 600 ns. This method of choosing the events results in a global deadtime but, as with the analogue deadtime, does not affect the distribution of events.

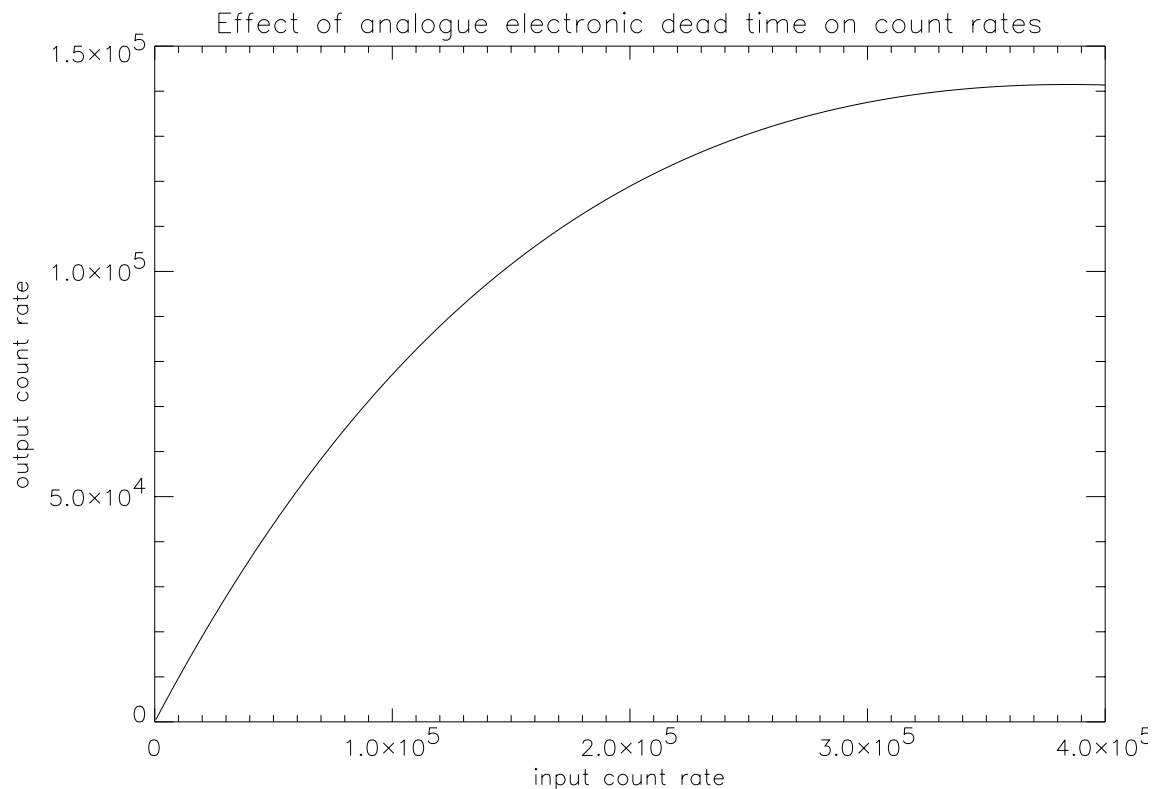


Figure 4. Plot of relationship between output and input count rates

The dead time used in the plot is $2.6 \mu\text{s}$. The curve rolls over at higher count rates leading to a reduction in output count rate at very high input count rates.

Unlike the electronic dead times, all the rest of the corrections need to be applied on a pixel by pixel basis.

8.3.2 Gain Depression

8.3.2.1 Long Term Gain Depression (LTGD)

The cause of this is simply usage of the MCP (see science note by RAH on 4th Feb. 1994). As charge is removed from the MCP channels, the gain is gradually reduced. This has the effect of reducing the apparent intensity of the line if the high voltage is not increased to compensate. For GIS, the parts of the detectors illuminated by bright lines will suffer first. Because of the wide range of intensities being viewed, it will not be possible to compensate for the LTGD in all lines at once by increasing the high voltage. A particularly intense line may cause gain depression in neighbouring regions up to a distance of 1 mm (2% of spectrum).

There are two problems here. One is the global decay of gain across the whole detector—caused by outgassing, plate ageing, filament useage *etc*. The other is differential decay caused by the fact that the spectrum is always illuminating the same parts of the detector. I would therefore suggest a two pronged attack.

Firstly, to monitor global decay by using repeated quiet sun measurements, background count rates or continuum. If quiet regions of the sun are considered to be stable, then any decrease in intensity can be monitored with regular viewing of quiet sun regions.

Secondly, to monitor differential decay both by using the quiet sun and the filaments. A sequence has been suggested which uses a wide slit to view the quiet sun. Differential decay should show up as dips in the slit image intensity.

The filament electrons illuminate the whole detector surface. Any regions suffering from gain depression will appear as a region of lower count rate.

As there are four detectors and two filaments, it is better to set up a filament with one detector at a time. Choose the filament which gives the flattest spectrum for the detector. In the FM TV test detectors 1 and 4 gave flattest spectrum with filament 2, and detectors 2 and 3 with filament 1. Take care to start with a low current and work upwards. Very high count rates can be obtained very easily and this may not be obvious with the counters limiting at $65,000 \text{ c s}^{-1}$.

- Choose a HV setting as before (§**Error! Reference source not found.** item 1.) and put a current through the filament until an event rate of about $5,000 \text{ c s}^{-1}$ is obtained (or until the correct count rate in non-bright-line regions is obtained—see below). The HV and filament current may need to be iterated until a suitable count rate and PHD is obtained.
- Take raw data and fit a LUT and then take a science data file of filament events. For a statistically significant histogram to the 5% level, it is necessary to take a data file with at least 400 events per pixel. (N.B. This is not necessarily the same as 800,000 counts in total in the event of a not very flat distribution.)
- Take a filament file for every detector regularly (daily at the beginning of the mission). Correct each histogram by dividing by the exposure time. Then divide the new histogram by the old to create a correction curve. Any low count rate areas will show up as depressions in the correction curve. It can be divided into the data to correct for LTGD.

It may be necessary to close the doors while the filament data is being taken, because there is no blank slit provided.

The problem with using filaments to monitor *global* decay is that they probably will not stay constant in time. The best use would be to set up the filament and the HV to give the same count rate in non-bright-line regions at all times. Then dividing one spectrum by the other will give values equal to 1.0 in non-bright-line regions, and more than 1.0 where there has been loss of sensitivity.

8.3.2.2 Count rate Dependent Gain Depression (CDGD)

This gain depression occurs when there is a high count rate such that the MCP cannot recharge fast enough to provide full gain for every event. The peak of the PHD for the affected area moves towards the LLD so that the number of events are not counted accurately.

Use of the PHD obtained from the raw data is limited because this is a mean PHD over the whole plate. If one bright line dominates, then the mean PHD may shift to the left. Seeing this, you may be encouraged to increase the high voltage, to return the PHD to the central position. However, this may be compromising the accurate intensity measurements of any lower count rate lines which are also of interest. The increase in voltage may force them over the ULD. If there is only one line of interest, it may be possible to change the HV until the intensity of that line is maximised.

An alternative method to changing the HV is to use a correction curve, as in figure 5 TBD. Problems occur in the regions of the curve which are double valued. The smallest slit should be used to minimise count rates and hence confusion.



Figure 5. Correction curve for CDGD

8.3.3 Background

The detector dark count is less than $1-2 \text{ c s}^{-1}$ per detector. Background due to scattered light from the telescope may need to be subtracted, particularly for detector 1.

8.3.4 Ghosts

Figure 3 shows the fitting of a LUT to a normal raw file. In the case of bright lines, the events will tend to spread across to the neighbouring arm (usually to the left). Ghosts of the line will then appear in the wrong part of the spectrum. Because of the type of distortion, the ghosts will always appear in well defined positions. A program called *ghost.pro* will give the possible positions of any ghosts and vice versa. The ghost intensity can be added to the true line intensity.

If there are distortions in the image which cannot be removed by adjusting the gain and offset parameters (see point 6. in §**Error! Reference source not found.**) this may also lead to ghosts.

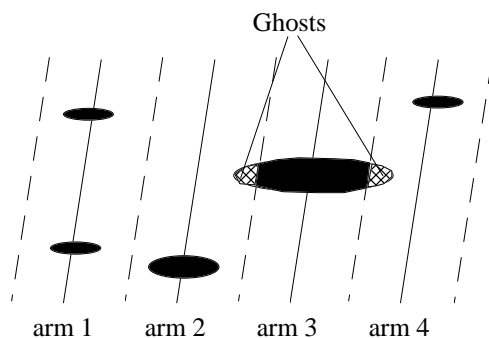


Figure 6. Demonstrating the cause of ghosting from one spiral arm to another.

Here, an event which should be on arm 3 is spreading to give ghosts on arms 2 and 4.

8.3.5 LUT corrections

If the *percent* parameter in the LUT is set to 100%, then the maximum number of events will be captured in the science data. There will undoubtedly be some ghosts, because of small distortions in the data. By adding the intensities from all the ghosts back onto the true lines the true intensity can be obtained. However, problems may occur when the ghost of one line appears at the true location of another line. In this case, it may be better to reduce the *percent* parameter to cut out the possibility of ghosting.

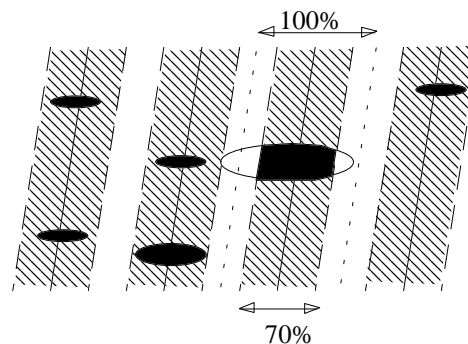


Figure 7. The use of percent to minimise ghosts

The disadvantage of this approach is that the intensity in the spectral lines are not given by the number of events in the received spectrum.

Using *Vrawnall.pro* correction factors can be obtained for this. The method is to select the part of the arm containing the line using *start* and *stop*. The percentage of events found within 100%, and also within *percent* % can then be measured. The ratio gives the correction factor. These correction factors are very dependent on the shape and fit of the data. It is for this reason that the reference file and knowledge of LUT *etc.* is so important.

Arm_line.pro can be used to work out the position in terms of pixels of a line given in terms of spiral arms.

8.3.6 Intensity Curves

Once all the corrections have been performed to the data, the received spectra can be compared with the intensity curves obtained using the calibration data.

8.3.7 Wavelength Corrections

The best fits are quadratic. There are two reasons for this. One fundamental reason is that the detectors are flat whereas the spectral axis is a curved Rowland circle, and the incident light is at a high grazing incidence angle. This leads to a quadratic error, as in figure 8.

The second reason is associated with the LUT. The convolution of the charge cloud with the anode leads to a reduction in spiral radius. The shrinkage is not proportional to radius. When a spiral is fitted to the output, the result is a spiral with fewer arms than in the anode design. Because the position of a spectral line in this polar plane only shifts in radius and not in θ , the line may appear to be on arm 3 rather than arm 5. This results in another quadratic error in the wavelength calibration, but this time dependent on the amount of shrinkage. It can easily be calculated if the LUT parameter *start* is known (figure 9).

There is a program (xerrcomb.pro) to calculate the geometrical error for each detector with the incident angles of the UV light adjusted accordingly. It also calculates the error due to the LUT and adds the two together.

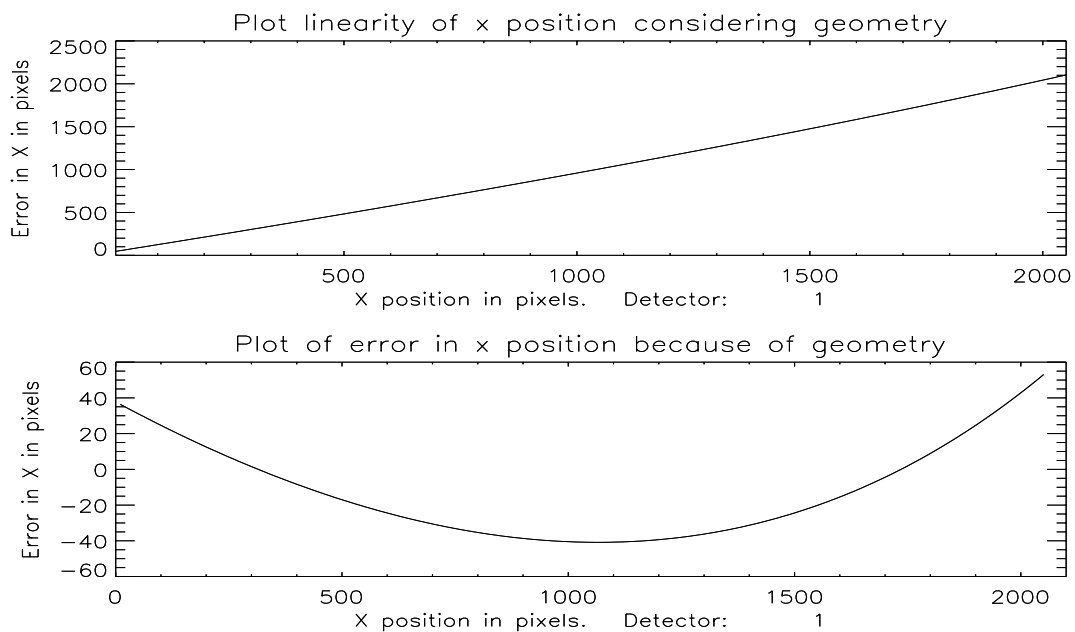


Figure 8. Error on wavelength calibration due to the geometry

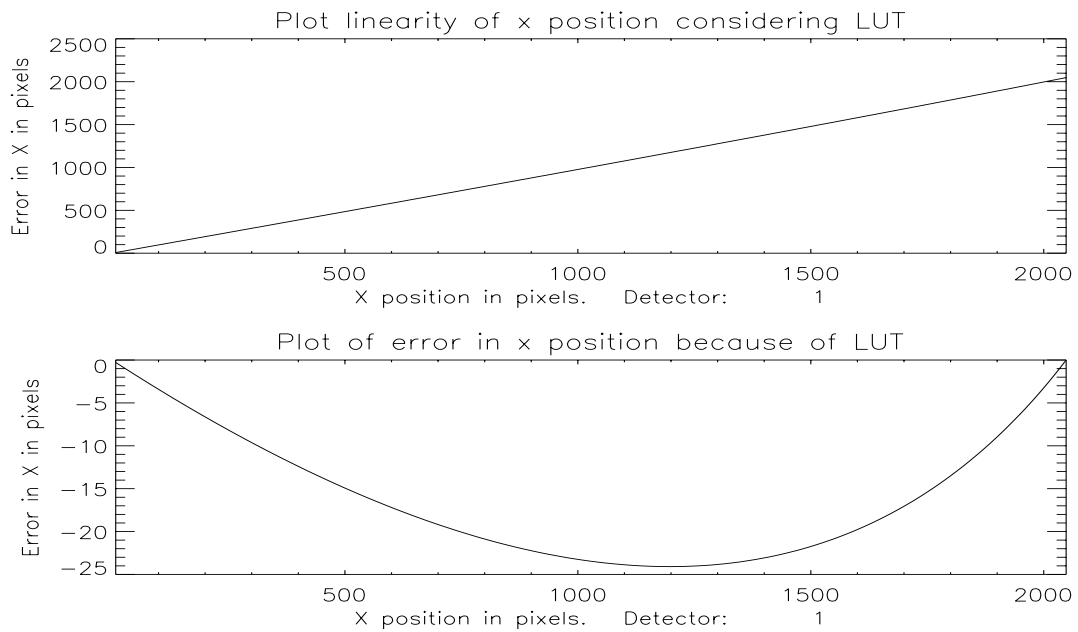


Figure 9. Non linearity in wavelength calibration due to LUT (with start = 4.1).

8.4 Summary of GIS pre-processing algorithms

8.4.1 Dead Times

8.4.1.1 Overview:

A correction is made which will compensate for the effects of two types of deadtime:-

- a) Analogue deadtime for each detector - 2.6 μ s
- b) Digital processing deadtime - 10 μ s

8.4.1.2 Input:

Raw count rate per detector, c_n , where $n = 1,2,3,4$

Science count rate, s_{sum}

8.4.1.3 Algorithm:

Let analogue throughput be a_n

Let digital throughput be d

Then:

$$a_n = \text{fn}(c_n)$$

$$d = \text{fn}(s_{sum})$$

8.4.1.4 Output:

5 values: $d c_n$

8.4.2 Ghosting

8.4.2.1 Overview

Because of imperfections in the SPAN pattern and the finite noise width, intense line features may cause ghost lines in other parts of the spectrum. This algorithm indicates ghost channels for any given channel number. The user may then use this algorithm in order to:-

- a) Identify counts from a line of interest which have appeared as ghosts, for the purpose of intensity measurements.
- b) Confirm that a weak feature is not the ghost from a strong line.

8.4.2.2 Input:

LUT parameters (*start* and *stop*)

8.4.2.3 Algorithm:

See elsewhere (IDL procedure *GHOST.PRO*)

8.4.2.4 Output:

Channel IDs as required by user.

8.4.3 LUT Correction

8.4.3.1 Overview

If the LUT involves <100% throughput, then a correction must be made to account for this loss. The loss will not be uniform over the spectrum but will be largest in those areas of the spiral where the greatest distortions have occurred.

8.4.3.2 Inputs

LUT parameters

Raw data

8.4.3.3 Algorithm

TBD

8.4.3.4 Output

Correction factor per channel per detector L_{nx} , where $x=1-2048$

8.4.4 Count-rate Dependent Gain Depression

8.4.4.1 Overview

Since MCP gain is reduced as the local count rate is increased, the effective throughput at any part of the spectrum is a function of the local count rate. This algorithm calculates the effect of this gain depression in terms of throughput per channel. An approximation is made in which the positional resolution from the electronic readout is considered small compared with the spectral line width. The user is provided with a correction curve which relates measured count rate with corrected rate per channel.

8.4.4.2 Input:

HV settings

CDGD curves developed from *e.g.* Spectral Atlas (data in curves must be already corrected for their own t , a_n , ghosts and L_{nx}).

8.4.4.3 Algorithm:

TBD

8.4.4.4 Output:

For each detector, factors R_{nx} where:

Corrected count rate in $x = R_{nx} \times m_x$ where:

$$m_x = (\text{measured c/r in } x \times L_{nx} + \text{measured c/r in ghost} \times L_{nghost}) \times t \times a_n$$

8.4.5 Long Term Gain Depression

8.4.5.1 Overview

MCPs retain a 'memory' of their previous count-rate history. As the detector is scrubbed then the gain falls with time. The approach taken here is to compare the most recent flat-field measurement with one made at the start of the mission in order to determine the present local throughput.

8.4.5.2 Input:

Flat-field at start of mission

Most recent Flat field

8.4.5.3 Algorithm:

Recent flat field / Early flat field - normalised to 1.0 for low rate parts of the spectrum.

8.4.5.4 Output:

2048 channel spectrum of corrections per detector = D_{nx}

8.4.6 Sensitivity

8.4.6.1 Overview

Regular measurements will be made of the overall sensitivity of the instrument. These will be phased with the flat field calibrations such that an estimate of this sensitivity will be made for each such measurement.

8.4.6.2 Input:

Quiet Sun science data close in time to the most recent flat field.

8.4.6.3 Algorithm:

Quiet Sun data with corrections applied for deadtimes, ghosts, LUT rejection, count-rate dependent gain depression and long term gain depression, instrument efficiency.

8.4.6.4 Output:

Factors S_{nx}

8.4.7 Intensity

True flux for detector n at position x :

$$=(\text{measured c/r at } x \times L_{nx} + \text{measured c/r in ghost} \times L_{nghost}) \times t \times a_n \times R_{nx} \times D_{nx} \times S_{nx}$$

9. Detailed VDS Procedures (WTT)

9.1 What

9.2 How

10. Engineering Activities (ECS)

10.1 Mechanism Maintenance

10.1.1 What

10.1.2 How

10.2 Mechanism Monitoring

10.3 Relay Monitoring

10.4 VDS Exposure Monitoring

10.5 Thermal Monitoring

10.6 Thermal Adjustment

10.7 Contamination Monitoring

QCM readings etc

11. Appendices

11.1 Command List

11.1.1 What

11.1.2 How

11.2 Telemetry Parameters

11.2.1 What

11.2.2 How

11.3 And all other IWS databases ...

11.3.1 What

11.3.2 How

11.3.3