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SWIFT UVOT USERS GUIDE

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REVISION SUMMARY

REV	RELEASE DATE	BRIEF DESCRIPTION/REASON FOR CHANGE	EFFECTED PAGES
--	07-Jul-2004	Initial Version	All
1	08-Sep-2004	Cross-references added to aid information access. Added section on DISMON circuit. Added some additional special operations. Added additional safety issue points. Some typos found and corrected. Text clarity improved. Some addresses corrected. Added description of pseudo sources to catalogue section. Added DPU response matrix. Added ICU response matrix. Added filter responses.	All
2	26-Nov-2004	Major revisions to limit violation table. Revised image intensifier diagram. Clarified many ICU SOFTWARE section items.	Section 2.4 Section 1.2.2.4 Section 1.3
3	19-Apr-2005	Modified AT, PT, Standard and Error Handling tables for revision 10.	Appendix A
		Modified DCS Event Table (ECR 205).	Appendix E
		Corrected many cross-references and hyperlinks.	All
		Documented NCR 22, NCR 74-82, NCR 94 and NCR 117.	Appendix F, section 1.3.7
		Updated list of RTSs for revision 10.	Section 1.3.8.2
		Added error codes to the errors messages section.	Appendix C
		Updated NCR/ECR section for release 10.	Appendix F
		Added section on ‘Useful Numbers’	Section 1.3.7.1
		Added example images of coincidence loss and excessive count rates to detector section.	Section 1.2.2
		Loading or dumping memory at the same time warning	Section 2.5.3

ACRONYM LIST

ACS	Attitude Control System
AT	Automatic Target
BA	Burst Advocate
BPE	Blue Processing Electronics – a.k.a. the Detector Electronics
CDS	Calibration Data Specialist
DCI	Data Capture Interface
DEM	Digital Electronics Module
DPU	Data Processing Unit
DTAS	Data Trending & Analysis System
EDT	Eastern Daylight Time
EEPROM	Electronically Erasable PROM
EF	Early Frequency
EST	Eastern Standard Time
FOT	Flight Operations Team
F/W	Filter Wheel
GSFC	Goddard Space Flight Center
HK	House Keeping
HV	High Voltage
HW	Hardware
ICU	Instrument Control Unit
L&EO	Launch & Early Orbit
MOC	Mission Operations Center
MSSL	Mullard Space Science Laboratory
NFI	Narrow Field Instrument
NHK	Non Periodic Housekeeping
OAB	Osservatorio Astronomico di Brera
OB	Optical Bench
ODS	Observatory Duty Scientist
RAM	Random Access Memory
PROM	Programmable Readonly Memory
PSF	Point Spread Function
PSU	The Pennsylvania State University
PT	Pre-Planned Target
QA	Quality Assurance
RF	Regular Frequency
RTS	Relative Time Sequence
SAA	South Atlantic Anomaly
S/C	Spacecraft
SDC	Swift Data Center
SERS	Spacecraft Emergency Response System
SOT	Science Operations Team
SW	Software
TBA	To Be Added
TDRSS	Tracking and Data Relay Satellite Systems
TM	Telescope Module
UDS	UVOT Instrument Duty Specialist
UIM	UVOT Institutional Manager
UVOT	Ultra Violet and Optical Telescope

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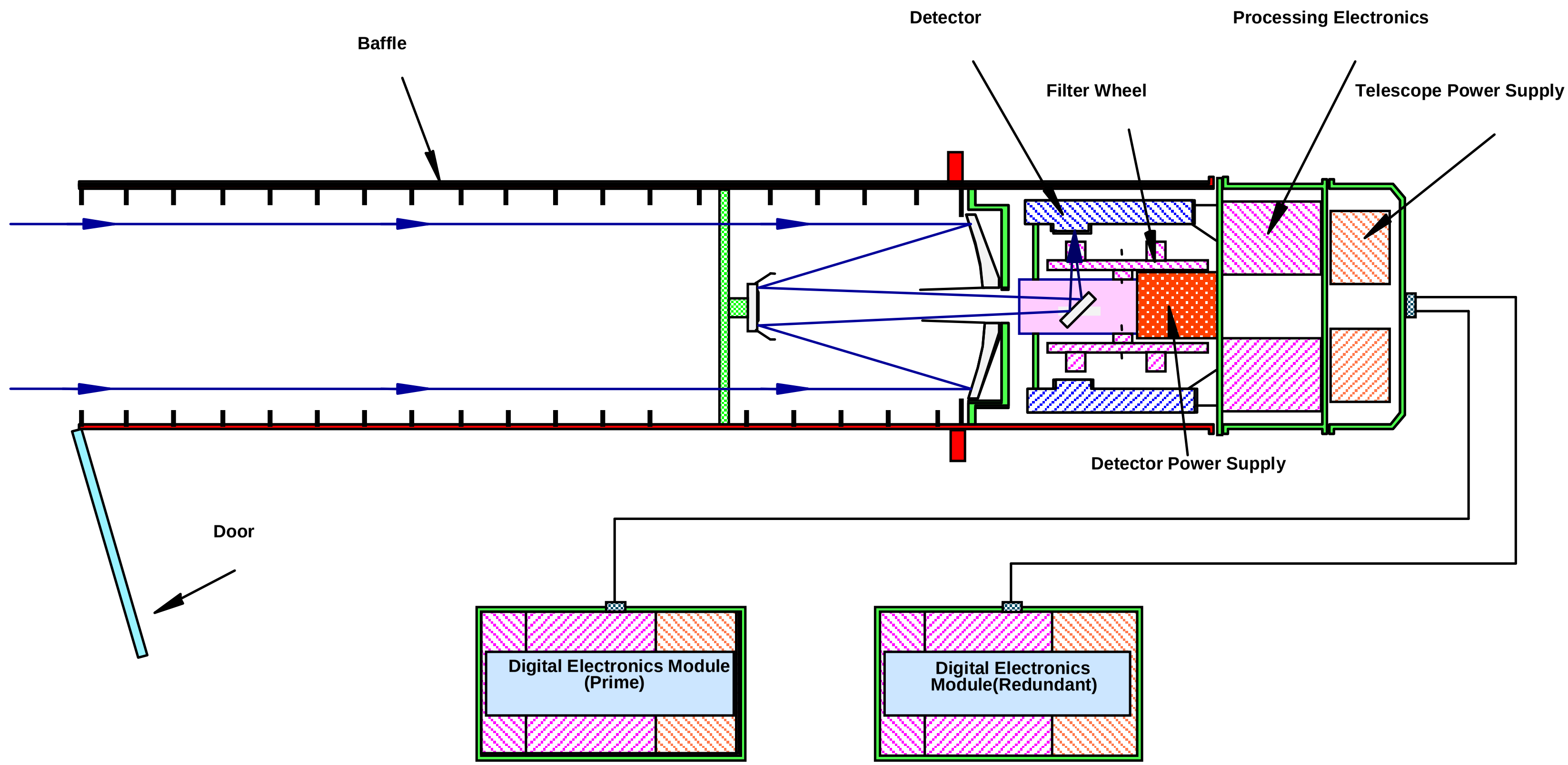
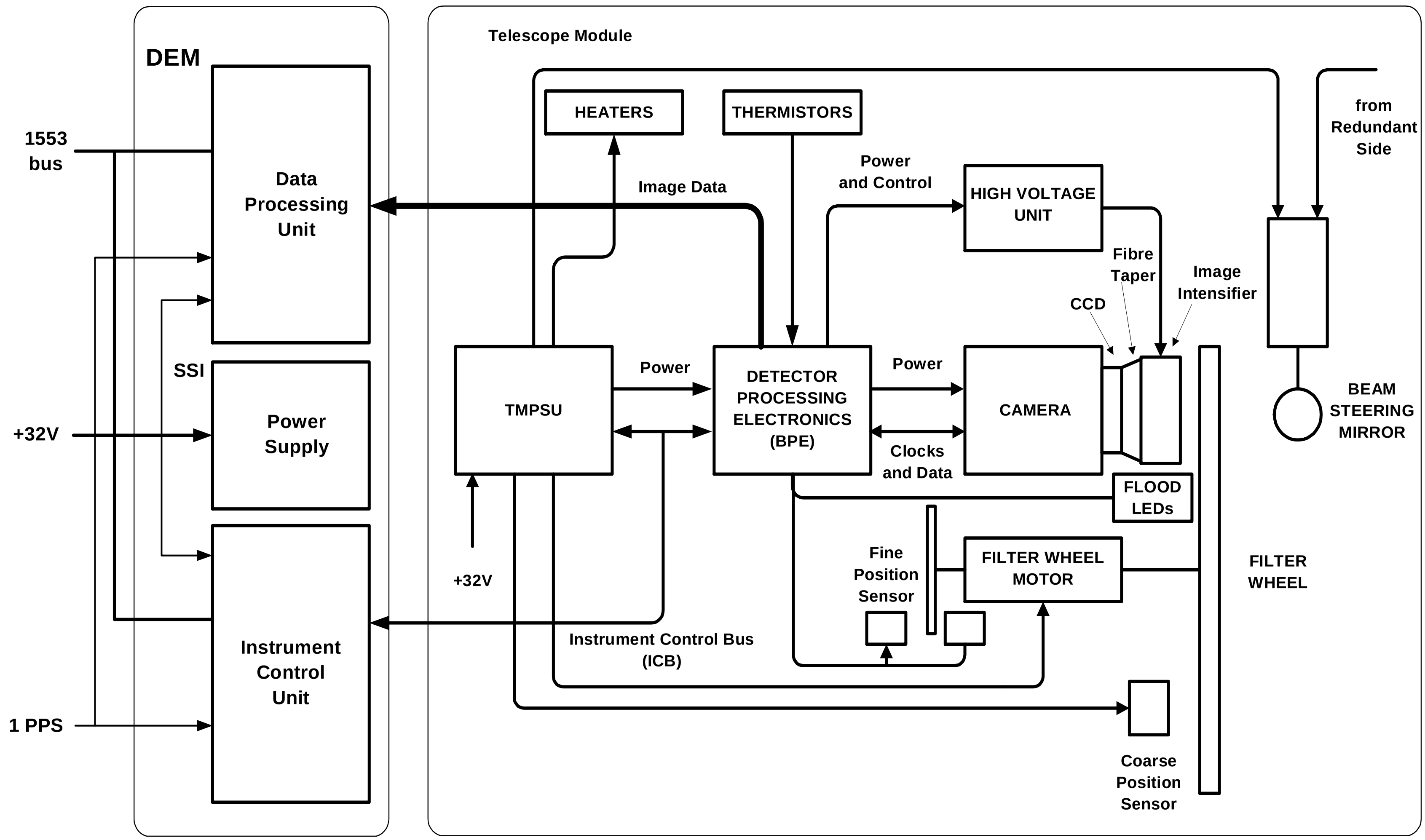

Baffle
Detector
Filter Wheel
Processing Electronics
Telescope Power Supply
Detector Power Supply
Door
Digital Electronics Module
(Prime)
Digital Electronics
Module(Redundant)

Swift-UVOT

Swift-UVOT: Electronic Architecture

(showing Prime only for clarity)



1. Instrument Description

1.1 Digital Electronics Module (DEM)

This controls all aspects of the UVOT operation. It is therefore powered on before, and powered off after, the telescope module (TM) – see section 1.2 for a description of the TM.

IMPORTANT SAFETY NOTE: If the DEM is powered off with the telescope module (TM) on, the TM will remain in the same state and, if that was observing with the high voltages at maximum, this loss of control of the TM could result in damage to the detector. Should this occur, only the SACSLEWSAFEREPLY handshake, with its lack of response from the UVOT DEM (as part of the slew warning sequence – see section 1.3.11.4) could help, as the S/C would then power off the TM.

1.1.1 ICU

1.1.1.1 ICU Overview

The ICU is responsible for controlling and managing all aspects of the UVOT's operation, including:

- Interacting with the spacecraft to ensure instrument safety during slews
- Autonomous instrument safing in off-nominal observatory conditions
- Emergency communications via the Tracking and Data Relay Satellite System (TDRSS)
- Autonomous protection of the detector from fields containing bright stars – this uses the combination of an on-board star catalogue and signals from a bright source detecting safing circuit
- Interacting with the Figure of Merit computer to select and execute appropriate science observations
- Control and monitoring of instrument thermal state, mechanisms and detector system

ICU capabilities are implemented via a combination of compiled Ada code and a customized interpreted scripting language (the RTS system), together with EEPROM located tables of exposure sequences, safety-related information and calibration data.

1.1.1.2 PROM

The PROM contains a bootstrap that, on power-up or reboot, copies the basic set of code from PROM into RAM and executes it. The basic code supports basic safing of the instrument, provides housekeeping and thermal control, initiates the loading of operational code into RAM for execution and permits updates to the operational code.

1.1.1.3 EEPROM

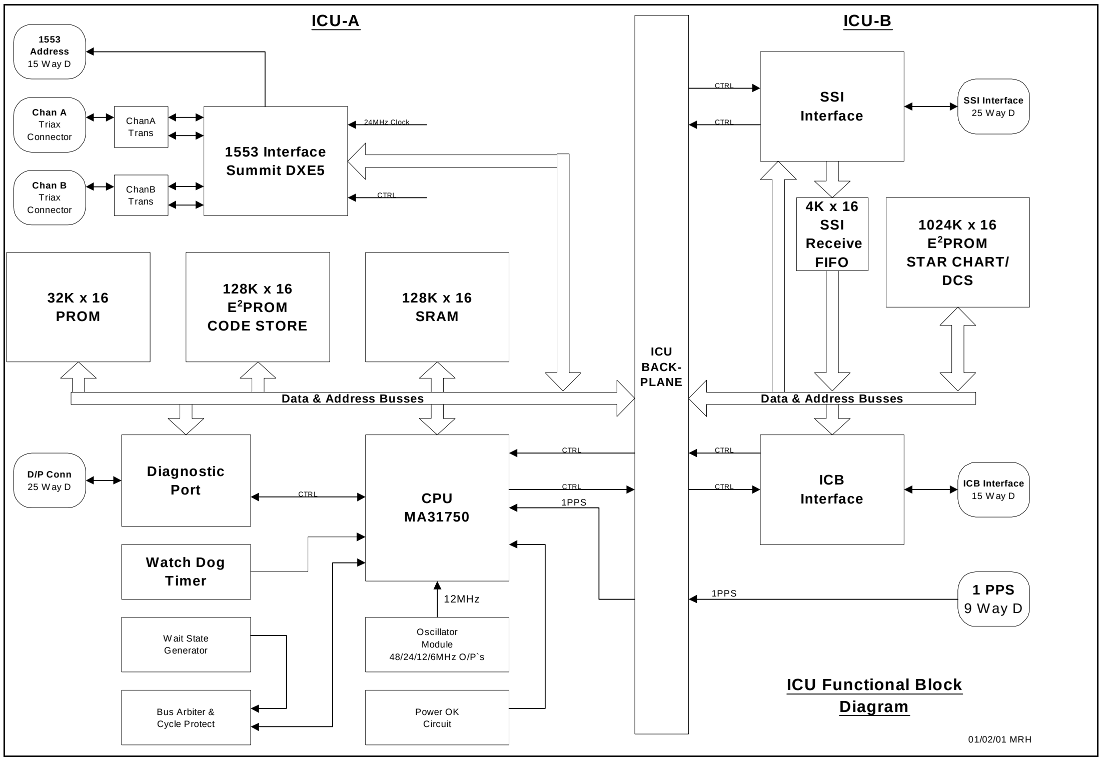
EEPROM-A contains the operational code and tables required by the basic code. EEPROM-B contains all remaining tables, the star catalogue and the RTS scripts – see later sections for descriptions of the star catalogue and the RTS system.

1.1.1.4 RAM

RAM consists of 64K words of code space and 64K words of data space. A 31750 word consists of 16 bits.

1.1.1.5 Watchdog

The ICU watchdog timer gives a timeout after 11 seconds. If the timer reaches zero a power down interrupt is generated and 256uS later, the ICU will be reset. This timer is disabled on power up and is enabled by ICU software. The timer can be enabled and disabled by ICU software. This timer is reset provided the ICU hardware and software is working normally. The reset period is commandable. On a less frequent, but also commandable time interval, the counter is reset provided 'aliveness' flags maintained by all software tasks in the ICU are being continuously reset by those tasks not deemed to be 'asleep'.



1.1.2 DPU

TBA – including reference to switched round thermostats on DEM (QAR 3442)?

1.1.3 Interfaces

1.1.3.1 1553 Interface

All data (includes commands, housekeeping, science data, time distribution messages, burst alert messages, and inter-instrument communications) is passed to/from the spacecraft and between instruments using a MIL-STD-1553 bus.

This interface is controlled by the Swift 1553 Bus Protocol Interface Control Document (Spectrum Astro 1143-EI-S19121), also referenced to in this document as the 1553 ICD.

Device	**RT Address**	**Sub-address**	**1553 Tranx**	**Data Words**	**Description**
UVOT DPU	6	11 – 25	RT Transmit	32 * 15	Instrument CCSDS Telemetry
		26	RT Receive	1	Telemetry “Done” Indicator
		27	RT Receive	31	Instrument CCSDS Telecommand
		29	RT Transmit	32	RT to RT Telecommand
		30	RT Rcv/Tx	1 to 32	Data Wrap-Around
UVOT ICU	9	11 – 25	RT Transmit	32 * 15	Instrument CCSDS Telemetry
		26	RT Receive	1	Telemetry “Done” Indicator
		27	RT Receive	31	Instrument CCSDS Telecommand
		29	RT Transmit	32	RT to RT Telecommand
		30	RT Rcv/Tx	1 to 32	Data Wrap-Around

The UVOT DPU and UVOT ICU each have a remote terminal addresses on the 1553 bus, as per table above. It should be noted that the UVOT ICU addresses are identical on both Prime and Redundant halves of the instrument. They should therefore ***NOT*** be turned on at the same time otherwise 1553 errors and packet loss is anticipated. A similar situation exists for the UVOT DPU.

The spacecraft can accommodate variable length packets in CCSDS packet telemetry format transmitted over the MIL-STD-1553 interface. However, all telemetry packets issued by the UVOT ICU are of fixed length.

1.1.3.2 Serial Synchronous Interface (SSI)

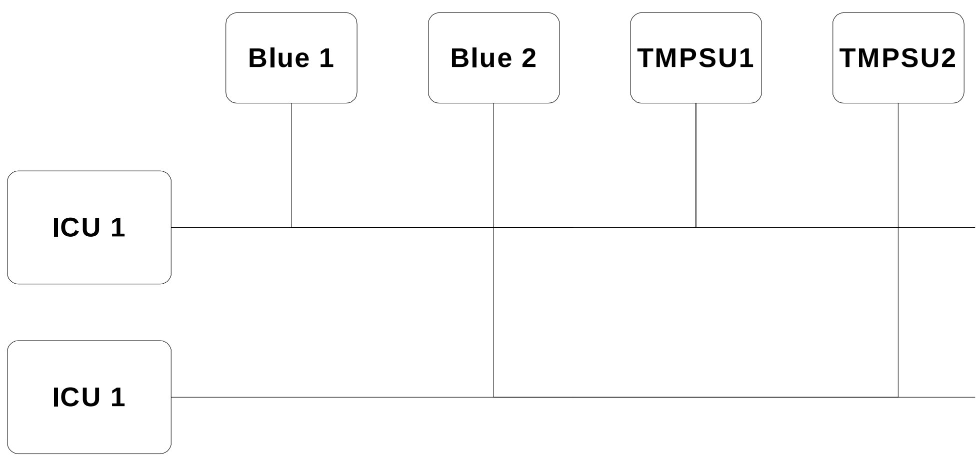
The SSI is a bi-directional communications interface between the DPU and ICU. Both the ICU and the DPU can send and receive data on this interface but the ICU is the master. Commands are sent from the ICU to the DPU. DPU responses are sent to the ICU. They are in data blocks identical in format to spacecraft packets. A receive FIFO is included in the design in order to offload processing overhead from the ICU.

The SSI clock frequency is 125 kHz producing a period of 8 us (1 bit-period). The SSI 16-bit data words are separated by at least one bit-period and at most the SSI block gap. The SSI data blocks are separated by at least the SSI block gap (defined in software).

For full details of the ICU/DPU protocol on this interface, refer to “ICD for the ICU/DPU protocol for the UVOT”, 03691-DPUICD-01.

1.1.3.3 Instrument Control Bus (ICB)

The ICU controls and monitors the telescope module via the ICB. The ICB is the digital data highway that the ICU uses to send and receive commands and status. An existing standard has been adopted for the ICB called the MACS bus (Modular Attitude Control Systems bus) detailed in the “MACS Handbook”, prepared by MATRA for ESA. It is a prioritized multi-master bus.



Because there are a number of units on the bus, the ICB has several functions. The detail of the functions performed on the bus is controlled by software in the ICU.

The functions performed via the ICB are:

- Loading of tables into the detectors
- Commanding of the detectors
- Status monitoring of detectors
- Reading filter wheel position sensors and temperature sensors.
- Controlling power switching
- Controlling heater switching
- Controlling motor drives
- Monitoring voltages/currents

The MACS bus specification defines a redundant bus. Redundancy is provided in Swift by two separate detector chains, and therefore only one MACS interface is used per redundant half.

The ICU always drives the clock on its bus.

Possible commands are:
- 16bit transfer of data from the ICU to the sub-system initiated by the ICU - ICBsend
- 16bit transfer of data from the sub-system to the ICU initiated by the ICU - ICBacquire

These ICB-commands are made up pairs of ICB-words. ICB-words are 24 bits long and can be of one of two types: ICBinstruction, or ICBdata:

ICBsend

ICBinstruction								**ICBdata**					
0	3	8	13	18	21	22	23	0	3	5	21	22	23
101	ICUaddr	dest	subaddr	010	par	err	ack	011	00	data	par	err	ack
3	5	5	5	3	1	1	1	3	2	16	1	1	1

The ICU generates both ICB-words.

ICUaddr	The ICB address of the ICU
Dest and subaddr	Define the sub-system which should respond to this command
Par	Parity for the word
Err	Error condition, if true the command should be ignored
Ack	Acknowledge, generated by the sub-system
data	16bit value to be used by the sub-system

ICBacquire

ICBinstruction								**ICBdata**					
0	3	8	13	18	21	22	23	0	3	5	21	22	23
101	ICUaddr	dest	subaddr	100	par	err	ack	011	00	data	par	err	ack
3	5	5	5	3	1	1	1	3	2	16	1	1	1

The ICU generates the ICB instruction word and the ICBdata word is then generated by the addressed sub-system.

ICUaddr	The ICB address of the ICU
Dest and subaddr	Defines the sub-system which should respond to this command
Par	Parity for the word
err	Error condition, if true during the instruction the command should be ignored, if true during ICBdata the response will be ignored by the ICU
Ack	Acknowledge, generated by the sub-system in response to the instruction, generated by the ICU in response to the ICBdata.
Data	16-bit value to be used by the sub-system

The clock frequency of the interface is 512 Hz.

1.1.3.4 Time

The ICU has two 1pps inputs: A and B. The two 1pps signals are both on, but a software-controlled switch in the ICU selects between A and B. Interrupts are generated once per second in the ICU from the selected 1pps signal.

Onboard time is managed using two components: spacecraft clock and a UT correlation factor (UTCF). The spacecraft clock is the spacecraft's internal clock used for the majority of onboard functions (e.g., all CCSDS secondary header time tags and management of stored command processing functions). The spacecraft clock is set at initial power-on and is nominally run at 1 Hz rate without adjustments. The UTCF is a bias that is adjusted such that the sum of the spacecraft clock with the UTCF yields a time that is as close as possible to UTC.

The spacecraft transmits time to all instruments. Spacecraft time and a Universal Time Correlation Factor are transmitted over the 1553 bus once every second and are valid at the next one pulse per second.

1.2 Telescope Module

1.2.1 TMPSU

The telescope module power supply (TMPSU) converts the spacecraft power bus to power rails within the telescope module. One set of rails powers the blue digital and analogue electronics and high voltages. The analogue electronics, in turn, controls the high voltages and powers filter wheel fine sensor LED and flood LEDs. The other set power the mechanisms and filter wheel coarse sensor. The integral ICB interface provides the channel for control of the coarse sensor, the flood LED's, the analogue and digital electronics and the return of current, high voltage and fine sensor status values. Additionally the main s/c power, routed via the TMPSU, is used to drive the heaters.

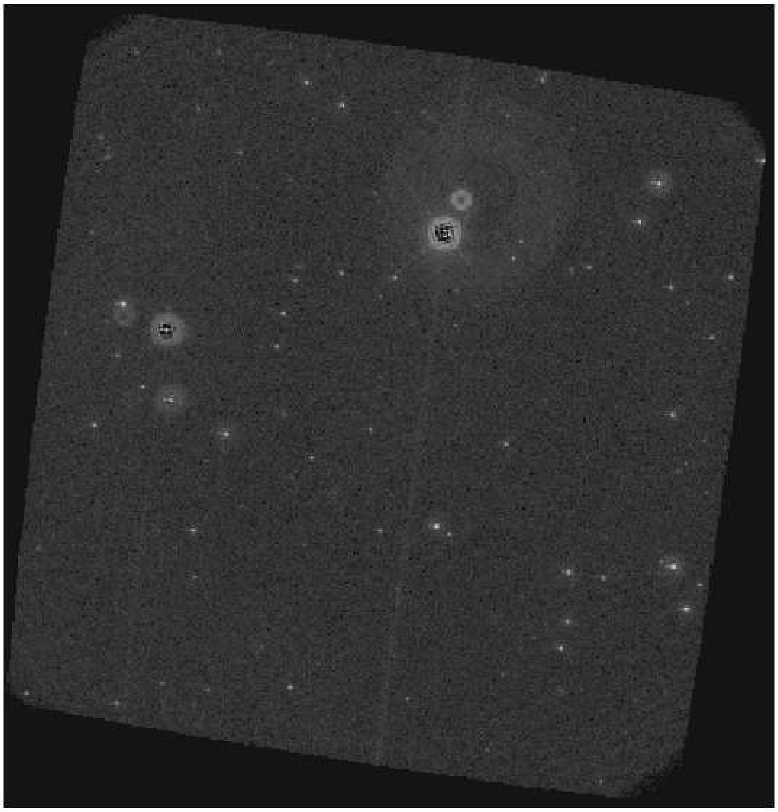
1.2.2 Detector System

1.2.2.1 Overview

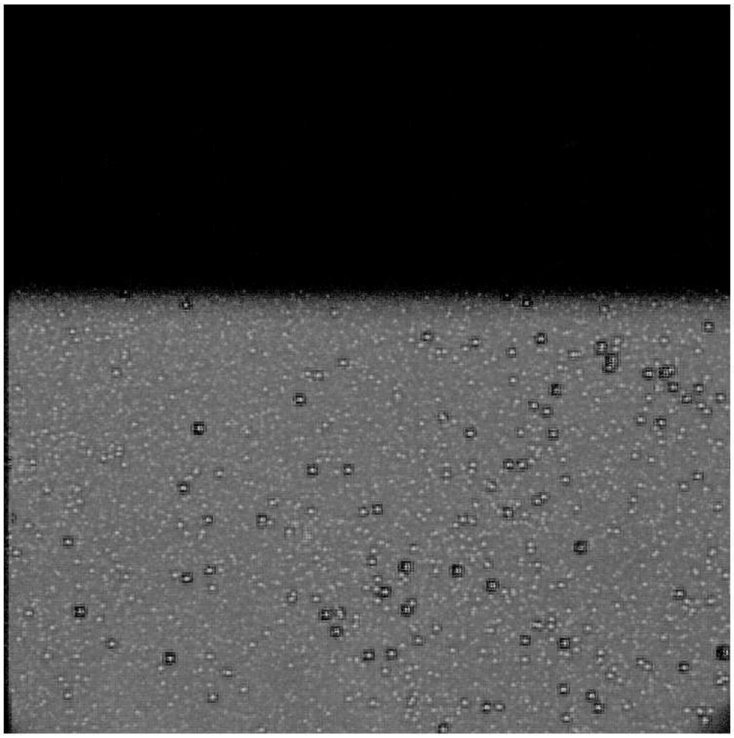
There are two detector assemblies. Each detector assembly consists of detector window that is slightly figured, a S20 photocathode, three Micro-Channel Plates (MCPs), a phosphor screen, tapered fiber-optics, and a CCD (see Figure 6. The photocathode is optimized for the UV and blue wavelengths. Although there are three separate MCPs, MCP2 and MCP3 are butted up against each other. The CCD has 385 x 288 pixels, 256 x 256 of which are usable for science observations. Each pixel has a size of 4 x 4 $arcsec^2$ on the sky affording a 17 x 17 $arcmin^2$ FOV. The first MCP pore sizes are 8 µm with distances of 10 µm between pore centers. The second and third MCPs have pore sizes of 10 µm with distances of 12 µm between pore centers.

Photons arriving from the BSM enter the detector window and strike the photocathode. Electrons discharged from the photocathode are then amplified by the first MCP creating an electron cloud. This electron cloud is further amplified by the combined second and third MCPs creating a larger electron cloud. This larger electron cloud then illuminates the phosphor screen. The photons created from the phosphor screen then travel to the CCD via the fiber-optics. This combination of MCPs and CCD provides an amplification of $\sim10^6$ of the original signal. The registering of photons is achieved by reading out the CCD at a high frame rate and calculating the photon splash's position by means of a centroiding algorithm. The centroiding algorithm also affords a large format to the CCD by sub sampling each of the 256 x 256 CCD pixels into 8 x 8 virtual pixels, thus providing an array of 2048 x 2048 virtual pixels with a size of 0.5 x 0.5 $arcsec^2$ on the sky. Faint residuals of a pattern formed by creating the 8 x 8 virtual pixels are removed by ground processing. Unlike most UV or optical telescopes, because of UVOT's high frame CCD read out rate, the UVOT can function in a photon-counting mode

As with all photon-counting detectors, there is a maximum count rate threshold. The frame rate of the UVOT detectors is 10.8 ms for a full 17 x 17 $arcmin^2$ frame; therefore, for count rates above ~10.8 counts/s, assuming a point source, a count rate correction needs to be applied. A CCD dead time correction also needs to be applied during the data processing. Because the local sensitivity of the photocathode can be permanently depressed, care must be taken when observing bright objects. This is accomplished through autonomous operations diminishing the time spent on these bright sources. The detector's dark noise is extremely low (approximately 4×10^{-5} counts/s/pixel) and can be ignored when compared to other sources of background noise.



High count rates will produce coincidence loss. This is an example image showing the effect.

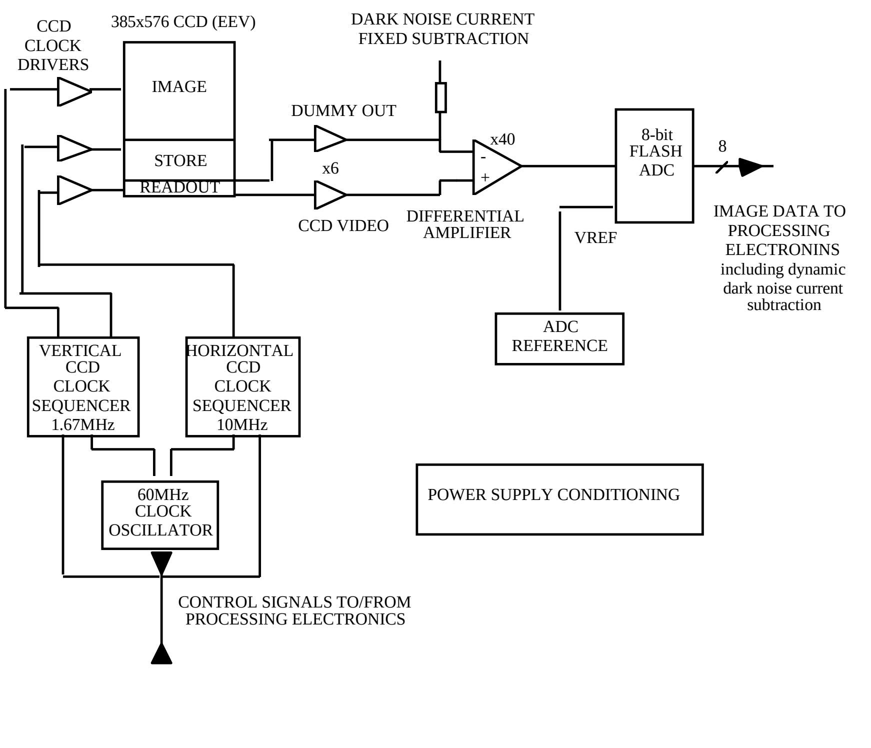


If the total counts per second on the whole detector are greater than 200,000, counts are lost in the electronics and a dark band appears in the image, as seen on this example image.

1.2.2.2 Camera Head

The sensor in the Camera Head (BCH) is an EEV CCD-02-06 which is a frame transfer device running with a vertical clock rate of 1.67 MHz and a horizontal readout rate of 10 MHz. The CCD is of well-proven design and is used in many monochrome commercial and scientific TV applications. The dummy output from the CCD is subtracted from the video signal to reduce the
level of saturation of the final video amplifier stage. The main cause of this is clock feed-through in the CCD wiring and the reset spike. The diagram below shows the functional blocks of the camera.

Under control from the Blue Processing Electronics (BPE), the camera is capable of reading out of a number of windows in the CCD image in rapid succession, or full 256 x 256 pixel frames. The integration time is typically 11 ms.



Block Diagram of Blue Camera Head Electronics

1.2.2.3 High Voltage Control Unit

The High Voltage Control Unit (HVU) comprises three converters (see figure). The converters 1 and 2, working in parallel, produce the voltage across the MCP1 bottom plate and the cathode ($V_{cathode}$), and the voltage across MCP1 (V_{mcp1}).

Converter 1 produces a negative voltage so that with the use of resistive division with converter 2 it obtains a zero volt output for $V_{cathode}$ on command. Potential reversal is possible but limited approximately to less than -15 volts by diode protection.

Converter 3 is in series with converter 1 and 2 and produces the bias voltage across mcp23 and the anode gap voltage known as V_{mcp23} and V_{anode} where V_{anode} is produced by extension of the voltage multiplier chain used to create V_{mcp23}.

In order to prevent potential reversal of any intensifier plate the bias voltages must be applied sequentially; this sequence being V_{anode}/V_{mcp23}-Vmcp1 then Vcathode. The HVU hardware will prevent any controlled static potentials from reverse bias conditions even if commanded to do so.

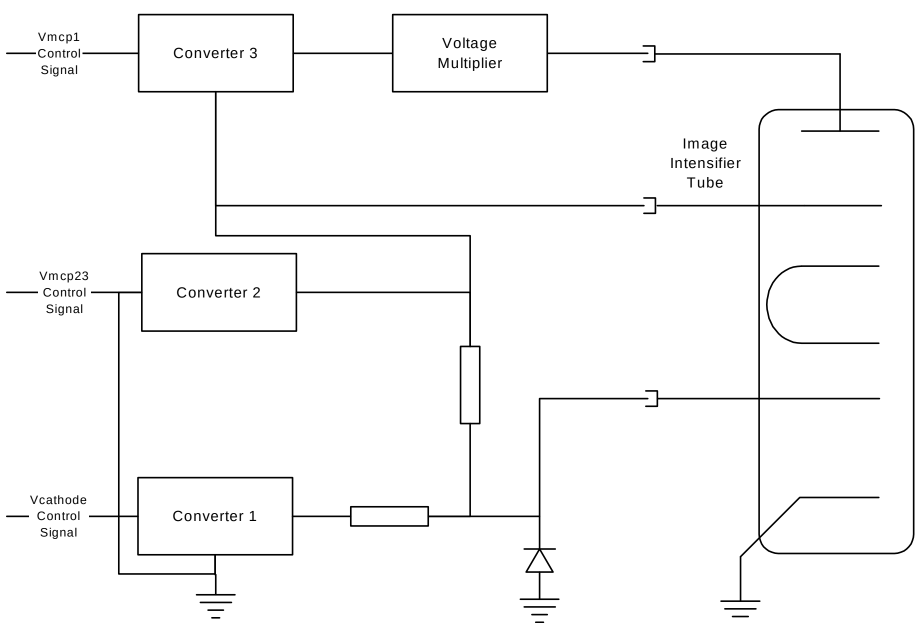
Due to the way the HVU works, there are conditions in which rapidly control signals could cause momentary reverse bias conditions. Because of this, it is necessary that software commanding for bias potentials be rise time limited.

It is recommended that any MCP rise time be limited to greater than 10 seconds from zero volts to maximum operating voltage and greater than 10 seconds from maximum operating voltage to zero volts.

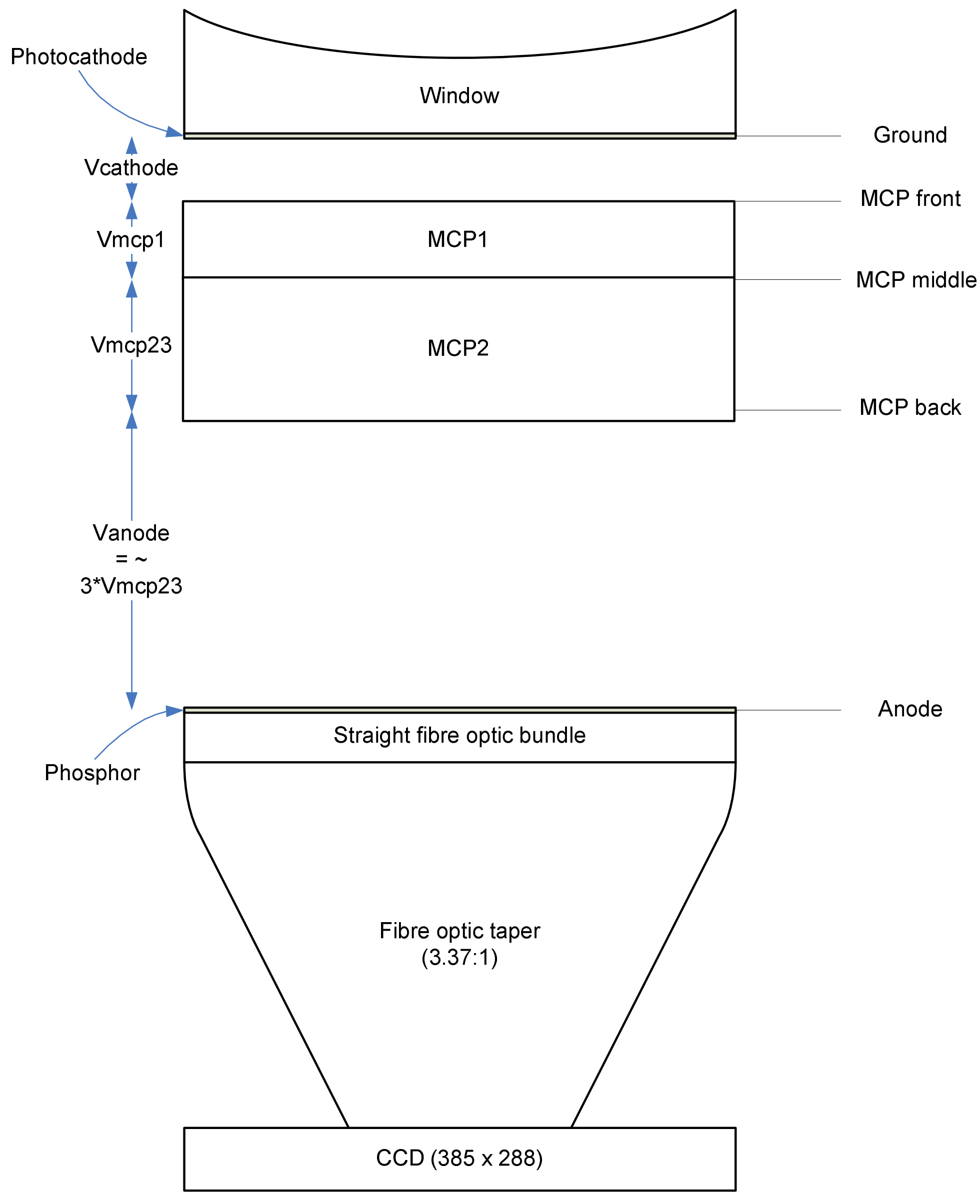
Protection of over voltage on any MCP is also incorporated into the HVU hardware such that any command above maximum operating voltage will remain at maximum voltage as set within the HVU. It should be noted that this condition produces excessive noise on all outputs and so the HVU should not be operated in this condition. If this condition does arise it is necessary to command the voltage below maximum in order to regain control. The voltage drop required is dependent on the particular MCP limiting and is shown in table 1.

To operate the intensifier, mcp23 is first raised to the desired operating voltage over a period defined by the rise time outlined above. V_{anode} will rise simultaneously with V_{mcp23} such that V_{anode}=1.57*V_{mcp23}. The voltage Vmcp1 will not be allowed to rise until V_{mcp23} is greater than 1100 volts (both intensifiers). Once V_{mcp23} is above this level, V_{mcp1} can be raised to the desired operating voltage and is again rate of rise limited. For redundant intensifier the voltage across mcp1 must be greater than 518 volts before $V_{cathode}$ is allowed to rise and will cause $V_{cathode}$ to collapse if less than 505 volts. For the prime intensifier these restrictions are not incorporated into the hardware. As before, the rate of voltage rise and decay for Vmcp1 should be limited as outlined above.

The cathode voltage $V_{cathode}$ is then raised to the desired operating level to effectively switch on the intensifier. To close down the intensifier the above procedure is reversed i.e. $V_{cathode}$ is set to zero volts then Vmcp1 and V_{mcp23}/V_{anode}. Both Vmcp1 and V_{mcp23}/V_{anode} decay rates are limited but $V_{cathode}$ can be commanded to zero instantly if required. Note that for the prime intensifier $V_{cathode}$ is limited to 530 volts and for the redundant intensifier $V_{cathode}$ is limited to 400 volts.



1.2.2.4 Image Intensifier



1.2.2.5 Detector Safety Circuit

1.2.2.5.1 Overview

If exposed to bright sources the UVOT detectors may be temporarily or permanently degraded. The main effects are

1. Fluorescence / phosphorescence: This is a temporal effect. If a 5.6mag A0 star illuminates the detector through the white filter for one minute, then its phosphorescence remains above detection limits (0.008 counts s^{-1}) for 16 hours

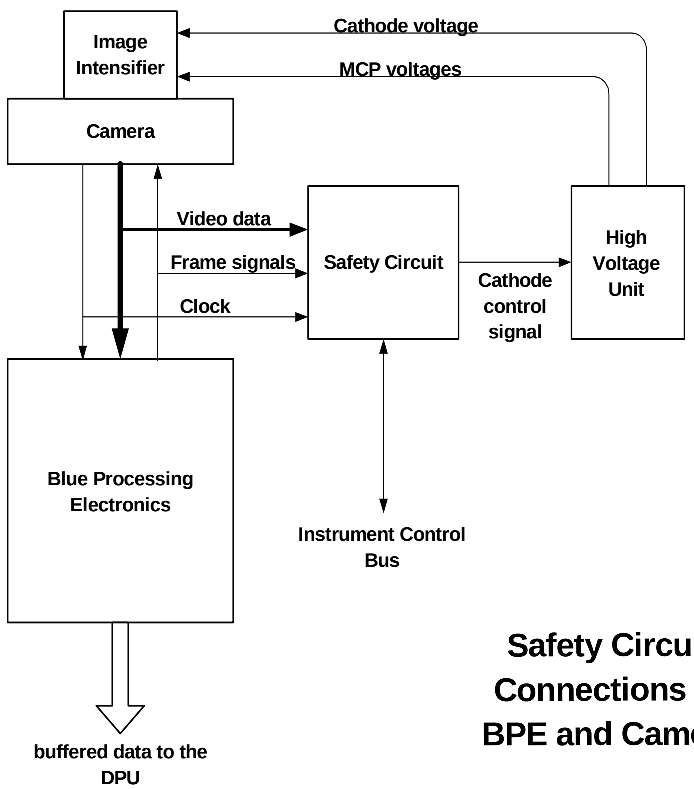
2. MCP gain loss and photocathode damage: This results in permanent performance degradation, due to a localized gain loss in the MCP and a loss in sensitivity of the photocathode due to ion feedback from MCP pores.

The UVOT safety circuit protects the detector against ***unexpected*** bright sources. The techniques used to limit or prevent observations when bright sources are known to be present are discussed in the software section of this document. This circuit operates independently of the ICU but is under its overall control. It has a fast response time of 10s of milliseconds to prevent damage to the detector system. The safety circuit is flexible enough to cope with changing circumstances, has the facility to be disabled and is insensitive to the effects of penetrating radiation in the CCD and detector.

During testing of the UVOT image tubes it was observed that in conditions of high event rates, when the overall system would, in normal operation, be showing significant coincidence losses, there was a broadening of the event profile. This was found to be predominantly an effect of the image tube. It was considered that this repeatable characteristic provided a good indication of source brightness. Consequently, the safety circuit design is based on measuring the maximum width of a star profile.

The system connects between the camera and the BPE and scans the raw video data for a predetermined number of consecutive pixels above a preset amplitude threshold – see diagram. To ensure immunity to the effects of penetrating radiation these consecutive pixels must be present for multiple consecutive frames. It is also necessary to ensure that only valid pixels from the camera were analyzed. This is achieved by synchronizing the pixel analysis to the frame sync signal issued at the start of each frame.

When the safety circuit detects a bright source, it automatically powers down the cathode voltage of the detector. This significantly reduces detector gain. It also reports the alert signal in the safety circuit status register. The ICU may then take extra safety actions: the MCP bias voltages will be ramped down to 0V, and the filter wheel is moved to the blocked position. For test purposes, the cathode voltage control circuit may be disabled, while still reporting the alert in the control register. The flow diagram below shows the potential logical flow for each valid raw pixel read out from the camera.



Safety Circuit Connections to BPE and Camera

1.2.2.5.2 Control interface

Two read/write ICB sub-addresses are used to control and monitor the safety circuit. The controls signals are:

System enable This function enables the safety circuit. When asserted the command is internally synchronized to the next IRUN signal, allowing the system to start in a predictable manner.

Alert flag This read register signal indicates when the safety circuit has fired. The cathode safe signal is asserted if the alert enable bit is set.

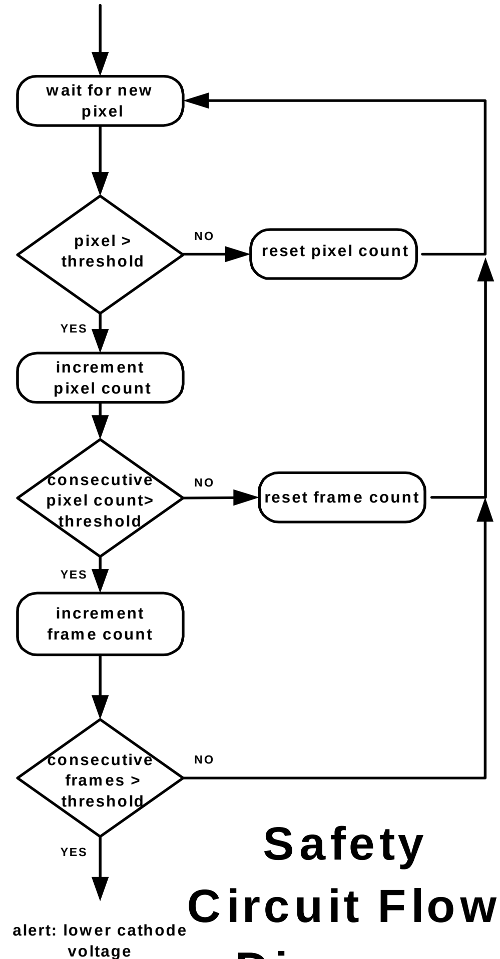
Alert reset This function resets the cathode safe signal register to its power-up default state "off" (allowing control of the cathode voltage) and returns the alert flag to zero. The safety circuit is also reset to its power up default state. It should be noted that safety circuit settings are not affected by this signal and that the previous state will be maintained until it is reconfigured or reset by power cycling. ***Note***: after asserting, this signal must be de-asserted otherwise the circuit will be continuously reset and therefore not function.

Alert enable This function enables the cathode voltage control register. The alert flag is not affected by this control. This allows for on orbit calibration of the system without turning the cathode voltage off whenever the alert flag is set.

Input threshold preset This read/write register allows the pixel threshold (STHOLD) to be set. Only the most significant five bits are used.

Consecutive pixel preset This read/write register sets the number of consecutive pixels (PCTHOLD) that must be greater than the input threshold to trigger the frame counter.

Consecutive frame preset This read/write register sets the number of consecutive frames (FCTHOLD) that are required to be above both the input and consecutive pixel thresholds to cause a safing action.



Safety Circuit Flow Diagram

1.2.2.5.3 Typical operational sequence

1. Set-up safety circuit pixel threshold
2. Set-up consecutive pixel and frame counts
3. Set system enable and alert enable bits
4. Read the alert flag bit at regular intervals
5. If the alert flag is set the cathode has been set to 0V automatically by the safety circuit. The ICU will set the cathode control to 0V, power down the other HV rails and reset the alert

A.1

1.2.2.5.4 Known problems

See MSSL NCR 121 - ISFTYSYSEN occasionally goes to 0.

All the early safety circuit trips were slewing over bright (mag 2-4) blue (like O and B) stars except for:

- 1 trip in a grism exposure with a slowly increasing background caused by the Earth approaching
- 2 trips observing and preparing to observe the SMC which has many bright stars which looks brighter to the safety circuit because of overlap
- 2 trips in the B filter for no apparent reason.

1.2.2.6 Detector Processing Electronics

1.2.2.6.1 General

The principal features of the detector processing electronics are:

- Generation of the Detector Head clock sequences to operate the CCD in a frame transfer mode
- Specification of the area (windows) of the CCD to be read out
- Event Detection
- Event Centroiding
- Engineering Data
- Construction and transmission of data to the DPU
- ICB interface for control of the above

Note. the detector processing electronics is often referred to as the Blue Processing Electronics (BPE). This refers to an earlier design of the heritage instrument XMM-OM that also included a detector more sensitive to the red end of the spectrum. The two detectors were labelled ‘blue’ and ‘red’.

A block diagram of the detector electronics is given below.

1.2.2.6.2 Window Bitmap RAM

Before the detector processing electronics may be used, the window bitmap RAM must be loaded. The RAM is 64k by 4 bits. The information loaded will cause only those CCD pixels within the desired windows to be readout i.e. a clocking sequence is generated for the desired camera format.

For every location on the CCD, there is a location in RAM. During row readout, the corresponding RAM contents are interpreted as a window ID. An ID in the range 1 to 15 is a valid window ID and the corresponding pixel *pair* is readout, whereas a value of zero means that it is not in any window and will not be readout. By loading up the RAM accordingly, the detector area can be thus divided up into a collection of windows of varying size. For full detector operation, an ID if 1 is loaded into all locations. **Note** that windows must start on an *even* number of CCD pixels in X and an *odd* number in Y. However, this even/odd offset is added internally by the ICU software when loading the commanded tables. The window commands specify their origins with respect to this offset and do not therefore follow this even/odd requirement.

For each *pair* of CCD rows, there is a location in the RAM containing a ‘row action code’. This will specify what to do with the row *pair* as a whole. The values and meanings are

0 Perform vertical transfer only, i.e. no horizontal readout. This is used for skipping unwanted rows
2 Readout the row, ignoring window IDs, thus dumping unwanted charge build-up.
3 Readout the row, taking note of window Ids and transmitting the event data to the DPU.
8 Complete horizontal readout and skip to the start of frame transfer i.e. skip to end.

The table is loaded from the ICU via the ICB.

1.2.2.6.3 Centroid Lookup RAM

Centroiding is the process of locating the position of an event to accuracy greater than that of a CCD pixel. For each event and in both the x and y-axes, the processing electronics produces two 8-bit numbers, labelled **m** and **n**. The division **m/n** is the fractional position within a CCD pixel of the event. The range is divided into 8 bins, otherwise known as sub-pixels. Rather than performing this calculation, there are two (64k by 4 bit) tables containing all possible results of the division. The **m** and **n** are combined into a single 16-bit address that is used to lookup the result. The result is in the range 0-7.

Preparing the table contents requires two sets of 9 ‘channel boundary’ values giving the edges of the sub-pixels in both x and y. They are in the range -1.00 to 1.00. These values are multiplied by 1000 for up-link purposes.

The tables are loaded from the ICU via the ICB.

1.2.2.6.4 Output Data Formats

The output of the processing electronics to the DPU is a series of 24 bit words, one per event processed. A maximum of 200,00 events is supported. The format of the word is determined by the data acquisition mode set via the ICB and is detailed in the figure overleaf. There are four scientific modes (numbered 0 to 3) and effectively two engineering modes (numbered 4 to 7). The normal mode for science observation is 3 (High Resolution, Full).

The scientific modes provide event positions in the form of the x and y CCD pixel number, the sub-pixel number in x and y and, for the windowed modes only (0 and 2) the window ID of the window in which they occurred. There are two full frame modes where the window ID is replaced by the most significant bits of the x and y CCD pixel counters, thus giving 16 tiles covering the full detector area.

NOTE: the windowed modes are present only because they were required for the heritage instrument XMM-OM. The ICU is still capable of commanding the instrument to supply this form of data. However, the DPU was not required to support them. Consequently, the UVOT only supports the full frame modes.

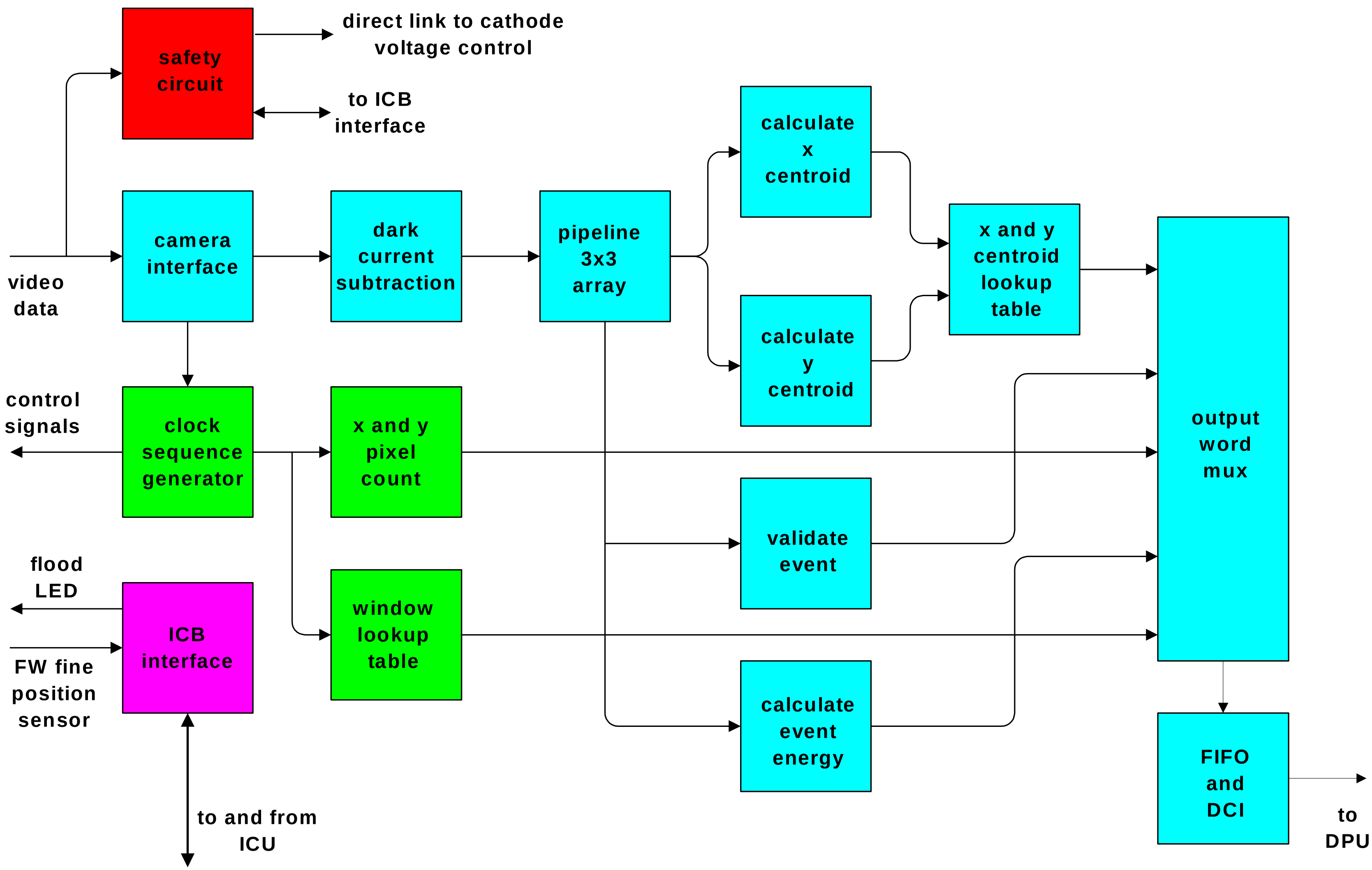
The engineering modes provide information for setting up and checking the detector. Modes 4 or 5 capture centroiding information in the form of events in which the x and y co-ordinates are replaced with the **m** and **n** values. The two 256 by 256 ‘pseudo images’ thus formed can be used to calculate a new sub-pixel channel boundaries from which the centroid lookup table can be reloaded. Note that a) modes 4 and 5 are equivalent and both formats are transmitted at once b) the first X M/N event for each frame is not transmitted. Modes 6 or 7 give event height leading to a 1D image i.e. a histogram. They also produce event energy records in which the energy value is set to zero, due to this feature being removed from the design. Therefore, all records of this format should be ignored. Note that mode 6 and 7 are equivalent and both formats are transmitted at once.

In addition, there are two words of all zeros, the ‘frame tags’, transmitted at the start of each frame. These are used for frame counting and timing purposes. This feature can be disabled via the ICB but defaults to enabled.

A height threshold, set via the ICB, is used to select valid events. This value should be set lower (~12) for engineering data to obtain a full pulse height distribution. Otherwise a value ~15 should be used.

When, following a command, integration is enabled, data is sent on to the DPU at the start of the next frame.

DETECTOR PROCESSING ELECTRONICS



Detector Data Transmission Formats

Science or Engineering	Detector Mode	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
Science	0	0	YC 6-0							y 2	y 1	XC 6-0							x 2	x 1	ID				P	Low Resolution, Windowed
Science	1	0	0	YC 5-0						y 2	y 1	0	XC 5-0						x 2	x 1	YC 7	YC 6	XC 7	XC 6	P	Low Resolution, Full Frame
Science	2	0	YC 5-0						y 2	y 1	y 0	XC 5-0						x 3	x 2	x 1	ID				P	High Resolution, Windowed
Science	3	0	YC 5-0						y 2	y 1	y 0	XC 5-0						x 3	x 2	x 1	YC 7	YC 6	XC 7	XC 6	P	High Resolution, Full Frame
Engineering	4	0	0	M value								0	N Value								0	0	0	1	P	Engineering, X M/N Data
Engineering	5	0	0	M value								0	N Value								0	0	1	0	P	Engineering, Y M/N Data
Engineering	6	0	0									0	Event Height								0	0	0	1	P	Engineering, Event Height
Engineering	7	0	0									0	0								0	0	1	0	P	Engineering, Event Energy (contains no meaningful data)

P = Parity (Odd)
XC = X CCD Pixel Co-ordinate modulo 64 (high resolution) or modulo 128 (low resolution)
YC = Y CCD Pixel Co-ordinate modulo 64 (high resolution) or modulo 128 (low resolution)
x = X Sub-Pixel Bit
y = Y Sub-Pixel Bit
ID = Window ID

1.2.3 Mechanisms

1.2.3.1 Filter Wheel

Eleven optical elements are placed at equal angles around the filter wheel. The wheel is driven by a pinion on a 4-phase stepper motor shaft, with a gear ratio of 11 to 1. Thus, one revolution of the motor, which requires 200 steps, moves the wheel from one optical element to another and 2200 steps will completely rotate the filter wheel.

Filter Number	Filter Description	Filter Position (steps from datum)	Sensor Value	
			Coarse	Fine
0	Blocked (Datum)	0	True	True
1	Grism 1 (UV)	200	False	True
2	UVW2	400	False	True
3	V	600	False	True
4	UVM2	800	False	True
5	Grism (Visible)	1000	False	True
6	UVW1	1200	False	True
7	U	1400	False	True
8	Magnifier	1600	False	True
9	B	1800	False	True
10	White	2000	False	True

The wheel position will normally be determined in open loop mode by step counting from a known datum position. Coarse and fine position sensors are provided to relocate the datum position should it be lost, verify the wheel position during and after every rotation and to confirm that the centre of any optical element has been found, although the element is not identified.

The reflective infrared *coarse* position sensor is fitted to the wheel and gives a true output when the wheel is within about ± 15° of the datum position i.e. the coarse sensor is only visible when the blocked (datum) position is in the field of view and typically for 90 steps around that position.

The infrared *fine* position sensor, which is used in transmissive mode, is fitted to the rear end of the motor. An occulting disk with a small aperture, through which the sensor looks, is fitted to the rear extension of the motor shaft. It is aligned such that an element will be correctly positioned when the fine sensor gives a true reading *and* the first phase is energized. Thus, the fine sensor is only visible for one step in every 200 steps i.e. at the centre of the datum (blocked) position and at the centre of every other of the 10 optical element positions. One-step either side and the fine sensor cannot be seen.

Therefore, it is only at the datum position that both the coarse and fine sensors give a true output (see table above).

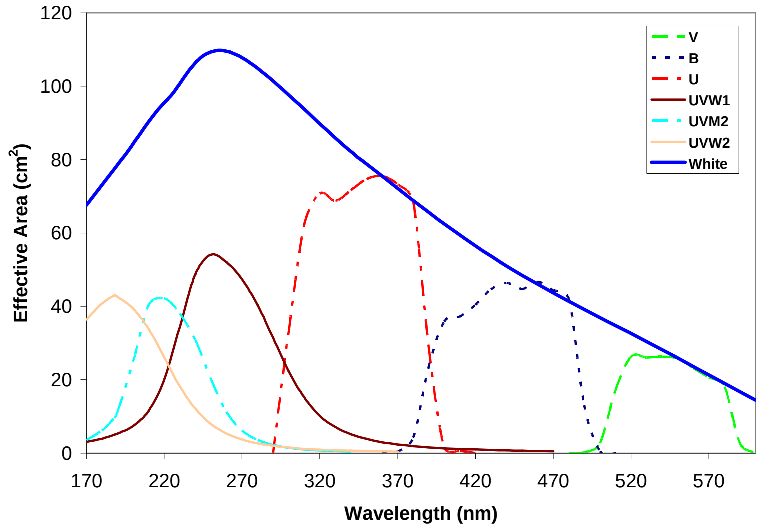
Tests indicated that the filter wheel should be rotated at a default pull-in speed of 200 Hz, a cruise speed of 420 Hz and an acceleration of 2000 Hz per second. These rates are applied when moving from filter to filter or from datum to filter. However, in order to ensure success when seeking datum, the filter wheel is rotated at a constant 200 Hz until the coarse sensor is detected and then at 10 Hz until the fine sensor is seen.

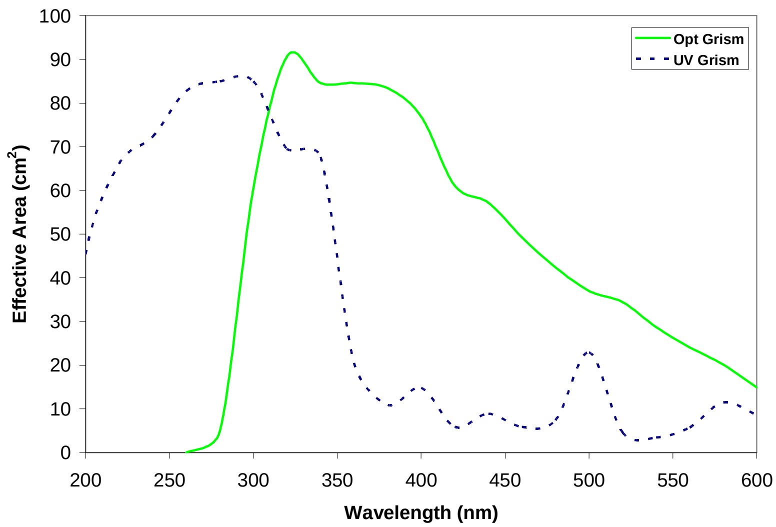
Points to Note:

- The filter wheel is a limited lifetime item – it has been designed and tested for 50,000 complete rotations for each redundant half of the instrument.

- The filter wheel movement is controlled via the ICB. This is also the main channel for acquiring housekeeping and controlling heaters. It was found during testing that activity on the ICB during a filter wheel movement could introduce erratic motion of the filter wheel and cause occasional failure in reading the fine sensor. Therefore, whilst the filter wheel is being moved, all other ICB activity (such a housekeeping acquisition and heater control) is stopped.
- Commands are sent internally to disable the flood LEDs (see below) prior to any filter wheel movement should they have been left on accidentally after e.g. a calibration exposure, to prevent an illumination excess on the detector
- The safety circuit (section **Error! Reference source not found.**) is also disabled to prevent false triggering.

1.2.3.1.1 Filter Responses





1.2.3.2 *Dichroic Mechanism*

The dichroic mechanism contains a mirror placed at 45° in the path of the incoming beam. The purpose of the mechanism in the TM is to steer the reflected light beam from one of two redundant detector systems to the other. It will be rotated from one position to the other by pulse counting. The final step will drive the rotor to its stop where it will be held by a magnetic detent. The dichroic mechanism is rotated 180° between the stops and by a 4 step per revolution motor geared at 14.5:1. Therefore, the motor needs to be driven up to 29 steps from one position to the other. One further step in each direction means that the rotor is driven hard onto its stop. Thus, the total number of steps required is 31. The step sequence has to be reversed to return. As there is no harm in overdriving the system against this stop, the motor is always driven the maximum number of steps required in the specified direction. Thedrive frequency is 2 Hz.

A pulse train must always finish on a particular phase. It is clear that this phase will be different at the two ends of the traverse. As there are no sensors in the system, the control mechanism is always open loop.

The following algorithm is used. If we label the 4 phases 1,2,3 and 4, a clockwise rotor drive (viewed from the shaft end) towards the redundant detector is achieved by stepping in a positive direction (e.g. the phases are energized in the order 1,2,3,4,1…) until the step count is equal to or greater than 31 and the phase is 1. Similarly a counter-clockwise rotor drive towards the primary detector is achieved by stepping in a negative direction (e.g. the phases are energized in the order 4,3,2,1,4…) until the step count is equal to or greater than 31 and the phase is 2.

1.2.3.3 *The Motor Temperature Control Circuit (DISMON)*

The DISMON circuit was included in the SWIFT TMPSU design to protect against the Filter Wheel and Dichroic motor windings being left on for an indefinite time and risk overheating the motors. For example, when a motor is being moved, the software gets an SEU and a motor winding is left energized. This circuit was not in the heritage instrument XMM-OM design.

There are two circuits, one for each motor. The circuits compare a thermistor on the sidewall of the TMPSU with thermistors on each of the ballast resistors in series with the motors. These ballast resistors are also on the sidewall of the TMPSU. When a winding is turned on, heat is dissipated in the ballast resistors so the temperature rises. When the temperature difference gets to a certain value the circuit trips and clears the register that is driving the motor windings. This register controls both motors and the two temperature sensing circuit outputs are ORed together to reset this latch. Once a circuit has tripped, the temperature must go back down before this latch can be successfully written to.

The DISMON circuits are enabled on power up of the TMPSU. The circuits can be enabled and disabled by writing to the MSB of address 3 in the memory map of the TMPSU. Writing to this bit controls both temperature control circuits. Writing a 'one' to this bit enables the circuits to control the motor latch (address 2) and writing a 'zero' to this bit disables the temperature circuit from controlling the motor latch. In the second case, no temperature effect can control the motor latch and the motors can be run indefinitely.

The status of the DISMON enable circuit is reported in the housekeeping. Bit 14 reflects whether the circuit is enabled or disabled. A 'one' indicates it is enabled, default condition on power on and a 'zero' indicated the circuit is disabled.

The status of the DISMON temperature circuits is reported as an analogue parameter in HK channel 7. During the Thermal Vacuum testing of the FM2 TMPSU, it was found that under hot temperature conditions the DISMON circuit tripped even though no winding was on. At room temperature the ballast resistor of the dichroic motor did not fire. The FM1 exhibits the same behaviour.

Note also the FM2 Filter Wheel circuit thermistor is not fitted so will never fire.

1.2.4 Flood LED's

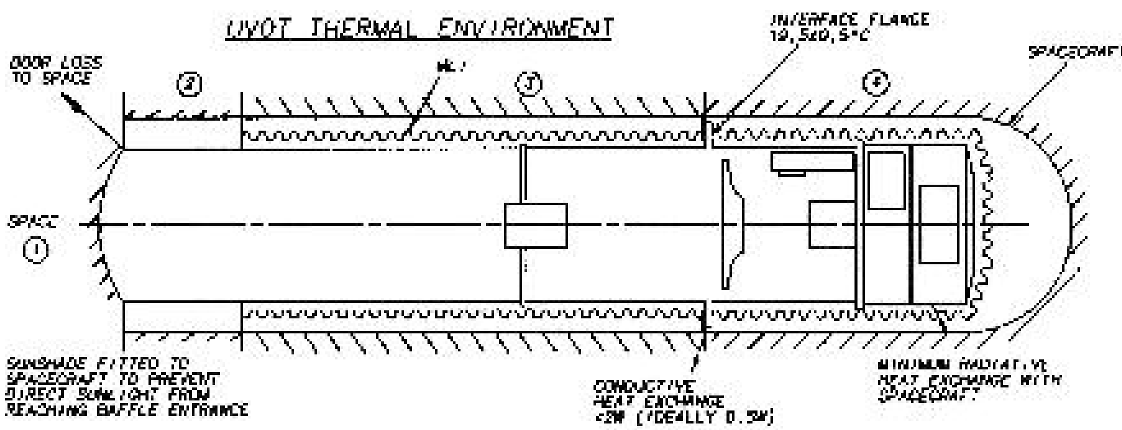
In order that the detector may be calibrated in flight, four flood-LED's are provided. They are located off-axis close to the detector. They are positioned so that their focused emission falls on the side of the filter facing the detector. The blank filter is used which then acts as a defocused 'screen' providing the flat field. They are green LED's but with emission in the UV range.

Their intensity is controlled via ICB commands routed from the Blue Detector analogue control card to a 4-bit port. There are thus 16 possible levels. They are driven in such a way that if one should fail the remaining LED's will remain fully functional.

1.2.5 Heaters and Thermistors

There are 8 thermistors named and located as follows:

Name	Channel	Location
BPE	0	Blue Processing Electronics
Ref B	1	Interface Flange
Ref C	2	Interface Flange
Main	3	Near Main Interface Heater
Forward 1	4	Near Forward Heater
Forward 2	5	Near Forward Heater
CCD	6	CCD
Ref A	7	Interface Flange



When the UVOT is in its nominal operating mode, the telescope mounting flange is required to be 19.5 ± 0.5 °C in order to minimize the heat transfer between the TM and the Optical Bench and the mirror section of the telescope must be held at 19.5 ± 1.5 °C to maintain the mirror separation. In addition, fine-tuning of the latter separation may be required on-orbit to maintain focus. These active controls are performed using four instrument heaters. Their functions are summarized as follows:

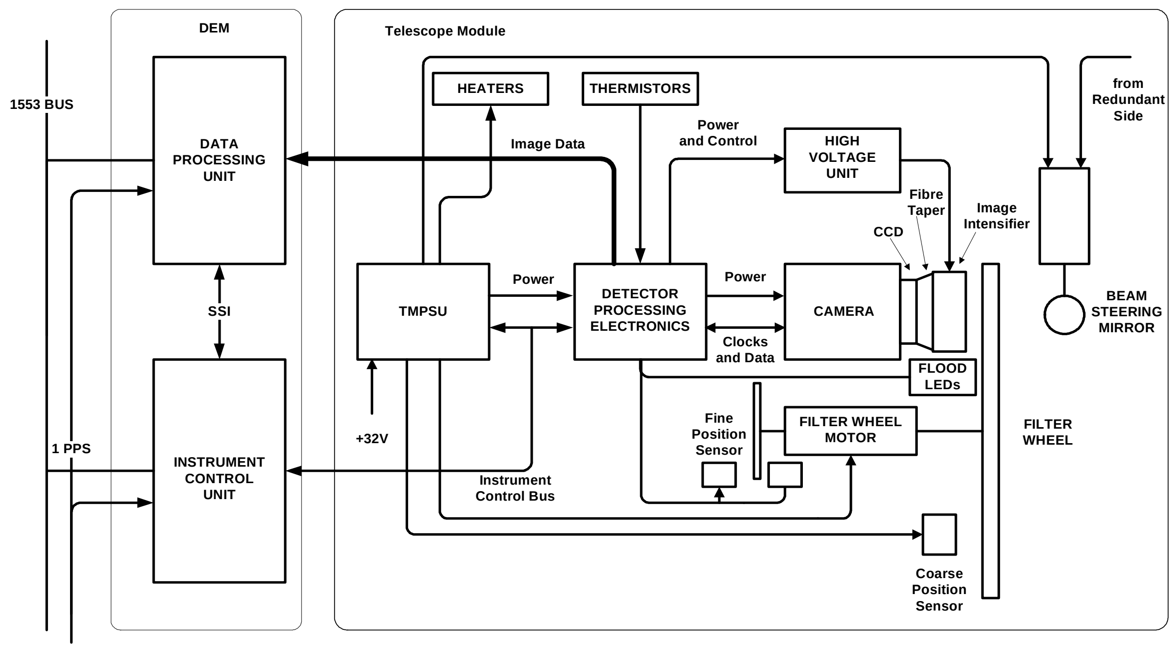
Heater	Purpose
Main Interface Heater (HTR1)	This is located close to the interface flange on the telescope tube, and is intended to control the temperature at the interface bolts to **19.5 ± 0.5 °C** using a closed loop algorithm – see section 2.5.4.3. It has a control thermistor (Main) located close to it and there are 3 monitoring thermistors (Ref A, Ref B and Ref C) on the interface flange.
Forward Heater (HTR2)	This is located at the forward of the telescope tube and is intended to control that area and hence the whole telescope tube to about the same temperature as the main interface heater - the default setting are **19.5 ± 1.5 °C** using a closed loop algorithm – see section 2.5.4.3. This should ensure that all of the telescope optical elements are sensibly isothermal. It is controlled by one of two thermistors (Forward 1 or Forward 2) mounted close to it.
Metering Rod Heaters (HTR3)	These are a set of three parallel heaters, one mounted on each of the metering rods. These are used to *extend* the distance between the primary and secondary mirror by a small amount if necessary. This is done using an open loop algorithm that defines an on-off ratio. The power developed is a function of the square of the current spacecraft voltage. This algorithm is disabled by default – see section 2.5.4.4.
Secondary Mirror Mount Heater (HTR4)	This heater is used to *shorten* the separation of the primary and secondary mirror. NOTE that therefore this heater and the metering rod heaters will not be powered at the same time during normal operation**.** This is done using an open loop algorithm that defines an on-off ratio. The power developed is a function of the square of the current spacecraft voltage. This algorithm is disabled by default – see section 2.5.4.4.

1.3 *ICU SOFTWARE*

1.3.1 Overview

This section describes the software components resident in the Instrument Control Unit (ICU) that are responsible for the autonomous control of exposures and for maintaining the health and safety of the instrument. All ICU resident code described is written in Ada except when speed requirements dictated assembler.

The diagram summarizes the electronic architecture of the UVOT. The ICU controls and monitors the telescope module (TM) via the instrument control bus (ICB). The TM contains the Telescope Module Power Supply (TMPSU) that controls (a) a filter wheel, the position of which is monitored by LED illuminated sensors, (b) the heaters and (c) a beam deflector that switches the optical path between the prime and redundant halves of the instrument. The Detector Processing Electronics, known as the BPE, acquires and forwards photon events to the Data Processing Unit (DPU) in the Digital Electronics Module (DEM). The BPE also (1) controls the high voltage unit attached to the image intensifier, (2) activates the calibration flood LEDs, (3) powers to the filter wheel position sensor and (4) monitors the effect of the heaters via thermistors. The Data Processing Unit (DPU) processes the photon events into lists, images and a parameterized finding chart that are then forwarded directly to the spacecraft.



UVOT Electronic Architecture

1.3.2 Scientific Requirements

In order to achieve the scientific goals of the UVOT, the ICU must autonomously control the instrument to perform two types of exposure sequences: automated and planned.

Automated - these occur when Gamma Ray Bursts (GRBs) are detected by the Burst Alert Telescope (BAT) or a Target of Opportunity (ToO) is detected by other spacecraft and ground based sources. On the first observation of the source, an event list is gathered while the spacecraft is still settling on the target. An exposure is then made from which a finding chart is constructed to permit optical counterpart identification. All subsequent exposures on this source, for this and later slews to the same source, will involve obtaining a sequence of images, event lists or combinations thereof in differing filters with increasing exposure lengths. The active area used on the detector (referred to as the window) will be refined if the X Ray Telescope (XRT) is able to supply an improved position before the end of the finding chart exposure.

Planned - this series of exposures obtains images, event lists or combinations thereof. They are in various instrument configurations loaded in on-board electrically erasable programmable read only memory (EEPROM) tables and selected by an up-linked plan.

1.3.3 Engineering Requirements

The ICU must respond to pointing constraints imposed by the Sun, Earth, Moon and planets.

Whilst observing a source, the ICU avoids damage to the instrument from *known* bright sources in, or close to, the field of view (FOV). These can cause irreparable damage to the UVOT instrument by depressing the gain of the Micro-Channel Plates (MCPs) or by damaging the photo-cathode.

Note: additional hardware protection against *unknown* bright sources is provided by the safety circuit described above in section 1.2.2.5.

The ICU needs to monitor critical parameters for out-of–limits conditions and take an appropriate recovery action.

It needs to protect the instrument during any loss of spacecraft attitude.

It must recover from any command failures.

It should respond quickly to an emergency shutdown warning from the spacecraft.

It is a project requirement that the code will need to run continuously for at least 72 hours without ground intervention.

It was anticipated that the optimal form of control of the UVOT for both science exposures and for handling, or recovering from, conditions that involve detector safety issues might not emerge until late in the development and test program. It may also change during the course of the mission in order to accommodate changes in ideas and circumstances. Therefore, the design attempts to be as flexible and readily re-configurable as possible.

1.3.4 Constraints on Observing

There are a number of reasons why it is impossible to perform a sequence of exposures continuously on either automated or planned targets.

There are pointing constraints imposed by the Sun, Moon and Earth. Each of these very bright, and therefore potentially damaging, sources has an avoidance angle constraint stored in EEPROM to which the satellite must adhere.

The Swift Observatory will be in a low Earth orbit with an orbital period of approximately 96 minutes. Assuming no additional pointing constraints imposed by the current position of the Sun or Moon, the Earth's avoidance angle implies that it will not be possible to observe any source for longer than about 45 minutes, at which time the satellite must slew to another source. For sources at high elevation above the satellite orbital plane, this maximum observing time is decreased, falling to zero at 84 degrees.

The detector is susceptible to damage from sources such as stars or planets brighter than about 8^{th} magnitude, depending on their colour. The ICU must monitor long exposures and ensure that the total accumulated counts on detector locations associated with a given source do not exceed a damage limit stored in EEPROM.

Because of the particle radiation present, the instrument may have to be protected during passages through the South Atlantic Anomaly (SAA). These interruptions will occur two or three times in any twenty-four hour period and each may last up to ten minutes. This protection is achieved by ramping down the high voltages controlling the image intensifier.

Because of the above constraints, the ICU design must:

- Allow for automated and planned observations to be interleaved.
- Expect either type of exposure to be interrupted by pointing and SAA constraints.
- Make decisions on exit from interruptions on how to reconfigure the instrument and restart the exposure.

- Permit the curtailing of all types of exposures to prevent detector damage.

1.3.5 Available Information

The following information is supplied to the ICU to enable it to determine its actions.

The spacecraft supplies an Attitude Control System (ACS) message SISCATTITUDE at a frequency of 5 Hz. This contains an identifier uniquely specifying the current observation. It also supplies Boolean flags indicating whether the spacecraft has settled, is within 10 arc minutes of its final position, and whether we are currently inside the SAA. It also includes a flag that, if true, signals that the spacecraft may be about to remove instrument power. Positional information, specifically the current right ascension and declination of the source and the satellite's latitude and longitude are supplied. Timing information, in the form of the current spacecraft clock setting, is contained within the same record.

The spacecraft supplies a hardware driven 1 Hz timing pulse, referred to as the 1PPS. Between these pulses, a message (SITIMETONE) that supplies the spacecraft clock and UTC values at the next pulse is sent.

Telecommands are sent by the spacecraft to notify the instrument when a slew is about to commence (SISLEWWARNIG) or if a signalled slew has been abandoned (SISLEWABORT).

Prior to slewing to the next source, referred to here as the target, the Figure of Merit Process (FOM) – an internal process in the BAT - sends out a FONEXTOBSINFO message detailing the next observation. This includes an identifier uniquely specifying the next observation and a flag identifying it as an automated or planned target. For an automated target the time since the source was detected and whether this is the first visit to that source are also given. The target right ascension, declination and roll are supplied, together with the anticipated maximum observing time on the source before the next interruption, allowing for anticipated interruptions by the SAA. For all types of observations, it further supplies a value known as the UVOT mode that the ICU uses to select the sequence of exposures to run on the target.

The BAT supplies a BATBRBFLUXINFO message detailing burst brightness information. If this indicates a bright source, the ICU may modify its choice of exposure sequence (see section 1.3.11.5).

Finally, the XRT may supply a refined position for a GRB using the XRTPOSITION message whilst the UVOT is performing the finding chart exposure. This will impact on the area of detector that needs to be processed to ensure the inclusion of the source.

1.3.6 Design Philosophy

In order to achieve the flexibility required, a design based primarily around three types of tables stored in EEPROM was chosen. All these tables have an associated Cyclic Redundancy Check (CRC) value that is used to validate each table as it is loaded into random access memory (RAM) prior to use. The design aim is that most, if not all, proposed changes to the behaviour of the system could be achieved by modifying one or more of these tables.

1.3.7 EEPROM Located Tables

There are three types of table images stored in EEPROM: Data Tables, Action Tables and RTS tables

Data Tables: These contain sets of numbers that may need to change in the course of the mission. These include calibration data for the on-board high voltage ramping and heater control algorithms. Two further tables contain the AT and PT exposure configurations. Count rate and avoidance angle tables are also present and are more fully described in the On-Board Catalogue section.

Action tables: They define actions that are to take place when an event or combination of on-board values occurs. Those actions are defined by declaring a Relative Time Sequence (RTS - see below) to be run. They consist of:

a) A state change table, the usage of which is described in the UVOT State Transitions section below.

b) A limit-checking table that states which RTS is to be run when a limit failure for a particular engineering item occurs – see below for a fuller description

c) An errors action table that states which RTS is to be run to perform an error recovery action. All telemetry from the ICU and DPU is internally monitored for error messages. When one is detected, the table is then consulted and, if required, the appropriate RTS is run. The design allows for up to 256 such messages.

RTS Images: These are sequences of command words derived from text files containing scripts known as Relative Time Sequences (RTSs). There are, in fact, two types. The first type contains the translated versions of the RTS scripts and the second an index into them.

In addition, to determine if there are known bright sources close to or in the field of view, a) planetary position calculations are performed and b) an on-board star catalogue is checked.

There is an NCR outstanding on the EEPROM tables – see Appendix F, MSSL NCR 94. In theory, it is possible for a CRC error on these tables to not be immediately detected as the CRC check is not performed every possible read to memory limitation issues. In flight so far, this does not appear to have been the case.

1.3.7.1 Useful Numbers in EEPROM

The following angular avoidance constraints for bright objects are stored in EEPROM.

- 25' for Mercury, Venus, Mars, Jupiter, Saturn and don't care for Uranus, Neptune and Pluto.
- 44 degrees for the Sun (Spacecraft avoids by 45, TAKO by 46).
- 28 degrees for the Moon (Spacecraft avoids by 30, TAKO by 32) - we may soon change this to 14 deg (Spacecraft avoids by 16, TAKO by 18).
- 92 degrees for the Earth (Spacecraft avoids by 94, TAKO by 99) (note- subtract 66 degrees to get avoidance from earth limb).
- 25' for stars magnitude = -1.4 -> -0.0.

In addition, if any star in the field of view would produce 200,000 count/s or more as determined from the on-board catalogue, the exposure is abandoned. At 200,000 count/s the following stars would be just observable.

Filter	Spectral Type	Magnitude
White	B1V	9.1
V	B1V	4.5
White	A1V	7.6
V	A1V	5.1
UVW2	A1V	3.2
White	G2V	7.0
V	G2V	5.1
V	M2V	5.0
White	M2V	7.0

If the total predicted counts received for any star during a pointing (0-45 min) reaches 1,000,000,000, the exposure is terminated and the next filter tested.

1.3.8 The RTS System

1.3.8.1 Overview

The RTS scripts provide a separate layer of “software” on top of the Ada code. They deal only with the higher-level aspects of UVOT control. As the Integrated Test and Operations System (ITOS) is used as the satellite control and monitoring system for the Swift mission, the syntax of the RTSs is, by design, similar to ITOS procedures (which, in turn, are somewhat like Unix scripts). RTSs therefore act as an on-board UVOT command facility into which changes in ideas and circumstances can more readily be incorporated.

Only one (top-level) RTS may run at any time, although it may call other RTSs as subroutines. Each RTS is assigned a priority, which is also used by any RTSs called. If a commanded RTS has a higher or same priority than the one currently running, the latter will be shut down and the new RTS run in its place. Any RTS with a priority greater than 32767 is treated as a pseudo-interrupt routine. When it completes, any RTS (or call stack of RTSs) interrupted is restarted at the top level. Priorities are set based firstly on safety and then on science considerations.

1.3.8.2 Summary of RTS Scripts

The list is for release 10.

RTS Name	**Code**	**Priority**	**Description**
`autostate`	19	1000	Requests ICU to autonomously decide and switch to the next state.
`blocked_failsafe`	1283	1000	Moves filter wheel to blocked position, transitions to Idle or SAA state (if s/c present in SAA), with HVs set accordingly.
`blocked_tdrss`	1284	1000	Same as 'blocked_failsafe' but also issues TDRSS message.
`bright_planets`	1007	0	Not used.
`change_state`	513	0	'Pokes' locations in ICU Ram with state code and issues NHK message to say State Change has taken place.
`controlled_off`	257	32765	Contingency RTS. Goes to Safe state then requests the S/C to turn off UVOT.
`controlled_tmoff`	258	32764	Contingency RTS. Goes to Safe state then requests the S/C to turn off UVOT Telescope Module only.
`diagnostic`	1280	0	Diagnostic RTS. Sends NHK event message with supplied 3 parameters inserted into it.
`do_exp`	48	0	Starts exposure (using 'start_exp'), waits for exposure length (plus DPU 'slack') then ends exposure (using 'end_exp').
`do_fc_exp`	1012	1000	Performs finding chart exposure. If allowed to go to completion, flags that the finding exposure has been achieved.
`do_pt_exp`	1014	1000	Performs Planned Target exposures, including Null or Idle type exposures.
`do_slew`	770	1000	Runs during slew. Allows any centroid table load to complete. Switches to appropriate exposure at start of settling/settled period.
`do_sttlng_exp`	1011	1000	Performs settling exposure, switches to finding chart exposure when settled flag goes 'true'.
`emergency_hvoff`	18	32766	Contingency RTS. Sets all HVs to zero *without* controlled ramp-down.
`end_exp`	50	0	Stops BPE events, failsafe turn-off flood LEDs, awaits completion of any centroid table load, signals ICU to stop counting events.
`fastsafe`	769	32764	Goes to state Safe quickly (Filter wheel to blocked, Vcathode set to zero, other HVs ramped down in 5 seconds each).
`fc_to_at`	837	1000	Called at end of finding chart exposure. Performs multiple AT exposures until next slew.
`get_at_config`	997	0	Not used.
`get_fc_config`	996	0	Not used.
`get_pt_config`	998	0	Not used.
`get_sp_config`	999	0	Not used.

RTS Name	Code	Priority	Description
get_sttling_config	995	0	Not used
gotobasic	768	32763	HVs set down quickly (Vcathode set to zero, other HVs ramped down in 5 seconds each). Goes to Basic state/
gotosaa	776	1000	Performs transition to SAA state. Any exposure is tidily interrupted and HVs set appropriately. No filter wheel movement performed.
gotosafe	17	32763	Performs nominal transition to Safe state from all states in operational code.
gotosafe_tdrss	1537	32763	Same as gotosafe except that a DCS Timeout message is also sent to TDRSS as it is called after timeout on waitfor instruction.
h_11	11	32767	Placeholder – not used.
h_12	12	32767	Placeholder – not used.
h_13	13	32767	Placeholder – not used.
h_14	14	32767	Placeholder – not used.
h_15	15	32767	Placeholder – not used.
h_basic	2	32767	Implemented in Ada rather than RTS. Causes transition to Basic state.
h_emergency_safe	3	32767	Implemented in Ada rather than RTS. Performs emergency fast transition to Safe state (HVs slugged to zero, filter wheel to datum
h_tm_off	4	32767	Implemented in Ada rather than RTS. Requests s/c to turn off UVOT Telescope Module.
h_uvot_off	5	32767	Implemented in Ada rather than RTS. Requests s/c to turn off UVOT.
hv231	1033	101	Ramps up Vmcp23 and Vmcp1 to nominal (see diagram is section 1.2.2.4 for definition of voltages).
hvcathode	1032	101	Ramps up Vcathode to nominal (see diagram is section 1.2.2.4 for definition of voltages).
hvidle_or_saa	1031	101	Ramps down Vcathode to zero then, if we are in the SAA, ramps down Vmcp23 and Vmcp1 to SAA levels (see diagram is section 1.2.2.4 for definition of voltages).
hvnominal	1028	101	Ramps up Vmcp23, Vmcp1and Vcathode to nominal (see diagram is section 1.2.2.4 for definition of voltages).
hvoff	1027	101	Ramps down Vcathode, Vmcp1 and Vmcp23 to zero (see diagram is section 1.2.2.4 for definition of voltages).
hvofffast	1030	101	HVs ramped down quickly (Vcathode set to zero, other HVs ramped down in 5 seconds each - see diagram is section 1.2.2.4 for definition of voltages)..
hvon	1026	100	Not used.
hvsaa	1029	101	Ramps HVs down to SAA levels.
idpumode	33	1	Sends DPU mode command and performs verification as described in the ICD for ICU/DPU protocol.

RTS Name	Code	Priority	Description
interrupt_exp	51	0	Interrupts current exposure – send stop command to DPU, stops events to DPU, tells ICU to stop counts received calculation.
line	1	0	Diagnostic – not used.
noaction	0	0	The RTS equivalent of a NOOP command – does nothing.
notallowed	32766	0	Reserved for ICU internal use.
obs_to_idle	1018	1000	Performs transition to Idle state from AT, PT, Finding, Settling and Safe Pointing states.
process_slew_warn	20	32768	Processes SISLEWWARNING – sends SISLEWWARNING after Vcathode =0 , then optionally calls do_slew.
pt_to_pt	870	1000	Performs multiple PT exposures until next slew.
retry_fw	1282	0	In the event of a filter wheel movement failure, attempts recovery by going to datum then trying again or goes to Safe state if fails again.
saa_to_idle	906	1000	Performs SAA to Idle state transition.
safe_to_idle	794	1001	Performs Safe to Idle state transition – note, may stop in SAA state if spacecraft is in the SAA.
safep_to_safep	887	1000	Not used.
send_slewsafe	994	0	Sends SACSLEWSAFEREPLY to spacecraft.
settling_to_fc	820	1000	Performs Settling to Finding Chart state transition.
sfty_reset	1794	0	Sets up safety circuit appropriately for observations.
sfty_reset_slew	1793	0	Sets up safety circuit appropriately for slewing.
slew_to_at	805	1000	Performs Slew to AT state transition.
slew_to_fc	804	1000	Performs Slew to Finding chart state transition.
slew_to_idle	810	1000	Performs Slew to Idle state transition.
slew_to_pt	806	1000	Performs Slew to PT state transition.
slew_to_safep	807	1000	Performs Slew to Safe Pointing state transition.
slew_to_settling	803	1000	Performs Slew to Settling state transition.
slewabort	21	1000	Processes SISLEWABORT command.
Start_exp	49	0	Starts and exposure (sets up BPU, commands DPU, starts events, tells ICU to start counting events)
Test	32	0	Not used.
testmode	1281	0	Not used.

RTS Name	Code	Priority	Description
`undefined`	32767	0	Not used

1.3.8.3 RTS Statements

A RTS may contain any of the following statements:

Any UVOT telecommand: The arguments supplied may be constants, references to the contents of standard memory locations or arguments given to the calling RTS. A secondary table, directly derived from the ITOS database, contains the formatting information for constructing the command on-board.

An RT-to-RT telecommand: These are system-to-system commands, for example the UVOT, after receiving a request to slew, acknowledges to the spacecraft that it is ready to slew using the SACSLEWSAFEREPLY message.

A call to another RTS: This is analogous to a subroutine call. The arguments supplied may be constants, references to the contents of standard memory locations or arguments given to the calling RTS.

A delay statement: This allows a RTS to delay its next action for a number of clock-ticks, where a clock-tick is 0.2 seconds. The delay may be a constant, a reference to the contents of standard memory locations or an argument given to the calling RTS.

A wait for event statement: This causes the RTS to wait for a specified number of seconds – the timeout – for a significant event to happen. An example of such an event is the successful completion of a filter wheel rotation to a commanded filter position. If the event has failed to occur by the end of the supplied timeout, the RTS could, for example, shut down and replace itself with another RTS using the chain statement (see below).

A chain statement: This is effectively an unconditional 'wait for event' with zero as the value for the timeout. It is used to shut down the current RTS and run a complete replacement.

Flow control statements: The `“if .. then … else”, “repeat … until” and “while”` constructs are supported. Blocks of statements are conditionally executed depending on the values of certain Boolean flags maintained by the underlying Ada code. For example, it is possible to respond differently if the instrument is in the SAA or when the 'wait for event' statement described above exceeds its time limit. The flow control statement also supports Boolean (for example 'and', 'or') and relational (for example 'greater than', 'less than') operators.

Internal calls: These are commands to procedures supplied by the underlying Ada code. They therefore act as calls to built-in functions. An example of this is a call to the procedure that loads the selected exposure configuration into RAM from EEPROM.

Return: In the case of a top-level RTS, this causes it to stop executing. For a lower-level RTS, it results in a return of control to the calling RTS.

Exit: The current RTS, and any RTSs calling it, stops executing.

Messages: A facility similar in concept to the Unix `echo` command is provided. This allows appropriate diagnostic or error messages to be sent to the ground.

Symbolic Constants and Comments: These are provided to make the scripts more human-readable.

1.3.9 The Bright Source System

To determine if there are ***known*** bright sources close to or in the field of view

a) planetary position calculations are performed and

b) the on-board star catalogue is checked.

Unknown or unexpected bright sources are handled by the safety circuit system – see section 1.2.2.5.

1.3.9.1 On-Board Catalogue

The ICU software uses an on-board star catalogue to determine the magnitude and colour of stars in, or close to, the target field of view. This information is used in two ways to protect the detector from bright source damage.

1. If the star is within an EEPROM tabulated angle of avoidance around the field of view for that magnitude, observation of that field of view is prohibited. This prevents stray light (for example, reflected off the baffle) entering the optics. There is an outstanding NCR on the code associated with this table – see Appendix F, MSSL NCR 117 - whereby 2 very bright stars may not be avoided by the distance required. Due to a change and lowering of the avoidance angle acceptable for these stars, this has proved not to be a problem.

2. If the star is in the field of view and does not violate any angle of avoidance criteria, its colour is used to index into a table giving the theoretical count rate as a function of filter. The colour index is a B-V magnitude. The count rate is then scaled by the catalogued magnitude. The count rate for each star thus calculated is used to decide how long, if at all, an observation at a particular pointing, in that filter, can safely continue and the 'worst case' used of al the stars used. The count rate deduced is used in 3 ways

    a. If the count rate exceeds a tabulated value (in the standard table area – see Appendix 3.6B.13), the star is not observed at all.

    b. If the total counts would exceed a tabulated value (in the standard table area – see Appendix 3.6B.13), the exposure is reduced in time so that value is not exceeded.

    c. If the reduced value of the exposure time falls below 10 seconds, the exposure is suppressed.

The catalogue is stored in EEPROM. It is divided into three contiguous sections: the main catalogue, the addendum and the pointer table

The main catalogue: This contains stars down to 12th magnitude. As the detector is more sensitive to blue than to red wavelengths, sources that are too red to affect the detector are filtered out. Over 200,000 stars are stored, derived from the Tycho II, GCVS III, NGC and Yale Bright Star catalogues. For efficiency of access, the catalogue is split into 2524 sky areas of approximately equal solid angle, in 44 declination bands. Within each area the position of each source is stored to +/- half an arc minute accuracy in the right ascension and declination axes, relative to the origin of the area, along with each source's associated magnitude and colour information. Each sky area is followed by a CRC value for memory corruption checking.

The addendum: This is an area left blank in case any sources were omitted from the catalogue prior to launch. At minimum, it consists of a marker to show that there are no more sources stored, and the remaining memory zero filled, except for the last word, which is a CRC value. If a source is added to the addendum then it will be put at the beginning of the area, and followed by the marker.

The pointer table: This allows quick access to catalogue data. It holds a set of pointers that, via two levels of direction, point to each sky area. It is CRC protected.

1.3.9.2 Planetary Positions

In order to protect the instrument from moving celestial object damage, the ICU calculates the positions of the Sun, Earth and Moon as a backup to the protection already provided by the spacecraft. In addition, similar calculations are performed for Venus, Mars, Jupiter, Saturn, Uranus and Neptune, as the spacecraft does not provide this information. All target fields of view are compared against these positions and an EEPROM located table of angles of avoidance. Any violation of those angles prevents the exposure except in the cases of the fainter planets Uranus and Neptune, which are considered as stars of the same colour index as the Sun and a maximum observing time deduced instead.

The ICU calculates the Sun, Moon and planetary positions on startup and every slew. The checks for constraint violations of the Sun, Earth and Moon are made every two seconds. The planets are checked for constraint violations every slew.

The positions are calculated using formulae, algorithms and data given in

1. U. S. Naval Observatory, *The Astronomical Almanac*, Government Printing Office, 2001.
2. P. Kenneth Seidelmann (Editor), "*The Explanatory Supplement to the Astronomical Almanac*", University Science Books, 1992.
3. Peter Duffet-Smith, *Practical Astronomy with Your Calculator - 3rd Edition*, Cambridge University Press, Cambridge, 1979.
4. Jean Meeus, Astronomical Formulae for Calculators, Willmann-Bell, 1985.

1.3.10 UVOT State Transitions

In order to achieve its goals, the ICU must successfully transition the UVOT between several instrument configuration states. The possible transitions are shown in the diagram.

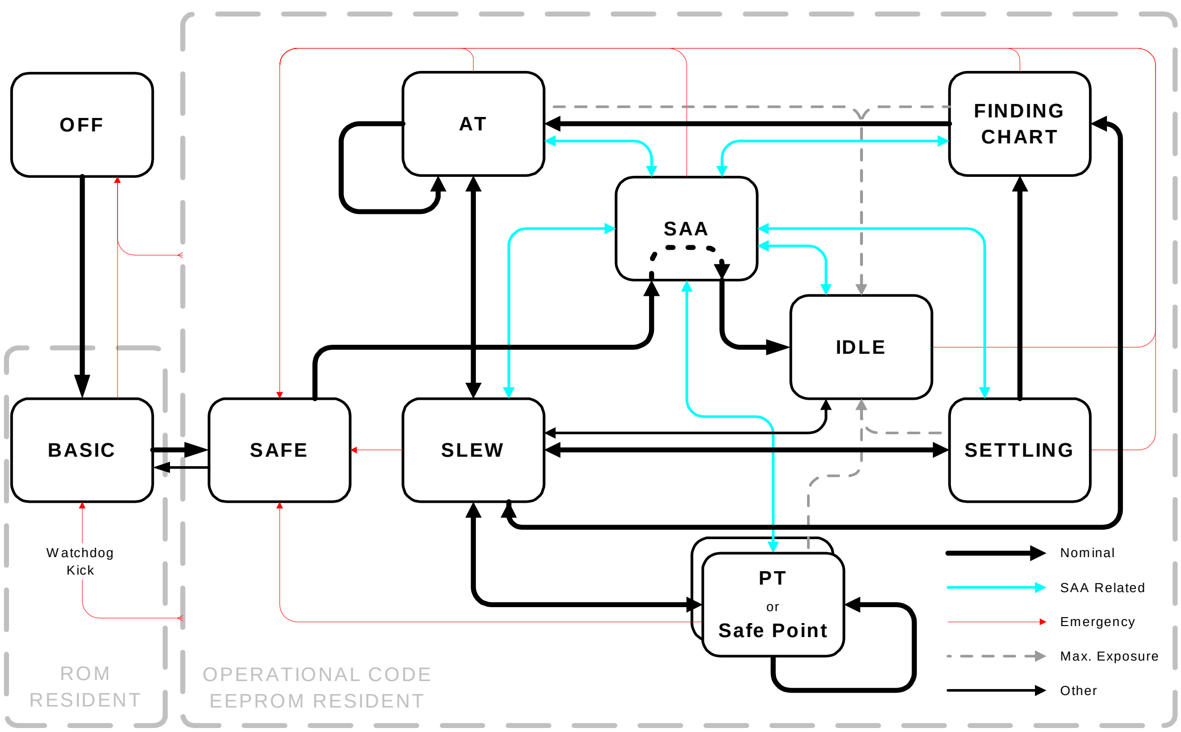
Each state transition is performed by a RTS. A look-up table located in EEPROM (see appendix B.12) contains a list of those RTSs against the requested transition. For those transitions that may be autonomous – see below – it also contains the required state of internal ICU flags for that particular transition to take place. This table is used in two ways.

On command: On reception of a telecommand requesting a particular transition that has been issued either from the ground or from a RTS, the table is scanned for a match against both the current state and the requested state. If a match is found, the relevant RTS is selected and executed. If no match is found, the command is rejected.

Autonomously: A number of events will cause the ICU to select the required state transition itself by comparing the table of internal ICU flags against the current values. If a match is found, the RTS is selected and executed. If no match is found, the request is ignored. The routine events that trigger such a response are:

- The settled flag becoming false in the SISCATTITUDE record
- The reception of the FONEXTOBSINFO message
- The 'within 10 arc minutes of target' flag being set to true in the SISCATTITUDE record
- Entry or exit from the SAA, as shown by a flag in the SISCATTITUDE record

In addition, an error may cause the ICU to select and run an RTS to handle the condition. These typically involve



going to the Safe state. The precise action is determined by EEPROM located tables. The errors are:

- Limit Violations (see appendix A.4 for details of the EEPROM table).
- Error condition caused by e.g. failure of a filter wheel move, CRC check failure set – see appendix B.8, "Errors Action Table", for details.
- The Safe Hold flag being set to true in the SISCATTITUDE record

The purpose and activities of each state are summarized below.

BASIC CODE ONLY.

Basic: The ICU enters this state on turn-on. The code executed in this state is resident in ROM and therefore cannot be updated. It ensures that the filter wheel is in the blocked position and that the high voltages are at zero. It maintains housekeeping, on-board autonomous limit checking, thermal control and enables the watchdog (see section 1.1.1.5). These latter processes continue to run in all other states. On command to go to the Safe state, it first loads the operational code from EEPROM into RAM and then performs the transition. All subsequent states are supported, only by the operational code.

There are a number of NCRs on this code (see Appendix F, MSSL NCR 22, MSSL NCR 74, MSSL NCR 75, MSSL NCR 76 and MSSL NCR 77). As this code is ROM based, they cannot be fixed.

OPERATIONAL CODE ONLY.

Safe: As its name implies, in this state the instrument is configured to be least susceptible to damage. The safety features that were performed in Basic are repeated i.e. the filter wheel is set in a blocked position and the high voltages (HVs) are set to zero. This is because we may return to this state without going through Basic state. It maintains housekeeping, on-board autonomous limit checking, thermal control and enables the watchdog (see section 1.1.1.5). These latter processes continue to run in all other states of the operational code..

Idle: The UVOT is configured to be ready to observe but is awaiting the next slew. As a safety precaution the cathode voltage is held down at zero and the filter wheel may be placed in the blocked position until observations commence.

Slewing: In this state the UVOT cleanly shuts down any current observation, prepares the instrument for slewing and informs the spacecraft when it is ready. As a safety precaution the cathode voltage is held down at zero. It then selects the next exposure and performs various safety calculations.

Settling: After a new GRB has entered the UVOT's field of view but before the spacecraft has settled, it is observed by collecting an event list. As the target will be moving rapidly, it is not possible to collect an image.

Finding Chart: If the target is a new GRB, then once the spacecraft has settled, a 100 second exposure is made in a standard filter to produce a finding chart that will be sent to the ground. In many cases, by the end of the exposure, the XRT will have reported an improved position for the source. The ICU uses that information, and the GRB brightness information supplied by the BAT, when it configures for the subsequent Automated Target exposures.

Automated Target (*AT*): During the period whilst a GRB has no pointing constraints – this is referred to as a snapshot – the ICU will configure and run a series of exposures in this state.

Planned Target (*PT*): The ICU will configure this type of exposure when the FOM informs the ICU, via the FONEXTOBSINFO record, that the spacecraft is performing a planned observation.

Safe Pointing (*SP*): The ICU will configure this when informed that the spacecraft is slewing to a safe pointing. This type of exposure occurs when no automated or planned targets are available.

South Atlantic Anomaly (SAA): In this configuration, the instrument is configured to be safe whilst passing through the SAA. In particular, the MCP bias voltages are held at 70% of their nominal value and the cathode voltage is at zero.

1.3.11 Observing Sequences

This section illustrates how the UVOT proceeds around the state diagram during operation. As mentioned above, these transitions are handled by the appropriate RTS. In particular, once the state has reached Idle and we are fully enabled for observations, the selection and running of the appropriate RTS to perform a given transition is performed autonomously.

1.3.11.1 Turn On

At turn on, the UVOT enters the Basic State.

1.3.11.2 Becoming Operational

Upon receiving the `/istate` command with the state set to Safe, the ICU loads its operational code from EEPROM-A into RAM, executes it and transitions to the Safe state. The instrument is in a safe condition and is not capable of performing observations.

1.3.11.3 Preparing to Observe

Upon receiving the `/istate` command with the state set to Idle, the ICU prepares the instrument for observing (e.g. HVs are enabled and Vmcp1 and Vmcp23 are ramped up to operational levels – see section 1.2.2.4, the filter wheel in blocked and the BPE tables - sections 1.2.2.6.2 and 1.2.2.6.3 - loaded) and will usually leave it in the Idle state. It should be noted, and as can be seen from the state diagram, that it does this via the SAA state. Should the spacecraft be within the SAA at the time of this transition, the ICU will leave the UVOT in the SAA state (with, for instance, Vmcp1 and Vmcp23 at 70% of their operational values) and will not complete the transition to Idle state until the SAA is exited. The housekeeping display will reflect this behaviour as, even when the spacecraft is not in the SAA, the SAA state may be briefly shown.

1.3.11.4 Slew Warning

Upon receiving a slew warning from the spacecraft in the form of an SISLEWWARNING record, the ICU ensures the Vcathode is set to zero. It then informs the spacecraft that we are safe to slew by sending an SACSLEWSAFEREPLY. At that point, it has transitioned to the Slew state.

If the UVOT then receives a FONEXTOBSINFO record, it performs an AT or PT observation in their respective states. If the contents of the 5 Hz attitude control system (ACS) record imply we are going to a safe pointing, it proceeds to the Safe Pointing state. If neither of the above happens, it assumes an error condition and proceeds to the Idle state.

However, for PT and AT exposures, the ICU has to verify for the target position that there are no bright planets and, by examining the on-board catalogue, that there are no detector-damaging bright stars present. If there are bright sources at, or close to, that position, it must ensure that the exposure does not take place and take appropriate corrective action, for example by reducing the gain of the image intensifier and placing the UVOT into idle state. The actions for Safe Pointing observations are described below in section 1.3.11.7.

1.3.11.5 AT Observation

NOTE: For all types of exposures, the ICU maintains a running theoretical total of counts received so far at each catalogued star position in the field of view. Should this number approach an EEPROM tabulated damage limit, it will shorten, or even suppress, the exposure accordingly. See also “SAA Interruptions”, section 1.3.11.8 below.

AT observations are handled in two distinct ways, depending on whether the source has been observed during a previous snapshot. If the IS_NEW_AT_SLEW parameter in the FONEXTOBSINFO record is true, then this is the first time it has been observed.

1.3.11.5.1 IS_NEW_AT_SLEW = True

The ICU will transition from the Slew state to the Settling state when the IS_IN_10_ARCMIN flag in the ACS becomes true. It will then perform a settling exposure until the spacecraft becomes settled (IS_SETTLED is True). It then transitions to the Finding Chart state and performs a 100 second finding chart exposure. Upon completion, it automatically transitions to the AT state and performs the first of a sequence of exposures. Its behaviour from this point is the same as if IS_NEW_AT_SLEW = False (see below).

1.3.11.5.2 IS_NEW_AT_SLEW = False

The UVOT transitions to the AT state and perform the first of a sequence of exposures. The precise sequence used is selected from a list stored in EEPROM using

1. The UVOT Mode parameter - which will be in the range 0x8000 to 0xfffe - supplied by the Figure of Merit (FOM) in the FONEXTOBSINFO record.
2. A refined target position which may be sent by the XRT during the finding chart exposure.
3. The intensity of the GRB as transmitted in the GRBFLUXINFO packet by the BAT instrument.

Which exposure is used within that sequence is a function of the time since the GRB was detected. This ‘time since burst’ selects a given time band. The next exposure configuration is then selected from a cyclic sequence specified for each time band unless, in a previous snapshot, a specified minimum exposure time was not obtained, in which case the current one is restarted. Upon completion of a given exposure, the UVOT resets itself by transitioning to the current AT state. It then selects the next exposure configuration. This process repeats until the next slew warning.

It is possible for the above behaviour to be modified. If the finding chart exposure was not successfully obtained in a previous snapshot (perhaps because the snapshot was too short or it was interrupted by entering the SAA) the UVOT will first transition to the Finding Chart state and retry the exposure. Up to three such attempts will be performed before they are abandoned.

1.3.11.6 PT Observation

NOTE: For all types of exposures, the ICU maintains a running theoretical total of counts received so far at each catalogued star position in the field of view. Should this number approach an EEPROM tabulated damage limit, it will shorten, or even suppress, the exposure accordingly. See also “SAA Interruptions”, section 1.3.11.8 below.

The UVOT Mode supplied in the FONEXTOBSINFO is used by the ICU to lookup from EEPROM located tables a list of exposures to be performed during the snapshot. For PT exposures, it has a value in the range 9 to 0x7ffe.

If the value of UVOT Mode is greater than or equal to 0x1000, the exposure times supplied for those exposures are scaled to fit into the expected possible observing time during the snapshot. This is obtained from the OBSERVE_SECONDS parameter in the FONEXTOBSINFO record. It is intended that this type of exposure will be used for science exposures. Note that it is assumed that the value of the OBSERVE_SECONDS parameter will take into account expected interruptions due to the SAA.

If the value of UVOT mode is less than 0x1000, then the exposure time remain unaltered. It is intended that this type of exposure will be used for calibration and engineering exposures.

Having performed the above adjustments, the ICU performs the first exposure in the list. Upon completion of the exposure, the UVOT resets itself by transitioning to the current PT state. It then selects the next exposure configuration. This process repeats until the next slew warning, when it transitions to the Slew state, or until the list of exposures is exhausted, in which case it will transition to the Idle state.

1.3.11.7 Safe Pointing Observation

NOTE: For all types of exposures, the ICU maintains a running theoretical total of counts received so far at each catalogued star position in the field of view. Should this number approach an EEPROM tabulated damage limit, it will shorten, or even suppress, the exposure accordingly. See also “SAA Interruptions”, section 1.3.11.8 below.

The ICU will transition to the Safe Pointing state when informed that the spacecraft is slewing to a safe pointing. This is done by the OBSERVATION_NUM being in the range 1=>6 in the ACS record. This type of exposure occurs when no automated or planned targets are available. They are treated internally in a similar manner to PT exposures. However, an important difference is that it is not possible to perform the safety calculations that are normally carried out in the slew state until arriving at the pointing position, as the target pointing information is not available until the spacecraft is settled. If it is determined that there are bright sources present, a transition to Idle will then occur.

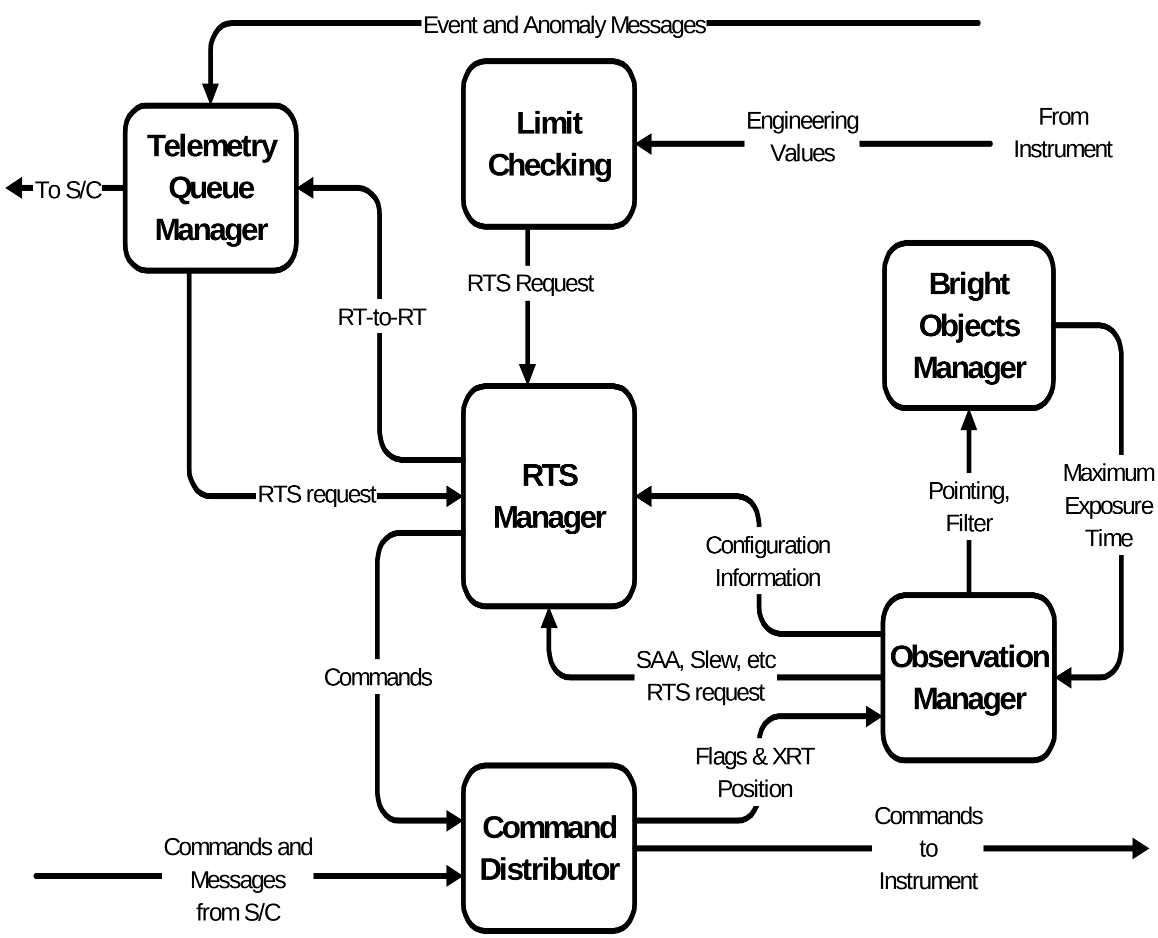
1.3.11.8 SAA Interruptions

All of the above actions may be interrupted by the spacecraft entering the SAA. When this happens, any exposures in progress are cleanly shut down and the ICU transitions to the SAA state (Vcathode off and Vmcp1 and Vmcp23 at 70% of nominal values).

Upon exiting from the SAA, the ICU attempts to transition back to the state it was in prior to the interruption. For PT and Safe Pointing exposures, the remaining time of the exposure in progress is executed. In the case of AT exposures, the next one is selected in the manner described above.

However, it may not be always possible to resume the previous state. For instance, a slew may now have started or taken place whilst the s/c was in the SAA or a settling period may have ended. In these cases, the ICU looks at the status and selects an appropriate state to which to transition.

1.3.12 Overall Data Flow



The figure illustrates how data flows between the software modules that make up the autonomous system of UVOT and the central position of the RTS system.

Command Distributor: This module receives not only all the commands and messages sent on the spacecraft bus, but also all commands internally generated by the RTS Manager. It then distributes them to the appropriate software module.

Observation Manager: This module monitors the spacecraft and FOM messages and maintains a record of the status of the ICU. It uses this information to determine when it is appropriate to issue a suitable RTS command. It accesses the state management tables as well as the AT and PT configuration tables described above as part of this process.

Bright Objects Manager: This returns information about planets and stars near or in the target field of view, using the star catalogue and avoidance angle tables described above.

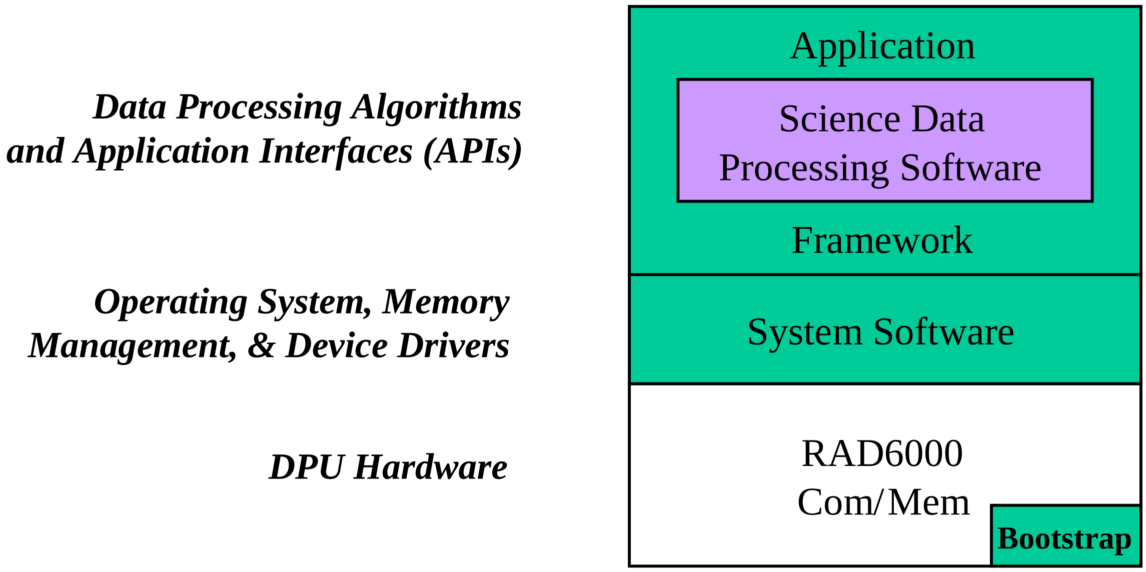
Limit Checking: This monitors critical engineering values. Using the table described above, it issues requests, if necessary, for a RTS to perform recovery actions from a limit failure.

Telemetry Queue Manager: This monitors all outgoing telemetry for error messages and, using the table described above, issues a request to run a recovery RTS if required.

RTS Manager: This module executes the RTS. It consists of the virtual CPU code to execute the RTS, together with software to scan the RTS index image to permit rapid location of a given RTS.

1.4 DPU Software

The DPU software is built upon a VxWorks™ Real-Time Operating System. Bootstrap and device driver software for the SSI, DCI, 1553 interfaces were developed by Southwest Research Institute (SwRI). Application-level science "Data Processing Algorithms" software was developed by Penn State University. This layered approach to software development was critical to completing the software on time and under budget, as it provided a clear division of labor between the two institutions.



The primary functions of the DPU Flight Software are:

- Receive and execute commands received from the ICU and the spacecraft
- Receive and process detector events from the UVOT Telescope Module
- Perform lossless data compression of image and/or photon event data
- On-board source detection for generation of UV/Optical finder chart
- Generate science data telemetry products
- Generate engineering data telemetry products
- Forward packetized compressed data to the spacecraft Solid State Recorder
- Maintain time synchronization with the spacecraft.

The DPU communicates with the ICU through the Synchronous Serial Interface, and receives raw photon position and timing data from detector electronics across a serial Data Capture Interface. Because the amount of photon event data that can be collected exceeds the UVOT telemetry allocation, the DPU employs histogramming and modified VBTWL data compression to reduce the size of its telemetry data products. The DPU formats data as Consultative Committee for Space Data Systems (CCSDS) Source Packets, and forwards telemetry to the Spacecraft Control Unit (SCU) through a MIL-STD-1553 (1553) interface. Housekeeping and science telemetry timestamps are synchronized with the spacecraft clock.

2. Instrument Operation

2.1 Safety Issues

The UVOT detector/telescope is damaged by bright light, particularly when the three high voltages are up (Vmcp23, Vmcp1 & Vcathode) and the filter wheel is not in blocked. Damage can be

1. Deterioration of the MCPs,
2. Deterioration of the photocathode
3. UV polymerization of contamination on the optical surfaces and
4. Bright focused light (heat) on the optical surfaces.

NOTE: It is important to realize that, even when powered off, it is *still* sensitive to damage by ultraviolet light and heat.

When preparing for a slew (i.e. after UVOT receives a slew warning – SISLEWWARNING - but before UVOT replies with a SACSLEWSAFEREPLY) the cathode voltage is set to zero. This reduces the gain of the detector considerably but assumes we are still obeying the pointing constraints (i.e. not close to the Earth, Sun & Moon). At this point, the UVOT is in SLEW state, which is not the same as SAFE state. When there is a risk from these objects, the UVOT a) ramps down all three high voltages to zero and then b) moves the filter wheel to its blocked position.

Operationally the important points are:

1. It is better to have the UVOT DEM powered on all the time (it cannot be damaged by pointing/light). The DEM can then control the telescope module (TM), in particular the filter wheel, and send back state of health data.
2. Powering off the TM by switching the main power (particularly when observing) should only be done in extreme circumstances. It is better to ramp up and down the high voltages slowly rather than ramping them quickly or simply switching them on or off.
3. Powering off the telescope is normally no better than leaving it powered with the high voltages powered off. When in full SAFE state (not the same state as SLEW), the high voltages and (normally) the camera are not powered and the filter wheel is in blocked. There is no gain from the MCPs. Powering off the TM when in SAFE powers off the interfaces and heaters. It does *not* provide any extra safety (unless something has already broken or is out of control).
4. The UVOT DEM is able to command the filter wheel to its blocked position. A simple power off of the telescope module may well leave the filter wheel in a filter other than blocked, thus allowing the passage of – and potentially damaging - light. After the DEM has commanded the filter wheel to the blocked position, the TM can be powered off but there seems little point unless the DEM has lost control.
5. The only known reason for powering off the UVOT TM is if the DEM has lost control of the TM. This could be caused by a failure to boot, a serious interface problem etc. The DEM can already request a TM power-off when it finds it can't control it. The Spacecraft can already power-off the TM when the DEM doesn't respond to a slew warning.
6. There should ***never*** be more than 1 DEM powered.
7. There should ***never*** be more than 1 TM powered.
8. The TM should ***never*** be powered alone.
9. Some light can get around the blocked filter to the detector but "observing" e.g. Capella with the blocked filter is not a problem.
10. If UVOT receives a slew warning but the spacecraft does not start to slew (UVOT determines this by monitoring the IS_SETTLED flag in the ACS record) within 30s, we will normally go to safe anyway (taking a little less than 3 min).
11. If the ICU watchdog reboots, it will check and make safe the high voltages and filter wheel.

We expect to go to SAFE state in three possible independent ways at three different levels of urgency. The slowest would normally be used unless there is an emergency:

1. Normal

```
/istate safe
wait 180
```

2. Fastsafe

```
/irtsrun rts=0x301       ; note this is in HEX
wait 14
```

3. Emergency Safe

```
/irtsrun rts=3
wait 5
```

During each of the above waits, the telescope is being made safer (i.e. after 1 s of "fastsafe" things are pretty safe and after 6s things are even better and after 14s we're as safe as we can be). Therefore, even if there is not time to wait 3 minutes, 14s or 5s it is still worth sending the command.

2.2 Noise on HV measurements

Note that, due to the noise in the A/D circuit of the HV of up to ± 5 raw units, it is possible to see HV values on the display with this excursion around the commanded value. Five raw units corresponds to a value of ~2.5, 13 and 49 volts for Vcathode, Vmcp1 and Vmcp23 respectively.

2.3 UVOT Procedures

This section gives background information of the consequences to the hardware and software of running each of the following written procedure documents. This includes more detail of the possible errors that may be seen because of the many separate actions implied by each telecommand of the procedure.

2.3.1 UVOT-01 Early Orbit Turn-on

This is described in UVOT Launch and Early Orbit Timeline and Turn-on Procedure, SWIFT-UVOT-040.

2.3.2 UVOT-02 Emergency Power Off

Under normal circumstances, a S/C problem (i.e. Safehold Mode) will place the UVOT into the Safe state. In the event this did not occur or a problem is discovered with the UVOT, the UVOT subsystem engineer may direct the FOT to execute this procedure.

The emergency power off procedure executes RTS 3 followed by procedures to fully power down the telescope modules and DEM. RTS 3 ***sets***, rather than ramps down, the high voltages to zero, turns off the camera, ensures the flood LEDs are set to zero and then initiates a filter move to blocked. However, no check is performed that the latter action actually occurs before setting the state to safe, as the emphasis is on speed. It is therefore possible, depending on the nature of the emergency and position of the filter wheel, to power off the UVOT before the filter wheel has finished moving, thus leaving it in an ‘open’ position.

As several of the above actions go against the advice given in the above section on safety issues, it is clearly advisable to only use this procedure in extreme circumstances.

The routine power off procedure will normally be used to power off the UVOT.

2.3.3 UVOT-03 Emergency Safing

Under normal circumstances, a S/C problem (i.e. Safehold Mode) will place the UVOT into the Safe state. In the event this did not occur or a problem is discovered with the UVOT, the UVOT subsystem engineer may direct the FOT to execute this procedure.

The emergency safe procedure executes RTS 3. As this is identical to the first part of UVOT-2, similar considerations apply.

As several of the above actions go against the advice given in the above section on safety issues, it is clearly advisable to only use this procedure in extreme circumstances.

The routine power off procedure will normally be used to power off the UVOT.

2.3.4 UVOT-04 Power Off and On

On rare occasions, the UVOT may need to be powered off and subsequently powered back on. This procedure should be followed for this purpose. Initial power on (i.e. L&EO) will be unique and described in the L&EO Timeline/Script.

The execution of power on and off should only be done if directed by the UVOT subsystem engineer or after getting concurrence from him.

2.3.4.1 Power-Off Procedure

The `uvot_power_off` proc will check that the ICU is in Basic or Safe state. If neither is true, it will request whether you would like to go to Safe. If this is declined, the proc will exit, as it is not appropriate that it continue until it is safe so to do.

If the instrument is not in Safe of Basic, the proc then start `icu_safe` proc. This procedure sends the /`istate safe`, which results in the execution of the `gotosafe` RTS (0x11). This RTS first ensures that any filter movement, BPE tables load and HV ramps in progress are terminated, the BPE flood LED is zeroed (if not already) and any DPU exposure stopped. The HV Vcathode voltage is set to zero in one step and the camera disabled. The filter wheel is then moved to the blocked position and the HVs Vmcp1 and Vmcp23 are ramped to zero in turn and the HV system then disabled.

It is possible for the filter wheel movement to fail if, for some reason, the fine sensor is not detected (see section 1.2.3.1). In this case the procedure attempts to recover by moving slowly up to the datum (which requires both fine and coarse sensors to be detected) and then, if that fails, the coarse position (which only requires detection of the coarse sensor). If this occurs, for each failure a “FW Lost Position” and its associated “DCS Event Time-out “ messages will be issued.

Similarly, it is possible for the HV ramps to fail with an “HV Ramp Failed” and its associated “DCS Event Time-out “ message if the actual voltage measured does not achieve the requested voltage within the timeout period. However, the HVs are always disabled at the end of the procedure even if this has occurred, but clearly the occurrence should be noted and brought to the attention of the UVOT team.

It is also important to verify that the filter wheel position is actually shown as blocked on the HK display when the state is shown as safe. The procedure go on to power down the UVOT, but the failure of the filter to achieve blocked should be brought to the attention of the UVOT team.

At the completion of the `icu_safe` proc, the proc then proceeds to power off the TM, waits for any exposure still being processed by the DPU to complete and empty its telemetry queue, ensures the s/c no longer expects a response to a slew request from UVOT then powers down the DEM.

2.3.4.2 Power-On Procedure

The `uvot_power_on` proc ensures that all the relevant UVOT pages are displayed, the 1553 enabled for the ICU and DPU and the DEM started. It then validates that the ICU is receiving telecommands from the spacecraft (SISCATTITUDE and TIMETONE) after power on before continuing with anything more. A deliberate wait is then imposed in order to deal with NCRs 60 and 85 (which relate when DPU HK may be considered valid). The spacecraft is then told to expect acknowledgements from the ICU to any slew request. The pages are then checked for validity so far before proceeding. The TM is then powered and a second check of the pages performed.

At this point, the ICU will be in Basic State. The command to go to Safe state is then issued. The 1PPS is enabled and the pages checked again. After a suitable wait to allow for NCR 85 problem, on-board ICU limit violation checking is then enabled.

2.3.5 UVOT-05 Recovery from Safehold

When the S/C enters Safehold mode the UVOT will be placed, via RTS, into one of three states:

a) Safe State
b) Only TM Powered
c) UVOT Powered Off

In all cases, before returning the UVOT to normal, the operations team should contact the UVOT subsystem engineer. Together, they should verify that the cause of the entry into Safehold is understood and the UVOT can safely be returned to normal operations.

2.3.5.1 Recovery from Safe State

NOTE: Until NCR 114 is fixed (see ICU software NCRs and ECRs, Appendix F), the transition safe to idle should not be performed if there is a risk we may enter the SAA during that long transition.

The `icu_idle` proc checks appropriate prerequisite conditions before commanding to idle state. The first check is that no Sun, Earth or Moon constraints are being violated. This is followed by a request to reset the safety circuit if required. Two of the checks can be bypassed if the s/c is not settled and there is less than 300 seconds to the next slew. However, this should only be done if directed by the UVOT subsystem engineer.

The `safe_to_idle` RTS (0x31a) – initiated by the `/istate idle` command – performs the necessary sequence of actions to ready the UVOT for observation and leaves it in the idle state. It runs at slightly higher than the normal priority to ensure it is not interrupted other than by urgent or safety requests (which lead to the initiated of higher priority RTSs).

Checks are first performed that no ICU s/w condition precludes such a transition, that the safety circuit is not on alert and that there is no sun, moon or earth constraint violation. The mechanism excessive temperature protection circuit (DISMON) is enabled and the values of the coarse and fine sensor illumination LEDs are set to their EEPROM tabulated values.

A failsafe attempt to move the filter wheel to blocked position is performed. It is possible for the filter wheel movement to fail if, for some reason, the fine sensor is not detected (see section 1.2.3.1). In this case the procedure attempts to recover by moving slowly up to the datum (which requires both fine and coarse sensors to be detected) and then, if that fails, the coarse position (which only requires detection of the coarse sensor). If this occurs, for each failure, a “FW Lost Position” and its associated “DCS Event Time-out” messages will be issued and the RTS will switch to an alternate RTS that will return the UVOT to safe.

The Vmcp23 and then Vmcp1 HV values are then ramped to 70% of their final values. These values are suitable for the SAA and are a precaution in case the SAA is encountered during the Safe to Idle transition. It is possible for the HV ramps to fail with an “HV Ramp Failed” and an associated “DCS Event Time-out” message if the actual voltage measured does not achieve the requested voltage within the timeout period. Should this occur, the RTS would switch to an alternate RTS that will return the UVOT to the safe state.

The centroid and window tables are then loaded with their EEPROM tabulated values. In each case, a verification of the contents is performed and, if necessary, a second attempt is performed. This would lead to “Centroid Table Load

Failure" and associated "DCS Event Time-out" messages. Should either load fail after the second attempt, the RTS would switch to an alternate RTS that will return the UVOT to the safe state.

The camera is then enabled and flags set that enable autonomous transitions to the AT, PT or Safe Pointing states should we now be interrupted by a slew. The RTS now drops its priority to normal level, sets the state to SAA and then, providing we are not in the SAA, performs the final ramping of the HVs (with the exception of Vcathode, which remains at zero) to their operational values. Again, any failure of this latter operation would lead to a return to safe state.

2.3.5.2 Recovery from TM only Power Off

The `uvot_tm_recovery` proc is run prior to running the `icu_idle` proc as above. This ensures that the TM is powered and the ICU is in Idle state. It is worth noting that, because the TM has been power cycled but the ICU has not, an ICU internal flag indicates the BPU tables are already loaded but the RAM of the TM BPE has been cleared. Therefore, this procedure reloads those tables.

2.3.5.3 Recovery from UVOT Power Off

The `uvot_poweron` proc (see section 2.3.4.2) is run prior to running the `icu_idle` proc as above.

2.3.6 UVOT-06 Safing and Recovery

During normal operations occasionally the UVOT may need to be placed into its Safe state for a number of reasons and then back to normal operations.

The proc `icu_safe` is first run to ensure the UVOT is in a safe state (see its description in section 2.3.4.1). After obtaining approval to return to normal operations, the `icu_idle` proc (see section 2.3.5.1) is run to return the ICU to idle as thus capable of performing observations.

2.3.7 UVOT-07 Recovery from Safety Circuit Trip

The UVOT has a safety circuit that trips when the UVOT views an unexpectedly bright source (as calculated from the ICU's star catalogue). The trip of this circuit should generate a TDRSS message sent to the ground and will show up as a Red Limit for the mnemonic **ISFTYALERTFLAG** on page **ihk**.

The resetting of this circuit should not be done until the source is determined and verified that it is not going to be viewed again.

The procedure runs the `icu_idle` proc, as already described in section 2.3.5.1.

2.3.8 UVOT-08 Observing Proc List

This lists the STOL procs available for managing the UVOT observing activities. This list is provided for informational purposes. These procs should only be run under direction from the UVOT subsystem engineer.

2.3.9 UVOT-09 Utility Proc List

This lists the STOL procs available for commanding the UVOT. This list is provided for informational purposes. These procs should only be run under direction from the UVOT subsystem engineer.

2.3.10 UVOT-10 TDRSS HK

This procedure describes the steps necessary to turn on and off the downlink of UVOT housekeeping for both the ICU and DPU.

During L&EO and possible anomaly conditions during the mission, housekeeping may need to be monitored during scheduled TDRSS contacts.

2.3.10.1 ICU

The proc `icu_tdrsshk_on` selects how many HK frames (up to a maximum of 300 every 10 seconds) will be sent to TDRSS. This can be terminated prematurely with the proc `icu_tdrsshk_off`.

2.3.10.2 DPU

The proc `dpu_tdrsshk_on` enables copying of HK frames to TDRSS. This must be terminated with the proc `dpu_tdrsshk_off`.

2.3.11 UVOT-11 Alert Message Response

To describe the alert messages issued by the UVOT.

Normally there's an internal ICU automatic response to an error. See Appendix C . The p1, p2 and p3 codes are usually to be interpreted by MSSL.

2.3.12 UVOT-12 Lost Filter Wheel Position

This procedure describes the response of the UVOT after a lost filter wheel position.

During operation, the filter wheel may lose its position. The recovery is usually autonomous in one of two ways when under the control of one of the many RTSs that are used to control transitions between states and perform observations (see section 1.3.8.2). However, they all use the same recovery technique.

2.3.12.1 Recovery 1

The filter wheel loses its position and recovers immediately; the partial messages reported will be as follows:

FW Lost Position
AT_REQUESTED_FILTER_POSITION

2.3.12.2 Recovery 2

The filter wheel loses its position and recovers after another attempt to move the filter wheel; the partial messages reported will be as follows:

FW Lost Position
FW Not Yet Datumed
AT_REQUESTED_FILTER_POSITION

Note: If the filter wheel cannot be recovered after two attempts, the ICU will be transitioned to SAFE mode using the RTS `gotosafe` (0x11). The UVOT subsystem engineer should be contacted immediately.

2.3.13 UVOT-13 ICU Code-RTS Upload

This procedure describes the steps necessary to load new ICU code and/or new RTS definitions.

If, during normal operations, it is determined that the ICU code or the default RTS definitions need to be modified, this procedure should be used as a template to accomplish this.

First, the `icu_safe` proc is run to ensure the ICU is in safe mode – see section 2.3.6 for details of this proc.

If the reload that is about to take place is to an area of EEPROM containing RTSs or the index to the RTSs, then the RTS system should be disabled with /`rtsdisable` disable=1 command.

The proc `iload_chunk` is then used to load to EEPROM – see the procedure for details.

A *spacecraft* RTS is then run to dump the memory loaded for verification.

If the code upload is to replace the ICU code, as opposed to and RTS location, the next step is replace the code currently running in RAM with the new version now in EEPROM. This is done using the `icu_reload` proc. This works by, once it has checked that the ICU is in Safe, requesting it to go again to safe. This is understood by the on-board code to force a reload of RAM from EEPROM. Whilst this process is taking place, the ICU is not functioning. Therefore, the procedure also informs the s/c not to expect a response to a slew warning.

The final stage in the process is to return the ICU to full operational state using the icu_idle proc. See section 2.3.5.1 for a description.

2.3.14 UVOT-14 DPU: Upload BC1 Code Image

TBA

2.3.15 UVOT-15 DPU: DCI Lockup Recovery

TBA

2.3.16 UVOT-16 Recovery from Watchdog Trip

This procedure describes the steps necessary to recover the UVOT after a Watchdog Trip.

Unexpected events are handled on the UVOT by a Watchdog Reset (see “Watchdog”, section 1.1.1.5). After the reset, the IUVOTSTATE will be BASIC.

Before returning the UVOT to normal operations, contact the UVOT subsystem engineer to verify the cause of the Watchdog Trip. The transition to SAFE state (using the `icu_safe` proc, described in section 2.3.4.1) can be done immediately. However, do not execute `icu_idle` (described in section 2.3.5.1) without the go ahead from the UVOT subsystem engineer.

2.3.17 UVOT-17 DPU: Upload Table

TBA

2.3.18 UVOT-18 DPU: Upload/Install Patch

TBA

2.4 Limit Violation Response Matrix

Notes

- All yellow and red limits should trigger a SERS page to the UDS.
- This table applies for normal operation**.**
- Powering off the UVOT will requires 2 passes to recover plus a centroid table exposure must be scheduled. (BUT NEED STABLE THERMAL ENVIRONMENT)
- Note that no emergency procs are used in this table. However they are available should the time to run normal safing is inadequate.
- Normally the ICU will have dealt with limit violations (typically sending the UVOT to safe) and this table describes backups and checks to that action.
- This table describes the actions for current limit violations, not violations that have occurred recently but are no longer current.
- The following items are, in fact, measurements of the same item but transmitted via different UVOT paths. As such, it is to be expected that they may enter and leave limit violations together. The table below shows the correspondence.

Description	**Measured by DPU and telemetered directly**	**Measured by DPU, sent to the ICU via the SSI and telemetered by the ICU**
DPU Voltage PSU A -12V	D_ADC_M12V	iDPUMinus12VA
DPU Voltage PSU -5V Ref	D_ADC_M5V_REF	iDPUMinus5Vref
DPU Parity Errors	D_DPA_ENVT_ERRS	iDPUParityErrors
DPU Voltage PSU A +12V	D_ADC_P12V	iDPUPlus12VA
DPU Voltage PSU A +5V	D_ADC_P5A	iDPUPlus5VA
DPU Voltage PSU +5V Ref	D_ADC_P5V_REF	iDPUPlus5VRef
DPU Temp DPU Comm/Mem Module	D_ADC_THERM_SCM	iDPUTempComm
DPU Temp ICU CPU Module	D_ADC_THERM_ICPU	iDPUTempICUCPU
DPU Temp ICU I/F Module	D_ADC_THERM_ICU	iDPUTempICUIF
DPU Temp PSU A	D_ADC_THERM_PSA	iDPUTempPSUA
DPU Temp PSU B	D_ADC_THERM_PSB	iDPUTempPSUB

2.4.1 ICU

Mnemonic	Meaning	Low Red	Low Yellow	High Yellow	High Red
IBPEACQMODE	BPE Acquisition Mode	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Investigate simultaneous UVOT error messages which may be associated. 3. UVOT: Investigate.			
IBPECCDTEMP	BPE CCD Thermistor Reading	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check nearby temperature sensors. page ihk: IBPE*TEMP, IDPUTEMP* page uvotsctm: SACEAD590CH11-15,17, SACEPRTCH2,5			1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check that ICU has gone to safe (page ihk: IUVOTSTATE=1=SAFE) and that UVOT camera is off (page ihk IBPECAMSTARTED = 4) 3. FOT: If not in safe, manually got to safe (i.e follow written procedure UVOT #6 "Safing and Recovery" executing the STOL proc start icu_safe). 4. FOT: Check nearby temperature sensors. page ihk: IBPE*TEMP, IDPUTEMP* page uvotsctm: SACEAD590CH11-15,17, SACEPRTCH2,5
IBPEEVENTTHOLD	Detector Event Detection Threshold	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Investigate simultaneous UVOT error messages which may be associated. 3. UVOT: Investigate.			
IBPEFORWARD1TEMP	TM Forward 1 Thermistor Reading	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check nearby temperature sensors. page ihk: IBPE*TEMP, IDPUTEMP* page uvotsctm: SACEAD590CH11-15,17, SACEPRTCH2,5			
IBPEFORWARD2TEMP	TM Forward 2 Thermistor Reading				
IBPEFRAMETAGNBLD	Frame Tag Enabled Status	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Investigate simultaneous UVOT error messages which may be related. 3. UVOT: Investigate.			
IBPEMAINTEMP	TM Main Thermistor Reading	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check nearby temperature sensors. page ihk: IBPE*TEMP, IDPUTEMP* page uvotsctm: SACEAD590CH11-15,17, SACEPRTCH2,5			
IBPEREFATEMP	TM Ref A Thermistor Reading	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check nearby temperature sensors. page ihk: IBPE*TEMP, IDPUTEMP* page uvotsctm: SACEAD590CH11-15,17, SACEPRTCH2,5			
IBPEREFBTEMP	TM Ref B Thermistor Reading	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check nearby temperature sensors. page ihk: IBPE*TEMP, IDPUTEMP* page uvotsctm: SACEAD590CH11-15,17, SACEPRTCH2,5			

Mnemonic	Meaning	Low Red	Low Yellow	High Yellow	High Red
IBPEREFCTEMP	TM Thermistor Reading	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check nearby temperature sensors. page ihk: IBPE*TEMP, IDPUTEMP* page uvotsctm: SACEAD590CH11-15,17, SACEPRTCH2,5			
IBPETEMP	BPE Thermistor Reading	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check nearby temperature sensors. page ihk: IBPE*TEMP, IDPUTEMP* page uvotsctm: SACEAD590CH11-15,17, SACEPRTCH2,5			
IDEBUG1STEX	Debug First Exception	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check ICU has rebooted into basic state. page ihk: IUVOTSTATE=0=BASIC 3. FOT: If not, manually reboot to basic (follow procedure #9 “Utility Procs” and start icu_reset). 4. UVOT: Do not go to safe until after investigation.			
IDEBUG1STPROG	Debug First Progress				
IDEBUGINTCNTR	Debug Interrupt Counter	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Investigate simultaneous UVOT error messages which may be related. 3. UVOT: Investigate.			
IDPUCOUNTRATE	DPU Calculated Count Rate	N/A.		1. FOT: Inform UVOT Duty Specialist. 2. UVOT: Investigate field. Make sure UVOT does not observe the same field background again.	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check ICU has gone to safe state (page ihk: IUVOTSTATE=1=SAFE) 3. FOT: If not, manually got to safe (i.e follow written procedure UVOT #6 “Safing and Recovery” executing the STOL proc start icu_safe). 4. UVOT: Investigate field. Make sure UVOT does not observe the same background field again.
IDPUMINUS12VA (see notes at top of section)	DPU Voltage PSU A -12V	**Note**: Limit violations are normal during UVOT power on. 1. FOT: Inform UVOT Duty Specialist. 2. FOT: Power off UVOT (follow procedure #4 and start uvot_power_off)..	**Note**: Limit violations are normal during UVOT power or DPU reboot. 1. FOT: Inform UVOT Duty Specialist. 2. FOT: Power off UVOT only if multiple consecutive excursions (follow procedure #4 and start uvot_power_off)..		**Note**: Limit violations are normal during UVOT power on. 1. FOT: Inform UVOT Duty Specialist. 2. FOT: Power off UVOT (follow procedure #4 and start uvot_power_off)..
IDPUMINUS5VREF (see notes at top of section)	DPU Voltage PSU -5V Ref	**Note**: Limit violations are normal during UVOT power on or DPU reboot. 1. FOT: Inform UVOT Duty Specialist.			
IDPUMONACTIVE	Active DPU Monitor	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Investigate simultaneous UVOT error messages which may be related. 3. UVOT: Investigate.			

Mnemonic	Meaning	Low Red	Low Yellow	High Yellow	High Red
IDPUPARITYERRORS (see notes at top of section)	DPU Parity Errors	1. FOT: Inform the UVOT Duty Specialist. 2. FOT:Before the next pass, increment the red limit in *uvot_limits.proc* to 1 + the last reported value. 3. FOT: Investigate simultaneous UVOT error messages which may be related. 4. UVOT: Investigate.			1. FOT: Inform the UVOT Duty Specialist. 2. FOT:Before the next pass, increment the red limit in *uvot_limits.proc* to 1 + the last reported value. 3. FOT: Investigate simultaneous UVOT error messages which may be related. 4. UVOT: Investigate.
IDPUPLUS12VA (see notes at top of section)	DPU Voltage PSU A +12V	Note: Limit violations are normal during UVOT power on. 1. FOT: Inform UVOT Duty Specialist. 2. FOT: Power off UVOT (follow procedure #4 and `start uvot_power_off`).	Note: Limit violations are normal during UVOT power on. 1. FOT: Inform UVOT Duty Specialist.		Note: Limit violations are normal during UVOT power on. 1. FOT: Inform UVOT Duty Specialist. 2. FOT: Power off UVOT (follow procedure #4 and `start uvot_power_off`).
IDPUPLUS5VA (see notes at top of section)	DPU Voltage PSU A +5V				
IDPUPLUS5VREF (see notes at top of section)	DPU Voltage PSU +5V Ref	**Note**: Limit violations are normal during UVOT power on. 1. FOT: Inform UVOT Duty Specialist.			
IDPUTEMPCOMM (see notes at top of section)	DPU Temp DPU Comm/Mem Module	**Note**: Limit violations are normal during UVOT power on. 1. FOT: Inform UVOT Duty Specialist. 2. FOT: Power off UVOT (follow procedure #4 and `start uvot_power_off`).	**Note**: Limit violations are normal during UVOT power on. 1. FOT: Inform UVOT Duty Specialist.		**Note**: Limit violations are normal during UVOT power on. 1. FOT: Inform UVOT Duty Specialist. 2. FOT: Power off UVOT (follow procedure #4 and `start uvot_power_off`).
IDPUTEMPCOMMF	DPU Temp DPU Comm/Mem Module Status Flags				
IDPUTEMPICUCPU (see notes at top of section)	DPU Temp ICU CPU Module	1. FOT: Inform UVOT representive. **NOTE**: This was disabled for redundant (see MSSL NCR 85). This may give incorrect readings, particularly after boot or when cool, and no action should be taken unless `IDPUTEMPICUIF` is also high or low.			

Mnemonic	**Meaning**	**Low Red**	**Low Yellow**	**High Yellow**	**High Red**
IDPUTEMPICUCPUF	DPU Temp ICU CPU Module Status Flags	**Note**: Limit violations are normal during UVOT power on. 1. FOT: Inform UVOT Duty Specialist. 2. FOT: Power off UVOT (follow procedure #4 and `start uvot_power_off`). 3. FOT: Inform UVOT Duty Specialist.	**Note**: Limit violations are normal during UVOT power on. 1. FOT: Inform UVOT Duty Specialist.		**Note**: Limit violations are normal during UVOT power on. 1. FOT: Inform UVOT Duty Specialist. 2. FOT: Power off UVOT (follow procedure #4 and `start uvot_power_off`).
IDPUTEMPICUIF (see notes at top of section)	DPU Temp ICU I/F Module				
IDPUTEMPICUIFF	DPU Temp ICU I/F Module Status Flags				
IDPUTEMPPSUA (see notes at top of section)	DPU Temp PSU A				
IDPUTEMPPSUAF	DPU Temp PSU A Status Flags				
IDPUTEMPPSUB (see notes at top of section)	DPU Temp PSU B				
IDPUTEMPPSUBF	DPU Temp PSU B Status Flags				
IEARTHCONSTVIOL	Earth Constraint Violation Status	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check UVOT has automatically gone to safe (page `ihk: IUVOTSTATE=1=SAFE`) else follow written procedure `UVOT #6` "Safing and Recovery" executing the STOL proc `start icu_safe` .			
IFWCOUNTER	F/W Position Counter	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Execute filter wheel lost position procedure #12.			
IHTRMETERING	Metering Rods Htr Status	1. FOT: Advise UVOT Duty Specialist. 2. FOT: Disable heater algorithm (/`ihtr off`) then re-enable (/`ihtr on`). 3. FOT: If still out-of-limits, go to basic (follow written procedure UVOT #6 "Safing and Recovery" executing the STOL proc start icu_safe and then follow procedure #9 "Utility Procs" and `start icu_reset`.			
IHTRSECONDARY	Secondary Mirror Htr Status				

Mnemonic	Meaning	Low Red	Low Yellow	High Yellow	High Red
IHVCATHODE	Vcathode value (volts)	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check UVOT has automatically gone to safe (page `ihk: IUVOTSTATE=1=SAFE`), else follow written procedure `UVOT #6` "Safing and Recovery" executing the STOL proc `start icu_safe`.	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Follow written procedure `UVOT #6` "Safing and Recovery" executing the STOL proc `start icu_safe`.		1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check UVOT has automatically gone to safe (page `ihk: IUVOTSTATE=1=SAFE`), else follow written procedure `UVOT #6` "Safing and Recovery" executing the STOL proc `start icu_safe` .
IHVMCP1	Vmcp1 value (volts)				
IHVMCP23	Vmcp23 value (volts)				
IICBALIVE	Whether ICB is Alive	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check if the UVOT TM has been powered off (see page `uvotsctm`). If it has, check for spacecraft safehold. If in safehold, fully understand the problem and deal with the spacecraft and then start uvot_tm_recovery. If TM is not powered off, power off the TM (follow procedure #4 and `start uvot_power_off` and click on "Cancel" when asked if you want to power off the DEM).			
IICBDIRECTCOM	ICB direct Commanding enabled flag	1. FOT: Inform UVOT Duty Specialist. 2. FOT: This is only used for interactive debugging with the UVOT Duty Specialist. If not, power off TM.			
IICBERRORS	ICB Error Count	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check TM is powered (page `uvotsctm: SPDLCB4?CDCB6PWR=0=ON`). 3. FOT: Before the next pass, increment the red limit in *uvot_limits.proc* to 1 + the last reported value.			
ILIMCHKSTATUS	Limit Checking Algorithm Status	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Go to basic (follow written procedure `UVOT #6` "Safing and Recovery" executing the STOL proc `start icu_safe` then follow procedure #9 "Utility Procs" and `start icu_reset`).			
ILVMINUS15	Low Voltage -15V	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check not due to TM having been powered off (page `uvotsctm: SPDLCB4?CDCB6PWR=1=OFF`). 3. FOT: Power off TM (follow procedure #4 and `start uvot_power_off` and click on "Cancel" when asked if you want to power off the DEM).	1. FOT: Inform UVOT Duty Specialist.		1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check not due to TM having been powered off (page `uvotsctm: SPDLCB4?CDCB6PWR=1=OFF`) 3. FOT: Power off TM (follow procedure #4 and `start uvot_power_off` and click on "Cancel" when asked if you want to power off the DEM).
ILVPLUS15	Low Voltage +15V				
ILVPLUS5	Low Voltage +5V				
ILVREF	Low Voltage 1.23 V Reference				
IMOONCONSTVIOL	Moon Constraint Violation Status	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check UVOT has automatically gone to safe (page `ihk: IUVOTSTATE=1=SAFE`), else follow written procedure `UVOT #6` "Safing and Recovery" executing the STOL proc `start icu_safe`.			
IONEPPSSYNCCHAN	Time Sync Channel	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Investigate simultaneous UVOT error messages which may be related. 3. UVOT: Investigate.			
IONEPPSSYNCSTAT	Time Sync Status				

Mnemonic	Meaning	Low Red	Low Yellow	High Yellow	High Red
IPACKETSLOST	Equal to iSC1553IHTC minus iSC1553TcPckt	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Follow written procedure UVOT #6 "Safing and Recovery" executing the STOL proc start icu_safe.			
IRT2RTBADPCKTS	Number of Bad RT2RT Packets	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Investigate simultaneous UVOT error messages which may be related. 3. UVOT: Investigate.			
ISC1553CHANNEL	1553 Channel	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Investigate simultaneous UVOT error messages which may be related. 3. UVOT: Investigate.			
ISC1553ERRORS	1553 Error Count	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Follow written procedure UVOT #6 "Safing and Recovery" executing the STOL proc start icu_safe.			
ISC1553INTREG	1553 Interrupt Register				
ISCVOLTAGE	S/C Voltage	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check not due to TM having been powered off (page uvotsctm: SPDLCB4?CDCB6PWR=1=OFF) 3. FOT: Power off TM (follow procedure #4 and start uvot_power_off and click on "Cancel" when asked if you want to power off the DEM).	1. FOT: Inform UVOT Duty Specialist.		1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check not due to TM having been powered off (page uvotsctm: SPDLCB4?CDCB6PWR=1=OFF) 3. FOT: Power off TM (follow procedure #4 and start uvot_power_off and click on "Cancel" when asked if you want to power off the DEM).
ISFTYALERTEN	Safety Cathode Control Enabled Status	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Investigate simultaneous UVOT error messages which may be related. 3. UVOT: Investigate.			
ISFTYALERTFLAG	Safety Alert Output	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check ICU has gone to safe state (page ihk: IUVOTSTATE=1=SAFE). 3. FOT: If not, manually got to safe (follow written procedure UVOT #6 "Safing and Recovery" executing the STOL proc start icu_safe). 4. UVOT: Investigate field. Make sure UVOT does not observe the same field again. 5. UVOT: When fully understood, advise FOT to run safety circuit recovery procedure.			
ISFTYSYSEN	Safety Circuit Enabled Status	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Investigate simultaneous UVOT error messages which may be related. 3. UVOT: Investigate.			
ISSIBAD	SSI Bad Packet Count	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Investigate simultaneous UVOT error messages which may be related. 3. UVOT: Investigate.			

Mnemonic	Meaning	Low Red	Low Yellow	High Yellow	High Red
ISSIERRORS	SSI Error Count				
ISUNCONSTVIOL	Sun Constraint Violation Status	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check UVOT has automatically gone to safe (page `ihk: IUVOTSTATE=1=SAFE`), else follow written procedure `UVOT #6` "Safing and Recovery" executing the STOL proc `start icu_safe`.			
ITCBADPCKTS	Number of Bad TC Packets	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check if the ICU has rebooted (UVOT state is basic). page `ihk: IUVOTSTATE=0=BASIC` 3. FOT: Investigate simultaneous UVOT error messages which may be related. 4. UVOT: Investigate. 5. UVOT: Consider rebooting (follow procedure #9 "Utility Procs" and `start icu_reset`). 6. FOT: Before the next pass, increment the red limit in *uvot_limits.proc* to 1 + the last reported value.			
ITDRSSPCKTCNT	TDRSS Packet Count	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Investigate simultaneous UVOT error messages which may be related. 3. UVOT: Investigate. 4. FOT: Check TM is powered (page `uvotsctm: SPDLCB4?CDCB6PWR=0=ON`) 5. FOT: Before the next pass, increment the red limit in *uvot_limits.proc* to 1 + the last reported value.			
ITMBADPCKTS	Number of Bad TM Packets	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check 1553 is enabled for UVOT-ICU (page `uvotsctm` `SBCPRMBUSICU=A` and `SBCRTENBLICU=ENABLED`). 3. FOT: Investigate simultaneous UVOT error messages which may be related. 4. UVOT: Investigate. 5. FOT: Before the next pass, increment the red limit in *uvot_limits.proc* to 1 + the last reported value.			
ITMPSUMINUS15	TMPSU -15V Rail Current	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check not due to TM having been powered off (page `uvotsctm: SPDLCB4?CDCB6PWR=1=OFF`) 3. FOT: Power off TM (follow procedure #4 and `start uvot_power_off` and click on "Cancel" when asked if you want to power off the DEM).		1. FOT: Inform UVOT Duty Specialist.	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check not due to TM having been powered off. (page `uvotsctm: SPDLCB4?CDCB6PWR=1=OFF`) 3. FOT: Power off TM (follow procedure #4 and `start uvot_power_off` and click on "Cancel" when asked if you want to power off the DEM).
ITMPSUMINUS5A	TMPSU –5VA Rail Current				
ITMPSUPLUS11	TMPSU +11V Rail Current				
ITMPSUPLUS15	TMPSU +15V Rail Current				
ITMPSUPLUS28	TMPSU +28V Rail Current				
ITMPSUPLUS5A	TMPSU +5VA Rail Current				
ITMPSUPLUS5B	TMPSU +5VB Rail Current				
IWATCHDOGNBLD	Watchdog Enabled	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Go to basic (follow written procedure `UVOT #6` "Safing and Recovery" executing the STOL proc `start icu_safe` and then follow procedure #9 "Utility Procs" and `start icu_reset`).			

Mnemonic	**Meaning**	**Low Red**	**Low Yellow**	**High Yellow**	**High Red**
UVOT_CONFIG_ERROR	Calculated power configuration	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check power status for both UVOT prime and redundant DEMs and both prime and redundant TMs (page uvotsctm: SPDLCB4ACB1EWR, SPDLCB4BCB1PWR, SPDLCVB4ACDCB2PWR , SPDLCVB4BCDCB2PWR, SPDLCB4ACB5EWR, SPDLCB4BCB5PWR, SPDLCB4ACDCB6PWR and SPDLCB4BCDCB6PWR). 3. UVOT: Investigate.			
UVOT_IGNORE_ERROR	Calculated ignore UVOT configuration	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Follow written procedure UVOT #6 "Safing and Recovery" executing the STOL proc start icu_safe.			
UVOT_ON_NO1553	Calculated configuration	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Check 1553 is enabled for UVOT-ICU (page uvotsctm SBCPRMBUSICU=A and SBCRTENBLICU=ENABLED). 3. UVOT: Investigate.			

2.4.2 DPU

Mnemonic	Meaning	Yellow Limit Action	Red Limit Action
D_ADC_P5V_REF (see notes at top of section)	Plus 5V Reference	**Note**: Limit violations are normal during UVOT power on and DPU reboot. 1. FOT: Inform UVOT Duty Specialist.	
D_ADC_M5V_REF (see notes at top of section)	Minus 5V Reference		
D_ADC_M12V (see notes at top of section)	Minus 12V supply DPU	**Note**: Limit violations are normal during UVOT power on and DPU reboot. 1. FOT: Inform UVOT Duty Specialist. 2. FOT: Power off UVOT only if multiple consecutive excursions (follow procedure #4 and `start uvot_power_off`).	**Note**: Limit violations are normal during UVOT power on and DPU reboot. 1. FOT: Inform UVOT Duty Specialist. 2. FOT: Power off UVOT (follow procedure #4 and `start uvot_power_off`).
D_ADC_P12V (see notes at top of section)	Plus 12V supply DPU		
D_ADC_P5VA (see notes at top of section)	Plus 5V supply DPU		
D_ADC_THERM_PSB (see notes at top of section)	Power Supply B Side Temperature	**Note**: Limit violations are normal during UVOT power on and DPU reboot. 1. FOT: Inform UVOT Duty Specialist. 2. FOT: Power off UVOT (follow procedure #4 and `start uvot_power_off`)..	**Note**: Limit violations are normal during UVOT power on and DPU reboot. 1. FOT: Inform UVOT Duty Specialist. 2. FOT: Power off UVOT (follow procedure #4 and `start uvot_power_off`).
D_ADC_THERM_PSA (see notes at top of section)	Power Supply A Side Temperature		
D_ADC_THERM_SCM (see notes at top of section)	DPU Summit Chip Temperature		
D_ADC_THERM_ICPU (see notes at top of section)	ICU CPU Temperature	1. FOT: Inform UVOT representive **NOTE**: This was disabled for redundant (see MSSL NCR 85). This may give incorrect readings, particularly after boot or when cool, and no action should be taken unless `IDPUTEMPICUIF` is also high or low..	
D_ADC_THERM_ICU (see notes at top of section)	ICU Interface Temperature	**Note**: Limit violations are normal during UVOT power on and DPU reboot. 1. FOT: Inform UVOT Duty Specialist.	**Note**: Limit violations are normal during UVOT power on and DPU reboot. 1. FOT: Power off UVOT (follow procedure #4 and `start uvot_power_off`).
D_BOOT_CNT	DPU Boot Counter. A red limit means that the DPU has rebooted several times since the last reported value.	1. FOT: Contact the UVOT Duty Specialist. 2. FOT: Before the next pass, increment both the red and yellow limits in *uvot_limits.proc* to 3+ the last reported value and 1 + the last reported value, respectively.	1. FOT: Initiate a normal UVOT power off sequence: *uvot_power_off.proc*. This proc take about TBD minutes to run. 2. FOT: Before powering on the UVOT, increment both the red and yellow limits in *uvot_limits.proc* to 3+ the last reported value and 1 + the last reported value, respectively.
D_CCM_NCMDS_REJ	Number of commands rejected by the DPU CCM task.	1. FOT: Contact the UVOT Duty Specialist. 2. FOT: Before the next pass, increment the yellow limit in *uvot_limits.proc* to 1 + the last reported value.	N/A
D_DPA_EVNT_ERRS (see notes at top of section)	Number of photon event errors detected on the DCI bus.	1. FOT: Contact the UVOT Duty Specialist. 2. FOT: Before the next pass, increment the yellow limit in *uvot_limits.proc* to 1 + the last reported value.	1. FOT: Inform UVOT Duty Specialist. 2. FOT: Investigate simultaneous UVOT error messages which may be related. 3. UVOT: Investigate

Mnemonic	Meaning	Yellow Limit Action	Red Limit Action
D_DRAM_MBE_CNT	Number of Multiple bit DRAM errors in the DPU.	1. FOT: Contact the UVOT Duty Specialist. 2. FOT: Before the next pass, increment the yellow limit in *uvot_limits.proc* to 1 + the last reported value.	N/A
D_DRAM_SBE_CNT	Number of Single bit DRAM errors in the DPU.	1. FOT: Contact the UVOT Duty Specialist. 2. FOT: Before the next pass, increment the yellow limit in *uvot_limits.proc* to 1 + the last reported value.	N/A
D_EEPRM_MBE_CNT	Number of Multiple bit EEPROM errors in the DPU.	1. FOT: Contact the UVOT Duty Specialist. 2. FOT: Before the next pass, increment the yellow limit in *uvot_limits.proc* to 1 + the last reported value.	N/A
D_EEPRM_SBE_CNT	Number of Single bit EEPROM errors in the DPU.	1. FOT: Contact the UVOT Duty Specialist. 2. FOT: Before the next pass, increment the yellow limit in *uvot_limits.proc* to 1 + the last reported value.	N/A
D_ICUI_NCMDS_REJ	Number of commands from the ICU rejected by the DPU.	1. FOT: Contact the UVOT Duty Specialist. 2. FOT: Before the next pass, increment the yellow limit in *uvot_limits.proc* to 1 + the last reported value.	N/A
D_ICUI_NMSG_ERRS	Number of messages from the ICU rejected by the DPU.	1. FOT: Contact the UVOT Duty Specialist. 2. FOT: Before the next pass, increment the yellow limit in *uvot_limits.proc* to 1 + the last reported value.	N/A
D_SCUI_NCMDS_REJ	Number of spacecraft commands rejected by the DPU.	1. FOT: Contact the UVOT Duty Specialist. 2. FOT: Before the next pass, increment the yellow limit in *uvot_limits.proc* to 1 + the last reported value.	N/A
D_SSI_ERR_INTR	Number of error interrupts from the Synchronous Serial Interface hardware.	1. FOT: Contact the UVOT Duty Specialist. 2. FOT: Before the next pass, increment the yellow limit in *uvot_limits.proc* to 1 + the last reported value.	N/A

2.4.3 Spacecraft

Mnemonic	Meaning	Low Red	Low Yellow	High Yellow	High Red
SACEAD590CH11	UVOT Temp UVOT TM door latch (Ch 11)	1. FOT: Inform all Duty Specialist. 2. FOT: Check nearby temperature sensors. page ihk: IBPE*TEMP, IDPUTEMP* page uvotsctm: SACEAD590CH11-15,17, SACEPRTCH2,5 3. FOT: check survival heaters page uvotsctm SPDLCB3[AB]FET6PWR, SPDLCB3[AB]FET2PWR.			
SACEAD590CH12	UVOT Temp UVOT TM OB/IF (Ch 12)				
SACEAD590CH13	UVOT Temp UVOT TM AFT (Ch 13)				
SACEAD590CH14	UVOT Temp UVOT DEM 1 R (Ch 14)				
SACEAD590CH15	UVOT Temp UVOT DEM 2 P (Ch 15)				
SACEAD590CH17	OB-2 FTE2 TOP CENTER				
SACEPRTCH2	OB-3 FTE3 corner near UVOT				
SACEPRTCH5	OB-4 FTE4 near 1553 between XRT & UVOT				

2.5 Special Operations

2.5.1 How to Override Table Values in Ram

The working copies of certain EEPROM tables are located at fixed locations in RAM. It is therefore possible to change locations in these tables 'on the fly' using the `/iicuload` command. This is useful if you wish to temporarily change standard operation as a "workaround" of a problem until the table can be properly reloaded.

These tables are the "Errors Action Table" - appendix B.8, the "Avoidance Angle Table" - appendix B.11 and the "Standard Table" - appendix B.13. Those appendices should be consulted for details of how to change the values.

2.5.2 Dumping or CRC Checking Memory when Observing

It is possible to dump or CRC memory check areas of EEPROM when observing. However, it should be noted that if a telecommand arrives at just the time that an RTS is reading the information from that table in EEPROM, a harmless 0x371 "busy" message will be issued and that particular dump or CRC won't work.

Note: When a memory dump or CRC is critical such as after a code load, we should and do stay in safe.

2.5.3 Loading or Dumping Memory at the Same Time

You should ***not*** do this! The error message 'Busy' will be produced each time a telecommand is received. If this is during an ITOS load, one will be produced every 1.3 s. This will put stress on the ICU code and may possibly lead to a reboot.

2.5.4 Heater Control Parameters - Use of /IHTRPARAMS

This command is used to specify temporary heater control algorithm parameters

2.5.4.1 Overview

Normally the behaviour of the heater control algorithm on UVOT is determined using parameters stored in an on-board EEPROM table. However, for testing purposes, it is useful to temporarily override some or all of these parameters without reloading the table. The command **`/iHtrParams`** provides this facility. It is used as follows:

First, disable the heater control algorithm

`/iHtr Off`

Then send up to 4 **`/iHtrParams`** command, 1 per heater, to alter the appropriate parameters.

```
/iHtrParams Number=1,... ;re-specify heater 1 parameters
/iHtrParams Number=2,... ;re-specify heater 2 parameters
... ;etc
```

Then re-enable the heater control algorithm

`/iHtr On`

The algorithm will then run with the parameters just specified. Any heater not re-specified will continue to run with the previous values.

To force a reload of the parameters stored in EEPROM, simply disable, then re-enable the algorithm i.e.

```
/iHtr Off
/iHtr On
```

2.5.4.2 *Parameter Description*

There are two types of heaters, focussing and non-focussing. The parameters are used in a different fashion for each type. Consequently, a separate description is given for each type.

2.5.4.3 *Non-Focussing*

These parameters specify a 'bang-bang' algorithm i.e. heaters should be off when the temperature is above a specified range, and on when below a specified range.

Number Specifies which heater. Values are 1 (=**`INTERFACE`**) or 2 (= **`FORWARD`**).

`OnTime` Ignored - should be set to zero.

`CycleTime` Ignored - should be set to zero.

`TMin_Vnom` Specifies the lower value of the allowed temperature in ***raw*** thermistor (i.e. uncalibrated) units.

`TMax_Vdrop` Specifies the upper value of the allowed temperature in ***raw*** thermistor (i.e. uncalibrated) units.

`NumThermistors` Specifies how many thermistors are to be polled. An average of those thermistor readings is then calculated and compared against the values given by TMin_VNom and TMax_VDrop. It can take the range 1 => 3. If its value is one, then the thermistor number given by Therm1 will be used. When the value is two, then the average of the thermistors, specified by Therm1 and Therm2, will be used etc.

`Therm1, Therm2, Therm3` The thermistors to be polled. The code numbers are as follows:

Thermistor	Description
0	BPE
1	Reference B
2	Reference C
3	Main
4	Forward 1
5	Forward 2
6	CCD
7	Reference A

2.5.4.4 *Focussing*

These parameters state the **nominal** length of time the specified heater should be on within a fixed cycle time –this is referred to as the duty cycle. However, the power developed is a function of potentially varying spacecraft voltage. The algorithm therefore monitors the spacecraft voltage via the ACS records and then adjusts the 'on' time of the heater accordingly. It is necessary to supply additional parameters Vnom and Vdrop to quantify this correction. The duty cycle is then corrected as follows:

If

F_n = Nominal Duty Cycle
F_c = Corrected Duty Cycle
V = Spacecraft Voltage
V_{drop} = Voltage drop to heater
V_{nom} = Nominal s/c voltage

then $F_c/F_n = ((V_{nom}-V_{drop})/(V-V_{drop}))^{**}2$

Number	Specifies which heater. Values are 3 (=METERING_RODS) or 4 (=SECONDARY_MIRROR).
OnTime	Specifies the nominal on time with the cycle. Units are 1/10 second. A value of zero disables that heater. NOTE - no more than one of the focussing heaters should be enabled. If both are enabled, the algorithm ignores heater 4.
CycleTime	Specifies the cycle time. Units are 1/10 second.
TMin_Vnom	Specifies the expected nominal spacecraft voltage. Units are 1/100 of a volt.
TMax_Vdrop	Specifies the voltage drop to heaters. Units are 1/100 of a volt.
NumThermistors	Ignored - should be set to zero.
Therm1, Therm2, Therm3	Ignored - should all be set to zero.

2.5.5 Direct Control and Monitoring of ICB Ports

NOTE: these commands are used for diagnostic purposes only. They are potentially dangerous since they bypass ***all*** protections in the on-board code. ***They should therefore only be used under the supervision of the UVOT instrument specialist.***

The capability to directly write, or read, from the ICB is *enabled* with the command

`/IICBENABLE ON`

The capability to directly write, or read, from the ICB is *disabled* with the command

`/IICBENABLE OFF`

Once enabled, it is possible to write directly to an ICB port with the command

`/IICBWRITE address=`*address*`, subaddress=`*subaddress*`, datum=`*datum*

where *address*, *subaddress* and *datum* are as described in the table below.

Similarly, once enabled, it is possible to poll an ICB port directly with the command.

`/IICBREAD address=`*address*`, subaddress=`*subaddress*

where *address*, and *subaddress* are as described in the table below.

The value (datum) read is returned in a “Task Report” packet and displayed in the `ICBREAD` sequence print. Its contents are described in the table below.

/IICBWRITE Address, Sub-Address and Datum Fields

Addr. (hex)	Sub-Addr.	Description	Datum Bits 15	14	13	12	11	10	09	08	07	06	05	04	03	02	01	00
(TMPSU) 7	0	MISC	CS			FW_PSC				Don't Care								
	1	ADC	Don't Care															
	2	Filter Wheel & Dichroic	F1	F2	F3	F4	D1	D2	D3	D4	Don't Care							
	3	Motor Temp Control	TC	Don't Care														
	4	Heaters	H1	H2	H3	H4	Don't Care											
(Detector) 0x18	0	Safety Circuit Register 1	X	PCTHOLD							OP	SY	AL	FCTHOLD				
	1	Safety Circuit Register 2	X			STHOLD [Bits 7:3]					X			RTHOLD [Bits 7:3]				
	2	Camera Start/Stop	Don't Care														R	SC
	3	Bitmap Address	Bitmap Y Address								Bitmap X Address							
	4	Bitmap Datum	Don't Care												Map Data			
	5	Event Detect Threshold	Don't Care								Event Height Threshold							
	7	Table Access Mode	Don't Care															TE
	8	Lookup Table Address	Lookup Address (M)								Lookup Address (N)							
	9	Lookup Table Datum	Don't Care									Y sub-pixel			X	X sub-pixel		
	10	Acq Mode, Frame Tag	Don't Care												FE	Int Mode		
	11	Integration Enable	Don't Care															IE
	12	MUX Address	Don't Care												MUX Address			
	13	$V_{cathode}$, V_{mcp23}	R2	V_{mcp23}							RV	$V_{cathode}$						
	14	Biases	Don't Care								Fine Sensor Current				Flood LED current			
	15	V_{mcp1}	EH	Don't Care					R1	V_{mcp1}								

Key for TMPSU Datums	
Abbreviation	**Description**
CS	Current Select Secondary Voltages
D1, D2, D3, D4	Phases 1 through 4 of the Dichroic Motor, 1 = energised
F1, F2, F3, F4	Phase 1 through 4 of the Filter Wheel Motor, 1 = energized
FW_PSC	Set current of coarse sensor illuminating LED
H1, H2	Heaters, 1 = On, H1 = Main Interface, H2 = Forward Tube
H3, H4	H3 = Metering Rods, H4 = Secondary Mirror
TC	Mechanism Motor Temperature Control, 1=enabled
X	Don't Care

Key for Detector Datums	
Abbreviation	**Description**
AL	ALERTEN, Safety Circuit Cathode Control, 1=Enabled
EH	Enable High Voltages, 1 = Enabled
FCTHOLD	Safety Circuit, Consecutive Frame Count
FE	Frame Tag enabled if zero
IE	Integration Enabled is set to 1
OP	OPRST, Safety Circuit Output Reset, 1=Reset
PCTHOLD	Safety Circuit, Consecutive Pixel Count
R	Reset Camera Head
R1,R2,RV	Range Bits for V_{mcp1}, V_{mcp23}, $V_{cathode}$
RTHOLD	Safety Circuit, Ratemeter Pixel Threshold
SC	1 = Start Frame Readout, 0 = No Frame Readout, bitmap RAM loadable
STHOLD	Safety Circuit, Pixel Threshold
SY	SYSEN, Safety Circuit System Enable, 1=Enabled
TE	Lookup Table access, 0 = Accessed by electronics, table **not** loadable
X	Don't Care

Information Supplied in the Task Report Packet after /ICBREAD command and displayed in the ICBread ITOS page

<table>
<tr><th rowspan="2">MACs Address (hex)</th><th rowspan="2">MACs Sub Address</th><th rowspan="2">Description</th><th colspan="16">Datum Bits</th></tr>
<tr><th>15</th><th>14</th><th>13</th><th>12</th><th>11</th><th>10</th><th>09</th><th>08</th><th>07</th><th>06</th><th>05</th><th>04</th><th>03</th><th>02</th><th>01</th><th>00</th></tr>
<tr><td>7-TMPSU</td><td>0</td><td>TMPSU Currents, F/W Coarse Sensor</td><td colspan="8">Current Value</td><td colspan="7">Don’t Care</td><td>CS</td></tr>
<tr><td rowspan="9">0x18 (Detector)</td><td>0</td><td>Safety Circuit, Register 1, REGID=0</td><td>0</td><td colspan="15">Rate Meter Output [Bits 15:1 i.e. no LSB]</td></tr>
<tr><td>0</td><td>Safety Circuit, Register 1, REGID=1</td><td>1</td><td colspan="2">X</td><td colspan="5">RTHOLD</td><td colspan="8">Rate Meter Output [Bits 23:16]</td></tr>
<tr><td>1</td><td>Safety Circuit, Register 2, REGID=0</td><td>0</td><td colspan="7">PCTHOLD [Bits 7:3 i.e. no 3 LSB]</td><td colspan="3">X</td><td colspan="5">STHOLD [Bits 7:3 i.e. no 3 LSB]</td></tr>
<tr><td>1</td><td>Safety Circuit, Register 2, REGID=1</td><td>1</td><td>AF</td><td>OP</td><td>AL</td><td>SY</td><td colspan="6">X</td><td colspan="5">FCTHOLD</td></tr>
<tr><td>2</td><td>Digital Electronics Status Word</td><td colspan="8">Don’t Care</td><td>IA</td><td colspan="3">Int Mode</td><td>FE</td><td>X</td><td>TE</td><td>ME</td></tr>
<tr><td>3</td><td>Digital Bitmap Datum</td><td colspan="12">Don’t Care</td><td colspan="4">Datum</td></tr>
<tr><td>4</td><td>Digital Centroid Table Datum</td><td colspan="8">Don’t Care</td><td>0</td><td colspan="3">Y sub-pixel</td><td>0</td><td colspan="3">X sub-pixel</td></tr>
<tr><td>5</td><td>ADC HK, HV Status, Fine Sensor</td><td colspan="4">ADC Address Echo</td><td>HE</td><td>FP</td><td colspan="10">ADC HK Value</td></tr>
<tr><td>6</td><td>Initiate ADC</td><td colspan="16">Don’t Care</td></tr>
</table>

Key

Abbrev.	Description
AF	ALERTFLAG, Alert Output Register
AL	ALERTEN, Enables cathode control
CS	F/W Coarse Sensor seen = 1
FCTHOLD	Consecutive Frame Count
FE	Frame Tag, 1 = No Frame Tags
FP	F/W Fine Sensor seen = 1
HE	High Voltages Enabled = 1
IA	Integration Active = 1
Int. Mode	Integration Mode
ME	0 = CCD clocks halted and access to Bitmap Ram, 1 = clocks running, no access to RAMs
OP	OPRST, Safety Circuit Reset
PCTHOLD	Consecutive Pixel Count
RTHOLD	Ratemeter Pixel Threshold
STHOLD	Pixel Threshold
SY	SYSEN, Enables Safety Circuit
TE	ICU can write to centroid lookup table = 1
X	Don’t Care

2.5.6 ICU Basic – Special Considerations.

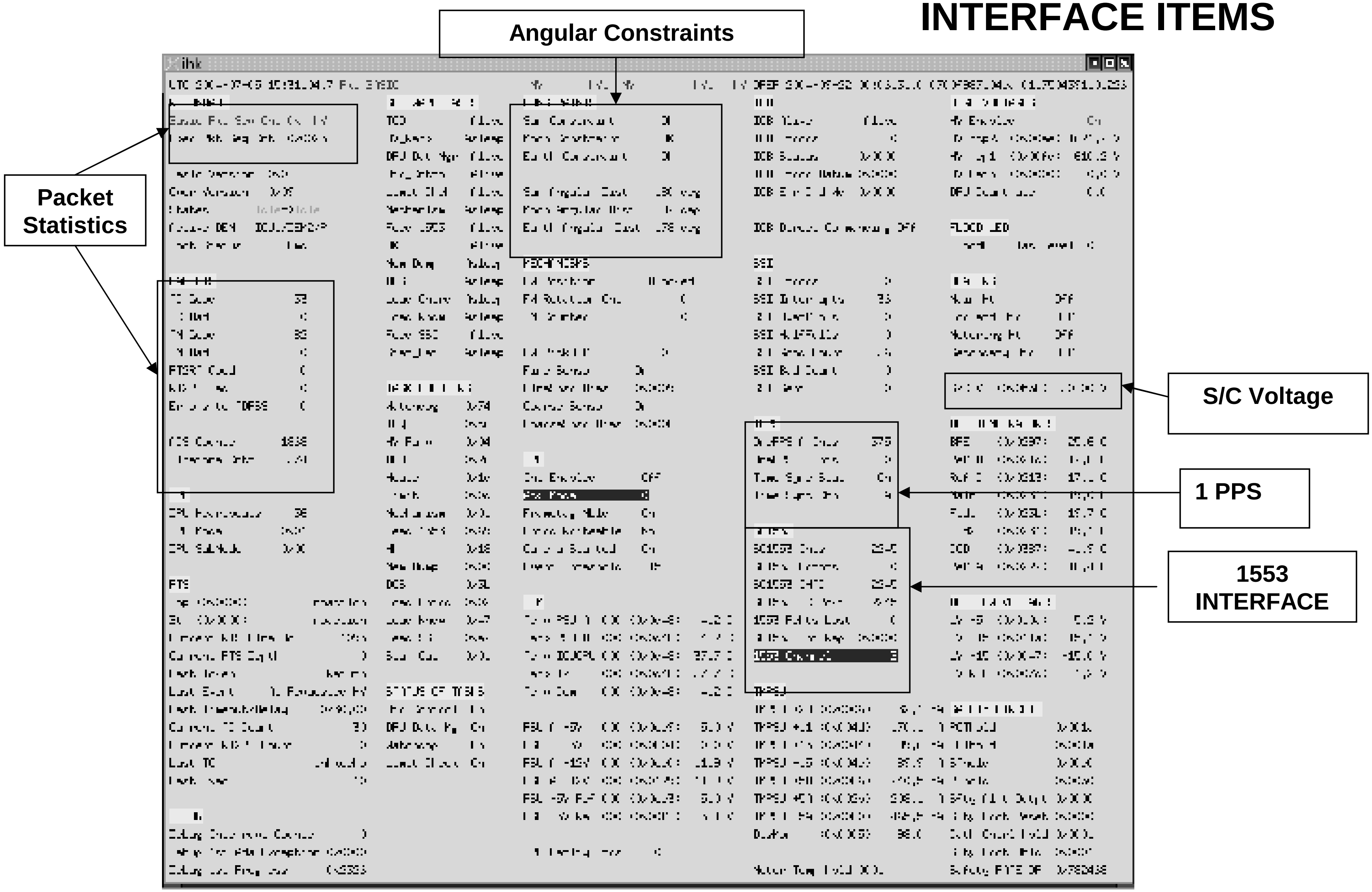
When the ICU is powered up or reset, the ICU Basic code is run. The code is stored in PROM. As a design precaution against possible undiscovered bugs in this unchangeable code, some delays are placed in the code to allow time to prevent certain tasks from starting should

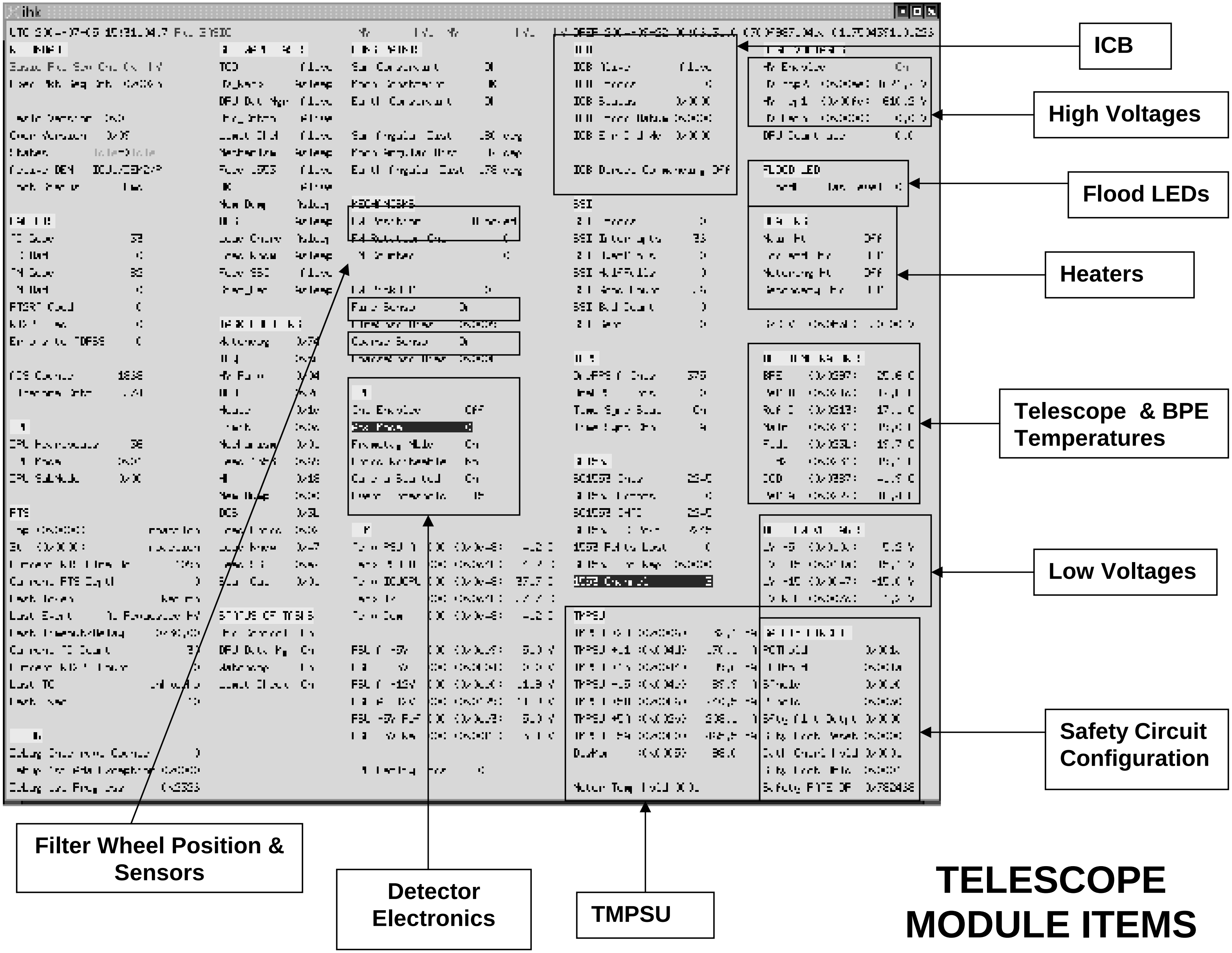
a) a bug be discovered in them or
b) an EEPROM table they depend on has become corrupted.

The tasks concerned are the heater control (stopped with an `/ihtroff` command), limit checking (stopped with an `/ilimitoff` command) and HK (stopped with an `/ihkoff` command). If these commands are issued prior to the relevant task starting (this occurs 18 s after the start of the power sequence), they will be placed in either a suspended or initial state, depending on the relative times at which the internal start command and the external stop commands are processed. The corresponding commands to start them again are `/ihtron`, `/ilimiton` and `/ihkon` respectively. ***Note*** that as a task make be in the suspended state, it will be necessary to issue the relevant start command *twice* to ensure it will start.

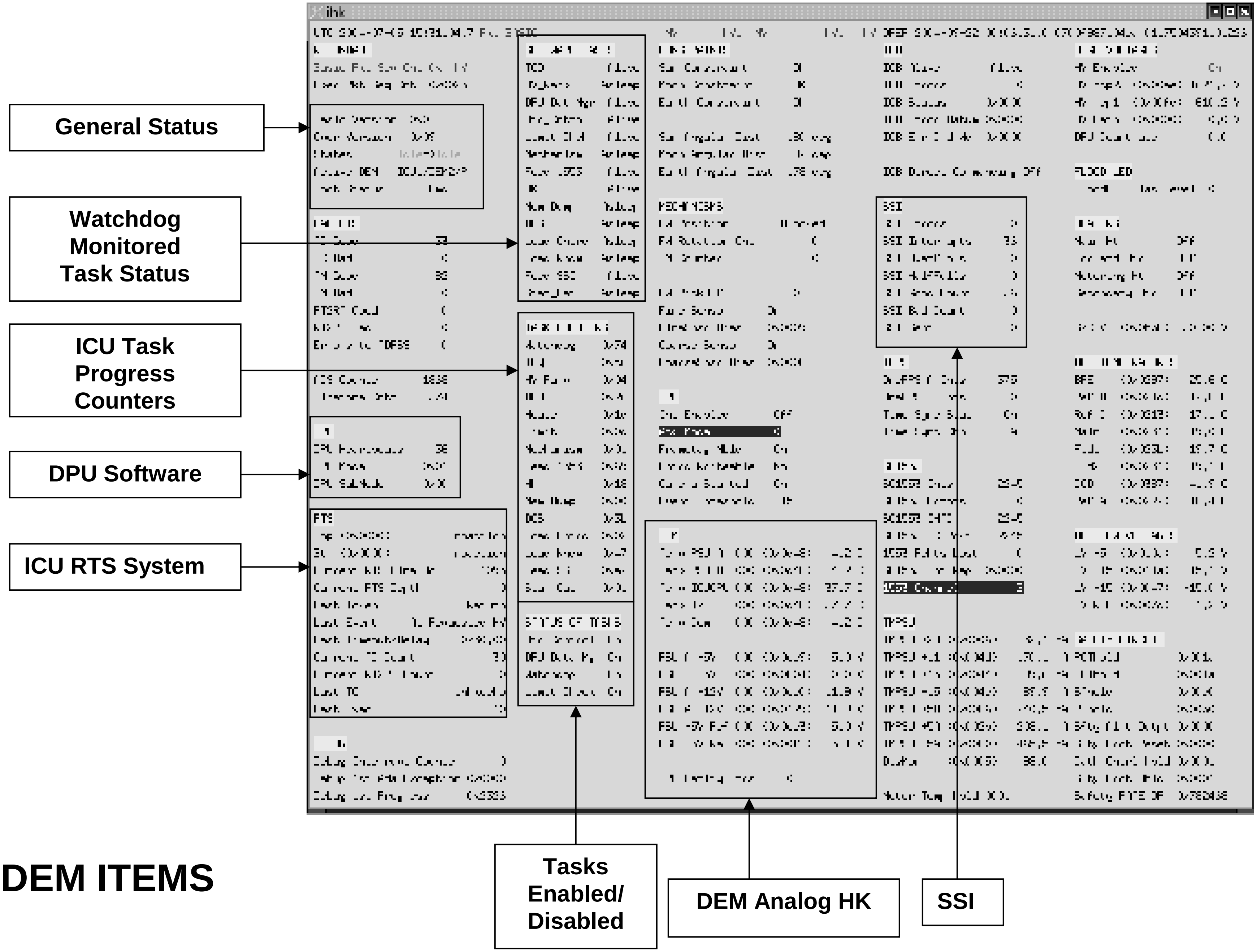
2.6 Guide to ICU HK Page

SPACECRAFT INTERFACE ITEMS





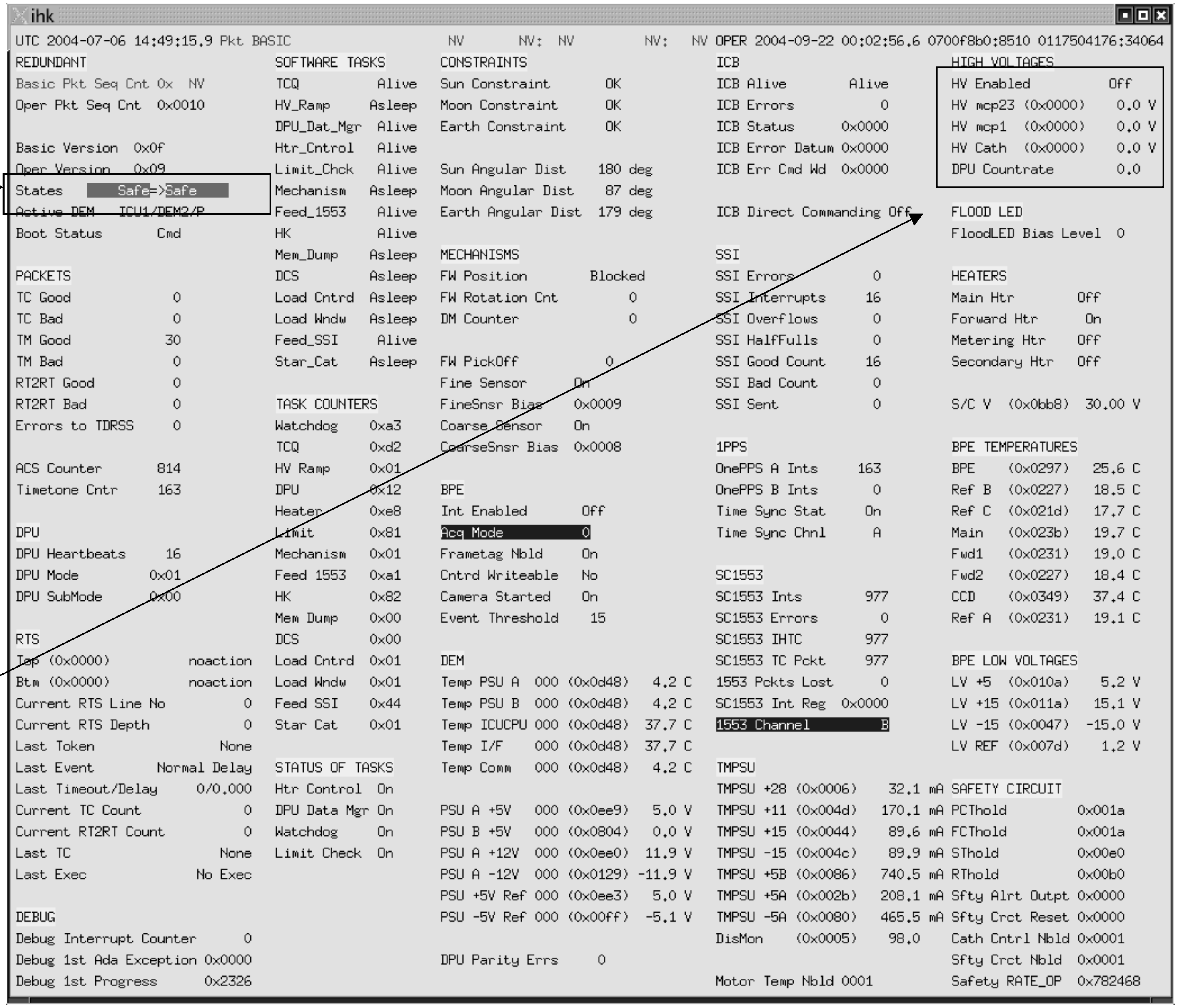
TELESCOPE MODULE ITEMS


General Status
Watchdog Monitored Task Status
ICU Task Progress Counters
DPU Software
ICU RTS System
Tasks Enabled/ Disabled
DEM Analog HK
SSI

DEM ITEMS

"States" shows SAFE=>SAFE, which means the current state is safe and the next state is safe (because we are not transitioning). If we were transitioning, the next state would show to what state.

The high voltages are showing 0V. ***Note*** - this snapshot is from a simulation. In reality, noise is usually seen, resulting in non-zero values even when the high voltages are off.

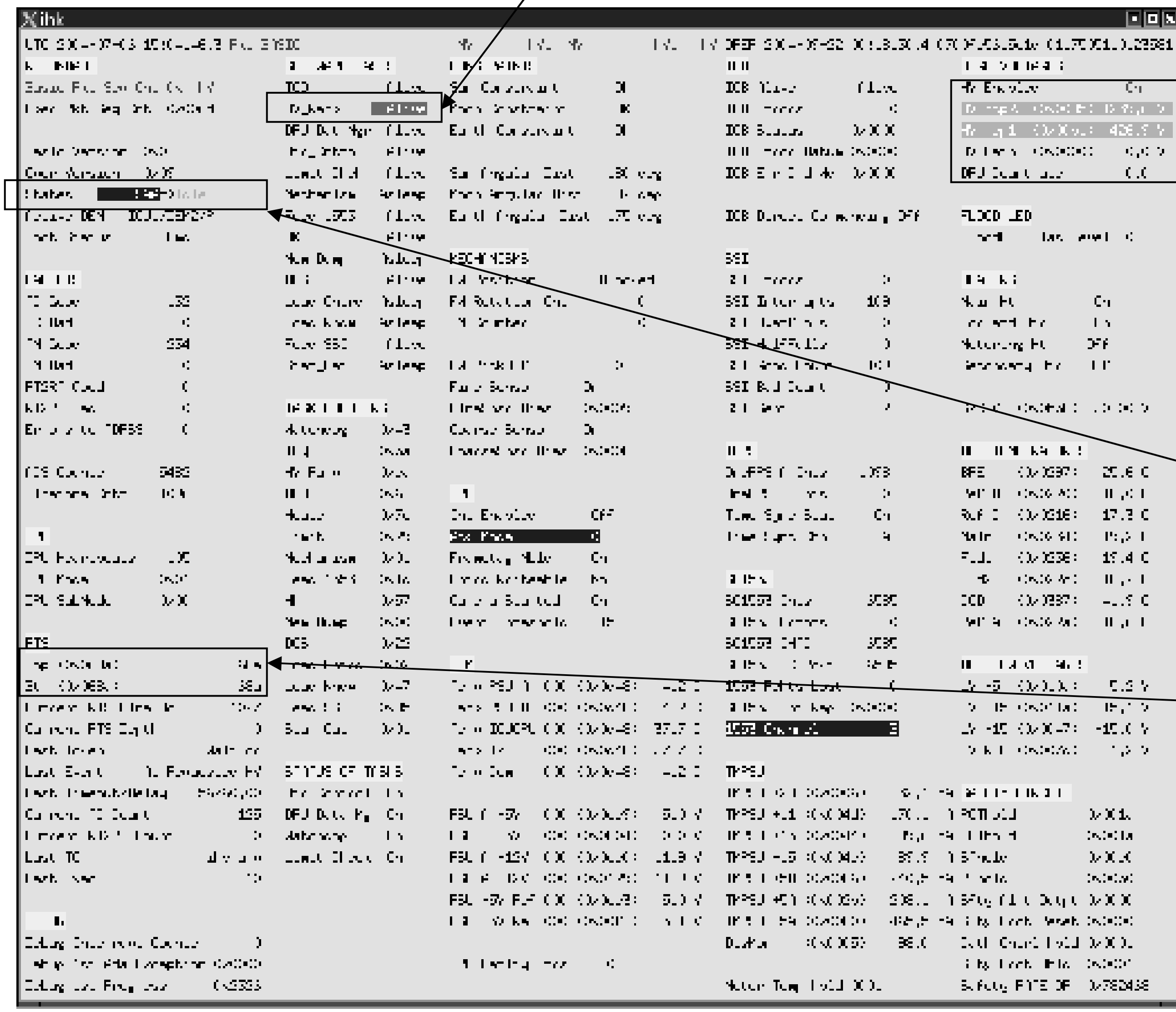


SAFE STATE EXAMPLE

Example of SAFE to IDLE Transition

As we are ramping up the HVs, the HV_ramp task is active. It would have been started by the RTS

HV mcp23 now shows 1239.6 V as it is on its way to up to its working voltage, HV mcp1 is at 426.9 V is on its way up to ~ 620 V and V cathode is at zero. ***Note***: Vcathode remains at zero until an observation is performed.

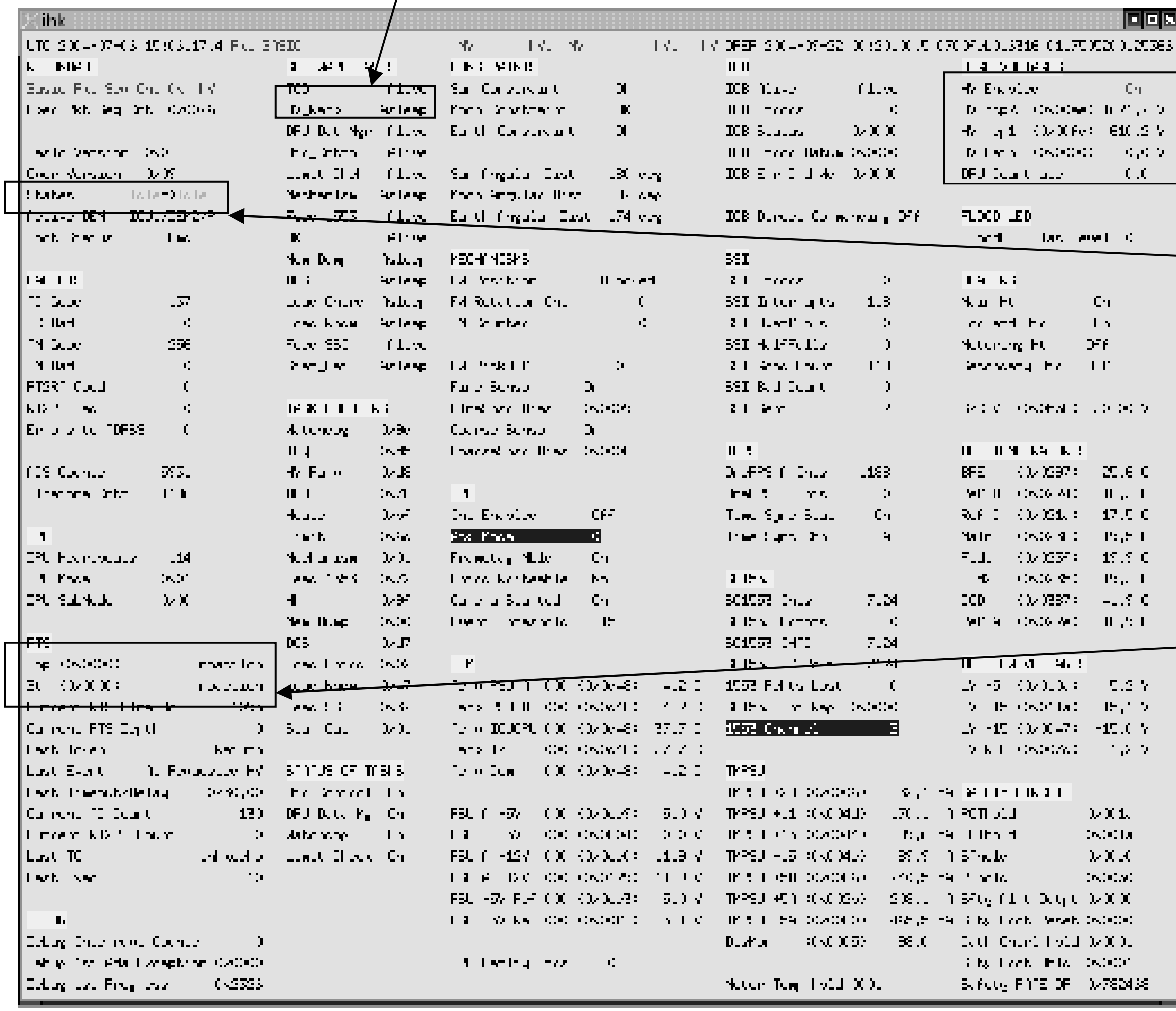


States now shows SAA=>IDLE as this is an intermediate state when going from Safe to Idle

This shows the RTS that is internally commanding the state transition.

Idle State at end of Safe => Idle Transition

HV ramping has finished, so the relevant s/w task is ‘asleep’



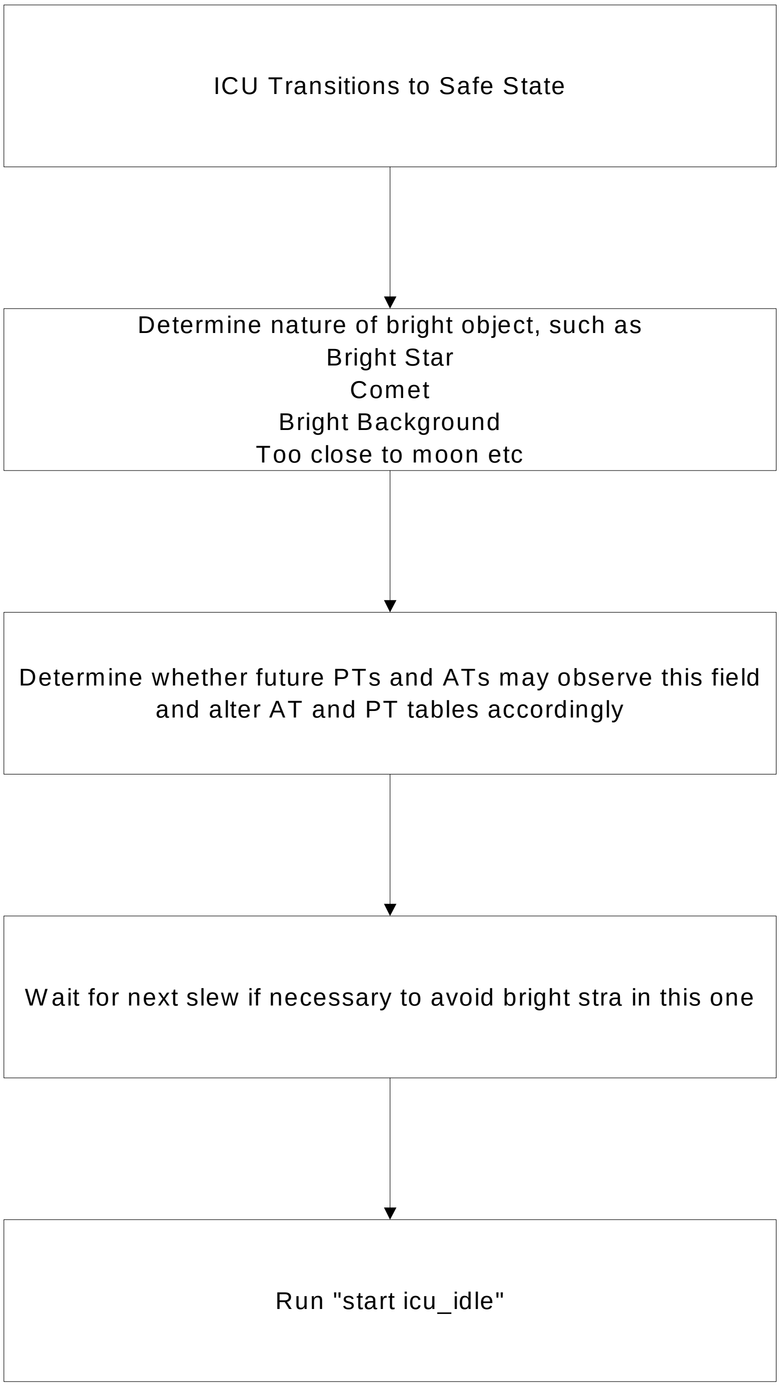
Vmcp23 and Vmcp1 are at their working voltages. Vcathode is at zero volts and it will remain so until an exposure starts.

State shows IDLE=>IDLE as we have finished the transition.

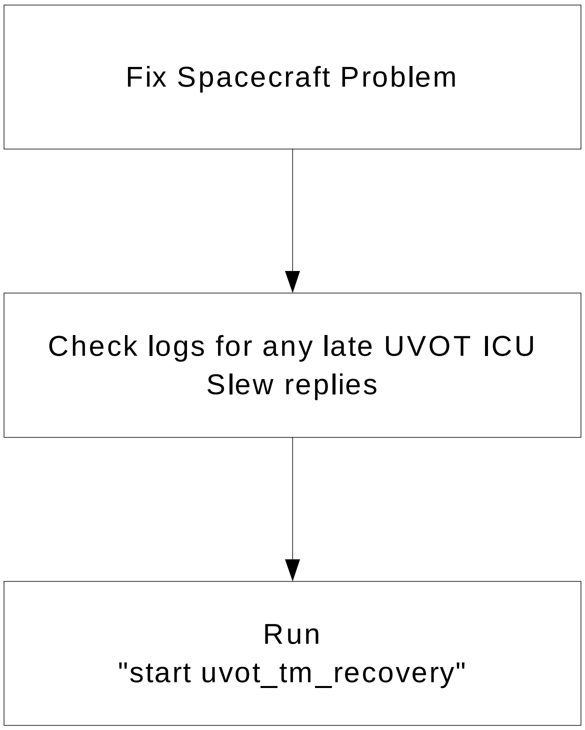
No RTS is running, as the state transition has finished.

3. Fault Trees

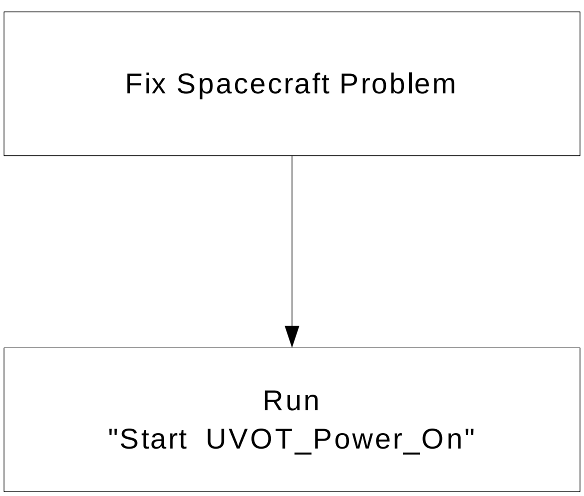
3.1 Safety Circuit Trip



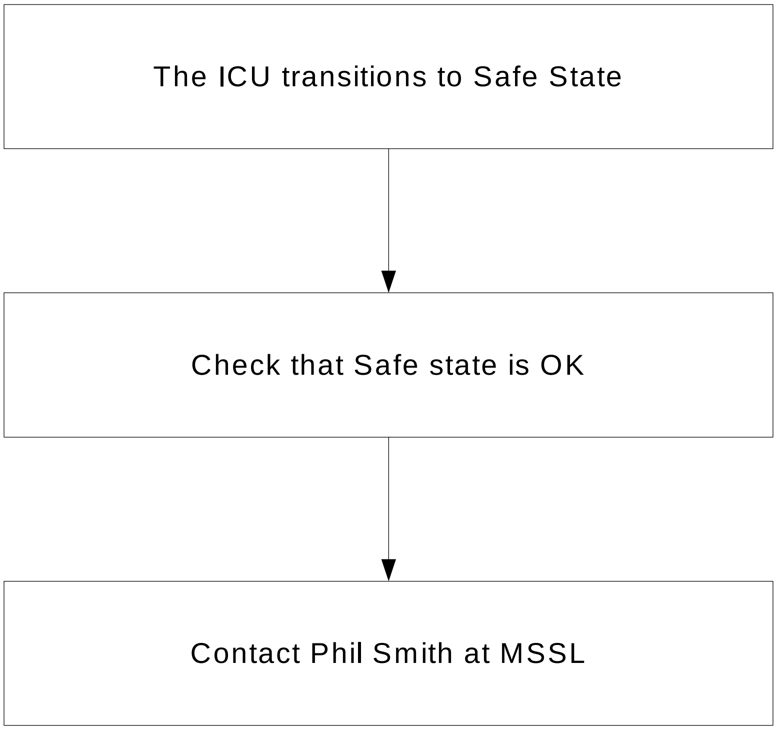
3.2 TM gets turned off



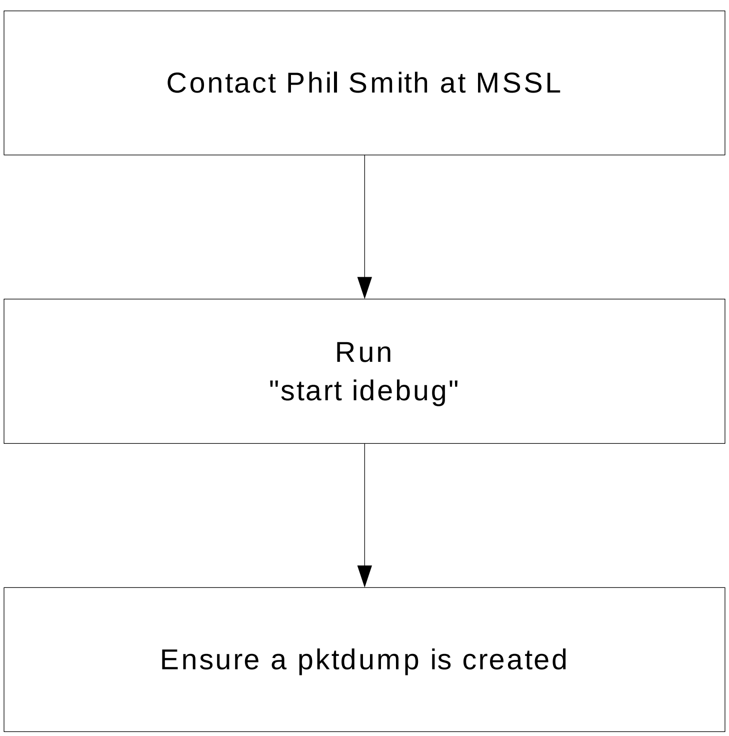
3.3 UVOT gets turned off



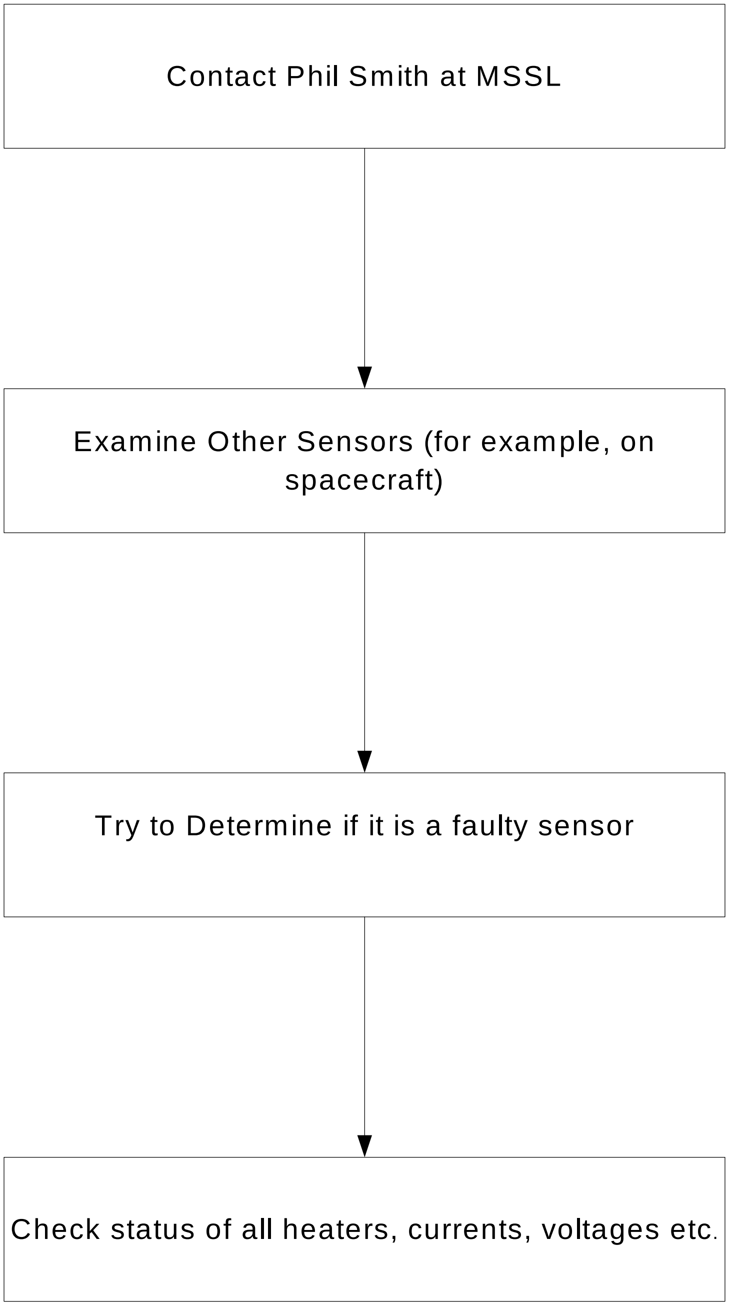
3.4 ICU has an error (not covered above)



3.5 ICU reboots and ends up in BASIC State



3.6 ICU has a limit violation



Appendix A Detailed Description of EEPROM-A Located Tables

A.1 Overview

The Basic code resident in ROM only has facilities to access data in the EEPROM-A bank. Therefore, the tables listed below are located in EEPROM-A to supply information needed by that code. In addition, because of the safety critical nature of that data, two copies are kept to guard against failure. The code will automatically switch to the second copy if it detects a CRC failure.

Name	Start	End	Comments
HEATER CONTROL	1FA00	1FA2F	Heater Control Parameters
HV RAMP	1FA30	1FA6F	High Voltage Ramp Parameters
LIMIT CHECK	1FA70	1FCFF	On-Board Limit Checking
HEATER CONTROL 2	1FD00	1FD2F	Copy of HEATER CONTROL
HV RAMP 2	1FD30	1FD6F	Copy of HV RAMP
LIMIT CHECK 2	1FD70	1FFFF	Copy of LIMIT CHECK

A.2 Heater Control

A.2.1 Overview

The behaviour of the heater control algorithms on UVOT is determined using parameters stored in this on-board EEPROM table. There are two types of heaters, focussing and non-focussing, with different algorithms.

A.2.2 Non-Focussing

The parameters control a 'bang-bang' algorithm i.e. the INTERFACE and FORWARD heaters should be off when the temperature is above a specified range, and on when below a specified range.

TMin_Vnom Specifies the lower value of the allowed temperature in **raw** thermistor (i.e. uncalibrated) units.

TMax_Vdrop Specifies the upper value of the allowed temperature in **raw** thermistor (i.e. uncalibrated) units.

NumThermistors Specifies how many thermistors are to be polled. An average of those thermistor readings is then calculated and compared against the values given by TMin_VNom and TMax_VDrop. It can take the range 1 -> 3. If its value is one, then the thermistor number given by Therm1 will be used. If its value is two, then the average of the thermistors specified by Therm1 and Therm2 will be used etc.

Therm1, Therm2, Therm3 Thermistors to be polled. The code numbers used are as follows:

Channel	Description
0	BPE
1	Reference B
2	Reference C
3	Main
4	Forward 1
5	Forward 2
6	CCD
7	Reference A

A.2.3 Focussing

The METERING_RODS and SECONDARY_MIRROR are the focussing heaters. The parameters described below state the **nominal** length of time the specified heater should be on within a fixed cycle time - this is referred to as the duty cycle

OnTime: Specifies the nominal on time within the cycle. Units are 1/10 second. A value of zero disables that heater. NOTE - no more than one of the focussing heaters should be enabled. If both are enabled, the algorithm ignores the SECONDARY_MIRROR heater parameters.

CycleTime: Specifies the cycle time. Units are 1/10 second.

However, the power actually developed is a function of a potentially varying spacecraft voltage. The algorithm therefore also monitors the spacecraft voltage via the ACS records and then adjusts the ‘on' time of the heater accordingly. It is necessary to supply additional parameters V_{nom} and V_{drop} to quantify this correction.

TMin_VNom: Specifies the expected nominal spacecraft voltage. Units are 1/100 of a volt.

TMax_VDrop: Specifies the voltage drop to heaters. Units are 1/100 of a volt.

The duty cycle is then corrected as follows:

If

F_n = Nominal Duty Cycle
F_c = Corrected Duty Cycle
V = Spacecraft Voltage
V_{drop} = Voltage drop to heater
V_{nom} = Nominal s/c voltage

then

$$F_c/F_n = ((V_{nom}-V_{drop})/(V-V_{drop}))^2$$

A.3 HV Ramp

This table supplies the calibration coefficients used by the code to control the three high voltage channels, Vcathode, Vmcp1 and Vmcp23. For each channel, two sets of calibration coefficients are required.

On the control side, the requested analogue voltage V is converted to a digital value D that is then sent over the ICB to the high voltage control unit. The formula used is of the form D=MV+C. The constants M and C are provided by the table.

Similarly, on the monitoring side, the digital representation D’ of the actual analogue voltage achieved is obtained via the ICB The analogue voltage V’ is then given by V’=M’D’+C’. The table supplies the constants M’ and C’.

A.4 Limit Check

An on-board algorithm monitors various safety critical items at all times. The information in this table controls the algorithm and consists of:

a) Whether an item should be monitored. This facility is provided as

    1. There is no support for the detector safety circuit in the basic code and therefore this subsystem should not be monitored by that code.

    2. During flight, due to a failure condition, we may choose to cease monitoring of a particular item to avoid multiple error messages.

b) The frequency of monitoring and the phasing of that monitoring within the cycle.

c) The valid range of data in raw i.e. un-calibrated units.

d) The number of times the range must be exceeded before it is considered an error – this is to allow for ‘noise’ on the value.

e) The recovery action to perform in the event of an error.

    1. For the Basic code, this will be a no-action, a request to the spacecraft to power down the telescope module or a request to power down UVOT.

    2. For Operational code, this will be either a no-action or a request to run an RTS.

Appendix B Detailed Description of EEPROM-B Located Tables

B.1 Location in Memory

Name	Start	End	Comments
Star Catalogue Pointers	00000	01412	Index into star catalogue – permits rapid access into relevant section for current exposure - see next item
Star Catalogue	01413	6F26C	Star Catalogue, including position, magnitude and colour.
Star Catalogue Addendum	6F26D	6F39C	Reserved for Catalogue additions -currently empty
Unused	6F39D	802FF	
Command Database	80300	80AFF	Derived from ITOS Database – used by RTS scripts to generate ICU internal commands
RTS Index	80B00	80CFF	Hash-based Index into RTS Library (see next item)
RTS Database	80D00	8214F	Compiled Library of RTS Scripts
Unused	82150	E30FF	
AT Configurations	E3100	E70FF	Automated target configurations selected from using UVOT mode.
PT Configurations	E7100	F827F	Planned Target configurations – includes Calibration, Engineering, Settling, Finding Chart and Safe Pointing
Errors Action Table	F8280	F82FF	Action (e.g. RTS called, TDRSS message) in the event of an error.
PT Configuration ID Table	F8300	FF37F	Specifies combination of PT configurations correspond to a particular UVOT Mode
Count Rate Table	FF380	FF4FF	Count rate table as function of colour and filter – used with catalogue to calculate maximum exposure time
Avoidance Angle Table	FF500	FF5FF	Avoidance angles for Earth, Sun, Moon, Planets and Bright Stars
State Change Table	FF600	FFEFF	Specifies conditions for autonomous state changes
Unused	FFF00	FFF7F	
Standard Table	FFF80	FFFFF	Miscellaneous configuration specification items that do not fit into the above categories

B.2 Swift Catalogue

B.2.1 Catalogue Compilation

The Swift catalogue was compiled from four catalogues: Tycho-2, GVCS III, NGC, and the Yale Bright Star Catalogue. All catalogues were pre-processed before compiling the Swift catalogue to achieve units. Next, they were merged into one catalogue before eliminating "red" objects and precessing all coordinates to epoch 2000.0. All magnitudes are Johnson magnitudes.

GENERATING MISSING MAGNITUDES

All missing V or B magnitudes from the catalogues were generated in preprocessing. If V was missing, V was set to "B - 0.3"; likewise, missing B was set to "V + 0.3". These values were chosen to indicate that the object could be "very blue". A "B - V" value of less than "-0.3" causes the object to be retained in the Swift catalogue after the "red" objects are eliminated. Even if this "B - V" value is invented, the UVOT is prevented from looking at potentially bright objects.

PROCESSING RED STARS

The aim of the Swift Catalogue is to prevent the Swift UVOT from looking at very bright objects, particularly in the blue range. Therefore, some fainter objects deemed "too red" to harm the UVOT have been eliminated from the catalogue. This process was done by retaining objects in the catalogue according to these limits:

```
A. B - V < -0.3, V <= 12.0
B. -0.3 <= B-V < -0.17, V <= 11.0
C. -0.17 <= B-V < 0.01, V <= 10.0
D. 0.01 <= B-V, V <= 9.5
```

Most faint objects with V_t higher than B_t could be thrown out according to these rules. This reduced the number of objects in the Swift catalogue by almost half.

PRECESSING STARS TO J2000.0

Just over 800 of the stars from the Tycho-2 catalogue gave data in epoch 1991.5, while around 3000 variable stars from the GCVS gave information in epoch 1950 coordinates. The right ascension and declination, both given in degrees, were converted to epoch 2000.0 using these equations:

```
"R.A. new" = "R.A. old" + (15/3600)*years*(3.074+1.336*sin((pi/360)* "R.A. old")*tan((pi/360)* "Dec old"))
"Dec new" = "Dec old" + (1/3600)*years*(20.038*cos((pi/360)* "R.A. old"))
```

"years" is the number of years between 2000.0 and the epoch given. This precession equation produces values accurate to < 1 second of right ascension and five arc seconds of declination. The equation was found on an Arizona State University astronomy class webpage:

http://ircamera.as.arizona.edu/astr_250/ProblemSets/tele_solv.html

PSEUDO SOURCES

Two pseudo-sources were added to the Swift catalogue. Both of the NGC objects given below are bright over a wide area, and cannot be modelled as a source with a single bright core. In the Swift catalogue as it stands there is a core source for each object, and the following two pseudo-sources will effectively 'extend' the objects to give more accurate brightness coverage.

RA	Dec	V	B	Object
140.356	-58.307028	10.4	10.1	NGC2867

```
251.127583  23.799278  9.41  9.11  NGC6210
```

COMPONENT CATALOGUES

TYCHO-2

The Tycho-2 catalogue gives astrometric and photometric (V_t and B_t) information for the 2.5 million brightest stars in the sky. 99% of all stars with V_t mag < 11.0 and 90% of all stars with V_t mag < 11.5 are included. Observation data from the ESA Hipparcos satellite provides the catalogue positions and magnitudes. Information about the Tycho-2 catalogue (ref. The Tycho-2 Catalogue of the 2.5 Million Brightest Stars Hog E., et al <Astron. Astrophys. (2000)> can be found on the Tycho homepage, `http://www.astro.ku.dk/~erik/Tycho-2`/. For convenience, Tycho-2 was subdivided into 3 processing chains:

Chain 1 contains all stars in Tycho 2 with a) B_t-V_t <= 0.18 down to a V_t of <= 11.25 and b) B_t-V_t > 0.18 down to a V_t of <= 10.25. The V_t and B_t were converted to Johnson magnitudes.

Chain 2 contains all the stars in Tycho2 with B_t-V_t < -0.35 in the range 11.25 < V_t <= 12.0. The V_t and B_t were converted to Johnson magnitudes.

Chain 3 contains all the stars in Tycho2 with either B_t or V_t not given, and the remaining V_t <= 12.0. If V_t was missing, V_t was set to "B_t + 0.3". If B_t was missing, B_t was set to "V_t - 0.3". Finally, V_t and B_t were converted to Johnson magnitudes.

GCVS III

The General Catalogue of Variable Stars lists coordinates, maximum light magnitude, and minimum light magnitude for over 28,000 variable stars in the Milky Way. The maximum magnitude in the V and B light has been retained in the Swift catalogue. (ref. Kholopov, P.N. (editor), et al, "The General Catalogue of Variable Stars" 4th Ed., vol. 1, Moscow, NAUKA, 1987).

All stars listed in the General Catalog of Variable Stars with max V <= 11.0 were processed. Missing B values were set to "V - 0.3".

Seven objects were removed from the GCVS catalogue prior to processing. These five supernova remnants were removed completely because their maximum V magnitudes had faded significantly since the supernova events had occurred:

NAME	RA (hh mm ss)	DEC (dd mm ss)	All J2000 coords.
S And	00 42 43.0	+41 16 04	
B Cas	00 09 10.7	+59 08 59	
Z Cen	13 39 57	-31 32.2	
V0843 Oph	17 30 37.2	-21 28 51	
CM Tau	05 34 32.0	+22 00 52.1	

Another 2 objects were removed from the GCSV catalogue because they already existed in the Yale Bright Star Catalogue:

NAME	RA (hhmmss)	DEC (ddmmss)	All J2000 Coords
SS Uma	14 02 03	+54 27.9	
VW Vir	12 27 16	+09 25.1	

NGC

The Tycho catalogue does not include extended sources, thus the NGC2000 catalogue (ref. J.L.E. Dreyer (edited by) R.W. Sinnott, <Sky Publishing Corporation and Cambridge University Press (1988)>) was used as the source of the brightest extended objects in the sky (800 objects brighter than 11th magnitude).

As we are interested in the brightness per unit MIC-coincidence-loss-area and not the total magnitude, a program was written to calculate the average surface brightness given the magnitude and spatial extent of the object. A difference in brightness between the nucleus and extended regions of the source was allowed for galaxies with bright nuclei; this difference was found empirically. Extended sources from the NGC catalogue with core V <= 11.0 were used. Core Bt magnitudes were inserted with value "V - 0.3".

YALE BRIGHT STAR CATALOGUE

The Yale Bright Star Catalogue (ref. Yale Bright Star Catalogue, 5th Revised Ed. (Hoffleit, Warren 1991))lists coordinates, magnitudes, and spectral information for over 9,000 of the sky's brightest stars. This catalogue was added since some of the very brightest stars (i.e., Sirius) seemed to be missing from Tycho-2. The catalogue contains stars and 14 other sources with V <= 6.5.

Empty "B-V" fields were set to "0.3". "B" fields were determined by "V + (B-V)".

B.2.2 Star Catalogue Structure

The onboard catalogue is split into three parts – the pointer table, the main catalogue and the addendum. It is stored in EEPROM B. The three parts of the catalogue follow each other sequentially, with no gaps. The pointer table allows quick access to catalogue data, and the addendum is an area left blank in case any sources need to be added to the catalogue after launch, for example if a supernova occurs during the mission.

B.2.3 Star Catalogue Pointers

The star catalogue is divided into sky areas of approximately equal solid angle. This pointer table holds a set of pointers to allow rapid access to a particular sky area and the start of the addendum. Each pointer is two words long.

The first 44 pointers each locate the start of a block of pointers within the pointer table itself. In turn, each of those point to a sky area in a band of the same declination. There are 2524 such pointers and 22 bands for each hemisphere. Each band is 255 arc-minute wide except for the polar, which is 45-arc minute wide. The bands run in order from the north band nearest the equator to the north polar band, followed by the south band nearest the equator to the south polar band. Each declination band is divided into a number of equal right ascension divisions, the number depending on how the width of the field of view changes with respect to right ascension at each declination, as per the table below. The sky areas run along the declination bands in increasing order of RA.
These are followed by a pointer to the start of the addendum. The last entry in the pointer table is a one word CRC value.

The number of areas in each declination band is shown in the following table.

Band	Number of Divisions
0	90
1	90
2	90
3	90
4	90
5	80
6	80
7	75
8	72
9	72
10	72

Band	Number of Divisions
11	60
12	54
13	50
14	45
15	40
16	36
17	27
18	24
19	15
20	8
21	2

B.2.4 Star Catalogue

The main catalogue is split into 2524 sky areas, in 44 declination bands, of 22 per hemisphere. Within each area the position of each source is stored to +/- half an arc minute accuracy in the RA and declination axes, on a 255 by 255 arc minute grid relative to the origin of the area, along with each source's associated magnitude information. If two or more sources are deemed coincident (to +/- half an arc minute accuracy) then their magnitudes are combined and the combined information only is stored. Each sky area is followed by a CRC value for memory corruption checking. It contains 223807 entries.

Each entry is stored as two words;

Byte	Contents
1	RA offset from the origin of the sky area (arc minutes).
2	Declination offset (arc minutes).
3	Magnitude code – see message table appendix D.5 for codes used.
4	Colour index code – see message table appendix D.6 for codes used.

Each sky area ends in a one word CRC value.

B.2.5 Star Catalogue Addendum

The addendum is a 304 word long area of memory, which can store up to 100 extra sources. At minimum, it will consist of a marker to show that there are no more sources stored, and the remaining memory zero filled, except for the last word, which is a CRC value. If a source is added to the addendum then it will be put at the beginning of the area, and followed by the marker. Any new source will not necessarily be added to the addendum – if it is coincident with a source already in the main catalogue then its magnitude information can be combined with that of the main catalogue source instead.

Each entry is stored as three words.

Byte	Contents
1	RA division the source is in – see 'Catalogue Star' in error message appendix
2	Encoded version of its declination band – see 'Catalogue Star' in error message appendix
3	RA offset from the origin of its sky area (arc minutes).
4	Declination offset (arc minutes).
5	Magnitude code – see message table appendix D.5 for codes used.
6	Colour index code – see message table appendix D.6 for codes used.

It also contains an end of list marker consisting of three words, all of them 0xFFFF. This will be positioned at the end of the relevant entries in the addendum. If there are no entries, it will be at the beginning of the addendum. All allotted space after the end of list marker is zero filled.

The last word of the addendum is the CRC value.

B.3 Command Database

This database is derived from the ITOS command database. It describes each command in sufficient detail for the RTS system to construct a command 'on the fly' for internal and occasionally external submission. Each command is described by a variable length block ending with a CRC.

The code used to represent a call to a particular command within an RTS script is the offset of that command with this database. This enables the code that executes an RTS to immediately locate the appropriate description within the database.

Each command block has the following format.

Word Offset	**Description**
0	Overall length of block in words, including itself and CRC
1	Command Code => APID and Function Code **– see note below for format details**.
2	Number of Fields (NF) i.e. command parameters – **may be zero**.
3	Value in Packet Length Field in final command
Followed by NF occurrences of a three-word block describing the location and size of the each field in the same order as the fields in the command.	
0	Starting word (0 is first word in packet)
1	Starting bit within word (0 is most significant)
2	Field length in bits.
Followed by	
0	CRC

Note: The Command Code word (offset 1) has the following format

MSB LSB

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
APID Band			APID Offset					Function Code							

'APID Band' converts to 'APID Base' as follows. The command APID is then constructed by adding 'APID Base' to 'APID Offset'.

APID Band	**APID Base**
0	0x600
1	0x620
2	0x640
3	0x660
4	0x680
5	0x700
6	0x700
7	0x700

B.4 RTS Index

This is used to determine the start address for a particular RTS located in the RTS Database area. The index is divided into `NHASH` sections, numbered 0 through `(NHASH-1)`. An RTS belongs in section `n` (say) if, upon dividing the code number of the RTS by `NHASH`, the result is `n`. Each item in a section describes a RTS by detailing its code, priority and address information. The index starts with a header that points to the start of each section.

The detailed format of the file is described below.

Word Offset	Description of Contents	Section
`0`	Header Size = `NHASH+2`	Index Header
`1`	Offset to start of section 0 (in this special case, will always point to offset `NHASH+2`)	
`2`	Offset to start of section 1	
… and so on until. …		
`NHASH`	Offset to start of section `(NHASH-1)`	
`HNASH+1`	CRC for Header	
This is immediately followed by section 0		
`NHASH+2`	Length (in words) of section 0 = `NWSECTION` (including itself and CRC at end of section)	Section 0
This is then followed by `NRTS` groups of three words describing an RTS, where `NRTS=(NWSECTION-2)/3`		
`NHASH+3`	Code for RTS belonging to section 0	
`NHASH+4`	Priority for RTS	
`NHASH+5`	Address of RTS divided by 0x20 (32 decimal) – because RTSs always start on a word boundary divisible by 32.	
… and so on until. …		
`NHASH+NWSECTION+1`	CRC for section 0	
Then we start section 1		
`NHASH+NWSECTION+2`	Length (in words) of section 1	Section 1
Remainder of section 1		
… and so on for `NHASH` sections until …		Section 2 through `NHASH-1`
End of index	CRC for whole index	End of Index

B.5 RTS Database

The RTS index (see above) gives the start address (RTS_START) of a particular RTS. That address is **always** a multiple of 32 16-bit words. The layout of each RTS is as follows:

Word Offset	**Description of Contents**
RTS_START	Length in words of RTS = RTS_LENGTH (including itself). As RTSs are often contiguous, this may also be the offset to the next RTS.
Then followed by up to RTS_LENGTH-2 RTS command tokens.	
Any unused words prior to the CRC are zero filled.	
RTS_START+RTS_LENGTH-1	CRC for RTS

B.6 AT Configurations

B.6.1 Overview

The AT configuration table contains a set of data blocks containing experiment configurations to be used during Automated Target exposures. Note that they do **not** include the finding chart or settling configurations, which are treated by the UVOT ICU as special cases of planned-target exposures (PT) – see appendix B.7. The data blocks are arranged as a series of linked lists, the order within the list being ‘time-since-burst’.

The precise configuration used is determined by

- The UVOT Mode parameter supplied by the Figure of Merit (FOM) in the FONEXTOBSINFO record.
- The intensity of the GRB as transmitted in the IGRBFLUXINFO packet.
- The time since the burst supplied in the FONEXTOBSINFO.
- Whether a refined XRT position in an XRTPOSITION message has been received.
- The filter used in the last AT exposure.

The following procedure is followed.

- If the intensity of the GRB is determined to be not bright, then the data block list indexed by the value of ‘UVOT Mode’ is searched. If the intensity of the GRB is deemed bright, then the data block list indexed by (‘UVOT Mode’ + 1) is searched.
- A linear search is then performed of the selected list, starting at the last location accessed within that list for the current pointing, until the a data block is found for which the actual time since burst is *less than or equal* to the tabulated time since burst.
- Each block contains appropriate experiment configurations for when an XRT position was supplied and for each filter except blocked. The next filter on the filter wheel from that used in the last AT exposure is normally selected. However, if the maximum exposure time specified in the table is zero, then it is skipped. If the tabulated minimum exposure time was not obtained in the previous exposure, the filter used will be re-selected and the exposure re-started.

<table>
<tr><th>Word Offset</th><th>Description</th></tr>
<tr><td>0</td><td>UVOT Mode (Range 0x8000 => 0xFFFE)</td></tr>
<tr><td>1</td><td rowspan="2">Time Since Burst (seconds)</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td><td rowspan="2">Unused</td></tr>
<tr><td>4</td></tr>
<tr><td colspan="2">Followed immediately by the configuration for Filter 1 (Grism1) without XRT position supplied</td></tr>
<tr><td>5</td><td>Minimum Exposure Time (seconds)</td></tr>
<tr><td>6</td><td>Exposure Time (seconds)</td></tr>
<tr><td>7</td><td>DPU Mode</td></tr>
<tr><td>8</td><td>DPU Sub-mode</td></tr>
<tr><td>9</td><td>DPU Binning Level</td></tr>
</table>

<table>
<tr><th>Word Offset</th><th colspan="2">Description</th></tr>
<tr><td>10</td><td colspan="2">DPU Image Window Size X (range 0 => 0x800)</td></tr>
<tr><td>11</td><td colspan="2">DPU Image Window Size Y (range 0 => 0x800)</td></tr>
<tr><td>12</td><td colspan="2">DPU Event Window Size X (range 0 => 0x800)</td></tr>
<tr><td>13</td><td colspan="2">DPU Event Window Size Y (range 0 => 0x800)</td></tr>
<tr><td>14</td><td colspan="2">Detector Window Size X (Units 2*2 CCD Pixels, range 1 =>0x80)</td></tr>
<tr><td>15</td><td colspan="2">Detector Window Size Y (Units 2*2 CCD Pixels, range 1 => 0x80)</td></tr>
<tr><td>16</td><td colspan="2" rowspan="2">DPU Minimum Tracking Window Area</td></tr>
<tr><td>17</td></tr>
<tr><td>18</td><td colspan="2">DPU Tracking Frame Time (seconds)</td></tr>
<tr><td>19</td><td colspan="2">DPU Number of Guide Stars (range 0 => 0x10)</td></tr>
<tr><td>20</td><td colspan="2">DPU Criteria Mask</td></tr>
<tr><td>21</td><td colspan="2">Unused</td></tr>
<tr><td>22</td><td colspan="2">Offset (clocked) position of filter (usually only grisms) – zero if not clocked.</td></tr>
<tr><td>23</td><td colspan="2">Unused</td></tr>
<tr><td>24</td><td colspan="2">Safety Circuit PCTHOLD (Consecutive Pixel Count) parameter (range 0=>7f)</td></tr>
<tr><td>25</td><td colspan="2">Safety Circuit FCTHOLD (Consecutive Frame Count) parameter (range 0=>1f)</td></tr>
<tr><td>26</td><td colspan="2">Safety Circuit STHOLD (Pixel Threshold) parameter (range 0=>ff)</td></tr>
<tr><td>27</td><td colspan="2">Safety Circuit RTHOLD (Rate meter Pixel Threshold) parameter (range 0=>ff)</td></tr>
<tr><td>28-50</td><td colspan="2">Followed immediately by the configuration for Filter 1 (Grism1) with XRT position supplied</td></tr>
<tr><td>51-73</td><td colspan="2">Followed immediately by the configuration for Filter 2 (UVW2) without XRT position supplied</td></tr>
<tr><td>74-96</td><td colspan="2">Followed immediately by the configuration for Filter 2 (UVW2) with XRT position supplied</td></tr>
<tr><td>97-464</td><td colspan="2">… and so on for filters 3 to 10.</td></tr>
<tr><td colspan="3">Followed by alternative formats for different time since burst.</td></tr>
<tr><td>465</td><td>Set to 0xFFFF to indicate no more data</td><td rowspan="4">Start of next block of configuration data for other UVOT Modes</td></tr>
<tr><td>466</td><td rowspan="2">Pointer to address in EEPROM of next data block for this UVOT Mode (Set to zero if no more blocks available for this UVOT Mode)</td></tr>
<tr><td>467</td></tr>
<tr><td>468</td><td>CRC of whole data block</td></tr>
</table>

B.7 PT Configurations

This table consists of a series of contiguous data blocks, each of which contains a possible planned UVOT experiment configuration. Note that they also include the finding chart or settling configurations. The PT Configuration ID table (see below) is used to specify, and point to, which one or more of these configurations correspond to a particular UVOT mode. The table below describes the content of each block.

Word Offset	Description
0	Configuration ID – simply a label, not to be confused with the UVOT Mode.
1	Exposure Time (seconds)
2	DPU Mode
3	DPU Sub-mode
4	DPU Binning Level
5	Detector Acquisition Mode
6	Filter (range 0=>10)
7	DPU Image Window Origin X (range 0 => 0x7ff)
8	DPU Image Window Origin Y (range 0 => 0x7ff)
9	DPU Image Window Size X (range 0 => 0x800)
10	DPU Image Window Size Y (range 0 => 0x800)
11	DPU Event Window Origin X (range 0 => 0x7ff)
12	DPU Event Window Origin Y (range 0 => 0x7ff)
13	DPU Event Window Size X (range 0 => 0x800)
14	DPU Event Window Size Y (range 0 => 0x800)
15	Detector Window Origin X (Units 2*2 CCD Pixels, range 0 =>0x7f)
16	Detector Window Origin Y (Units 2*2 CCD Pixels, range 0 => 0x7f)
17	Detector Window Size X (Units 2*2 CCD Pixels, range 1 =>0x80)
18	Detector Window Size Y (Units 2*2 CCD Pixels, range 1 => 0x80)
19 20	DPU Finding Chart Control Word
21 22	DPU Minimum Tracking Window Area
23	DPU Tracking Frame Time (seconds)
24	DPU Number of Guide Stars (range 0 => 0x10)
25	DPU Criteria Mask
26	Flood LED Setting (range 0 => 15)
27	Detector Threshold
28	Exposure Modifier: 0= PT-Normal, 1 = PT-Null, 2 = PT-Idle (see table below)

Word Offset	Description
29	If not equal to zero, actual filter wheel position required – usually for clocked grisms
30	Unused
31	Safety Circuit PCTHOLD (Consecutive Pixel Count) parameter (range 0=>7f)
32	Safety Circuit FCTHOLD (Consecutive Frame Count) parameter (range 0=>1f)
33	Safety Circuit STHOLD (Pixel Threshold) parameter (range 0=>ff)
34	Safety Circuit RTHOLD (Rate meter Pixel Threshold) parameter (range 0=>ff)
35	CRC

Exposure Modifier Table

Exposure Modifier	Description
PT-Normal	Exposure carried out as normal.
PT-Null	The filter wheel is left at its current position and the cathode is set down.
PT-Idle	The filter wheel is moved to blocked and the cathode set down

B.8 Errors Action Table

This table contains a series of contiguous records that describe the actions the UVOT ICU should perform in the event of certain NHK error message being generated. Up to 256 records are allowed. A CRC for the whole table is then appended.

The format and meaning of each field of a record is described in the table below.

Word Offset	**Description**
0	Error code and action bits – see 'Word 0' table below. The action is only performed if a match is found with both the error code and the NHK 1st parameter value (see next item)..
1	Value to match against 1st parameters of NHK message – action only performed if match found with error code and this value. If this value is 0xFFFF, all values of the NHK parameter match. The NHK messages are described in Appendix C
2	The code number of the RTS to run in the event of a match being found (see table D.1 for the code values). A value of zero indicates no RTS is to be run.

Word 0 Table: The contents of the word at offset 0 are as follows:

MSB **LSB**

0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
X	X	X	X	X	N	S	T	NHK Error Code to Match (see Appendix C)							

Where:

X	Don't Care.
N	If set (e.g. by a bit mask of 0x400), any specified RTS should not be run if the UVOT is in the Safe state.
S	If set (e.g. by a bit mask of 0x200), forces the UVOT to stay in Safe state afterwards.
T	If set (e.g. by a bit mask of 0x100), an echo of the NHK message is sent on TDRSS.

The numerical values of the symbolic constants shown can be in seen in tables D.14 and D.15, and in the part of the Message Tables appendix (Appendix C) associated with that particular error. The codes of the RTS to be run can be found in table D.1 and section 1.3.8.2 (Summary of RTS Scripts) .

Note – the working copy of this table is located in RAM, starting at address 0x900. It is therefore possible to change locations in this table 'on the fly' using the `/iicuload` command e.g.

```
/iicuload1 mid=0,offset=0x900+<record_offset> + <word offset>, data=<value>
```

where the items in <> are replaced with the relevant values. For example, in order to change the action associated with a `TIMESYNC_JUMP` error to that of 'noaction', the data value (from section 1.3.8.2) needs to be a zero. From the table below, the offset address of the record containing that action code is 150. From the word-offset table above, it can be seen that action codes are always loaded into offset 2 within the record. Therefore, the command would be

```
/iicuload1 mid=0,offset=0x900+150+2,data=0
```

It can also be seen from the table below that the "Error code and action bits" field (word offset zero) normally contain 0x400+0x100+25 (**N** and **T** bits set plus an error code). To also force the UVOT to stay in safe after the error occurs, i.e. the **S** bit is set (bit mask = 0x100), the value can be changed with the command:

```
/iicuload1 mid=0,offset=0x900+150+0,data=0x400+0x200+0x100+25
```

For release 10 of the UVOT ICU code, the contents of the table are shown below.

Record Offset	N	S	T	NHK Error Code	NHK Parameter Match	RTS to run
0	Table length in words					
1	1	-	1	HEATER_ICB_SHUTDOWN	match_all	noaction
4	1	1	1	CORRUPTED_EEPROM	CMD_DTB_ID	h_emergency_safe
7	1	1	1	CORRUPTED_EEPROM	RTS_NDX_ID	h_emergency_safe
10	1	1	1	CORRUPTED_EEPROM	RTS_NDX_HDR_ID	h_emergency_safe
13	1	1	1	CORRUPTED_EEPROM	RTS_STORE_ID	h_emergency_safe
16	1	1	1	CORRUPTED_EEPROM	HV_CALIB_ID	noaction
19	1	1	1	CORRUPTED_EEPROM	HV_CALIB_2_ID	gotosafe
22	-	-	1	CORRUPTED_EEPROM	LIMIT_CHECK_TABLE_ID	h_basic
25	-	-	1	CORRUPTED_EEPROM	HEATER_TABLE_ID	h_basic
28	1	-	1	CORRUPTED_EEPROM	STARCAT_ID	gotosafe
31	1	1	1	CORRUPTED_EEPROM	AVOIDANCE_ANGLES_ID	gotosafe
34	1	-	1	CORRUPTED_EEPROM	AT_CONFIG_TABLE_ID	gotosafe
37	1	-	1	CORRUPTED_EEPROM	PT_CONFIG_TABLE_ID	gotosafe
40	1	-	1	CORRUPTED_EEPROM	PT_CONFIG_ID_ID	gotosafe
43	1	1	-	CORRUPTED_EEPROM	STANDARD_TABLE_ID	gotosafe
46	1	1	1	CORRUPTED_EEPROM	STATE_TABLE_ID	gotosafe
49	1	1	-	CORRUPTED_EEPROM	ERRORS_ACTION_TABLE_ID	gotosafe
52	1	1	1	CORRUPTED_EEPROM	COUNT_RATE_TABLE_ID	gotosafe
55	1	1	1	CORRUPTED_EEPROM	match_all	gotosafe
58	-	1	1	BAD_DATA_IN_EEPROM	RTS_NDX_HDR_ID	h_emergency_safe
61	-	1	1	BAD_DATA_IN_EEPROM	CMD_DTB_ID	h_emergency_safe
64	1	1	1	BAD_DATA_IN_EEPROM	HV_CALIB_ID	noaction
67	1	1	1	BAD_DATA_IN_EEPROM	HV_CALIB_2_ID	gotosafe
70	-	1	1	BAD_DATA_IN_EEPROM	HEATER_TABLE_ID	h_basic
73	-	1	1	BAD_DATA_IN_EEPROM	LIMIT_CHECK_TABLE_ID	h_basic
76	1	-	1	ACS_MISSING	match_all	fastsafe
79	1	-	1	NO_SUCH_UVOT_MODE	match_all	noaction
82	1	-	-	NO_USABLE_FILTERS_IN_CONFIG	match_all	noaction
85	1	-	1	NO_SUCH_CONFIG	match_all	noaction
88	1	-	1	UNACCEPTABLE_OVERALL_DRIFT	match_all	fastsafe
91	1	-	1	UNACCEPTABLE_DIFF_DRIFT	match_all	blocked_failsafe
94	1	-	1	NOT_AT_PREDICTED_POSITION	match_all	gotosafe
97	1	-	1	UNEXPECTED_IS_SETTLED_FLAG_OFF	match_all	gotosafe
100	1	1	1	IMPOSSIBLE_STATE_TRANSITION	match_all	gotosafe
103	1	1	1	FORBIDDEN_STATE_RTS	match_all	gotosafe
106	1	-	1	ANGULAR_CONSTRAINT_VIOLATION	match_all	gotosafe
109	1	-	1	BRIGHT_OBJECT_PRESENT	match_all	noaction
112	1	-	1	SAFETY_CIRCUIT_ALERT	match_all	gotosafe
115	1	-	1	BAD_VALUE	ACS_BUS_VOLTAGE	gotosafe
118	1	-	1	BAD_VALUE	ACS_PACKET_RA	fastsafe
121	1	-	1	BAD_VALUE	ACS_PACKET_DEC	fastsafe
124	1	-	1	BAD_VALUE	ACS_PACKET_ROLL	fastsafe
127	1	-	1	BAD_VALUE	ACS_PACKET_LATITUDE	fastsafe
130	1	-	1	BAD_VALUE	ACS_PACKET_LONGITUDE	fastsafe
133	1	-	1	BAD_VALUE	ACS_BUS_VOLTAGE	gotosafe
136	1	-	1	BAD_VALUE	NEXTOBS_NEXT_RA	blocked_failsafe
139	1	-	1	BAD_VALUE	NEXTOBS_NEXT_DEC	blocked_failsafe
142	1	-	1	BAD_VALUE	NEXTOBS_NEXT_ROLL	blocked_failsafe
145	1	-	1	BAD_VALUE	match_all	noaction
148	1	-	1	TIMESYNC_JUMP	match_all	gotosafe
151	1	1	1	TIMESYNC_OVERFLOW	match_all	gotosafe
154	1	-	1	TIMESYNC_TOOLATE	match_all	gotosafe
157	1	-	1	TIMESYNC_TOOLONGSINCE	match_all	gotosafe
160	1	1	1	TIMESYNC_TOOBIG	match_all	gotosafe
163	1	1	1	SC1553_READ_ERROR	match_all	gotosafe
166	1	-	1	FW_LOST_POSITION	match_all	noaction
169	1	-	1	DM_LOST_POSITION	match_all	noaction
172	1	-	1	DPU_TIMEOUT	match_all	noaction
175	1	-	1	DPU_NAK	match_all	noaction
178	1	-	1	DPU_INCORRECT_ACK	match_all	noaction
181	1	-	1	DPU_INVALID_APID_OR_ID	match_all	noaction
184	1	-	1	DPU_INCONSISTENT_APID_ID	match_all	noaction
187	1	-	1	SSI_ERROR	match_all	noaction
190	1	-	1	WINDOW_TABLE_LOAD_FAILURE	match_all	noaction
193	1	-	1	CENTROID_TABLE_LOAD_FAILURE	match_all	noaction
196	1	1	1	HV_RAMP_FAILED	match_all	noaction
199	-	-	1	ADA_EXCEPTION	match_all	h_basic
202	-	-	1	LIMIT_EXCEEDED	match_all	noaction

Record Offset	N	S	T	NHK Error Code	NHK Parameter Match	RTS to run
205	1	1	1	DCS_STACK_EXCEEDED	match_all	gotosafe
208	1	1	1	DCS_INVALID_COMMAND_TOKEN	match_all	h_emergency_safe
211	1	1	1	DCS_INVALID_EXEC_TOKEN	match_all	h_emergency_safe
214	1	1	1	DCS_INVALID_POKE_OFFSET	Match_all	h_emergency_safe
217	1	1	1	DCS_CALL_DEPTH_EXCEEDED	match_all	gotosafe
220	1	-	1	DCS_NO_SUCH_RTS	match_all	noaction

B.9 PT Configuration ID Table

This table is used to derive the sequence of exposures to which the UVOT Mode, supplied in the FONEXTOBSINFO, corresponds. It consists of a series of data blocks, each linked to the next by a memory pointer, although (for release 10 of the UVOT ICU code) they are actually contiguous in memory. As the list is searched linearly, the less frequently used UVOT Modes as stored in the later blocks. Each block is terminated with a CRC for the whole block. Within each block, there are a series of contiguous three word records of the following form.

Word Offset	Description
0	UVOT Mode (0 => 0x7ffE) – **Note**: 1=>8 are used for safe pointing, settling and finding exposures.
1	Location of an exposure configuration in the PT Configurations table (see above)
2	

The ICU determines the exposure configurations required for a given snapshot by scanning this set of linked blocks. On finding a record within a block that contains an UVOT Mode matching that in the associated FONEXTOBSINFO, the code scans *only* the rest of that block for any further records that match the UVOT Mode. The resulting list of exposures is used for the current snapshot. If the UVOT mode is greater than or equal to 0x1000, all the separate requested exposure times in the indicated exposures are summed. This number is compared to the time available for observing that is also supplied in the FONEXTOBSINFO record, and the exposure times scaled accordingly to fit. For other values of UVOT mode, the exposure times are unaltered. The exposures are then executed in the order given in this table.

Each block is terminated with a record of the following form that indicates the location of the next block.

Word Offset	Description
0	Set to 0x7FFF to indicate it is a pointer block
1	Location of next block within the PT Configurations ID table **ALTERNATIVELY,** set to zero to indicate this is the last block.
2	

B.10 Count Rate Table

The contents of this table are estimated count rates for a magnitude 10 object as a function of filter number and colour index used by the star catalogue. They are used by the UVOT ICU to calculate expected fluxes from known sources in the field of view, such as catalogued stars and planets.

Word Offsets	Description
0	Count rate * 100 for the Blocked filter for a colour index of 0 (B-V < -0.33)
1	
2	Count rate * 100 for the Blocked filter for a colour index of 1 (-0.33 <= B-V < -0.27)
3	
4	Count rate * 100 for the Blocked filter for a colour index of 2 (-0.27 <= B-V < -0.17)
5	
6	Count rate * 100 for the Blocked filter for a colour index of 3 (-0.17 <= B-V < -0.11)
7	
8	Count rate * 100 for the Blocked filter for a colour index of 4 (-0.11 <= B-V < 0.01)
9	
10	Count rate * 100 for the Blocked filter for a colour index of 5 (-0.01 <= B-V < 0.15)
11	
12	Count rate * 100 for the Blocked filter for a colour index of 6 (-0.15 <= B-V < 0.30)
13	
14	Count rate * 100 for the Blocked filter for a colour index of 7 (-0.30 <= B-V < 0.44)
15	
16	Count rate * 100 for the Blocked filter for a colour index of 8 (-0.44 <= B-V < 0.52)
17	
18	Count rate * 100 for the Blocked filter for a colour index of 9 (-0.52 <= B-V < 0.63)
19	
20	Count rate * 100 for the Blocked filter for a colour index of 10 (-0.63 <= B-V < 0.68)
21	
22	Count rate * 100 for the Blocked filter for a colour index of 11 (-0.68 <= B-V < 0.74)
23	
24	Count rate * 100 for the Blocked filter for a colour index of 12 (-0.74 <= B-V < 0.81)
25	
26	Count rate * 100 for the Blocked filter for a colour index of 13 (-0.81 <= B-V < 1.10)
27	
28	Count rate * 100 for the Blocked filter for a colour index of 13 (-1.10 <= B-V < 1.49)
29	
30	Count rate * 100 for the Blocked filter for a colour index of 15 (-1.49 <= B-V < 01.64)
31	

Word Offsets	Description
32	Count rate * 100 for the Blocked filter for a colour index of 16 (-B-V >= 1.64)
33	
34-67	Count rates * 100 for the Grism1uv filter.
68-101	Count rates * 100 for the UVW2 filter.
102-135	Count rates * 100 for the V filter.
136-169	Count rates * 100 for the UVM2 filter.
170-203	Count rates * 100 for the Grism2visible filter.
204-237	Count rates * 100 for the UVW1 filter.
238-271	Count rates * 100 for the U filter.
272-305	Count rates * 100 for the Magnifier.
306-339	Count rates * 100 for the B filter.
340-373	Count rates * 100 for the White filter.
374	CRC for entire table

B.11 Avoidance Angle Table

This table is used to store the avoidance angles used by the ICU to determine if a angular constraint violation has occurred. The units are minutes of arc. If the angular separation of the pointing position from the object listed is less than the angle given, then a constraint violation has occurred.

Note – the working copy of this table is located in RAM, starting at address 0xA00. It is therefore possible to change locations in this table 'on the fly' using the `/iicuload` command e.g.

```
/iicuload1 mid=0,offset=0xa00+<word offset>,data=<value>
```

where the items in <> are replaced with the relevant values.

An avoidance angle of zero disables the test.

Word Offset	Description
0	Avoidance angle for Mercury **– units are minutes of arc**
1	Avoidance angle for Venus**– units are minutes of arc**
2	Avoidance angle for Mars**– units are minutes of arc**
3	Avoidance angle for Jupiter**– units are minutes of arc**
4	Avoidance angle for Saturn**– units are minutes of arc**
5	Avoidance angle for Uranus**– units are minutes of arc**
6	Avoidance angle for Neptune**– units are minutes of arc**
7	Avoidance angle for Pluto**– units are minutes of arc**
8	Avoidance angle for Sun**– units are minutes of arc**
9	Avoidance angle for Moon**– units are minutes of arc**
10	Avoidance angle for Earth**– units are minutes of arc**
11-145	Followed by 135 entries similar entries giving the avoidance angles for objects with magnitude codes in the order 0 => 134 as used in the on-board star catalogue – see Magnitude Code table (D.5) in the Message Tables section
146	CRC for whole table

B.12 State Change Table

In order to achieve its goals, the ICU must successfully transition the UVOT between several instrument configuration states.

Each state transition is performed by a RTS. This look-up table contains a list of those RTSs against the requested transition. For those transitions that may be autonomous – see below – it also contains the required state of internal ICU flags for that particular transition to take place. Note, these items are shown with a grey background in the table below.

This table is used in two ways.

1. *On command*: The table is scanned for a match against both the current state and the requested state. If a match is found, the relevant RTS is selected and executed. If no match is found, the command is rejected.
2. *Autonomously*: Certain events will cause the ICU to self-select the required state transition. It compares internal ICU flags against the expected values given in this table. If a match is found, the associated RTS is executed. If no match is found, no action is performed. The events that trigger such a response are:
    - The settled flag becoming false in the SISCATTITUDE record.
    - The reception of the FONEXTOBSINFO message.
    - The ‘within 10 arc minutes of target’ flag being set to true in the SISCATTITUDE record.
    - Entry or exit from the SAA, as shown by a flag in the SISCATTITUDE record.
    - The Safe Hold flag being set to true in the SISCATTITUDE record.

The table consists of a series of records, one for every ‘current state’/‘next state’ combination. Each record has the following format. Unless stated otherwise, values used in the table are 0 = false, 1 = true, 255 = Don’t Care. The records are ordered by first the numerical values of ‘Current State’ and then ‘Next State’.

Word Offset	Description	Category
0	Current state (see table D.8)	State Information
1	Next state (see table D.8)	
2	Out of safe enabled	Whether various transitions are allowed
3	AT observations enabled	
4	PT observation enabled	
5	Safepoint Observations enabled	
6	Autonomous transition allowed	
7	In SAA	Information derived from the ACS record
8	Within 10 Arc Min	
9	Settled	
10	Power Down Safe	
11	NEW AT SLEW	Derived from the FONEXTOBSINFO
12	AT/PT/SAFEPOINT = 0/1/2	
13	Slew warning received	Internal ICU Flags
14	Finding Chart acquired or abandoned	
15	RTS/no action/not allowed = RTS code - see table D.1/0/0x7ffe	RTS to run

B.13 Standard Table

This table contains a miscellany of numerical values, describing various systems that do not readily belong in the other tables.

Note – the working copy of this table is located in RAM, starting at address 0xb7f. It is therefore possible to change locations in this table 'on the fly' using the `/iicuload` command e.g.

```
/iicuload1 mid=0,offset=0xb7f+<word offset>,data=<value>
```

where the items in <> are replaced with the relevant values.

Word Offset	**Description**	
	TMPSU	
0	Temperature Control Circuit Status (0/1 = off/on)	
1	Coarse Position Sensor Current (range 0 => 15)	
	BPE ANALOGUE	
2	Fine Position Sensor Current (range 0 => 15)	
3	Vmcp1 Nomimal	HV Nominal Settings (volts)
4	Vmcp23 Nominal	
5	Vcathode Nominal	
6	Vmcp1 SAA	HV Settings whilst in SAA (volts)
7	Vmcp23 SAA	
8	Vcathode SAA	
9	Vmcp1 SLEW	HV Settings whilst slewing (volts)
10	Vmcp23 SLEW	
11	Vcathode SLEW	
	BPE DIGITAL	
12	xlow	Window configuration - defaults to full frame (units CCD pixels)
13	ylow	
14	xsize	
15	ysize	
16	Channel Boundary X0	Channel Boundaries (range –1000 => 1000) X0 <= X1 ... <= X8 Y0 <= Y1 ... <= Y8
17	Channel Boundary X1	
18	Channel Boundary X2	
19	Channel Boundary X3	
20	Channel Boundary X4	
21	Channel Boundary X5	
22	Channel Boundary X6	
23	Channel Boundary X7	
24	Channel Boundary X8	
25	Channel Boundary Y0	
26	Channel Boundary Y1	
27	Channel Boundary Y2	
28	Channel Boundary Y3	
29	Channel Boundary Y4	

Word Offset	Description	
30	Channel Boundary Y5	
31	Channel Boundary Y6	
32	Channel Boundary Y7	
33	Channel Boundary Y8	
34	Not Used	
35		
36		
	BPE Safety Circuit	
37	PCTHOLD (range 0 => 0x7f)	Safety Circuit thresholds (see section 1.2.2.5.2)
38	FCTHOLD (Range 0 => 0x1f)	
39	STHOLD (range 0 => 0xff)	
40	RTHOLD (range 0 => 0xff)	
	General Detector Information	
41	Radius of Field of View (arcmin)	
42	Boresight offset x – centroided pixels from centre at (1024,1024)	
43	Boresight offset y - centroided pixels from centre at (1024,1024)	
44	Boresight Offset in Roll in arcmin - same handedness as ROLL.	
45	Damage limit (counts)	
46		
47	Standard Settling UVOT mode	
48	standard Finding UVOT mode	
49	Standard DPU Exposure 'slack' in ticks of 1/5 second units	
	Late Additions	
50	Maximum attempts at Finding Chart before abandoning	
51	Event detection threshold (0 => 255)	
52	Acceptable differential drift during observation	units of arcmin
53	Acceptable overall drift during observation	
54	Vcathode default ramp rate	Volts/seconds
55	Vmcp1 default ramp rate	
56	Vmcp23 default ramp rate	
57	Vcathode tolerance	Volts
58	Vmcp1 tolerance	
59	Vmcp23 tolerance	
	HV ***Raw*** Limit Ranges (Safe, Slew, SAA, Operational)	
60	Vcathode nominal value	Safe state. Uncalibrated units.
61	Vcathode error value	
62	Vmcp1 nominal value	
63	Vmcp1 error value	
64	Vmcp23 nominal value	
65	Vmcp23 error value	

Word Offset	Description	
66	Vcathode nominal value	Slew state Uncalibrated units
67	Vcathode error valu	
68	Vmcp1 nominal value	
69	Vmcp1 error value	
70	Vmcp23 nominal value	
71	Vmcp23 error value	
72	Vcathode nominal value	SAA state Uncalibrated units
73	Vcathode error value	
74	Vmcp1 nominal value	
75	Vmcp1 error value	
76	Vmcp23 nominal value	
77	Vmcp23 error value	
78	Vcathode nominal value	Nominal. Uncalibrated units.
79	Vcathode error value	
80	Vmcp1 nominal value	
81	Vmcp1 error value	
82	Vmcp23 nominal value	
83	Vmcp23 error value	
84	Settling Exposure Catalogue Search Radius	Units arc minutes
85	Settling Target-Pointing Limit	
	Tolerance on HV noise	
86	Vcathode noise tolerance	Volts
87	Vmcp1 noise tolerance	
88	Vmcp23 nois tolerance	
	Exposure overheads (includes DPU 'slack' and BAT warning waits)	
89	AT Exposure overhead	Units are seconds
90	PT Exposure overhead	
	Exposure Thresholds (used when processing GRBFLUXINFO to determine if bright)	
91	Setting Exposure Threshold	
92		
93	FC Exposure Threshold	
94		
95	Bright GRB Threshold	
96		
	RTS Index	
97	Address of start of RTS Index (table B.4)	
98		
	Warning BAT about Filter wheel movements	
99	BAT warning delay, 0 = disabled, units: 0.1 s – **see note 1.**	
100	Early in burst definition is <= this value, units: 1 s	

Word Offset	Description
Config Addresses	
101	Address of start of AT Configs (table B.6)
102	
103	Address of start of PT Configs (table B.7)
104	
Grism Positions	
105	UV (Nomimal Value 200)
106	Visible (Nominal value 1000)
XRT Position Calculation Axes Bit Flips	
107	Invert sense of x/y/roll = 1/2/4 masks
Spare	
108	Maximum Count Rate
109	Safety circuit Pcthold value in slews
110	Earth avoidance angle in slews (minutes of arc)
110 => 126	Spare locations
127	CRC of Table

Notes

The BAT delay should not be any higher that 3 seconds. If this occurs, the filter wheel timeouts may trigger on time-consuming movements e.g. going to datum.

Appendix C Error and Event Messages

C.1 Overview

(**NOTE**: Normally, there is an automatic response by the ICU to any errors. The parameters associated with each error are normally interpreted by MSSL staff)

Listed below, in alphabetical order, are the ICU NHK (**N**on periodic **H**ouse**K**eeping) and Verification Error messages that may be displayed on the ITOS icuevents window (the error/event code for these messages are given in brackets). The DPU event messages, forwarded via the ICU, are also given for convenience. There are three types of ICU messages:

1. an Event Message that simply indicates that something useful happened
2. a Major Anomaly message that indicates an error, usually serious, occurred.
3. a Verification Error message, which may be either an Unsuccessful Acceptance or Unsuccessful Execution. These are issued when a command with the indicated APID and Function Code has been rejected or has failed to execute respectively- see the Command Table (appendix D.2) for a list of the associated APIDs and Functions Codes (F/C).

Details of the 0 to 3 associated parameters are given with each message. **Note:** the value of the parameters is always displayed in hex.

Many messages refer to an RTS (Relative Time Sequence) by number. The number and name correspondence (in number order) are given in the RTS (appendix D.1).

Each NHK message also has a package code detailing which code module (usually an Ada Package) issued the message. These are listed in numerical order in the Message Codes appendix D.16.

The ICU error and event codes are also listed in numerical order in the Message Codes appendix D.14.

Some error messages result in the ICU performing an autonomous corrective action. This may take the form of running an RTS, copying the error message to TDRSS to alert the ground, forcing the ICU to stay in the Safe state or a combination of all of these. Where applicable, details are given with the appropriate error message. They are for release 10 of the ICU code. The precise action is determined one of three ways.

1. From the details given in the errors action table in EEPROM-B (described in appendix B.8).
2. In the case of a Limit Violation, from the Limit Check table stored in EEPROM-A. (described in appendix A.4)
3. From the time-out action detailed in the currently running RTS if an expected action fail to occur.

C.2 5 ACS Packets Missing (8f hex)

No SISCATTITUDE packets were counted in 1s. This is caused by loss of Spacecraft SISCATTITUDE packets or the UVOT ICU telecommand software is not working or being slowed by other tasks. There are no parameters associated with this message.

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.3 Ada Exception (ec hex)

An Ada exception has occurred.

P1=FIRST_EXCEPTION the first exception of a sequence of exceptions
P2=LAST_EXCEPTION the last exception of a sequence of exceptions
P3=FIRST_PROGRESS the last progress line passed at the time of the first exception

The format of the parameters, in hex, is of the form PPNN. PP is a code (see the Message Codes appendix D.16) indicating which Ada package issued the exception or in which the progress line is located. NN is used in two ways. For exceptions, it indicates both which procedure in that package issued the exception and what type. The precise values used can only be obtained by examining the code and will change with each version. For progress lines, NN indicates the procedure and the code location where the progress line was executed. The precise values used are obtained by examining the code.

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.4 Already at Requested HV (15 hex)

This event message is issued when, within the default tolerance, the HV channel is already at the requested voltage. The parameters are the same as for the HV Ramp Failed message (appendix C.68).

C.5 Angular Constraint Violation (54 hex)

This error message is issued when an angular constraint has been violated.

P1 = Earth angular distance from pointing position in degrees and hex.
P2 = Sun angular distance from pointing position in degrees and hex.
P3 = Moon angular distance from pointing position in degrees and hex.

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.6 Automatic State Trans'n Req'd (53 hex)

This event message is issued when an event on the spacecraft has resulted in the ICU making an autonomous decision to transition to another state.

P1 = RTS number in hex to be executed to perform the state transit (see RTS codes in the message code appendix D.1)
P2 = Current State (see state codes, appendix D.8,in the Message Codes appendix).
P3 = AA (hex)

C.7 Bad Data in EEPROM (93 hex)

This error message is issued when bad data (i.e. nonsensical) has been detected in an EEPROM section. This is not the same as Corrupted EEPROM Data. That is caused by a CRC failure.

The ICU response is detailed in the Errors Action Table, see appendix B.8.

Description	P1 (hex)	P2 (hex)	P3 (hex)
HV_CALIB_ID	1	see P1 for HV Ramp Failed	0
Limit Table	2	see P1 for Limit Exceeded	0
Heater	3	See Heater Codes in the Message Codes appendix D.9	0
CMD_DTB_ID	B	Command offset within the table	Length of command dataset
RTS_NDX_HDR_ID	10	see RTS Table in the message code appendix D.1	Index Header Length
RTS_NDX_ID	11	see RTS Table in the message code appendix D.1	Section Length Detected
HV_CALIB_ID2	21	see P1 for HV Ramp Failed	0

C.8 Bad Value (8e hex)

Several IEEE format numbers are supplied to the ICU via the spacecraft. When converted into the internal floating-point format used by the ICU and found to be out of the expected range, this error message is issued. Parameters p2 and p3 are always zero.

IEEE Number Description	P1 (hex) = ID
ACS_PACKET_RA	1
ACS_PACKET_DEC	2
ACS_PACKET_ROLL	3
ACS_PACKET_LATITUDE	4
ACS_PACKET_LONGITUDE	5
XRTPOS_XRT_RA	6
XRTPOS_XRT_DEC	7
ACS_BUS_VOLTAGE	8
NEXTOBS_NEXT_RA	9
NEXTOBS_NEXT_DEC	a
NEXTOBS_NEXT_ROLL	b
BATGRBFLUX_PEAK	c

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.9 BATGRBFLUXINFO Proc Stat (58 hex)

This message is issued as a major anomaly if no BATGRBFLUXINFO message is received from the BAT at the start of a burst, or as an event message if that message is received. The parameters summarize the result of the processing of the message.

P1 = 0/1 = Not OK/OK to proceed with the settling exposure respectively.
P2 = 0/1 = Not OK/OK to proceed with the finding chart exposure respectively.
P3 = 0/1 = Proceed with normal exposure sequence/Bright GRB exposure sequence respectively.

C.10 Boot Dump Report SID (d9 hex)

This returns a memory dump of some key variables to assist in the diagnose of crashes

C.11 Bright Object Present (46 hex)

This major anomaly message is issued if, on updating the sun, moon and planets positions (usually once-per-slew via an exec call to bright_planets from an RTS) it is detected than one or more of those sources is now violating its angular constraint. Note that it is an event message so that any error handling is performed by the calling RTS rather than by the table controlled NHK error handling mechanisms.

P1 = 1 => 10 (hex a) defines which bright object- see Planet Code Table D.7 in the Message Codes appendix.
P2 = Angular distance from current pointing position of source (in minutes of arc and hex).
P3 = Current UVOT Mode.

The ICU response is detailed in the Errors Action Table, see appendix B.8

C.12 Bright Star Report SID (da hex)

This message is issued to indicate that, relative to the predicted target position and according to the on-board catalogue, the described bright star is within its tabulated angle of avoidance. This normally precludes a safe observation as the maximum safe exposure length is then set to zero. The format of this message is non-standard. The fields are the same as in the Catalogue Star message described in appendix C.15.

C.13 Bright Star Store Exhausted (4f hex)

This event message is issued when the on-board working copy of catalogued stars in the current target field of view has exceeded its memory allocation. This normally precludes a safe observation as the maximum safe exposure length is then set to zero.

P1 = the number of stars found so far in the target field of view at the time the condition was detected.
P2 = the maximum number of stars allowed in the working copy (this should be one less than P1).
P3 = the current UVOT Mode.

C.14 Busy (82 hex)

This verification failure message is issued when a command has been rejected because an on-board process is still busy performing an earlier command. In this case, the 2 parameters associated with this type of message are always set to zero. However, the TC APID and TC Function Code also given in the message specify which process was still busy.

TC APID (hex)	TC Function Code (hex)	Comments
660 or 670	1	The BPE centroid table-loading task is still loading.
660 or 670	3	The BPE window table-loading task is still loading.
660 or 670	d	The HV ramping task has not completed a previous ramp.
660 or 670	44 to 49	The filter-wheel moving task is busy.
662 or 672	0	The load ICU memory task is busy.
662 or 672	1	The dump ICU memory task is busy.
66a or 67a	Any	The ICU-DPU command queue is full, probably because the DPU is busy.

Note: an APID in the range 670 to 67f (hex) indicates that the command was issued on board from an RTS.

C.15 Catalogue Star (dc hex)

This message is issued to indicate that the predicted field of view, according to the on-board catalogue, has the described source located in it. The format of this message is non-standard. The fields are described below.

RA: the source's RA expressed and rounded up to the nearest minute of arc (hex).

Dec: the source's (DEC+100 degrees) rounded up and expressed to the nearest minute of arc (hex).

Mag: A code number (in hex) representing the magnitude of the source - see the Magnitude Code Table in the Message Codes appendix D.5.

Ang Dist: The source's offset from the predicted position rounded up to the nearest minute of arc (hex).

Col Index: A code number (in hex) representing the B-V 'colour' of the source - see the Colour Index Table D.6 in the Message Codes appendix.

Sky Area: If it has the value 7005 or 7006 hex, then this indicates that Uranus or Neptune respectively is in the predicted field of view. Otherwise, it is a code number (in hex) representing the individual sky area in the main catalogue containing the source. To work out which

Convert it to a decimal value

Left pad it with zeros to make a 5 digit number

If the first digit is 1, it is a southern hemisphere area, otherwise it is northern

The second and third digits are the declination band (see below).

The fourth and fifth digits are the right ascension division (see below)

So for example, 0x04C0 becomes decimal 01216, which indicates sky area north, declination band 12 and right ascension division 16.

Each hemisphere is split into 22 declination bands, numbered 0 to 21 starting from the equator and going to the pole. Each band is 255 arc-minute wide except for the polar bands, which are 45 arc minute wide. Any source within half an arc minute of the equator is taken to be in the first band of the northern hemisphere only. Each declination band is divided into a number of equal right ascension divisions, the number depending on how the width of the field of view changes with respect to right ascension at each declination.

Declination Band	Right Ascension Divisions
0 to 4	90
5 and 6	80
7	75
8 to 10	72
11	60
12	54
13	50
14	45
15	40
16	36
17	27
18	24
19	15
20	8
21	2

Within each declination band, the right ascension divisions are numbered from 0 upwards starting at RA 0.0 degrees. So for example, sky area south 12 30 would be in the southern hemisphere in declination band 12, which extends from 51 degrees to 55 degrees 15 arc minute, and right ascension division 30, which in this band extends from 200 degrees to 206 degrees 40 arc min.

Offsets: Contains the offsets of the source from the origin of the sky area, the first byte is the RA offset and the second is the declination offset. Each sky area is subdivided into a 255 by 255 grid and every source assigned to its nearest grid point. The RA and declination offsets stored in the catalogue are the coordinates of this grid point within the sky area, counting from 0 to 254 in each axis. Positional accuracy in the field of view in either axis is to half an arc minute or better at all times.

If the source is Uranus or Neptune, then this value is always zero.

C.16 Centroid Table Already Loaded (5e hex)

This event message is issued when the parameters of a load centroid table command are the same as the on-board record of what was last loaded. The table load is therefore suppressed. There are no parameters associated with this message.

C.17 Centroid Table Load Aborted (6e hex)

This event message is issued as confirmation when a load centroid table command is stopped by command.

C.18 Centroid Table Load Failure (64 hex)

This error message is issued when a centroid table load fails. This happens when there has been 1) MACSbus errors when writing or reading the table or 2) verification errors caused by a mismatch between what was found in the table and what was expected.

P1	Macs bus Errors	Verification Errors
0	Yes	No
1	No	Yes
2	Yes	Yes

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.19 Centroid Table Load OK (63 hex)

This event message is issued as confirmation when a load centroid table command has completed successfully.

C.20 Corrupted EEPROM Data (92 hex)

This error message is issued when an area of EEPROM has failed its CRC check (the CRC for any of the designated areas should always be zero).

The ICU response is detailed by the Errors Action Table, see appendix B.8.

Description	P1 = ID (Hex)	P2 (hex)	P3 (hex)
HV_CALIB_ID	1	CRC Found	0
LIMIT_CHECK_TABLE_ID:	2	0	0
HEATER_TABLE_ID	3	0	0
STARCAT_ID:	4	Star Catalogue Section ID	CRC found
AVOIDANCE_ANGLES_TABLE_ID	5	CRC found	0
AT_CONFIG_ID:	7	AT Block	CRC fund
PT_CONFIG_ID:	8	0	CRC found
STANDARD_TABLE_ID	9	CRC found	0
STATE_TABLE_ID:	A	CRC found	0
CMD_DTB_ID:	B	CMD offset	Value at Offset
RTS_STORE_ID:	C	RTS Number	0
ERRORS_ACTION_TABLE_ID	D	CRC found	0
COUNT_RATE_TABLE_ID	E	CRC found	0

PT_CONFIG_ID_ID	F	PT Mode	CRC found
RTS_NDX_ID:	10	RTS Number	Section Number
RTS_NDX_HDR_ID:	11	RTS Number	Header Length
HV_CALIB_2_ID	21	CRC Found	0
LIMIT_CHECK_TABLE_2_ID:	22	0	0
HEATER_TABLE_2_ID	23	0	0

C.21 Count Rate too High (dd hex)

This event message is sent when the calculated count rate for a catalogued star in the field of view is too high in this filter to safely proceed.

P1 = Star number counting from one and indicates which associated Catalogue Star message to examine for object details.
P2 = 0.
P3 = 0.

C.22 DCS Aborting (70 hex)

This event message is issued when an RTS is requested to stop, either by direct command or if an event has occurred that requires a higher priority RTS to run.

P1 = Current RTS number (in hex) - see RTS table (appendix D.1) in the Message Codes appendix.

C.23 DCS Call Depth Exceeded (74 hex)

This error message is issued when an attempt is made to call an RTS from another RTS that is too deeply nested.

P1 is set to hex C.
P2 = Current RTS number (in hex) - see RTS table (appendix D.1) in the Message Codes appendix,

P3 = Call depth (in hex).

The ICU response is detailed in the Errors Action Table.

C.24 DCS Event Time-out (81 hex)

The event message is issued when an RTS is waiting for an event (e.g. the end of a filter wheel movement) that does not occur within the maximum anticipated time.

P1 = Event code (see DCS event code table, appendix D.10, in the Message Codes appendix).
P2 = Current RTS number (in hex) - see RTS table, appendix D.1, in the Message Codes appendix.
P3 = Current line number (in hex) within that RTS.

The ICU's response to this message is determined by the logic of the RTS it happens to be running.

For a timeout on the 'within 10 arc min flag, 'settled' flag, arrival of a FONEXTOBSINFO record or the start of a slew the ICU runs the gotosafe_tdrss RTS.

For a timeout on a filter wheel move, the ICU will attempt to recover by moving to the datum position and then retrying. If that fails, it runs the gotosafe RTS.

For a timeout on a HV ramp, the ICU will take appropriate action to return the ICU to the Safe state.

For a timeout on a centroid or window table load, after a retry, the gotosafe RTS will be run.

For a timeout on a DPU Ack or DPU mode ready, the ICU will run the blocked_tdrss RTS.

C.25 DCS Exiting RTS (83 hex)

This event message is issued when an RTS completes normally.

P1 = Current RTS number (in hex) - see RTS table, appendix D.1, in the Message Codes appendix.

C.26 DCS Insufficient Priority (76 hex)

This event message is issued when an RTS is unable to run because another RTS of a higher priority is already running.

P1 = RTS number of rejected RTS (in hex) - see RTS table, appendix D.1, in the Message Codes appendix.
P2 = Priority of currently running RTS (hex).
P3 = Priority of rejected RTS (hex).

C.27 DCS Invalid Command Token (73 hex)

This error message is issued when an attempt is made to execute an invalid command token. This usually occurs if there has been a corruption of EEPROM.

P1 = the invalid command token (in hex).
P2 = the most significant word of the EEPROM address containing the token.
P3 = the least significant word of the EEPROM address containing the token.

The ICU response is detailed in the Errors Action Table, appendix B.8.

C.28 DCS Invalid Exec Token (86 hex)

This error message is issued when an attempt is made to execute an invalid exec function token. This usually occurs if there has been a corruption of EEPROM.

P1 = the invalid exec token (in hex).
P2 = the most significant word of the EEPROM address containing the token.
P3 = the least significant word of the EEPROM address containing the token.

The ICU response is detailed in the Errors Action Table, appendix B.8.

C.29 DCS Invalid Poke Offset (87 hex)

This error message is issued when an attempt is made to ‘poke’ to an address outside the valid range for RTS access. This usually occurs if there has been a corruption of EEPROM.

P1 = the invalid poke offset relative to the valid address range base (in hex).
P2 = the most significant word of the EEPROM address containing the token.
P3 = the least significant word of the EEPROM address containing the token.

The ICU response is detailed in the Errors Action Table, appendix B.8.

C.30 DCS No Such RTS (71 hex)

This error message is issued when an attempt is made to run a non-existent RTS.

P1 = RTS number of rejected RTS (in hex) - see RTS table, appendix D.1, in the Message Codes appendix.

The ICU response is detailed in the Errors Action Table, appendix B.8.

C.31 DCS RTS Already Running (80 hex)

This event message is issued when an attempt is made to run an RTS that is already running. The run request is ignored.

P1 = RTS number (in hex) - see RTS table, appendix D.1, in the message code appendix.

C.32 DCS Stack Exceeded (72 hex)

This error message is issued when the stack depth of the on-board 'virtual machine' that is used to execute RTS is exceeded.

The circumstances of the detection lead to different values of the parameters. If P3 is zero, then the condition was detected whilst the stack pointer was being increased. If P3 is 1 then it was detected just prior to an attempt to place the current RTS argument number P2 out of a total of P3 on the stack.

The ICU response is detailed in the Errors Action Table, appendix B.8.

C.33 DCS Starting RTS (79 hex)

This event message is issued as an RTS (defined by P1 - see RTS table (appendix D.1) in the Message Codes appendix) starts. P2 and P3 are set to zero.

C.34 DCS State Table Match Fail (7a hex)

This error message is issued when the ICU is unable to decide what autonomous transition is should perform. There are no parameters associated with the message.

C.35 DCS Too Few RTS Arguments (85 hex)

This error message is returned if less than the expected number of arguments are supplied in a call to an RTS.

P1 = Number of supplied arguments.
P2 = Argument number at which the problem was detected.

C.36 Debug Output (f0 hex)

The value of the parameters is determined by the values the programmer has chosen to supply.

C.37 DM at Requested Position (68 hex)

This event message is issued as confirmation that a dichroic move was successful.

P1 = 0 if it was being moved to its maximum excursion, otherwise it was being moved a requested number of steps.
P2 = 1 if it was being moved in a positive direction (prime to redundant), 3 if it was being moved in a negative direction (redundant to prime).

C.38 DM Lost Position (6a hex)

This error message is issued when a dichroic move was aborted on command.

P1 = 0 if it was being moved to its maximum excursion, otherwise it was being moved a requested number of steps.
P2 = 1 if it was being moved in a positive direction (prime to redundant), 3 if it was being moved in a negative direction (redundant to prime).

The ICU response is detailed in the Errors Action Table, appendix B.8.

C.39 DPU Ack/Nack (No error/event code displayed)

This DPU event message is forwarded via the ICU when the DPU receives a command from the ICU. ACK is displayed if the checksum was correct, NAK if was not. The function code of the received command is also shown. For full details, see 'ICD for the ICU/DPU Protocol for the UVOT'.

C.40 DPU Bad Bounds (36 hex)

This error message is issued when the ICU has detected that the channel boundaries supplied by the DPU are invalid.

P1 is always set to 0xffff, p2 and p3 to zero.

C.41 DPU BootCmplt (No error/event code displayed)

This DPU event message is forwarded via the ICU immediately after the DPU has completed the boot process. For full details, see 'ICD for the ICU/DPU Protocol for the UVOT'.

C.42 DPU ChnBndClc (No error/event code displayed)

This DPU event message is sent to the ICU to inform it of the channel boundaries produced in the Channel Boundaries Engineering mode. For full details, see 'ICD for the ICU/DPU Protocol for the UVOT'.

C.43 DPU Inconsistent APID ID (34 hex)

All message packets received by the ICU from the DPU should have an APID of the form 0x380+y and contain a Message Identifier field of the form 0x0C00+z where y should be equal to z. This major anomaly message is issued of this is not the case. Both y and z should be the function code of the message and therefore should be in the range 0 => 255.

P1 = APID received.
P2 = Message Identifier received.
P3 = 0.

The ICU response is detailed in the Errors Action Table, appendix B.8.

C.44 DPU Incorrect ACK (32 hex)

All command packets sent to the DPU from the ICU should be acknowledged with an ACK or NAK message. This major anomaly packet is issued when an ACK is received but its function code field does not contain the function code of the command that was sent.

P1 = Function Code sent.
P2 = 0.
P3 = 0.

The ICU response is detailed in the Errors Action Table, appendix B.8.

C.45 DPU Invalid APID or ID (35 hex)

All message packets received by the ICU from the DPU should have an APID of the form 0x380+y and contain a Message Identifier field of the form 0x0C00+z where y should be equal to z. Both y and z should be the function code of the message and therefore should be in the range 0 => 255. This major anomaly message is issued if either the APID or Message Identifier is outside the expected range.

P1 = APID received.
P2 = Message Identifier received.
P3 = 0.

The ICU response is detailed in the Errors Action Table, appendix B.8.

C.46 DPU Mode Cmpl (No error/event code displayed)

This DPU event message is forwarded via the ICU when all events for a commanded mode have been processed. Mode, Submode received by the DPU are displayed, together with the completion status of NORMAL, STOPPED, ABORTED or ERROR. For full details, see 'ICD for the ICU/DPU Protocol for the UVOT'. For full details, see 'ICD for the ICU/DPU Protocol for the UVOT'.

C.47 DPU Mode Rdy (No error/event code displayed)

This DPU event message is forwarded via the ICU when the DPU is ready to acquire new event data in the most recently specified Mode command. For full details, see 'ICD for the ICU/DPU Protocol for the UVOT'.

C.48 DPU NAK (30 hex)

All command packets sent to the DPU from the ICU should be acknowledged with an ACK or NAK message. This major anomaly packet is issued when an NAK is received.

P1 = Function Code sent.
P2 = 0.
P3 = 0.

The ICU response is detailed in the Errors Action Table, appendix B.8.

C.49 DPU Time-out (31 hex)

All command packets sent to the DPU from the ICU should be acknowledged with an ACK or NAK message. This major anomaly packet is issued when this does not happen a) after 1 second in the case of the Mode command or b) for all other commands, after 1 second followed by a resend of the command and then another second has passed.

P1 = Function Code sent.
P2 = 0.
P3 = 0.

The ICU response is detailed in the Errors Action Table, appendix B.8.

C.50 DPU Unexpected ACK/NAK (33 hex)

All command packets sent to the DPU from the ICU should be acknowledged with an ACK or NAK message. This major anomaly packet is issued when an ACK or NAK is received by the ICU when it was not expecting one.

P1 = Function Code in ACK/NAK message.
P2 = 0.
P3 = 0.

C.51 DPU Upld Strt (No error/event code displayed)

This DPU event message is forwarded via the ICU immediately before the DPU starts an upload. For full details, see 'ICD for the ICU/DPU Protocol for the UVOT'.

C.52 DPU Upld End (No error/event code displayed)

This DPU event message forwarded via the ICU immediately after the DPU ends an upload. For full details, see 'ICD for the ICU/DPU Protocol for the UVOT'.

C.53 EEPROM Code Compare Error (a7 hex)

This error message is issued when, after writing data to EEPROM A and reading it back, the two did not compare well.

P1 = word written.
P2 = word read back that did not match.

C.54 EEPROM Star Cat Compare Error (a8 hex)

This error message is issued that, after writing data to EEPROM B and reading it back, the two did not compare.

P1 = word written.
P2 = word read back that didn't match.

C.55 EEPROM Write Error (88 hex)

This error message is issued when there is a lock or timeout error when writing to the EEPROM.

P1 = Error code.
P2 = MID (the memory identifier).

C.56 Exit from Safe Forbidden (52 hex)

This event message is issued when an attempt has been made to exit from the safe state after an error condition has occurred which makes it inadvisable to do so without first resetting the ICU. The state change request will not be obeyed.

P1 = Current State (should be 1 - see state table codes (appendix D.8) in the Message codes appendix).
P2 = Requested State (see state table codes (appendix D.8) in the Message codes appendix)
P3 = 0.

C.57 Flood LEDs Turned Off (5d hex)

This error message is sent if the filter wheel is being moved and the flood led is at a non-zero value. The flood led is set to zero before the filter wheel is moved. There are no associated parameters.

C.58 FONEXTOBSINFO Processing Stat (57 hex)

If issued as an event message then the processing of the FONEXTOBSINFO record was nominal. If issued as an error message then the processing was not optimal. An additional error message detailing the nature of the problem (e.g. supplied target RA and DEC are out of range) will also be present.

Description	**P1 (Hex)**	**P2 (Hex)**	**P3 (Hex)**
Event Message	UVOT Mode	1 = Is New At Slew	Next Obs = 0 /1 /10 =AT/ PT/ IDLE
Error Message	N/A	N/A	N/A

C.59 Forbidden State RTS (42 hex)

This error message is issued when a state change command has been issued and the on-board table of transitions (described in appendix B.12) indicates that it is not allowed.

P1 = Current State (see state table codes - appendix B.8 - in the Message Codes appendix).
P2 = Requested State (see state table codes - appendix B.8 - in the Message Codes appendix).
P3 = 0.

The ICU response is detailed in the Errors Action Table, appendix B.8.

C.60 FW at Requested Position (67 hex)

This event message is issued as confirmation that a Filter Wheel move was successful. For additional information, see the Filter Table in the Message Codes appendix

P1 = Type of Filter Wheel movement requested (see 'Types of F/W Movement' table, appendix D.3, in the Message Codes appendix)
P2 = Number of steps just moved (this may be shown as 0898 – 2200 decimal – which actually means zero!).
P3 = Current Filter Position (for conversion to filter value, see ‘FILTER TABLE’, appendix D.4)

C.61 FW Lost Position (69 hex)

This error message is issued when a filter wheel move was unsuccessful because 1) the fine sensor was not detected after a normal filter wheel move or 2) either the fine or coarse sensor was not detected after a move to datum.

P1 = Type of Filter Wheel movement requested (see 'Types of F/W Movement' table, appendix D.3, in the Message Codes appendix)
P2 = Number of steps just moved.
P3 = 2200.

The ICU response is detailed in the Errors Action Table, appendix B.8.

C.62 FW Move Aborted (6d hex)

This event message is issued as confirmation that a Filter Wheel move was aborted by command.

P1 = Type of Filter Wheel movement requested (see 'Types of F/W Movement' table, appendix D.3, in the Message Codes appendix)
P2 = Number of steps just moved.
P3 = Current Filter Position (for conversion to filter value, see ‘FILTER TABLE’, appendix D.4)

C.63 FW Not at Blocked (6c hex)

This is issued both as a Verification Error and as a Major Anomaly message, depending on the circumstances.

A Verification Error is issued when and attempt is made to set the flood led to a non-zero value when the filter is not at blocked. The APID and Function Code returned should be used in conjunction with the Command Table in the Message Codes appendix D.2 to determine which command was rejected.

An Major Anomaly message is issued when and attempt is made to ramp up the High Voltages when we are in the Safe state and the Filter Wheel is not in a blocked position. The parameters are as for HV Ramp Failed message, see appendix C.68.

C.64 FW Not Yet Datumed (6b hex)

This verification error message is issued when an attempt is made to move the filter wheel to an absolute, rather than relative, position before it has been previously datumed (and thus has its current position established). The APID and Function Code returned should be used in conjunction with the Command Table, appendix D.2, in the Message Codes appendix to determine which command was rejected.

C.65 HV Above/Below Requested (11 hex)

This error message is issued when an HV ramp is aborted because

1. the target voltage is already above the current voltage when a ramp rate has been explicitly commanded as positive.
2. the target voltage is already below the current voltage when a ramp rate has been explicitly commanded as negative.

The parameters are the same as for HV Ramp Failed, see appendix C.68.

C.66 HV Calibration Data Failure (14 hex)

This verification failure message is issued when an attempt to command the high voltages fails because the on-board calibration data is not sensible. This usually indicates human error in the compilation of that table. The APID and Function Code returned should be used in conjunction with the Command Table, appendix D.2, in the Message Codes appendix to determine which command was rejected.

C.67 HV Ramp Aborted (12 hex)

This event message is issued when an HV ramp is aborted by command. The parameters are the same as for the HV Ramp Failed message in appendix C.68.

C.68 HV Ramp Failed (10 hex)

This error message is issued when an HV ramp fails. The parameters are as follows:

P1 = HV Channel code (see HV Channel Code Table D.13 in the Message Codes appendix).
P2 = Target Voltage (in hex).

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.69 HV Ramp Succeeded (13 hex)

This event message is issued when an HV ramp succeeds. The parameters are the same as for HV Ramp Failed

C.70 ICB Error (b0 hex)

This verification error message is issued when a direct read or write to the telescope module via the ICB (instrument control bus) has failed due to an error on that bus. The APID and Function Code returned should be used in conjunction with the Command Table D.2 in the Message Codes appendix to determine which command was rejected.

C.71 ICB Errs Forced Htr Shut-down (b1 hex)

This major anomaly message is issued after the heater control algorithm has made 10 unsuccessful attempts to communicate with the telescope module. All parameters are set to zero. The heater control task is then stopped.

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.72 ICU Watchdog Trip (90 hex)

This error message is issued when the ICU hardware watchdog has tripped.

P1 = 0.
P2 = 0.
P3 = 0.

C.73 Illegal APID (00 hex)

This verification error message is issued when a command, with the indicated APID and Function Code, is received with an APID outside the valid range.

P1 = APID received.
P2 = 0.

C.74 Illegal APID Length (0e hex)

This major anomaly message is issued when the ICU attempts to issue a telemetry packet in which either the packet-length or APID is outside the expected range.

P1 = APID (in hex).
P2 = Packet length (in hex).
P3 = 0.

C.75 Illegal Function Code (08 hex)

This verification error message is issued when a command packet, with the indicated APID and Function Code, is received with a function code outside the range expected for the packet APID.

C.76 Illegal Memory APID (0d hex)

This error message is issued when the APID provided to which to dump memory was invalid.

P1 = APID sent.
P2 = 0.
P3 = 0.

C.77 Illegal MID (0b hex)

This error message is issued when the MID (memory bank identifier) from which to dump was invalid.

P1 =incorrect MID.
P2 =0.
P3 =0.

C.78 Illegal Parameter Values (04 hex)

This verification failure message is issued when one or more of the parameters in the command with the indicated APID and Function Code is outside the expected range - see the Command Table, appendix D.2, in the Message Codes appendix for a list of the APIDs and Functions Codes.

C.79 Illegal Start Address (0c hex)

This error message is issued when the start address from which to dump was invalid.

P1 = Memory address high word.
P2 = Memory address low word.
P3 = 0.

C.80 Illegal State (0a hex)

This verification failure message is issued when the state parameter in the command with the indicated APID and Function Code is outside the expected range - see the Command Table, appendix D.2, in the Message Codes appendix for a list of the APIDs and Functions Codes and the state table (appendix D.8) for a list of valid states.

C.81 Impossible State Transition (43 hex)

This error message is issued when a state change command has been issued and the ICU is unable to find such a transition in its on-board table (described in appendix B.12). This usually indicates a corruption of the table that has survived a CRC check. The probability is therefore that human error occurred when compiling the table.

P1 = Current State (see state table, appendix D.8, in the Message Codes appendix).
P2 = Requested State (see state table, appendix D.8, in the Message Codes appendix)
P3 = 0.

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.82 Incorrect Checksum (01 hex)

This verification error message is issued when a command, with the indicated APID and Function Code, is received with an incorrect checksum - see the Command Table, appendix D.2, in the Message Codes appendix for a list of the APIDs and Functions Codes.

P1 = 0.
P2 = 0.

C.83 Invalid for this State (c2 hex)

This verification failure message is issued the command with the indicated APID and Function Code is received when the UVOT is in a state for which the command is illegal - see the Command Table, appendix D.2, in the Message Codes appendix for a list of the APIDs and Functions Codes and also the state table , appendix D.8, for a list of states.

C.84 Invalid Length (05 hex)

This verification error message is issued when a command, with the indicated APID and Function Code, is received with the contents of the packet length field outside the valid range - see the Command Table, appendix D.2, in the Message Codes appendix for a list of the APIDs and Functions Codes.

P1 = Contents of the packet length field.
P2 = 0.

C.85 Limit Exceeded (91 hex)

This error message is issued when a limit is exceeded for n successive times. An on-board table (described in appendix A.4) specifies n.

P1 = Item (in hex) for which the limit is exceeded (see limit item table, appendix D.11, in the Message Codes appendix)
P2 = Value (in hex) that exceeded the limit.

The ICU response is detailed in both the Errors Action Table, see appendix B.8, and the Limit Check table, appendix A.4, (the latter usually being to run the gotosafe RTS).

C.86 No Such UVOT AT Mode (44 hex)

This error message is issued when the ICU could not find a match in the Automated Target (AT) table for the current observation. This may be because either that UVOT mode is non-existent or because it has no entries for that value of the time-since-burst. The AT table is described in appendix B.6.

P1 = Requested UVOT Mode.
P2 = Most Significant Word of the time-since-burst in seconds and hex.
P3 = Least Significant Word of the time-since-burst in seconds and hex.

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.87 No Such UVOT PT Mode (48 hex)

This error message is issued when the ICU could not find a match in the Planned Target (PT) table for the current observation. The PT table is described in appendix B.9.

P1 = Requested UVOT Mode.

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.88 No Usable Filters in Config (4a hex)

This error message is issued when the ICU could not find a suitable filter when attempting to perform an AT exposure. This happens if, in human error, the exposure table – described in appendix B.6- has accidentally specified that no filters should be used for the UVOT mode or, for safety reasons, it is no longer possible to exposure in any filter.

P1 = Requested UVOT Mode.
P2 = 0.
P3 = 0.

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.89 Not at Predicted Position (4e hex)

This error message is issued when the ICU detects that we are not pointing at a predicted position within tolerances specified in the on-board ‘standard’ EEPROM table described in appendix B.13.

P1 = 0 if detected when we are settled, 1 if detected when we are settling.
P2 = the current RA expressed and rounded up to the nearest minute of arc (hex).
P3 = the current (DEC+100 degrees) rounded up and expressed to the nearest minute of arc (hex).

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.90 Reducing Requested Exp Time (4b hex)

This event message is issued when, because of on-board calculations, the ICU has reduced the requested exposure for detector safety reasons.

P1 = Current UVOT Mode.
P2 = Requested exposure length (in seconds and hex).
P3 = Allowed exposure length (in seconds and hex).

C.91 RTS Line Trace (77 hex)

This event message is issued as a diagnostic when enabled by an `/irtstrace` on command. It shows the current progress of RTS execution.

P1 = Current RTS line number (in hex starting from 1).
P2 = Current RTS (in hex - see RTS table, appendix D.1, in the Message Codes appendix).
P3 = Call depth (zero = top).

C.92 Running Recovery RTS (ff hex)

This event message is issued when an RTS has been run by the ICU in an attempt to recover from an error indicated by the associated Major Anomaly (error) message (which is often displayed immediately *after* this message).

P1 = the RTS being run (in hex - see RTS table, appendix D.1, in the Message Codes appendix).
P2 = the associated error code (see Error Codes in Numerical Order, appendix D.14, table in the Message Codes appendix).
P3 = the first parameter of the associated error (as this is often used in conjunction with P2 to determine which RTS to run).

C.93 Safety Circuit Alert (5a hex)

This major anomaly message is issued when an attempt is made to configure the safety circuit when it is not safe so to. This usually happens after the safety circuit has tripped and a safety circuit configuration is attempted before going to the safe state.

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.94 SC1553 Dump Report SID (d8 hex)

This error message may be used, in the future, to give a memory dump of important 1553 registers following an error. (Note - this message is currently not used.)

C.95 SC1553 Read Error (8c hex)

This error message is issued on encountering an error when reading 1553 messages (telecommands).

P1 = Error code.
P2 = SC1553_ERROR error counter from interrupt handler.
P3 = SC1553_INTERRUPT pending interrupt register.

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.96 SC1553 Startup Error (89 hex)

This error message may be used, in future releases, to indicate as starting up error in the 1553. (Note – this message is currently not used.)

C.97 SLEWABORT Received (59 hex)

This major anomaly report indicates that a SLEWABORT message was received from the spacecraft. All parameters are set to zero.

C.98 SSI Error (c1 hex)

This error message is issued on encountering an error on the SSI interface

P1 = Error code.
P2 = 0.
P3 = 0.

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.99 State Transition Complete (41 hex)

This event message is issued when the ICU successfully transitions to a new state, defined by P1 (see state table, appendix D.8, in the Message Codes appendix). P2 and P3 are set to zero.

C.100 Switching RTS (78 hex)

This event message is issued as an RTS shuts itself down in favour or another RTS (given by P1 - see RTS table, appendix D.1, in the Message Codes appendix). P2 and P3 are set to zero.

C.101 Timesync Jump (25 hex)

This error message is issued when the Spacecraft time (or Mission Elapsed Time - MET) has jumped forwards or backwards by more than about 1s.

P1 = MET at last sync (seconds) first word.
P2 = MET at last sync (seconds) second word.
P2 = MET at penultimate sync (seconds) second word.

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.102 Timesync Overflow (24 hex)

This error message is issued when part of the time calculation overflowed.

P1 = 0xFFFF.
P2 = MET (Mission Elapsed Time) at last sync (seconds) first word.
P3 = MET at last sync (seconds) second word.

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.103 Timesync Too Big (21 hex)

This error message is issued when a different part of the time calculation overflowed.

P1 = Variable TIME_TEMP high word.
P2 = Variable TIME_TEMP low word.
P3 = 0

C.104 Timesync Too Late (23 hex)

This error message is issued when the flight software was too slow or busy, causing the time code to miss time synchronization (or the TIMETONE and 1pps arrived at the wrong times

P1 = 0x8888.
P2 = Variable SECONDS high word.
P3 = Variable SECONDS low word.

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.105 Timesync Too Long Since (22 hex)

This error message is issued when there has been no 1pps for more than two s.

P1 = Seconds since last 1pps.
P2 = SYNCHRONIZE_ME time sync status variable.
P3 = 0.

C.106 Too Many Acc'd Cts Report SID (db hex)

This message is issued to indicate that in the predicted field of view, the theoretical accumulated counts on the described source have reached a maximum limit. This usually precludes observing as the maximum exposure time is set to zero. The format of this message is non-standard. The fields are the same as the Catalogue Star message.

C.107 Total Exposure Time Is Zero (55 hex)

This error message is issued when the ICU, whilst trying to scale a series of PT exposures to a snapshot length, detects that the total length of the exposures to be scaled is zero seconds. This is usually caused by the PT exposure configurations table – appendix B.7 - containing incorrect data.

P1 = UVOT Mode.
P2 = PT configuration ID (i.e. the 'label') of the first exposure for which the condition was detected.

C.108 Unacceptable Absolute Drift (4d hex)

This error message is issued when a target position has been specified earlier (e.g. in a FONEXTOBSINFO message) and we are settled but we have drifted away from that target position by more than the expected absolute drift. The ‘standard’ on-board table - appendix B.13 - specifies the acceptable level of absolute drift.

P1 = the drift detected expressed and rounded up to the nearest minute of arc (hex).
P2 = the current RA expressed and rounded up to the nearest minute of arc (hex).
P3 = the current (DEC+100 degrees) rounded up and expressed to the nearest minute of arc (hex).

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.109 Unacceptable Diff'ntial Drift (4c hex)

This error message is issued when we are settled and the drift between successive monitored attitude packets has exceeded the expected relative drift. The ‘standard’ on-board table - appendix B.13 - specifies the acceptable level of relative drift.

P1 = the drift detected expressed and rounded up to the nearest minute of arc (hex).
P2 = the current RA expressed and rounded up to the nearest minute of arc (hex).
P3 = the current (DEC+100 degrees) rounded up and expressed to the nearest minute of arc (hex).

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.110 Undefined State Transition (40 hex)

This event report should only be issued as a diagnostic. It occurs when a deliberate attempt is made to run the RTS whose code is designated as 'undefined' and therefore would normally not be run by the ICU. There are no associated parameters.

C.111 Unexpected IsSettled Flag Off (50 hex)

This error message is issued when the ICU detects that the settled flag in the ACS record has changed to false without a preceding SISLEWWARNING message. There are no parameters associated with this message.

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.112 UVOT Mode Exhausted (49 hex)

This event message is issued at the end of a sequence of PT exposures associated with a requested UVOT Mode when there is time left before the next slew. P1 is set to the UVOT Mode.

C.113 Watchdog Reports a Task Hang (ed hex)

This error message is issued when the watchdog task detects that another ADA task has been inactive for some time.

P1 = Task Identifier (see Task Identifier Table, appendix D.12, in the Message Codes appendix).

C.114 Window Table Already Loaded (5f hex)

This event message is issued when the parameters of a load window table command are the same as the on-board record of what was last loaded. The table load is therefore suppressed. There are no parameters associated with this message.

C.115 Window Table Load Aborted (6f hex)

This event message is issued as confirmation when a load window table command is stopped by command.

C.116 Window Table Load Failure (66 hex)

This error message is issued when a window table load fails. This happens when there has been 1) MACSbus errors when writing or reading the table or 2) verification errors caused by a mismatch between what was found in the table and what was expected.

P1	Macs bus Errors	Verification Errors
0	Yes	No
1	No	Yes
2	Yes	Yes

The ICU response is detailed in the Errors Action Table, see appendix B.8.

C.117 Window Table Load Okay (65 hex)

This event message is issued as confirmation when a load window table command has completed successfully.

C.118 XRTPOS Processing Status (56 hex)

If issued as an event message then the processing of XRTPOS record was nominal. If issued as an error message then the processing was not optimal. If there is no other error message detailing the nature of the problem (e.g. XRT supplied RA and DEC are out of range) then this indicates that the position supplied was outside the field of view and was ignored.

Description	P1 (Hex)	P2 (Hex)	P3 (Hex)
Event Message	XRT Position X Pixel Offset (2s compliment)	XRT Position Y Pixel Offset (2s compliment)	Radial distance in minutes
Error Message	N/A	N/A	N/A

Appendix D Message Codes

This appendix contains the tables of codes issued by the messages described in Appendix C .

D.1 RTS TABLE

The table is in numerical order.

RTS Number (in hex)	RTS Name
0000	noaction
0001	line
0002	h_basic
0003	h_emergency_safe
0004	h_tm_off
0005	h_uvot_off
000b	h_11
000c	h_12
000d	h_13
000e	h_14
000f	h_15
0010	ok_to_slew
0011	gotosafe
0012	emergency_hvoff
0013	autostate
0014	process_slew_warn
0015	slewabort
0020	test
0021	idpumode
0022	dpu_abort
0030	do_exp
0031	start_exp
0032	end_exp
0033	interrupt_exp
0101	controlled_off
0102	controlled_tmoff
0200	pokedataram
0201	change_state

RTS Number (in hex)	**RTS Name**
0300	gotobasic
0301	fastsafe
0302	do_slew
0308	gotosaa
031a	safe_to_idle
0323	slew_to_settling
0324	slew_to_fc
0325	slew_to_at
0326	slew_to_pt
0327	slew_to_safep
032a	slew_to_idle
0334	settling_to_fc
0345	fc_to_at
0366	pt_to_pt
0377	safep_to_safep
038a	saa_to_idle
03e2	send_slewsafe
03e3	get_sttlng_config
03e4	get_fc_config
03e5	get_at_config
03e6	get_pt_config
03e7	get_sp_config
03ef	bright_planets
03f3	do_sttlng_exp
03f4	do_fc_exp
03fa	obs_to_idle
0402	hvon
0403	hvoff
0404	hvnominal
0405	hvsaa
0406	hvofffast
0407	hvidle_or_saa

RTS Number (in hex)	RTS Name
0408	hvcathode
0409	hv231
0500	diagnostic
0501	testmode
0502	retry_fw
0503	blocked_failsafe
7ffe	notallowed
7fff	undefined

D.2 ICU COMMAND TABLE

Note: an APID in the range 670 to 67f (hex) indicates that the command was issued on board from an RTS **and therefore will not be observed in basic state.** The table is ordered by APID and then function code (F/C). See also "Telecommand Summary in Alphabetical Order", appendix E.1, for a brief description of each command.

APID (hex)	F/C (hex)	Command
660 or 670	00	/IBPESTOPCNTRDLD
660 or 670	01	/IBPESTARTCNTRDLD
660 or 670	02	/IBPESTOPWNDWLD
660 or 670	03	/IBPESTARTWNDWLD
660 or 670	04	/IBPEINTEG
660 or 670	05	/IBPEACQMODE
660 or 670	06	/IBPETHRESHOLD
660 or 670	07	/IBPELED
660 or 670	08	/IBPEFRAMETAGS
660 or 670	09	/IBPECAMERA
660 or 670	0a	/IBPEHEAD
660 or 670	0b	/IHVSET
660 or 670	0c	/IHVSTOPRAMP
660 or 670	0d	/IHVAUTORAMP
660 or 670	0d	/IHVRAMP
660 or 670	0e	/IHVENABLE
660 or 670	20	/IICBENABLE
660 or 670	21	/IICBWRITE

APID (hex)	F/C (hex)	Command
660 or 670	00	/IBPESTOPCNTRDLD
660 or 670	22	/IICBREAD
660 or 670	30	/IWATCHDOG
660 or 670	31	/IWATCHDOGINT
660 or 670	40	/IFWSTOP
660 or 670	41	/IFWSETCOARSE
660 or 670	42	/IFWSETFINE
660 or 670	43	/IFWSETRATE
660 or 670	44	/IFWFILTER
660 or 670	45	/IFWABS
660 or 670	46	/IFWREL
660 or 670	47	/IFWPULSE
660 or 670	48	/IFWDATUM
660 or 670	49	/IFWCOARSE
660 or 670	50	/IDMSTOP
660 or 670	51	/IDMMOVE
660 or 670	5f	/IMOTORINHIBIT
660 or 670	62	/IHTR
660 or 670	62	/IHTROFF
660 or 670	62	/IHTRON
660 or 670	63	/IHTRPARAMS
660 or 670	70	/IBPESFTYCONFIG
660 or 670	80	/IRTSRUN
660 or 670	81	/IRTSKILL
660 or 670	81	/IRTDISABLE
660 or 670	82	/IRTSTRACE
660 or 670	92	/IHK
660 or 670	92	/IHKOFF
660 or 670	92	/IHKON
660 or 670	93	/IHKRATE
660 or 670	94	/IHKTDRSS

APID (hex)	**F/C (hex)**	**Command**
660 or 670	00	/IBPESTOPCNTRDLD
660 or 670	95	/IDPUTASK
660 or 670	a0	/ILIMIT
660 or 670	a0	/ILIMITOFF
660 or 670	a0	/ILIMITON
660 or 670	a1	/ICHANGELIMITS
660 or 670	b0	/ITIMESYNC
661 or 671	00	/ISTATE
661 or 671	01	/ISTATETRANS
662 or 672	00	/IICULOAD0
662 or 672	00	/IICULOAD
662 or 672	00	/IICULOAD1
662 or 672	00	/IICULOAD3
662 or 672	01	/IICUDUMP
662 or 672	01	/IICUDUMP2
662 or 672	02	/IICUCRC
662 or 672	03	/IICUDUMPABORT
665 or 675	00	/ITEST
665 or 675	01	/INHKECHO
66a or 67a	05	/IDPUMODE
66a or 67a	06	/IDPUSTOP
66a or 67a	09	/IDPUXRTPOS
66a or 67a	0a	/IDPUABORT
66a or 67a	24	/IDPUNOOP
66a or 67a	40	/IDPUPURGEDCX
66a or 67a	41	/IDPUPURGESCI
66a or 67a	42	/IDPUREBOOT

D.3 TYPES OF FILTER WHEEL MOVEMENT

Code	Type of Movement
4	Move Filter Wheel to FILTER Number
5	Move Filter Wheel to Absolute Position
6	Move Filter Wheel to Relative Position
7	Move Filter Wheel by Fine Sensor
8	Move Filter Wheel to Datum
9	Move Filter Wheel to Coarse

D.4 FILTER TABLE

Filter Number	Position	Description
0	0 (0x0)	Blocked Filter (Datum)
1	200 (0xC8)	Grism 1 (UV) Filter
2	400 (0x190)	UVW2 Filter
3	600 (0x258)	V Filter
4	800 (0x320)	UVM2 Filter
5	1000 (0x3eb)	Grism (Visible) Filter
6	1200 (0x4b0)	UVW1 Filter
7	1400 (0x578)	U Filter
8	1600 (0x640)	Magnifier
9	1800 (0x708)	B Filter
10 (0xa)	2000 (0x7d0)	White Filter

Note – In HK and sequence print messages, the value 2200 is used to represent ‘Unknown Position’ and the value 2201 represents ‘f/w moving’.

D.5 MAGNITUDE CODE TABLE

The magnitude code stored on board in the catalogue is derived from the visual magnitude (Johnson V magnitude).

If V is < -1.4 then the code is 0.

From there on, the magnitudes are gathered into bands, each 0.1 of a magnitude wide, numbered from 1 to 134 ascending.

So for example,

-1.3 > V >= -1.4 has code 1.
-1.2 > V >= -1.3 has code 2.
11.9> V >= 11.8 has code 133.

V >= 11.9 has code 134.

Note: no source fainter than V = 12.0 is stored in the catalogue.

The following table gives this explicitly as a function on the magnitude code.

Magnitude Code		**Magnitude Range**
Hex	**Decimal**	
0	0	Brighter than -1.4
1	1	Brighter than -1.3 up to exactly -1.4
2	2	Brighter than -1.2 up to exactly -1.3
3	3	Brighter than -1.1 up to exactly -1.2
4	4	Brighter than -1 up to exactly -1.1
5	5	Brighter than -0.9 up to exactly -1
6	6	Brighter than -0.8 up to exactly -0.9
7	7	Brighter than -0.7 up to exactly -0.8
8	8	Brighter than -0.6 up to exactly -0.7
9	9	Brighter than -0.5 up to exactly -0.6
a	10	Brighter than -0.4 up to exactly -0.5
b	11	Brighter than -0.3 up to exactly -0.4
c	12	Brighter than -0.2 up to exactly -0.3
d	13	Brighter than -0.1 up to exactly -0.2
e	14	Brighter than 0.0 up to exactly -0.1
f	15	Brighter than 0.1 up to exactly 0.0
10	16	Brighter than 0.2 up to exactly 0.1
11	17	Brighter than 0.3 up to exactly 0.2
12	18	Brighter than 0.4 up to exactly 0.3

Magnitude Code		**Magnitude Range**
Hex	**Decimal**	
13	19	Brighter than 0.5 up to exactly 0.4
14	20	Brighter than 0.6 up to exactly 0.5
15	21	Brighter than 0.7 up to exactly 0.6
16	22	Brighter than 0.8 up to exactly 0.7
17	23	Brighter than 0.9 up to exactly 0.8
18	24	Brighter than 1 up to exactly 0.9
19	25	Brighter than 1.1 up to exactly 1
1a	26	Brighter than 1.2 up to exactly 1.1
1b	27	Brighter than 1.3 up to exactly 1.2
1c	28	Brighter than 1.4 up to exactly 1.3
1d	29	Brighter than 1.5 up to exactly 1.4
1e	30	Brighter than 1.6 up to exactly 1.5
1f	31	Brighter than 1.7 up to exactly 1.6
20	32	Brighter than 1.8 up to exactly 1.7
21	33	Brighter than 1.9 up to exactly 1.8
22	34	Brighter than 2 up to exactly 1.9
23	35	Brighter than 2.1 up to exactly 2
24	36	Brighter than 2.2 up to exactly 2.1
25	37	Brighter than 2.3 up to exactly 2.2
26	38	Brighter than 2.4 up to exactly 2.3
27	39	Brighter than 2.5 up to exactly 2.4
28	40	Brighter than 2.6 up to exactly 2.5
29	41	Brighter than 2.7 up to exactly 2.6
2a	42	Brighter than 2.8 up to exactly 2.7
2b	43	Brighter than 2.9 up to exactly 2.8
2c	44	Brighter than 3 up to exactly 2.9
2d	45	Brighter than 3.1 up to exactly 3
2e	46	Brighter than 3.2 up to exactly 3.1
2f	47	Brighter than 3.3 up to exactly 3.2
30	48	Brighter than 3.4 up to exactly 3.3
31	49	Brighter than 3.5 up to exactly 3.4

Magnitude Code		Magnitude Range
Hex	Decimal	
32	50	Brighter than 3.6 up to exactly 3.5
33	51	Brighter than 3.7 up to exactly 3.6
34	52	Brighter than 3.8 up to exactly 3.7
35	53	Brighter than 3.9 up to exactly 3.8
36	54	Brighter than 4 up to exactly 3.9
37	55	Brighter than 4.1 up to exactly 4
38	56	Brighter than 4.2 up to exactly 4.1
39	57	Brighter than 4.3 up to exactly 4.2
3a	58	Brighter than 4.4 up to exactly 4.3
3b	59	Brighter than 4.5 up to exactly 4.4
3c	60	Brighter than 4.6 up to exactly 4.5
3d	61	Brighter than 4.7 up to exactly 4.6
3e	61	Brighter than 4.8 up to exactly 4.7
3f	63	Brighter than 4.9 up to exactly 4.8
40	64	Brighter than 5 up to exactly 4.9
41	65	Brighter than 5.1 up to exactly 5
42	66	Brighter than 5.2 up to exactly 5.1
43	67	Brighter than 5.3 up to exactly 5.2
44	68	Brighter than 5.4 up to exactly 5.3
45	69	Brighter than 5.5 up to exactly 5.4
46	70	Brighter than 5.6 up to exactly 5.5
47	71	Brighter than 5.7 up to exactly 5.6
48	72	Brighter than 5.8 up to exactly 5.7
49	73	Brighter than 5.9 up to exactly 5.8
4a	74	Brighter than 6 up to exactly 5.9
4b	74	Brighter than 6.1 up to exactly 6
4c	76	Brighter than 6.2 up to exactly 6.1
4d	77	Brighter than 6.3 up to exactly 6.2
4e	78	Brighter than 6.4 up to exactly 6.3
4f	79	Brighter than 6.5 up to exactly 6.4
50	80	Brighter than 6.6 up to exactly 6.5

Magnitude Code		Magnitude Range
Hex	**Decimal**	
51	81	Brighter than 6.7 up to exactly 6.6
52	82	Brighter than 6.8 up to exactly 6.7
53	83	Brighter than 6.9 up to exactly 6.8
54	84	Brighter than 7 up to exactly 6.9
55	85	Brighter than 7.1 up to exactly 7
56	86	Brighter than 7.2 up to exactly 7.1
57	87	Brighter than 7.3 up to exactly 7.2
58	88	Brighter than 7.4 up to exactly 7.3
59	89	Brighter than 7.5 up to exactly 7.4
5a	90	Brighter than 7.6 up to exactly 7.5
5b	91	Brighter than 7.7 up to exactly 7.6
5c	92	Brighter than 7.8 up to exactly 7.7
5d	93	Brighter than 7.9 up to exactly 7.8
5e	94	Brighter than 8 up to exactly 7.9
5f	95	Brighter than 8.1 up to exactly 8
60	96	Brighter than 8.2 up to exactly 8.1
61	97	Brighter than 8.3 up to exactly 8.2
62	98	Brighter than 8.4 up to exactly 8.3
63	99	Brighter than 8.5 up to exactly 8.4
64	100	Brighter than 8.6 up to exactly 8.5
65	101	Brighter than 8.7 up to exactly 8.6
66	102	Brighter than 8.8 up to exactly 8.7
67	103	Brighter than 8.9 up to exactly 8.8
68	104	Brighter than 9 up to exactly 8.9
69	105	Brighter than 9.1 up to exactly 9
6a	106	Brighter than 9.2 up to exactly 9.1
6b	107	Brighter than 9.3 up to exactly 9.2
6c	108	Brighter than 9.4 up to exactly 9.3
6d	109	Brighter than 9.5 up to exactly 9.4
6e	110	Brighter than 9.6 up to exactly 9.5
6f	112	Brighter than 9.7 up to exactly 9.6

Magnitude Code		Magnitude Range
Hex	Decimal	
70	112	Brighter than 9.8 up to exactly 9.7
71	113	Brighter than 9.9 up to exactly 9.8
72	114	Brighter than 10 up to exactly 9.9
73	115	Brighter than 10.1 up to exactly 10
74	116	Brighter than 10.2 up to exactly 10.1
75	117	Brighter than 10.3 up to exactly 10.2
76	118	Brighter than 10.4 up to exactly 10.3
77	119	Brighter than 10.5 up to exactly 10.4
78	120	Brighter than 10.6 up to exactly 10.5
79	121	Brighter than 10.7 up to exactly 10.6
7a	122	Brighter than 10.8 up to exactly 10.7
7b	123	Brighter than 10.9 up to exactly 10.8
7c	124	Brighter than 11 up to exactly 10.9
7d	125	Brighter than 11.1 up to exactly 11
7e	126	Brighter than 11.2 up to exactly 11.1
7f	127	Brighter than 11.3 up to exactly 11.2
80	128	Brighter than 11.4 up to exactly 11.3
81	129	Brighter than 11.5 up to exactly 11.4
82	130	Brighter than 11.6 up to exactly 11.5
83	131	Brighter than 11.7 up to exactly 11.6
84	132	Brighter than 11.8 up to exactly 11.7
85	133	Brighter than 11.9 up to exactly 11.8
86	134	Brighter than 12 up to exactly 11.9

D.6 COLOUR INDEX TABLE

The colour index used in the star catalogue is a B-V in Johnson magnitudes. The larger the code number, the 'redder' is the object. The codes represent uneven width bands as shown in the table below.

Colour Index		**B-V**
Hex	**Decimal**	
0	0	B-V < -0.33
1	1	-0.33 <= B-V < -0.27
2	2	-0.27 <= B-V < -0.17
3	3	-0.17 <= B-V < -0.11
4	4	-0.11 <= B-V < 0.01
5	5	0.01 <= B-V < 0.15
6	6	0.15 <= B-V < 0.30
7	7	0.30 <= B-V < 0.44
8	8	0.44 <= B-V < 0.52
9	9	0.52 <= B-V < 0.63
a	10	0.63 <= B-V < 0.68
b	11	0.68 <= B-V < 0.74
c	12	0.74 <= B-V < 0.81
d	13	0.81 <= B-V < 1.10
e	14	1.10 <= B-V < 1.49
f	15	1.49 <= B-V < 1.64
10	16	B-V >= 1.64

D.7 PLANET CODE TABLE

Code (hex)	Planet
1	VENUS
2	MARS
3	JUPITER
4	SATURN
5	URANUS
6	NEPTUNE
8	SUN
9	MOON
A	EARTH

D.8 STATE TABLE

Value (Hex)	State.
0	BASIC
1	SAFE
2	SLEW
3	SETTLING
4	FINDING
5	AUTOMATED
6	PLANNED
7	SAFEPOINT
8	SAA
a	IDLE
b	OFFURGENT
c	OFFUVOT
d	OFFUVOTTM

D.9 HEATER TABLE

Heater	Description
1	INTERFACE
2	FORWARD
3	METERING_RODS
4	SECONDARY_MIRROR

D.10 DCS EVENT CODE TABLE

Event Code		Event Description
Hex	Decimal	
0	0	NORMAL_DELAY
1	1	AT_REQUESTED_HV
2	2	AT_REQUESTED_FILTER_POSITION
3	3	DPU_MODE_READY
4	4	DPU_ACK
5	5	CENTROID_TABLE_LOADED
6	6	WINDOW_TABLE_LOADED
7	7	NEXTOBSINFO
8	8	WITHIN_10_ARCMIN
9	9	SETTLED
A	10	CHAIN_CODE
B	11	SLEW_START
C	12	BATGRBFLUXINFO packet received
63	99	Issued by RTS gotosafe_tdrss after SLEW_START, WITHIN_10_ARCMIN, SETTLED time-out. Issued by RTS blocked_tdrss after DPU_ACK time-out via TDRSS.

D.11 LIMIT ITEM TABLE

Item (hex)	Description	System	Enabled in Basic
1	+28 V	TMPSU	Yes
2	+11 V	TMPSU	Yes
3	+15 V	TMPSU	Yes
4	-15 V	TMPSU	Yes
5	+5 VB	TMPSU	Yes
6	+5 VA	TMPSU	Yes
7	-5 VA	TMPSU	Yes
8	DISMON	TMPSU	Yes
9	BPE Thermistor	BPE	Yes
a	Ref B Thermistor	BPE	Yes
b	Ref C Thermistor	BPE	Yes
c	Main Thermistor	BPE	Yes
d	Forward1 Thermistor	BPE	Yes
e	Forward2 Thermistor	BPE	Yes
f	CCD Thermistor	BPE	Yes
10	Ref A Thermistor	BPE	Yes
11	Vcathode	BPE	Yes
12	Vmcp1	BPE	Yes
13	Vmcp23	BPE	Yes
14	+5V	BPE	Yes
15	+15V	BPE	Yes
16	-15V	BPE	Yes
17	1.23V Reference	BPE	Yes
18	F/W Analogue Pickoff	BPE	Yes
19	Temp PSU Mod A	DEM via DPU	Yes
1a	Temp PSU Mod B	DEM via DPU	Yes
1b	ICU CPU Module	DEM via DPU	Yes
1c	ICU Interface Module	DEM via DPU	Yes
1d	DPU Comm/Mem Module	DEM via DPU	Yes
1e	Reserved	DEM via DPU	Yes

Item (hex)	Description	System	Enabled in Basic
1f	Reserved	DEM via DPU	Yes
20	PSU A +5V	DEM via DPU	Yes
21	PSU B +5V	DEM via DPU	Yes
22	PSU A +12V	DEM via DPU	Yes
23	PSU A -12V	DEM via DPU	Yes
24	PSU +5V Ref Input	DEM via DPU	Yes
25	PSU -5V Ref Input	DEM via DPU	Yes
26	Reserved Input	DEM via DPU	Yes
27	DCI Parity Errors	DEM via DPU	Yes
28	Reserved	DEM via DPU	Yes
29	Reserved	DEM via DPU	Yes
2a	DPU Heartbeat Increment	DPU	Yes
2b	Validity bits check	DPU	Yes
2c	Op Count >> 8	Safety Circuit	No
2d	Alert Flag	Safety Circuit	No

D.12 TASK IDENTIFIER TABLE

Task ID (hex)	Task Description and Name
0	Telecommand Monitor : TCQ
1	HV Ramping : HV_RAMP
2	DPU Message Monitor : DPU_DATA_MANAGER
3	Heaters Controller : HEATER_CONTROL
4	Limit Monitoring : LIMIT_CHECK
5	Filter Wheel and Dichroic Moving : MECHANISM_MOVE
6	S/C Interface Telemetry Feeder : FEED_1553
7	HK Monitoring : HOUSEKEEPING
8	Memory Dumping : MEMORY_DUMP
9	RTS Execution (the 'virtual machine') : DCS
a	Centroid Table Loader : LOAD_CENTROID_TABLE
b	Window Table Loader : LOAD_WINDOW_TABLE
c	DPU Commands Feeder : FEED_SSI
d	Star Catalogue Scanner : STAR_CAT

D.13 HV CHANNEL CODE TABLE

HV Channel Code	Description
1	VCATHODE
2	VMCP1
3	VMCP23

D.14 ICU ERROR/EVENT CODES IN NUMERICAL ORDER

(**Note** – turn to the next table for the error codes in alphabetical order).

Error/Event Code (hex)	Description
0	Illegal APID
1	Incorrect Checksum
4	Illegal Parameter Values
5	Invalid Length
8	Illegal Function Code
a	Illegal State
b	Illegal MID
c	Illegal Start Address
d	Illegal Memory APID
e	Illegal APID Length
10	HV Ramp Failed
11	HV Above/Below Requested
12	HV Ramp Aborted
13	HV Ramp Succeeded
14	HV Calibration Data Failure
15	Already at Requested HV
21	Timesync Too Big
22	Timesync Too Long Since
23	Timesync Too Late
24	Timesync Overflow
25	Timesync Jump
30	DPU NAK
31	DPU Timeout
32	DPU Incorrect ACK
33	DPU Unexpected ACK/NAK
34	DPU Inconsistent APID ID
35	DPU Invalid APID or ID
36	DPU Bad Bounds
40	Undefined State Transition

Error/Event Code (hex)	Description
41	State Transition Complete
42	Forbidden State RTS
43	Impossible State Transition
44	No Such UVOT AT Mode
46	Bright Object Present
48	No Such UVOT PT Mode
49	UVOT Mode Exhausted
4a	No Usable Filters in Config
4b	Reducing Requested Exp Time
4c	Unacceptable Diff'ntial Drift
4d	Unacceptable Absolute Drift
4e	Not at Predicted Position
4f	Bright Star Store Exhausted
50	Unexpected IsSettled Flag Off
52	Exit From Safe Forbidden
53	Automatic State Trans'n Req'd
54	Angular Constraint Violation
55	Total Exposure Time Is Zero
56	XRTPOS Processing Status
57	FONEXTOBSINFO Processing Stat
58	BATGRBFLUXINFO Proc Stat
59	SLEWABORT Received
5a	Safety Circuit Alert
5d	Flood LEDs turned off
5e	Centroid Table Already Loaded
5f	Window Table Already Loaded
63	Centroid Table Load OK
64	Centroid Table Load Failure
65	Window Table Load Okay
66	Window Table Load Failure
67	FW at Requested Position

Error/Event Code (hex)	Description
68	DM at Requested Position
69	FW Lost Position
6a	DM Lost Position
6b	FW Not Yet Datumed
6c	FW Not at Blocked
6d	FW Move Aborted
6e	Centroid Table Load Aborted
6f	Window Table Load Aborted
70	DCS Aborting
71	DCS No Such RTS
72	DCS Stack Exceeded
73	DCS Invalid Command Token
74	DCS Call Depth Exceeded
76	DCS Insufficient Priority
77	RTS Line Trace
78	Switching RTS
79	DCS Starting RTS
7a	DCS State Table Match Fail
80	DCS RTS Already Running
81	DCS Event Timeout
82	Busy
83	DCS Exiting RTS
85	DCS Too Few RTS Arguments
86	DCS Invalid Exec Token
87	DCS Invalid Poke Offset
88	EEPROM Write Error
89	SC1553 Startup Error
8c	SC1553 Read Error
8e	Bad Value
8f	5 ACS Packets Missing
90	ICU Watchdog Trip

Error/Event Code (hex)	**Description**
91	Limit Exceeded
92	Corrupted EEPROM Data
93	Bad Data in EEPROM
a7	EEPROM Code Compare Error
a8	EEPROM Star Cat Compare Error
b0	ICB Error
b1	ICB Errs Forced Htr Shutdown
c1	SSI Error
c2	Invalid for this State
d8	SC1553 Dump Report SID
da	Bright Star Report SID
db	Too Many Acc'd Cts Report SID
dc	Catalogue Star
ec	Ada Exception
ed	Watchdog Reports a Task Hang
f0	Debug Output
ff	Running Recovery RTS

D.15 ICU ERROR/EVENT CODES IN ALPHABETICAL ORDER

(**Note** – turn to the previous table for the error codes in numerical order).

Error/Event Code (hex)	Description
8f	5 ACS Packets Missing
ec	Ada Exception
15	Already at Requested HV
54	Angular Constraint Violation
53	Automatic State Trans'n Req'd
93	Bad Data in EEPROM
8e	Bad Value
58	BATGRBFLUXINFO Proc Stat
46	Bright Object Present
da	Bright Star Report SID
4f	Bright Star Store Exhausted
82	Busy
dc	Catalogue Star
5e	Centroid Table Already Loaded
6e	Centroid Table Load Aborted
64	Centroid Table Load Failure
63	Centroid Table Load OK
92	Corrupted EEPROM Data
70	DCS Aborting
74	DCS Call Depth Exceeded
81	DCS Event Timeout
83	DCS Exiting RTS
76	DCS Insufficient Priority
73	DCS Invalid Command Token
86	DCS Invalid Exec Token
87	DCS Invalid Poke Offset
71	DCS No Such RTS
80	DCS RTS Already Running
72	DCS Stack Exceeded

Error/Event Code (hex)	Description
79	DCS Starting RTS
7a	DCS State Table Match Fail
85	DCS Too Few RTS Arguments
86	DCS_Invalid_Exec_Token
f0	Debug Output
68	DM at Requested Position
6a	DM Lost Position
36	DPU Bad Bounds
34	DPU Inconsistent APID ID
32	DPU Incorrect ACK
35	DPU Invalid APID or ID
30	DPU NAK
31	DPU Timeout
33	DPU Unexpected ACK/NAK
a7	EEPROM Code Compare Error
a8	EEPROM Star Cat Compare Error
88	EEPROM Write Error
52	Exit From Safe Forbidden
5d	Flood LEDs turned off
57	FONEXTOBSINFO Processing Stat
42	Forbidden State RTS
67	FW at Requested Position
69	FW Lost Position
6d	FW Move Aborted
6c	FW Not at Blocked
6b	FW Not Yet Datumed
11	HV Above/Below Requested
14	HV Calibration Data Failure
12	HV Ramp Aborted
10	HV Ramp Failed
13	HV Ramp Succeeded

Error/Event Code (hex)	Description
b0	ICB Error
b1	ICB Errs Forced Htr Shutdown
90	ICU Watchdog Trip
0	Illegal APID
e	Illegal APID Length
8	Illegal Function Code
d	Illegal Memory APID
b	Illegal MID
4	Illegal Parameter Values
c	Illegal Start Address
a	Illegal State
43	Impossible State Transition
1	Incorrect Checksum
c2	Invalid for this State
5	Invalid Length
91	Limit Exceeded
44	No Such UVOT AT Mode
48	No Such UVOT PT Mode
4a	No Usable Filters in Config
4e	Not at Predicted Position
4b	Reducing Requested Exp Time
77	RTS Line Trace
ff	Running Recovery RTS
5a	Safety Circuit Alert
d8	SC1553 Dump Report SID
8c	SC1553 Read Error
89	SC1553 Startup Error
59	SLEWABORT Received
c1	SSI Error
41	State Transition Complete
78	Switching RTS

Error/Event Code (hex)	Description
25	Timesync Jump
24	Timesync Overflow
21	Timesync Too Big
23	Timesync Too Late
22	Timesync Too Long Since
db	Too Many Acc'd Cts Report SID
55	Total Exposure Time Is Zero
4d	Unacceptable Absolute Drift
4c	Unacceptable Diff'ntial Drift
40	Undefined State Transition
50	Unexpected IsSettled Flag Off
49	UVOT Mode Exhausted
ed	Watchdog Reports a Task Hang
5f	Window Table Already Loaded
6f	Window Table Load Aborted
66	Window Table Load Failure
65	Window Table Load Okay
56	XRTPOS Processing Status

D.16 PACKAGE CODES IN NUMERICAL ORDER

(Note – on the ITOS icuevents window, only the 2 most significant digits are displayed as the last 2 are always zero).

Package	Code
ICU	0x1000
LIMIT	0x1100
ICU_MEM_MANAGER	0x1200
MEM_MANAGER	0x1300
SC1553	0x1500
WATCHDOG	0x1600
ICB	0x1C00
ICB_DRIVER	0x1D00
IEEE	0x1e00
TIME	0x2100
HK	0x2300
UVOTMAN	0x2400
NHK_PACKAGE	0x2500
TASK_REPORT	0x2700
TASKMAN	0x2800
TC_VERIFY	0x2B00
TCQ	0x2C00
TMPSU	0x2E00
TMQ	0x2F00
MECHANISM	0x4000
TIMER_A_IH	0x4400
MUTEX	0x4500
HEATER	0x4600
SSI	0x5500
SAFING	0x5A00
RTS_PACKAGE	0x5C00
DEBUG_TEXT	0x6000
TEXT_PACKETS	0x6100
ASTRO	0x8500
BOOT_DUMP	0xBD00

Package	**Code**
CRC	0xC200
CHCKSUM	0xC500
STARCAT	0xCA00
COMMAND_DISTRIBUTOR	0xCD00
DPU	0xD000
DETSAFETY	0xD500
DETANALOG	0xDA00
DEBUG	0xDB00
DCS	0xDC00
DETDIGITAL	0xDD00
TM_MAN	0xE500
EEPROM	0xEE00

Appendix E Telecommands

E.1 Telecommand Summary in Alphabetical Order

Note – naming convention used means that the commands are listed in sub-system order. The third column indicates its support in basic.

NAME	**Description**	**Basic?**
/FONEXTOBSINFO	Info about next target to be observed	No
/IBATGRBFLUXINFO	BAT GRB flux info	No
/IBPEACQMODE	Set BPE Acq Mode	No
/IBPECAMERA	Enable Disable Camera Running	No
/IBPEFRAMETAGS	Enable Disable Frame Tags	No
/IBPEHEAD	Reset Camera Head	No
/IBPEINTEG	Start BPE Events	No
/IBPELED	Set LED	No
/IBPESFTYCONFIG	Specify BPE Safing	No
/IBPESTARTCNTRDLD	Start BPE Centroid Table Load	No
/IBPESTARTWNDWLD	Start BPE Window Table Load	No
/IBPESTOPCNTRDLD	Stop BPE Centroid Table Load	No
/IBPESTOPWNDWLD	Stop BPE Window Table Load	No
/IBPETHRESHOLD	Set BPE Threshold	No
/ICHANGELIMITS	Change Limit Table Entry	No
/IDMMOVE	Move Dichroic	No
/IDMSTOP	Stop Dichroic Movement	No
/IDPUABORT	Abort DPU	No
/IDPUMODE	DPU Mode command	No
/IDPUNOOP	DPU No-op	No
/IDPUPURGEDCX	Flush Compression Buffer	No
/IDPUPURGESCI	Flush Science Buffer	No
/IDPUREBOOT	Reboot DPU	No
/IDPUSTOP	Stop DPU Mode	No
/IDPUTASK	Enables or Disables DPU Monitoring Task	Yes
/IDPUXRTPOS	XRT Position	No
/IFWABS	Move F/W to Absolute Position	No
/IFWCOARSE	Move F/W to the Coarse Position	No
/IFWDATUM	Move F/W to Datum	No
/IFWFILTER	Move F/W Position by filter number	No

NAME	Description	Basic?
/IFWPULSE	Move F/W Position by Fine Sensor Pulses	No
/IFWREL	Move F/W to Relative Position	No
/IFWSETCOARSE	Set Coarse Sensor Current	No
/IFWSETFINE	Set Fine Sensor Current	No
/IFWSETRATE	Set F/W Movement Parameters	No
/IFWSTOP	Stop F/W Movement	No
/IHK	Enables or Disables HK	Yes
/IHKOFF	Disables HK	Yes
/IHKON	Enables HK	Yes
/IHKRATE	Change HK Rate	Yes
/IHKTDRSS	Enable HK Copy on TDRSS	Yes
/IHTR	Enable/Disable Htrs	Yes
/IHTROFF	Disable Htrs	Yes
/IHTRON	Enable Htrs	Yes
/IHTRPARAMS	Specify Heater Algorithm Parameters	No
/IHVAUTORAMP	Ramp HV	No
/IHVENABLE	Enable HV Ramping	No
/IHVRAMP	Ramp HV	No
/IHVSET	Ramp HV	No
/IHVSTOPRAMP	Stop HV Ramp	No
/IICBENABLE	Enable/Disable Direct ICB Commands	Yes
/IICBREAD	Read Direct ICB Command	Yes
/IICBWRITE	Write Direct ICB Commands	Yes
/IICUCRC	"ICU CRC calc command"	No support for MID 5
/IICUDUMP	"ICU dump command"	No support for MID 5
/IICUDUMPABORT	"ICU Abort Memory Dump"	Yes
/IICULOAD	"ICU load command"	Only support for MIDs 0, 1 and 4
/IICULOAD1	"ICU load one value command"	Only support for MIDs 0, 1 and 4
/IICULOAD3	"ICU load three values command"	Only support for MIDs 0, 1 and 4
/ILIMIT	Enables or Disables Limit Checking	Yes
/ILIMITOFF	Disables Limit Checking	Yes
/ILIMITON	Enables Limit Checking	Yes
/IMOTORINHIBIT	Enable/disable auto inhibit of drive	Yes
/INHKECHO	The ICU echoes this as an NHK	No
/IRTSDISABLE	Disable the RTS system.	No

NAME	**Description**	**Basic?**
/IRTSKILL	Kills an RTS	No
/IRTSRUN	Runs a relative time sequence	No
/IRTSTRACE	Start/stops trace on RTSs	No
/ISTATE	State Manager Command	Only transitions to Safe or Basic
/ISTATETRANS	Sets allowed automatic state transitions	No
/ITEST	Test or Null Command	Yes
/ITIMESYNC	Set Time Sync Parameters	No
/IWATCHDOG	Enable Disable Watchdog	Yes
/IWATCHDOGINT	Set Reset Interval	Yes
/SILONGTIMETONE	Time signal indicator - but too long	Acknowledge only
/SINOOP	Broadcast received	Yes
/SISCATTITUDE	S/c attitude and slew status info	Acknowledge only
/SISLEWABORT	Notification s/c has aborted slew	Acknowledge only
/SISLEWWARNING	Notification s/c is about to slew	/SACSLEWSAFEREPLY response always
/SITIMETONE	Time signal indicator	Acknowledge only
/XRTCENTROIDERR	XRT centroiding error info	Acknowledge only
/XRTPOSITION	XRT pointing info	Acknowledge only

Appendix F ICU software NCRs and ECRs

This is a summary of MSSL UVOT ICU NCRs, ECRs and open issues as of release 10 of the ICU code. The official and original documents are available from MSSL, PSU and GSFC QA.

F.1 Goddard NCR SWIFT2002103006

During UVOT Thermal Balance, the survival heaters were not able to maintain the detectors at their desired survival temperatures

F.2 Goddard NCR SWIFT2002103007

During Thermal Balance the UVOT Door Module approach its survival/operational temperature prior to the cold sink temperature being reached. It appeared the door would exceed the survival temperature if the space enclosure plate was allowed to continue go to its sink temperature. Space plate was at -45 degrees C, required temperature was to be at -106 degrees C. Door temperature operational limit -35 degree C survival -45 degree C.

F.3 Goddard NCR SWIFT2002112002

Twice today, the DPU ended an exposure prematurely. Both exposures were run under conditions in which the TMALI queue in the DPU was filling from time to time.

F.4 MSSL NCR 22 Basic Code

If, after a reboot, the limit checking is commanded off (`/limit off`) before it is started automatically and is then commanded off again, in order to start the limit checking afterwards, the `/limit on` command must be sent twice.

F.5 MSSL NCR 74 BASIC code

The watchdog telecommand runs code that has a delay that means it cannot be sent twice in close succession.

F.6 MSSL NCR 75 BASIC code

If the ICU loses DPU heartbeats, it gives Ada exceptions after 1-2 days.

F.7 MSSL NCR 76 BASIC code

If the first copy of EEPROM tables is corrupt, there's no NHK message to say so.

F.8 MSSL NCR 77 BASIC code

EEPROM reads/writes can conflict because they are not mutex protected. It is therefore not possible to dump and load at the same time.

F.9 MSSL NCR 78 BASIC code

ICU_MEM_MANAGER memory dumps increment the task counter once per dump not once per loop.

F.10 MSSL NCR 79 BASIC code

ICU_MEM_MANAGER CRC reports give the wrong start-address when more than a small area of memory is checksummed.

F.11 MSSL NCR 80 BASIC code

Threshold is not set to 15 on startup: this is only important if the camera is on.

F.12 MSSL NCR 81 BASIC code

If the DPU heartbeat data are "suspect" they are still used. This may not be a problem.

F.13 MSSL NCR 82 BASIC code

Task accepts have delays which should not be there.

F.14 MSSL NCR 83 BASIC code

When the watchdog is tripped to go from safe to basic, the NEXT STATE shows SAFE and the current state shows BASIC.

F.15 MSSL NCR 94

The QM ICU at MSSL had a bit error in EEPROM-B which was correctly noticed by the flight software. However, the star catalogue, count rate table and RTS index and table are not CRC-checked every read but only at the start of a group of reads. AT and PT configuration tables have the same problem but they are probably not a safety issue. Since EEPROM bit-errors have been observed at MSSL and elsewhere with a bit changing from 0 to 1 and back on a very short timescale, these tables should all be read into RAM and CRC checked before the values are used and the values used should only be read out of RAM.

Suggested fix: Change the Ada code to perform a running CRC until the required part of a table is found or cache the EEPROM and checksum each segment against stored checksums.

Impact of the fix to the ground/ITOS

Image changes and load procedure changes may be required.

F.16 MSSL NCR 110

Filter wheel position lost.

Operational Impact – see procedure UVOT-12.

F.17 MSSL NCR 117

There is an error in the star catalogue code which means that 2 very bright stars may not be avoided by the distance specified in the angular constraint table.

F.18 MSSL NCR 121

ISFTYSYSEN occasionally goes to 0.

F.19 MSSL NCR 125

Heater set command Vmin > Vmax causes reboot.

F.20 MSSL NCR 129

When the observatory is in Safehold, the ICU still checks against a Sun constraint angle of 30, when it should use a value of 20 (an no constraint for the Earth and Moon). This is because, in the original specification, it was incorrectly documented that the ICU would be off.

F.21 MSSL NCR 132

The ICU code unnecessarily checks for within 10 arcmin when in SAFE state.

F.22 MSSL NCR 134; SERS S-0067

The ICU timed out waiting for a slew to start on 2005-02-21. This was because the ICU was busy checking the star catalogue after settling on a safepoint when another slew was requested. Was this a little abnormal because of the crazy BAT recovery (see Anomaly Report S-0065) but is nevertheless a bug in the ICU Ada code. Ada function

GET_PT_CONFIG can take a long time and needs first of all to be *timed* to see how long it takes and then needs to be changed to make it interruptable by a high priority RTS.

F.23 MSSL ECR 153

The filter wheel (FW) rotation life consumed by the 80-96 PT snapshots expected per day is a significant concern. The current ICU design provides no mechanism to keep the UVOT idle during un-interesting PT snapshots, preventing FW motion. It seems possible that the SOT may from time to time wish to point Swift at a target that's known to be unsafe for the UVOT, or at an "uninteresting" target that would produce more wear on the detector than scientific benefit. The current ICU design provides no mechanism to explicitly keep the detector Cathode down in such circumstances. Both the FW life concern and the safety concern could be addressed by implementing a UVOT_MODE value that causes the FW to not be moved, the Cathode to remain down, and no exposure to be taken.

F.24 MSSL ECR 169

The AT exposure overhead is 3s and the science output would be better if this could be reduced. This could be helped by removing the delays between safety circuit commands. Most of the improvement can be gained by optimizing the disabling of the heaters to avoid unnecessary delay (see NCR 95). See also ECR 178.

Risk of not fixing
This can lead to loss of science data. It is significant for short exposures and at the start of a GRB, when a quick response is important.

F.25 MSSL ECR 178

The failsafe filter wheel stops and table load aborts should be dealt more efficiently. This could be considered part of ECR 169.

Suggested fix
Add logic to only do the filter wheel stops and table load aborts if there is already a movement/load in progress.

Impact of the fix to the ground/ITOS
None.

Risk of not fixing
Time wasted before exposures.

F.26 MSSL ECR 191

When the ICU calculates that there is no observing time left (countrate budget is used up) the ICU should lower the cathode and only move the filter wheel to blocked if there are still many predicted counts with the cathode down.

F.27 MSSL ECR 192

BAT filter wheel delay code can be removed. There must still be a 0.7s delay for the heaters to turn off. This is a optional modification to release code space for additional modifications.

F.28 MSSL ECR 194

Remove focus heater control code. This is a optional modification to release code space for additional modifications.

F.29 MSSL ECR 195

Remove bright star avoidance code. This is a optional modification to release code space for additional modifications.

F.30 MSSL ECR 196

Remove twilight zone code. This is a optional modification to release code space for additional modifications.

F.31 MSSL ECR 198

Remove beam steerer code. This is a optional modification to release code space for additional modifications.

F.32 MSSL ECR 199

Remove the code to remove the optional axis flips when calculating the XRT pos shift. This is a optional modification to release code space for additional modifications.

F.33 MSSL ECR 202

The diagnostic rts 'line' should be removed as it is never used. This is a optional modification to release code space for additional modifications.

F.34 MSSL ECR 207

In order to facilitate ground analysis of ATs, the Ada code should be modified such that a single image exposure in 1 filter can be replaced by multiple shorter exposures in the same filter contiguously.

F.35 MSSL ECR 208

Allow 2 lines of settling exposure definitions. If the first is too bright and shortened to less than 10s, it falls through the next filter but if it is greater than or equal to 10s, it does only that exposure.