SWIFT-UVOT

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SWIFT-UVOT ICU ON-BOARD SOFTWARE REQUIREMENTS

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1. Introduction

1.1 Scope

The software requirements described in this document are for the Instrument Control Unit (ICU) for the SWIFT-UVOT instrument only. The software requirements for the DPU, which provides the software to process the science data, are described elsewhere.

1.2 Definitions, Acronyms and Abbreviations

1553	MIL-STD 1553B Interface
ACK	Acknowledgement
APID	Application Identifier
AT	Automated Target
BLUE	The photon counting detector of the instrument sensitive to the short wavelength regime
BPE	Blue Processing Electronics
CCD	Charge Coupled Device – the centroiding element of the BLUE detector.
CCSDS	Consultative Committee for Space Data Systems
CRC	Cyclic Redundancy Code
DCI	Data Capture Interface – BPE - DPU interface along which detector events are sent.
DCS	Deferred Command Store
DEM	Digital Electronics Module
DPU	Data Processing Unit
FoM	Figure of Merit Processor
FoV	Field of View
FSW	Flight Software
F/W	Filter Wheel
GRB	Gamma Ray Burst
HK	House Keeping
HV	High Voltage
ICB	Instrument Control Bus
ICU	Instrument Control Unit
LED	Light Emitting Diode
MIC	Micro-Channel Plate Intensified CCD – the photon counting detector system
NAK	No AcKnowledgement
PT	Planned Target
RTS	Relative Time Sequence
SAA	South Atlantic Anomaly
S/C I/F	Spacecraft Interface
SID	Structure Identifier
SRD	Software Requirements Document
SSI	Serial Synchronous Interface
S/W	Software
TBC	To Be Confirmed
TBD	To Be Defined
TC	TeleCommands
TDRSS	Tracking and Data Relay Satellite System
TM	TeleMetry
TM	Telescope Module
TMPSU	Telescope Module Power Supply Unit
ToO	Target of Opportunity
UVOT	Ultra Violet Optical Telescope
$V_{cathode}$, V_{mcp1}, V_{mcp23}	Control Voltages for the blue detector image intensifier tube
XRT	X-Ray Telescope

1.3 Applicable Documents

APP-1	UVOT Specification	SWIFT-UVOT-002
APP-2	ICU/DPU Interface Control Document	03691-DPUICD
APP-3	1553 Bus Protocol Interface Control Document	1143-EI-S19121
APP-4	TMPSU Interface Control Document	XMM-OM/IALS/SP/002
APP-5	BPE Digital Electronics Interface Control Document	XMM-OM/MSSL/SP/0077
APP-6	BPE Analogue Electronics Interface Control Document	XMM-OM/MSSL/SP/81
APP-7	Swift Interface Requirements Document	GSFC-730-SWIFT-IRD
APP-8	REMOVED	
APP-9	REMOVED	
APP-10	UVOT ICU TC-TM Specification	SWIFT-UVOT-009
APP-11	XRT Telemetry Data Formats	XRT-PSU-028

1.4 ICU Overview

The ICU flight software (FSW) controls the telescope and overall instrument functions. The ICU monitors and controls the Telescope Module (TM) high voltage power, thermal status and filter position via the Instrument Control Bus (ICB). The ICU monitors and controls the DPU via the Synchronous Serial Interface (SSI) bus. The ICU FSW provides a deferred command store (DCS) that contains pre-loaded relative time sequences (RTS). Each RTS contains sequences of commands that establish the instrument configuration. Observations are carried out by executing a selected RTS which is based on the identification of a target of interest by the Figure of Merit (FoM). The ICU produces periodic housekeeping telemetry that is reported to the spacecraft over the MIL-STD-1553B (1553) interface. A local copy of the spacecraft clock is maintained which is used to timestamp telemetry packets, which are formatted as Consultative Committee for Space Data Systems (CCSDS) Source Packets.

1.4.1 Functions

The ICU FSW is written in Ada and assembly language and executes on a 31750 processor. The ICU FSW has the following primary functions, to:

1. Receive and execute telecommands from the spacecraft and other instruments.
2. Monitor the instrument status and report housekeeping to the spacecraft.
3. Configure the instrument
4. Schedule and monitor observation sequences, based on messages received from the spacecraft, using pre-loaded RTSs.
5. Maintain instrument safety by detecting instrument error and failure conditions autonomously.
6. Examine an on-board star catalogue and calculate planetary positions during a slew in order to choose an appropriate filter for the destination field of view.
7. Provide the capability to uplink new ICU FSW code modules.
8. Monitor and maintain thermal control of the UVOT.
9. Receive a time message from the spacecraft and synchronize the local copy of the spacecraft clock

The ICU software consists of 3 software units:

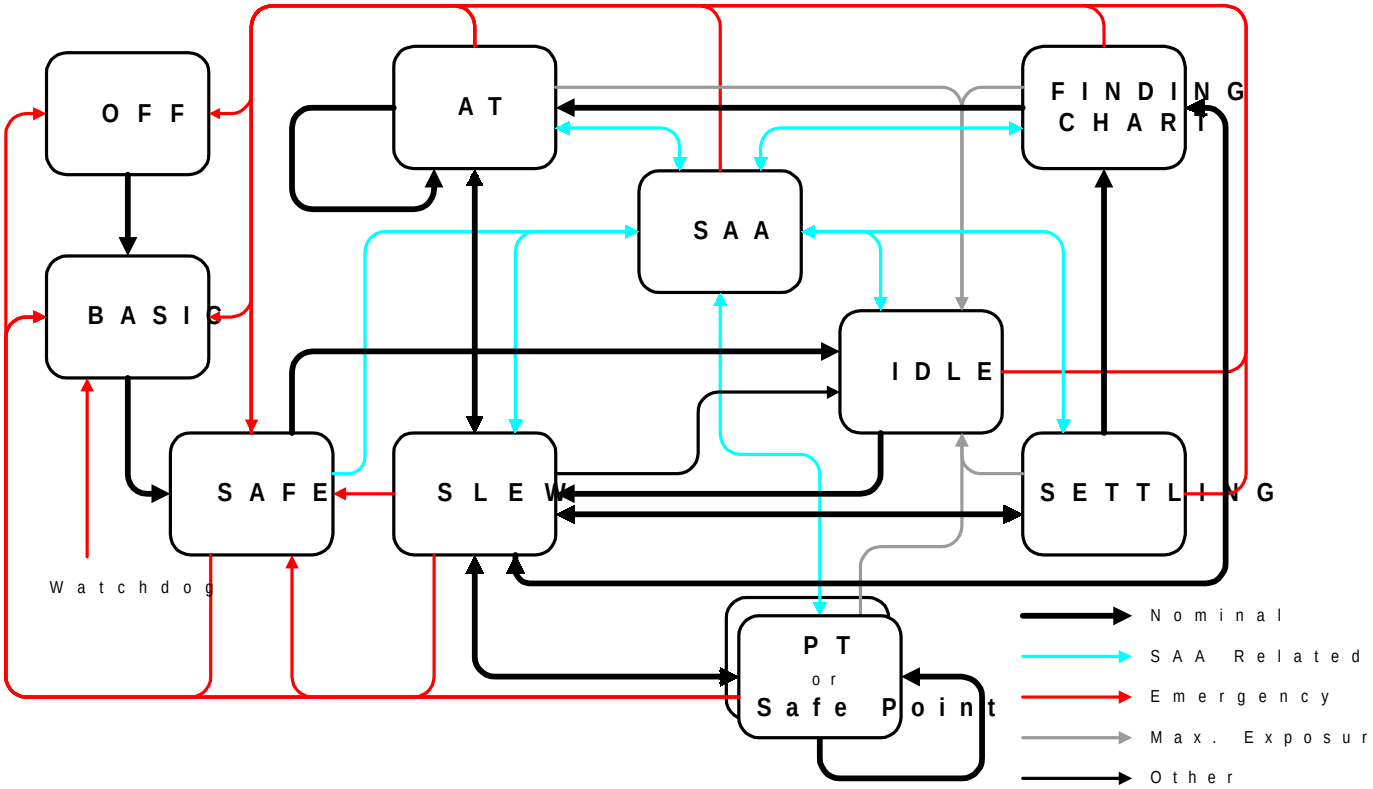
BOOTSTRAP This resides in ROM and is copied into RAM for execution. It is responsible for bringing up the ICU in a known state after turn on or after a watchdog reset. It copies the basic state software (see below) from ROM to RAM. It also supplies routines to copy the operational code (see below) from EEPROM to RAM

BASIC This resides in ROM and is copied into RAM for execution by the bootstrap. Basic is responsible for loading the ICU operational mode code from EEPROM into RAM and for basic housekeeping. It also allows modification of the EEPROM code. It ensures basic safing of the instrument.

OPERATIONAL This resides in EEPROM and is copied into RAM for execution by routines resident in the bootstrap. Operational provides the full functionality of the ICU.

1.4.2 Instrument States

The UVOT has ten powered states: Basic, Safe, Idle, Slew, Settling, Finding Chart, Automated Target (AT), Planned Target (PT), South Atlantic Anomaly (SAA) and Safe Point. The following diagram illustrates the states and transitions between them.



Off **(or Safehold)**	The transitions to the OFF state are controlled by the spacecraft, and therefore could occur at any time. However, to prevent detector degradation, the UVOT should not be turned off when the high voltages are up and therefore the table illustrates those states in which it is safe to turn UVOT off.
Basic	The 1553 Interface is readied so that housekeeping telemetry and commanding is supported. A check is made to see if the telescope module is powered. If so, High Voltages are ramped down. The ICU watchdog is enabled. The DPU Heartbeat watchdog is enabled. ICU EEPROM code can be reloaded or executed. If entry to this state was not via an ICU watchdog trip, DPU EEPROM code will be running. All subsequent states are run from code loaded from EEPROM.
Safe	The ICU ensures that the telescope module is powered and that the HV is off. The ICU ensures that the filter wheel is in the blocked position. Thermal control is activated. It will be possible to move the dichroic in this state.
Settling, Finding Chart, **AT, Safepoint**	On entry to these states, events are sent to the DPU via the Data Capture Interface (DCI). On exit from these states, sending events along the DCI is stopped. The type of observation performed is determined by the state, subject to flood LED level must be zero. The full area of the detector must be enabled for detector safety monitoring purposes. A continuous assessment is made as to whether the observation should continue due to the presence of catalogued bright sources capable of detector degradation in the field of view.

PT	On entry to this state, events are sent to the DPU via the DCI. On exit from this state, sending events along the DCI is stopped. Planned engineering observations are performed. Flood LED level may be non-zero. The enabled area of the detector may not include the full detector.
Slew	The on-board catalogue is examined to see if there will be bright stars in the destination field of view. A check is also made of the positions of the planets and minor planets. An initial assessment is made as to whether there will be a bright source capable of detector degradation in the destination field of view. The $V_{cathode}$ is set to zero to protect the instrument.
SAA	V_{mcp23} is set to 70% and the $V_{cathode}$ is set to zero.
Idle	Vcathode is set to zero. The filter wheel may optionally be left in its current position. No observations are performed.

2. ICU REQUIREMENTS

2.1 Bootstrap Code Requirements

1.1	ICU Basic state code shall be copied from PROM into RAM within 3 s. The PROMs shall then be powered off.
1.2	A means shall be provided to copy Operational State code from EEPROM into RAM. It will overwrite the locations occupied by Basic. It shall then switch automatically to Operational State.
1.3	The bootstrap code shall disable interrupts.
1.4	The ICU shall switch automatically to the Basic code after the Bootstrap has completed.
1.5	Removed

2.2 Basic Code Requirements

2.1	Basic code shall be stored in ROM.
2.2	The 1553 Interface shall be readied so that housekeeping telemetry and commanding will be supported.
2.3	Housekeeping records shall be provided in telemetry. They shall contain those items as defined in table 1.
2.4	A telecommand shall be provided to change the sampling rate of housekeeping to any value between 4 seconds and 1 minute to a resolution of 1 second. The default value shall be 10 seconds.
2.5	A check shall be made to see if the telescope module is powered. If so, the ICU shall ensure that the high voltages are set to zero volts and that the filter wheel position is set to blocked
2.6	The ICU watchdog shall be enabled.
2.7	Removed
2.8	It shall be possible to reload and dump the ICU EEPROM code. Checksum checks shall be performed on code load.
2.9	It shall be possible to load and dump a specified area of the ICU RAM.
2.10	It shall be possible to calculate a cyclic redundancy code (CRC) for a specified area of RAM or EEPROM.
2.11	It shall be possible to switch to Operational code on command using routines provided in the bootstrap area of code.
2.12	It shall support the ability to synchronise the ICU clock to that of the spacecraft.
2.13	A telecommand that does nothing other than require an acknowledgement shall be provided as an 'aliveness' test of the software.
2.14	The bootstrap and basic codes together must fit within 32K 16-bit words.
2.15	On reception of the SISLEWWARNING message from the spacecraft alerting the ICU to the imminence of a slew, the ICU will : 1. ensure that the blue detector voltage $V_{cathode}$ is set to zero. 2. send a SACSLEWSAFEREPLY acknowledgement to the spacecraft indicating it is safe to slew.
2.16	1553 'Mode' commands shall be supported.
2.17	The main interface heaters shall be controlled so as to maintain the Interface thermistor within 19.5±0.5 °C.

2.18	The forward tube heaters shall be controlled so as to maintain either the forward-1 or forward-2 thermistor within 19.5±1.5 °C..
2.19	All required calibration and control parameters shall be stored in EEPROM.
2.20	The ICU shall issue a TDRSS message – see table 3 - if a watchdog reset is detected and a similar message shall be sent direct to the spacecraft.
2.21	The ICU shall monitor those parameters as detailed in table 1 for an out-of-limit condition. In the event of such a condition being detected, then an emergency TDRSS message – see table 3 - shall be issued and a message sent to the spacecraft requesting that the telescope module be powered down. The list of parameters to be checked and the associated limits shall be stored in EEPROM.
2.23	In the event of an error being detected in the data stored in EEPROM, the ICU shall 1. send an emergency message via TDRSS – see table 3. 2. set the High Voltages directly to zero 3. move the f/w to blocked.

2.3 Operational Code Requirements

2.3.1 General

3.1.1	Operational code shall be stored in EEPROM.
3.1.2	The ICU shall inform the DPU of any change in the telescope module configuration via the Serial Synchronous Interface (SSI) using messages documented in APP-2.

2.3.2 Interface Support

3.2.1	The ICU shall control and monitor the DPU via the SSI using commands and messages defined in document APP-2.
3.2.2	The ICU shall control and monitor the telescope module (mechanisms, heaters, thermistors, flood LEDs and BPE) via the ICB (Instrument Control Bus) using commands as defined in the documents APP-4, APP-5 and APP-6.
3.2.3	The ICU shall support telecommands and telemetry via the 1553 bus as defined in APP-3.

2.3.3 Autonomous Control of Instrument

3.3.1	The ICU shall be capable of controlling the instrument autonomously for up to 72 hours.
3.3.2	The ICU shall provide a means of storing in EEPROM Relative Time Sequences (RTS) that are capable of running one or more exposure sequences.
3.3.3	The ICU shall control autonomous science collection by selecting and executing an appropriate RTS on the basis of messages received from the spacecraft and FoM as defined in APP-7.
3.3.4	The ICU shall support the ability to run an RTS from within any other RTS.
3.3.5	The ICU shall support a 'semaphore' capability, whereby RTS execution is suspended until a specified event occurs.
3.3.6	Telecommands shall be provided to allow for the uplinking of new RTS.
3.3.7	Telecommands shall be provided to allow for the deletion of a specified RTS.
3.3.8	A telecommand shall be provided to start execution of a specified RTS. It may not contain parameters for the RTS.
3.3.9	A telecommand shall be provided to stop execution of a specified RTS at any time.
3.3.10	SUPERCEDED – see requirements 3.3.17 onwards.
3.3.11	SUPERCEDED – see requirements 3.3.17 onwards.
3.3.12	SUPERCEDED – see requirements 3.3.17 onwards.
3.3.13	SUPERCEDED – see requirements 3.3.17 onwards.
3.3.14	SUPERCEDED – see requirements 3.3.17 onwards.
3.3.15	REMOVED.
3.3.16	It shall be possible to store all telecommands defined in APP-10 in an RTS.

3.3.17	In the case of 1. We are slewing to an AT 2. IS_NEW_AT_SLEW flag = 1 3. 'Within 10 arc min' flag is set a settling exposure shall be performed until such time as the 'settled' flag is set. The ICU shall then switch to performing a finding chart exposure. An on-board table shall define the exposure configuration used.
3.3.18	In the case of 1. We have slewed to an AT 2. IS_NEW_AT_SLEW flag = 1 3. 'Within 10 arc min' flag is set 4. 'Settled' flag is set a finding chart exposure shall be performed. An on-board table shall define the exposure configuration used.
3.3.19	Should a finding chart exposure be interrupted (by e.g. entering the SAA or a pointing constraint) the exposure shall be completely retaken as soon as the spacecraft returns to the source. The process shall be repeated N times. The value of N shall be stored in an on-board table with a launch value of 3.
3.3.20	An on-board table shall define the AT configurations. It shall consist of a 'time-since-burst' ordered and labelled set of instrument configurations. Every configuration will contain an exposure time for each filter except blank. The table will contain, for each filter, a configuration to be used if there is, or is not, an supplied XRT position. The table will also contain a minimum exposure time.
3.3.21	Upon the start of each AT exposure, the ICU will choose the appropriate configuration based on 'time since burst' and whether an XRT position was supplied. It will then choose the next filter in the list since the last AT exposure and use its specified exposure time. However, if that time is zero, it will skip on to the next filter.
3.3.22	If an AT exposure is interrupted, the ICU will move on to the next filter on return to the source unless the minimum exposure time was not obtained, in which case the entire exposure will be retaken.
3.3.23	A set of PT configurations will be stored in EEPROM. Unlike the AT tables, each configuration will only contain an exposure time for one filter. Each configuration will be labelled with a 'Configuration ID'. There will then be a further table, each entry of which will indexed by the 'UVOT Mode' in the NEXTOBSINFO packet (this is sent at the start of each new pointing). Each entry will contain a list of 'Configuration Ids' that define the order and content of each exposure within that pointing.
3.3.24	At the start of a PT exposure sequence, the ICU shall normalise the exposure times given in each 'Configuration ID' so that their total equals the 'Observe_Seconds' field in the NEXTOBSINFO packet unless the UVOT_MODE is in the range 0.. 0x1000 (see requirement 3.3.27).
3.3.25	Should a PT exposure be interrupted by a transition into the SAA state, the ICU will simply restart the current exposure where it left off i.e. if the requested exposure time is t seconds and we have already exposed for x seconds, then the exposure will restart with an exposure time of t-x. Note that this procedure implicitly assumes that the ground planning will have already taken the SAA interruption into account.
3.3.26	Targets of opportunity will be handled as an AT or PT according the value of the UVOT Mode in the NEXTOBSINFO packet.
3.3.27	PT exposures using UVOT_MODES in the range 0.. 0x1000 will be used to define those calibration sequences for which the exposure times must not be scaled. These will include those that allow setting of the flood LEDs.
3.3.28	PT exposures interrupted by an AT shall be abandoned.

3.3.29	UVOT_MODEs 1..6 are reserved for internal use to define the exposure configuration to be used for the six safe pointing positions.
3.3.30	UVOT_MODE of 7 is reserved for the exposure configuration to be used in the settling exposure.
3.3.31	UVOT_MODE of 8 is reserved for the exposure configuration to be used in the finding chart exposure.

2.3.4 Instrument Safety

2.3.4.1 Preparation for Slew

3.4.1.1	On reception of the SISLEWWARNING message via the spacecraft alerting the ICU to the imminence of a slew, the ICU will: 1. set the blue detector voltage $V_{cathode}$ to zero. 2. send a SACSLEWSAFEREPLY acknowledgement to the spacecraft indicating it is safe to slew.

2.3.4.2 Bright Source Avoidance

2.3.4.2.1 Stars

3.4.2.1.1	The ICU shall maintain a catalogue of bright stars for the whole sky whose brightness is greater or equal to Mv=10. Each catalogue entry will have positions to one arc minute accuracy, together with the magnitude and spectral type or colour information.
3.4.2.1.2	If a star is known to be variable, its brightest known magnitude will be stored in the catalogue and considered its magnitude at all times.
3.4.2.1.3	The ICU shall access those stars from the catalogue within any given UVOT field of view within 1 second.
3.4.2.1.4	For a given pointing, the ICU shall derive from the visual magnitude and spectral type/colour information of sources in the field of view, a maximum exposure time sufficient to avoid detector damage. This time may be zero. The exposure active at the time this value is exceeded shall be stopped and the filter wheel moved to blocked. Any further exposure requests at the current pointing shall be ignored.

2.3.4.2.2 Planets

3.4.2.2.1	The ICU shall calculate within 1 second duration and to within 1 arc minute in position, the positions and brightness of the planets for: 1. The destination position of a slew. 2. The current pointing position at every slew during an observation. The ICU shall then 1. reduce the $V_{cathode}$ to zero. 2. move the filter wheel to the blocked position. if a planet is located within the avoidance angles from the centre of that field of view defined in an on-board table. It shall then inform the DPU of this action by means of messages documented in APP-2. **Note**: The planets are defined as Venus, Mars, Jupiter, Saturn, Uranus and Neptune.

3.4.2.2.2	A telecommand shall be provided to change the avoidance angles for the planets in the on-board table.
3.4.2.2.3	REMOVED.

2.3.4.2.3 Sun, Moon and Earth.

3.4.2.3.1	The ICU shall calculate the positions of the Sun and Moon every slew. Should the spacecraft attitude come within less than avoidance angles of the Sun or the Moon, the ICU shall command the instrument to the Safe state. The avoidance angles shall be stored in an on-board table.
3.4.2.3.2	The ICU shall calculate the positions of the Earth every second. Should the spacecraft attitude come within less than avoidance angle of the Earth , the ICU shall command the instrument to the Safe state. The avoidance angle shall be stored in an on-board table.

2.3.4.2.4 General

3.4.2.4.1	Telecommands shall be provided for the enabling and disabling of all or any of the above Bright Source Avoidance Algorithms.

2.3.4.3 Detector Safing Circuit

3.4.3.1	The ICU will monitor at all times a) the bright source threshold flag and b) the count rate provided by the BPE safing circuit at intervals defined by an on-board table. If the threshold flag is set or the count rate is above a specified value, an RTS will be executed to safe the instrument.
3.4.3.2	A telecommand shall be provided to set the video threshold.
3.4.3.3	A telecommand shall be provided to set the maximum counts per second.
3.4.3.4	A telecommand shall be provided to set the threshold number of consecutive saturated pixels per frame.
3.4.3.5	A telecommand shall be provided to set the threshold number of consecutive frames with saturated pixels.
3.4.3.6	A telecommand shall be provided to enable or disable the safety circuit.
3.4.3.7	A telecommand shall be provided to reset the safety circuit.

2.3.4.4 South Atlantic Anomaly

3.4.4.1	Removed.
3.4.4.2	On deriving, from the spacecraft attitude information messages, that the ICU has entered the SAA, the ICU shall: 1. Set $V_{cathode}$ to zero. 2. Set V_{mcp23} to 70% of its nominal value.
3.4.4.3	On deriving, from the spacecraft attitude information messages that the ICU has exited from the SAA, the ICU shall return the high voltages to their nominal values.

2.3.4.5 Out-of-Limits Conditions

3.4.5.1	The ICU shall monitor the items shown in table 1 for out of limit conditions at the time intervals specified in an on-board table.
3.4.5.2	There shall be one class of out-of-limit conditions, specifically error.
3.4.5.3	The range of values defining the error condition shall be defined in an on-board table.
3.4.5.4	REMOVED.
3.4.5.5	The ICU shall take the recovery actions by running an appropriate RTS specified in an on-board table.
3.4.5.6	Telecommands shall be provided for the enabling and disabling of all out-of-limits monitoring.
3.4.5.7	Telecommands shall be provided for the enabling and disabling of specific out of-limits monitoring.
3.4.5.8	Telecommands shall be provided to change the actions associated with a specific out-of-limits condition.
3.4.5.9	An on-board table shall specify how many times the limit shall be exceeded before it is considered an error.

2.3.4.6 Spacecraft Attitude

3.4.6.1	In the event of loss of spacecraft attitude information, the ICU shall command the instrument to safe state. Loss of spacecraft attitude information is defined as the absence of 5 successive attitude packets at the expected 5 Hz rate.
3.4.6.2	If, during the course of an exposure, the spacecraft attitude information indicates drift from the attitude at the start of the exposure, the ICU shall command the instrument to the Safe State. The drift limit shall be stored in an on-board table.
3.4.6.3	Telecommands shall be provided to enable and disable automatic safing based on the spacecraft Attitude information.

2.3.4.7 Safehold

3.4.7.1	In the event of the ICU receiving a 'safehold' message (indicated by the setting of IN_SAFE_MODE flag in the SISCATTITUDE packet) the ICU action shall be to 1. Set $V_{cathode}$ to zero 2. Set V_{mcp1} to zero 3. Set V_{mcp23} to zero 4. Commence moving f/w to blocked.

2.3.5 DPU Control and Monitoring

3.5.1	Telecommands shall be provided to support all commands documented in APP-2.
3.5.2	The ICU shall monitor the DPU for heartbeats at 10 s intervals. Upon failing to receive heartbeats for more than 3 minutes, it shall run an RTS as specified in an on-board table to perform a recovery action.

3.5.3	A telecommand shall be provided to start or stop the DPU Heartbeat Monitor watchdog.
3.5.4	The ICU shall load up the Centroid Lookup Table of the blue electronics as derived from channel boundaries supplied by the DPU via the SSI in a message packet defined in APP-2.
3.5.5	The ICU shall take actions upon receiving error message packets from the DPU as defined in APP-2.
3.5.6	On receiving the X-Ray Telescope (XRT) position via a message documented in APP-11, the ICU shall provide the position in detector coordinates to the DPU via messages defined in APP-2.

2.3.6 Telescope Module

2.3.6.1 ICB Ports

3.6.1.1	Telecommands shall be provided for diagnostic purposes that allow direct commanding and monitoring of the ICB ports at the address and sub-address level.
3.6.1.2	A telecommand shall be provided to enable and disable direct commanding and monitoring of the ICB ports. By default, this commanding shall be disabled.

2.3.6.2 Detector Digital Electronics

3.6.2.1	Telecommands shall be provided that derive and load the Centroid Table from supplied channel boundaries.
3.6.2.2	Telecommands shall be provided that derive and load the Window Table from supplied window size and position information.
3.6.2.3	Telecommands shall be provided for diagnostic purposes to load and dump the Centroid and Window tables.
3.6.2.4	A telecommand shall be provided that enables or disables the detector integration.
3.6.2.5	A telecommand shall be provided that sets the detector acquisition mode.
3.6.2.6	A telecommand shall be provided that sets the detector event threshold level.
3.6.2.7	A telecommand shall be provided for diagnostic purposes that enables or disables the frame tags in the data sent down the DCI.
3.6.2.8	A telecommand shall be provided that starts or stops the camera.
3.6.2.9	A telecommand shall be provided that resets the camera head electronics.

2.3.6.3 Detector Analogue Electronics

Note – requirements for the detector safing circuit are detailed in the 'Instrument Safing' section.

3.6.3.1	Telecommands shall be provided that start or stop high voltage ramp-up or down to specified values.
3.6.3.2	A telecommand shall be provided that sets the flood LED current.

2.3.6.4 Mechanisms

2.3.6.4.1 General

3.6.4.1.1	Telecommands shall be provided to enable or disable the automatic inhibition of the motor drives in the event of the ambient box temperature becoming too warm.

2.3.6.4.2 Filter Wheel

3.6.4.2.1	Telecommands shall be provided to control the brightness of the illuminating LEDs for the filter wheel coarse and fine sensors.
3.6.4.2.2	Telecommands shall be provided to set the step rate and acceleration or deceleration of the filter wheel.
3.6.4.2.3	Telecommands shall be provided to move the filter wheel to a specified filter.
3.6.4.2.4	Telecommands shall be provided to move the filter wheel to an absolute position in units of stepper motor increments from datum.
3.6.4.2.5	Telecommands shall be provided to move the filter wheel to a position relative to the current one in units of stepper motor increments.
3.6.4.2.6	Telecommands shall be provided to move the filter wheel by a requested number of fine sensor pulses.
3.6.4.2.7	Telecommands shall be provided to move the filter wheel to the datum position (in which both coarse and fine position sensors are detected).
3.6.4.2.8	Telecommands shall be provided to move the filter wheel until the coarse position sensor is detected.

2.3.6.4.3 Dichroic

3.6.5.3.1	Telecommands shall be provided to start or stop movement of the dichroic.
3.6.5.3.2	Telecommands shall be provided to set the direction of the dichroic movement.
3.6.5.3.3	REMOVED.

2.3.6.5 Thermal Control

3.6.6.1	Telecommands shall be provided to request any on/off combination of heaters. These will require that any automatic control of the heaters (see below) is disabled.
3.6.6.2	Telecommands shall be provided to enable and disable the automatic powering on or off of the main interface heaters so as to maintain the mean of Reference A, B and C thermistors within 19.5±0.5 °C.
3.6.6.3	Telecommands shall be provided to enable and disable the automatic powering on or off of the forward tube heaters so as to maintain either the forward-1or forward-2 thermistor within 19.5±1.5 °C..
3.6.6.4	A telecommand shall be provided to select either the forward-1 or forward-2 thermistor to monitor the forward telescope tube temperature.
3.6.6.5	Telecommands shall be provided to enable and disable the automatic powering on or off of the focussing heaters based on the supplied on and off cycle times.
3.6.6.6	Focussing Heater on-off times shall be modified to allow for variations in power delivered due to variations in the supplied spacecraft voltage.

2.3.7 ICU Watchdog

3.7.1	Telecommands shall be provided to enable or disable the ICU watchdog.
3.7.2	Telecommands shall be provided to set or reset the ICU watchdog timeout parameter.
3.7.3	If the watchdog trips, the ICU shall reboot and run Basic.

2.3.8 Housekeeping Control

3.8.1	A telecommand shall be provided to enable or disable the acquisition of housekeeping.
3.8.2	A telecommand shall be provided to change the sampling rate of housekeeping to any value between 4 seconds and 1 minute to a resolution of 1 second. The default value shall be 10 seconds.

2.3.9 State Transitions

3.9.1	A telecommand shall be provided to request a UVOT state transition to a given state.

2.3.10 Memory Maintenance

3.10.1	It shall be possible to load and dump a specified area of RAM.
3.10.2	It shall be possible to load and dump a specified area of EEPROM.
3.10.3	It shall be possible to calculate a CRC for a specified area of RAM or EEPROM.

2.3.11 Telemetry Control

3.11.1	REMOVED.
3.11.2	REMOVED.

2.3.12 Timing

3.12.1	Telecommands shall be provided to request the synchronisation of the ICU clock to the spacecraft on reception of the next 1 pulse per second signal.

2.3.13 Telecommands

2.3.13.1 General

3.13.1.1	The ICU shall support a telecommand rate of 2 kbit s^{-1}.
3.13.1.2	The ICU shall interpret and commence execution of spacecraft commands within 1 s of receipt.
3.13.1.3	The ICU shall verify all commands by confirming that the Application ID (APID), function code and checksum are valid and send an appropriate acknowledgement (ACK) or no-acknowledgement (NAK) as a log message.
3.13.1.4	The format of the telecommands shall be defined in document APP-10.
3.13.1.5	A telecommand that does nothing other than require an acknowledgement shall be provided as an 'aliveness' test of the software.

2.3.13.2 Specific

See under individual systems above.

2.3.14 Telemetry

2.3.14.1 General

3.14.1.1	All telemetry shall be time stamped to an absolute accuracy of 10 ms.
3.14.1.2	The ICU shall produce a telemetry packet at a minimum of every 10 seconds to provide an indication of instrument aliveness to the spacecraft.
3.14.1.3	The ICU shall produce a maximum of 0.5 kbit s^{-1} of telemetry.
3.14.1.4	The ICU packets shall be un-segmented packets of length 223 bytes or less, or exactly 230 bytes.

2.3.14.2 Housekeeping

3.14.2.1	Housekeeping packets shall be provided in telemetry at the requested rate. They shall contain the items documented in table 1.
3.14.2.2	Housekeeping packets shall be constructed in a fixed area of memory to enable debugging via memory dump.
3.14.2.3	The housekeeping format shall be defined in document APP-10.

2.3.14.3 Log Packets

3.14.3.1	Log packets shall be provided in telemetry. They will provide a record of: 1. All commands accepted or rejected, either from the spacecraft or issued via an RTS. 2. All significant events e.g. filter wheel movement, loss of filter wheel position. 3. All errors.
3.14.3.2	The log packet format shall be defined in document APP-10.

2.3.14.4 Memory Dumps

3.14.4.1	REMOVED

2.3.14.5 Telemetry Management

3.14.5.1	REMOVED.

Table 1 : Housekeeping and Out-of-Limits Monitoring

Housekeeping Description				Monitored for out-of-limits conditions		Present In Basic
				Basic	Oper	(note 1)
0	BPE	Thermistors		Yes	Yes	Yes
1	REF B			Yes	Yes	Yes
2	REF C			Yes	Yes	Yes
3	MAIN			Yes	Yes	Yes
4	FORWARD-1			Yes	Yes	Yes
5	FORWARD-2			Yes	Yes	Yes
6	CCD			Yes	Yes	Yes
7	REF A			Yes	Yes	Yes
High Voltage Enabled/Disabled				-	-	Yes
Fine Pick-Off Sensor			Analogue	-	-	Yes
V_{mcp1}		High	Blue	Yes	Yes	Yes
V_{mcp23}		Voltage	Processing	Yes	Yes	Yes
$V_{cathode}$		Monitor	Electronics	Yes	Yes	Yes
+5 V		Low		Yes	Yes	Yes
+15 V		Voltage		Yes	Yes	Yes
-15 V		Monitor		Yes	Yes	Yes
1.23 V Reference				Yes	Yes	Yes
Filter Wheel Pickoff (Analogue)				-	-	Yes
Flood LED Bias Current				-	-	-
Fine Position Sensor LED Drive Current				-	-	Yes
FCTHOLD		Thresholds		-	-	-
RTHOLD				-	-	Yes
STHOLD			Safing	-	-	Yes
PCTHOLD			Circuit	-	-	Yes
RATEOP				No	Yes	Yes
ALERT status				-	-	Yes
Circuit Status				-	-	-
Integration Enabled/Disabled				-	-	Yes
Acquisition Mode			Digital	-	-	Yes
Frame Tag Enabled/Disabled			Blue	-	-	Yes
Table Access Mode/Centroid Table			Processing	-	-	Yes
Camera Start/Stop - Window Table			Electronics	-	-	Yes
Event Detection Threshold				-	-	-
Commanded Heater Status				-	-	Yes
Coarse Position Sensor LED Current				-	-	Yes
Coarse Position Sensor Status				-	-	Yes
S/W Filter Wheel Position Counter				-	-	Yes
S/W Dichroic Position Counter			TMPSU	-	-	-
+28		TMPSU Currents		Yes	Yes	Yes
+11				Yes	Yes	Yes
+15				Yes	Yes	Yes
-15				Yes	Yes	Yes
+5A				Yes	Yes	Yes
+5B				Yes	Yes	Yes
-5B				Yes	Yes	Yes
DISMON	Comparator status			Yes	Yes	Yes
Temp Control Circuit Status				-	-	Yes

(continued overleaf)

Table 1 : Housekeeping and Out-of-Limits Monitoring (continued)

Housekeeping Description (Continued)		Monitored for out-of-limits conditions		Present In Basic (note 1)
		Basic	Oper	
ICB Status Register at last error	ICB	-	-	Yes
ICB Error Count modulo 255 (255->1 wraparound)		-	-	Yes
ICB Powered		-	-	Yes
S/W Version Basic	S/W	-	-	Yes
S/W Version Operational		-	-	Yes
Progress counters for each ADA task		-	-	Yes
S/W Exception Error Counts		-	-	Yes
Error Counters	S/C I/F	-	-	Yes
SSI Good Blocks	SSI	-	-	Yes
SSI Bad Blocks		-	-	Yes
TC Good Packet Count	Packet Counters	-	-	Yes
TC Bad Packet Count		-	-	Yes
TM Good Packet Count		-	-	Yes
TM Bad Packet Count		-	-	Yes
RT-RT Good Packet Count		-	-	Yes
RT-RT Bad Packet Count		-	-	Yes
UVOT State	General	-	-	Yes
Prime/Redundant Flag (Prime = 1)		-	-	Yes
DPU Heartbeat Count	DPU	-	-	Yes
DPU Mode and Submode		-	-	Yes
DPU Supplied Temperatures		Yes	Yes	Yes
DPU Supplied Voltages		Yes	Yes	Yes
Observation Progress Counters	DCS	-	-	-

Notes.

1. Indicates whether item is to be monitored and placed in HK when the ICU is in Basic mode – some items may only be valid if the Telescope Module is powered.

Table 2: Safing/Recovery Actions

REMOVED – actions are defined by on-board re-loadable RTSs

Table 3: List of Emergency TDRSS Messages for Basic Code

Message	Autonomous Onboard Action	Expected S/C Action	Expected Ground Action	Description
ICU Watchdog Trip	HV Safed, Filter Wheel to Blocked. Should either fail, a message is sent to the spacecraft requesting that the telescope module be powered off.	Possible Power Down of Telescope Module.	Run Diagnostics	The ICU watchdog has tripped and rebooted to basic mode where basic safing actions are performed.
Limits exceeded in basic mode	A message is sent to the spacecraft requesting that the telescope module is powered off.	Power Down of Telescope Module.	Run Diagnostics	One or more safety limits are exceeded whilst in basic mode. As safing facilities are limited in this mode, a request is made to the spacecraft to power down the telescope module.
Corrupted EEPROM	HV set immediately to zero, Filter wheel to blocked.		Run Diagnostics	Corrupted EEPROM containing safety limits and calibration coefficients has been found to be corrupt. Therefore it is not possible to monitor limits on board.