SWIFT-UVOT-002-R04

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SPECIFICATION DOCUMENT FOR THE SWIFT ULTRAVIOLET OPTICAL TELESCOPE

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1. SCOPE, OBJECTIVES, AND DESCRIPTION

1.1 Scope

The purpose of this Instrument Specification is to document the technical and programmatic requirements of the UltraViolet Optical Telescope (UVOT) in terms of compliance, detailed specification, and special requirements. This document will be used as the basis for spacecraft/instrument interface requirements, for functional and performance specifications, and for verification.

The MSSL portion of the UVOT instrument is a heritage instrument and as such is being produced to XMM-OM level requirements. US leveled requirements will be evaluated and differences so noted but they will not be binding to the MSSL portion of the Instrument as stated in the SWIFT MAR.

1.2 General Description

This section describes the planned features and performance for the UVOT instrument. Items required by the project are mentioned along with the reference to the document specifying the requirement.

The UVOT instrument is specifically designed for afterglow studies of GRBs, reference Table 1-1. Ground Observations of GRBs have shown that optical afterglows typically decline in brightness as $t^{-1.1}$ to $t^{-2.1}$. Rapid response is required to observe these counterparts and determine their redshift while they are still bright. The UVOT instrument, as part of the SWIFT spacecraft, provides a rapid UV response capability that is not possible from the ground and cannot be clouded out. The UVOT enables optimal ground-based observations by providing rapid optical images of the GRB field so that any optical or IR counterpart can be quickly identified and studied. Stars in the FOV of the UVOT will provide an astrometric grid for the GRB field (MRD 3.2.5, 4.5).

Table 1-1 UVOT Specification

Telescope	Modified Ritchey – Chretien
Aperture	30 cm diameter
F-number	12.7
Detector	Intensified CCD
Detector Operation	Photon Counting
Field of View	16 x 16 arcmin
Detection Element	256 x 256 pixels
Resolution	2048 x 2048 after centroiding
Telescope PSF	0.9 arcsec FWHM @350nm
Wavelength Range	170-600 nm
Filters	11 (one blocked)
Sensitivity	B=24.0 in white light in 1000s
Pixel Scale	0.5 arcsec

The process of GRB observation begins with the detection of a GRB by the Burst Alert Telescope (BAT). Immediately after the BAT detects a GRB, the SWIFT spacecraft will slew to point both the

UVOT and the X-Ray Telescope (XRT) at the GRB location. The spacecraft's expected 20-70 second time-to-target means that ~100 GRBs per year will be observed by the narrow field instruments during the gamma ray emission.

When the spacecraft acquires a new GRB, the UVOT will go through a predetermined program of exposure time and filter combinations. The initial image will be parameterized and immediately sent to the ground for use as a finding chart by ground-based observers, and for comparison with archival observations of the same patch of sky to detect a variable source that could be the optical counterpart. The filtered observations will give the temporal behavior as a function of wavelength. If the GRB is at a distance greater than z = 1, six-band photometry will measure the redshift of the GRB. In the absence of new GRBs being detected, pre-planned programmed observations will be conducted.

The UVOT detectors are copies of the two micro-channel plate intensified CCD (MIC) detectors from the XMM/OM design. They are photon-counting devices capable of detecting very low signal levels and shall allow the UVOT to detect faint objects over the wavelength range 170-600nm (MRD 3.4.3, 3.4.4). The design is able to operate in a photon counting mode, unaffected by CCD read noise and cosmic ray events on the CCD. The UVOT should have the capability to autonomously determine the spacecraft drift using guide stars in the FOV. As in the XMM/OM, an 11-position filter wheel in front of each detector allows the selection of optical elements to be brought into the field of view. Two grism elements will be used to obtain low-resolution spectra of the brightest bursts with m_B<17.

Once Swift has slewed to a new burst, the UVOT acquires a 100s exposure of the target field. A list of field stars will be extracted from the 8x8 $arcmin^2$ portion of the frame surrounding the GRB position provided by the BAT and telemetered to the ground within 270s (MRD 3.2.5). The SWIFT operations center will automatically post this image to the GRB Coordinates Network. During the next ground contact, the full frame of the finding chart image is telemetered, as well as all other GRB data collected by UVOT. These images should contain at least 15 serendipitous stars listed in existing astrometric catalogs, allowing less than 0.3 arcsec positional accuracy (MRD 4.5). The UVOT will autonomously reduce high-voltage on the cathode of the detector when bright (m_B < 8) stars or earthlight (30° of limb) are in the FOV.

The UVOT is sensitive to a 24^{th} magnitude point source in 1000s using the open filter [MRD 3.4.2]. A comparable 30 cm ground-based telescope is limited to 20^{th} magnitude due to sky brightness and visibility. Observing from space, the UVOT has very low sky brightness, better spatial resolution, and a zero read-noise detector, making it competitive with a 4 meter ground-based telescope.

1.3 Organizational and Management Relationships

The following sections detail the overall management structure and Institutional responsibilities of the UVOT team.

1.3.1 Management Structure

The management structure of the UVOT development is shown in Figure 1-1

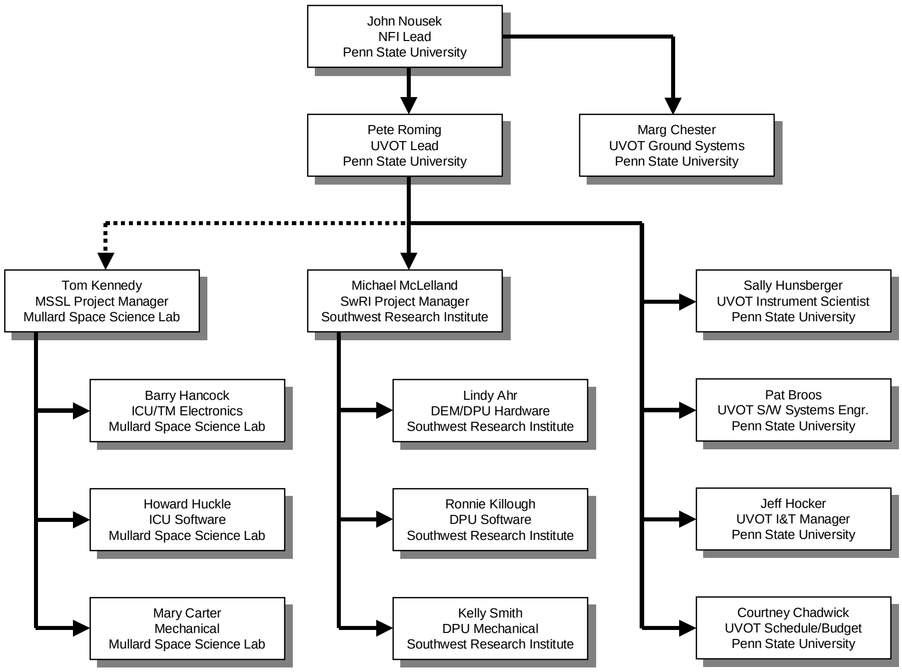


Figure 1-1 UVOT Management Tree

1.3.2 Institutional Responsibility

The responsibilities of the participating institutions are outlined in Table 1-2:

Table 1-2 Institutional Responsibilities

Institution	**Responsibilities**	**Notes**
Pennsylvania State University	Principal Investigator	
	Program Management	
	Systems Engineering	Support from MSSL
	System-level Integration	
	System-level Testing	
	System-level Calibration	
	System EGSE	
	Door	
	DPU Science Software	
Mullard Space Science Laboratory	Instrument Control Unit Electronics and Software	
	Blue Detector	
	Filter Wheel Mechanism	
	Dichroic Mechanism	
	Telescope Structure	
	Thermal Blankets	
	System MGSE (supplied by GSFC/PSU)	
Southwest Research Institution	Digital Electronics Module Structure	
	Data Processing Unit Electronics	
	DPU System Software	
Goddard Spaceflight Center	System Level Test Facilities	
	Outstanding System Engineering	

2. APPLICABLE DOCUMENTS

2.1 Parent Documents

Figure 2-1 presents the overall document structure of the SWIFT program and where this document is located within that context. All requirements enumerated herein shall be traceable to the Swift Safety Reliability & Quality Assurance Program (SRQAP), Swift Science Requirements Document (SRD), Swift Mission Requirements Document (MRD), Swift Interface Requirements Document (IRD), and/or Swift System Verification Requirements Document (SVRD).

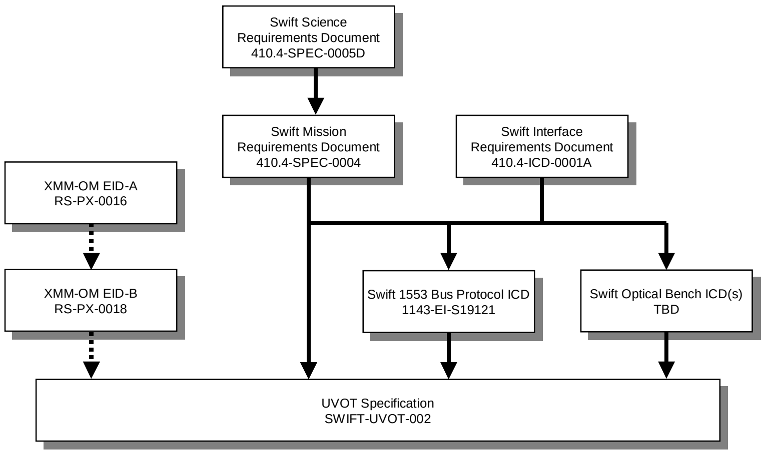


Figure 2-1 Swift Document Tree

2.2 UVOT Documents

This section defines the document tree for the UVOT Instrument. The UVOT document tree is shown in Figure 2-2.

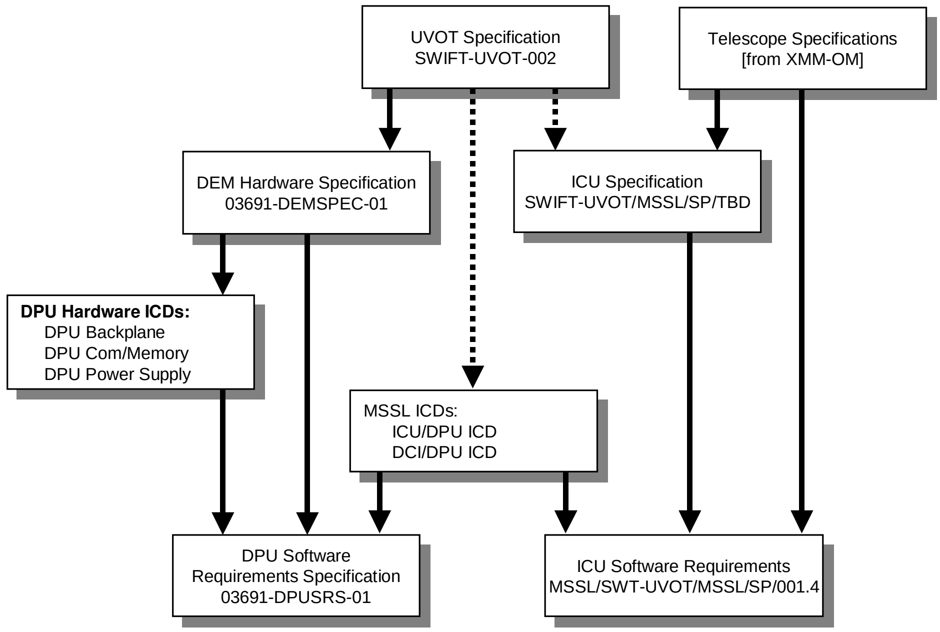


Figure 2-2 UVOT document tree

2.3 Government Furnished Property List

Table 2-1 lists the Property to be furnished to Penn State University by Goddard Space Flight Center.

Table 2-1 GSFC Furnished Property

Description	Manufacture	Part Number	Required Date	Qty.
Flight Qualified RAD6000 Radiation Hardened Processor Module	Lockheed Martin			3
Engineering Breadboard RAD6000	Lockheed Martin			1
Space Station Furnace Facility Motherboard				1
Space Station Furnace Facility Cabinet				1
Furnace Facility P/S				1

2.4 Other Applicable Documents

2.4.1 NASA Documents

TM 4527	Natural Orbital Environment Guidelines for Use in Aerospace Vehicle Development
GSFC-410-MIDEX-001	MIDEX Assurance Guidelines
GSFC-410-MIDEX-002	MIDEX Assurance Requirements
NHB 1700.1	NASA Safety Policy and Requirements Document
NHB 5300.4(3A-2)	Requirements for Soldered Electrical Connections
NHB 5300.4(3G)	Requirements for Interconnecting Cables, Harnesses and Wiring
NHB 5300.4(3H)	Requirements for Crimping and Wire Wrap
NHB 5300.4(3I)	Requirements for Printed Wiring Boards
NHB 5300.4(3J)	Requirements for Conformal Coating and Staking of Printed Wiring Boards and Electronic Assemblies
NHB 5300.4(3K)	Design Requirements for Rigid Printed Wiring Boards and Assemblies
NHB 6000.1D	Requirements for Packaging, Handling, and Transportation for Aeronautical and Space Systems, Equipment, and Associated Components

2.4.2 Military Documents

MIL-STD-461C	Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference
MIL-STD-462C	Measurement of Electromagnetic Interference Characteristics
MIL-B-5087B	Bonding, Electrical, and Lightning Protection for Aerospace Systems
EWR 127-1	Eastern and Western Range Safety Regulation
MIL-STD-1553B	Aircraft Internal Time Division Command/Response Multiplex Data Bus, Notes 1 and 2
MIL-PRF-13830B	General Specification Governing the Manufacture, Assembly, and Inspection of Optical Components
MIL-F-48616	General Specification for Filter (Coatings)

2.4.3 ESA Documents

RS-PX-0016 EID-A	X-RAY Multi Mirror Mission Experiment Interface Document Part A
RS-PX-0016 EID-B	X-RAY Multi Mirror Mission Experiment Interface Document Part B

2.4.4 Industry Documents

ANSI/EIA-232-D-1986	Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange
CCSDS 102.0-B-3	Consultative Committee for Space Data Systems - Packet Telemetry
CCSDS 301.0-B-2	Consultative Committee for Space Data Systems - Time Code For

2.4.5 Penn State Documents

PAIP-96-15-8089	Penn State Performance Assurance Implementation Plan

2.4.6 Project Documents

Phase A Study	Swift – A Panchromatic GRB MIDEX Mission

Report in Response to AO-98-055-03

2.5 Acronym List

A/D	Analog to Digital
AC	Alternating Current
Amps	Amperes
AOCS	Attitude Orbiting Control System
B	Blue apparent magnitude
BAT	Burst Alert Telescope
BCH	Blue Camera Head
BPE	Blue Processing Electronics
C	Celsius
C&DH	Command and Data Handling
CCD	Charge Coupled Device
CCSDS	Consultative Committee for Space Data Systems
CDR	Critical Design Review
COP	Common On-chip Processor
CPM	Central Processor Module
CPT	Comprehensive Performance Test
CREME	Cosmic Ray Effects of Microelectronics
CVCM	Collected Volatile Condensable Materials
DB	Decibel
DC	Direct Current
DCI	Data Capture Interface
DCS	Deferred Command Store
DEM	Digital Electronics Module
DPU	Digital Processing Unit
DRAM	Dynamic Random Access Memory
EDAC	Error Detection and Correction
EEE	Electronic, Electrical and Electromechanical
EEPROM	Electrically Erasable Programmable Read Only Memory
EGSE	Electrical Ground System Equipment
EIA	Electronic Industry Association
EID	Experiment Interface Document
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interface
ESA	European Space Agency
ESD	Electrostatic Discharge
FEM	Finite Element Model
FIFO	First In First Out
FM	Flight Model
FoM	Figure of Merit
FOV	Field-of-View
FS	Factor of Safety
FSW	Flight Soft Ware
g	Gravitational Acceleration
GCN	GRB Coordinates Network
GRB	Gamma Ray Burst

GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
GUI	Graphical User Interface
HK	Housekeeping
HOP	High Output Paraffin
H/W	Hard Ware
HV	High Voltage
HVU	High Voltage Unit
Hz	Hertz
ICB	Instrument Control Bus
ICU	Instrument Control Unit
IFT	Instrument Functional Test
IHU	Interconnecting Harness Units
ITOS	Integrated Test and Operations System
IR	InfraRed
IRD	Interface Requirements Document
LED	Light Emitting Diode
LET	Latchup Event Threshold
Max	Maximum
MAR	Mission Assurance Requirements
MB	Motherboard
MECO	Main Engine Cut Off
MIC	Micro-channel plate Intensified Channel
MICD	Mechanical Interface Control Document
MIL	Military
MIME	Multipurpose Internet Mail Extensions
MGSE	Mechanical Ground Support Equipment
min	Minute
MLI	Multi-Layer Insulation
MRD	Mission Requirements Document
MS	Margin of Safety
MSSL	Mullard Space Science Laboratory
MUX	Multiplexor
NASA	National Aeronautics and Space Administration
NASTRAN	NASA Structural Analysis
NCR	Non-Conformance Report
NFI	Narrow Field Instrument
OB	Optical Bench
OBIF	Optical Bench Interface Flange
oct	Octave
OGSE	Optical Ground Support Equipment
Pa	Pascal
PAIP	Product Assurance Implementation Plan
PPS	Pulses Per Second
PROM	Programmable Read Only Memory
PSF	Point Spread Function
PSI	Pounds per Square Inch
PSM	Power Supply Module

PSU	The Pennsylvania State University
RAM	Random Access Memory
RISC	Reduced Instruction Set Computer
RMS	Root Mean Square
RT	Remote Terminal
RTS	Relative Time Sequence
S/C	Space Craft
S/W	Soft Ware
SAA	South Atlantic Anomaly
SCM	Swift Communications Module
SCU	Spacecraft Control Unit
SDAT	Science Data Analysis Terminal
SEB	Single Event Burnout
sec	Second
SEE	Single Event Effects
SEGR	Single Event Gate Rupture
SEL	Single Event Latchup
SEU	Single Event Upset
SFT	Short Functional Test
SOW	Statement Of Work
SRD	Science Requirements Document
SRQAP	Swift Safety Reliability & Quality Assurance Program
SSI	Synchronous Serial Interface
ST	Star Tracker
STOL	Systems Test and Operations Language
SVRD	Swift System Verification Requirements Document
SwRI	Southwest Research Institute
TBD	To Be Determined
TBR	To Be Reviewed
TDRSS	Tracking and Data Relay Satellite System
TIA	Telecommunications Industry Association
TICD	Thermal Interface Control Document
TM	Telescope Module
TML	Total Mass Loss
TMPSU	Telescope Module Power Supply Unit
TQCM	Temperature-controlled Quartz Crystal Microbalance
UVOT	UltraViolet Optical Telescope
VME	Versa Module Eurocard
XMM-OM	X-ray Multi-mirror Mission – Optical Monitor
XRT	X-Ray Telescope

3. INSTRUMENT REQUIREMENTS

This section documents the UVOT science and mission requirements. It has been separated into three sections; Project Level Requirements from the MRD levied upon the UVOT, UVOT Instrument Specific Requirements, and Additional UVOT Requirements.

3.1 SWIFT Project Level Requirements from MRD

The project level requirements for the UVOT as set forth by the Swift Project in the MRD are listed below. The applicable sections from the MRD are listed in parenthesis.

3.1.1 Finding Chart Timing

The UVOT will provide an optical finding chart to the ground in t ≤ 270 s after a BAT trigger. (SRD 2.5; MRD 3.2.5).

3.1.2 Finding Chart Accuracy

The GRB optical finding chart positional accuracy for relative astrometry shall be < 0.3 arcsec (SRD 2.6; MRD 3.2.6).

3.1.3 Resolving Power

The GRB UV/optical resolving power by UVOT grism [$\lambda/\Delta\lambda$ at 300 nm for V < 17] shall be > 300 (SRD 3.2; MRD 3.3.2).

3.1.4 Sensitivity

The GRB UV/optical sensitivity by UVOT [blue magnitude in 1000 s with open filter] shall be > 24 (SRD 4.2; MRD 3.4.2).

3.1.5 Long Wavelength Limit

The long wavelength limit to cover optical band by UVOT shall be no less than 600 nm (SRD 4.3; MRD 3.4.3).

3.1.6 Short Wavelength Limit

The short wavelength limit to cover UV band by UVOT shall be no greater than 170 nm (SRD 4.4; MRD 3.4.4).

3.1.7 Observing Program

The UVOT shall have the capability to modify automated on-board observing program (SRD 4.6; MRD 3.4.6).

3.1.8 Relative Time Accuracy

Maximum relative time tag errors for UVOT science products shall be 20 ms, (e.g., UVOT Timing Mode products time-tagged with identical times have relative errors of up to 20 ms) (SRD 7.5; MRD 3.7.5).

3.1.9 Data Loss

The UVOT will restrict the data processor end-to-end data loss to ≤ 10% (SRD 7.8; MRD 3.7.8).

3.1.10 Observing Efficiency

Observing efficiency outside SAA shall be greater than 80%. (SRD 7.9; MRD 3.7.9).

3.1.11 Mission Lifetime

UVOT shall be designed for a mission lifetime of 2 years, which includes a 30-day on-orbit checkout (SRD 7.10; MRD 3.7.10; MRD 4.1.5).

3.1.12 Applicable Document Hierarchy

Unless otherwise stated in this document, all inconsistencies shall be resolved in the following order (MRD 2.0):

1. Swift Science Requirements Document
2. Swift Mission Requirements Document
3. Swift Interface Requirements Document
4. Swift Safety, Reliability and Quality Assurance Requirements
5. Swift Verification Plan and Environmental Specifications

3.1.13 Parameterized Source List

Using the burst location provided by the BAT, a parameterized source list of objects will be generated (MRD 3.2.6).

3.1.14 Launch Date

The launch date shall be no later than December 5, 2003 (4.1.3).

3.1.15 Autonomous Operations

The UVOT shall be designed for autonomous operations for up to 72 hours without human intervention. (MRD 4.1.6).

3.1.16 Performance Assurance Implementation Plan

The developer shall provide a quality plan in accordance with the requirements of GSFC-SWIFT-410-SPEC-002 "Swift Program Mission Assurance Requirements [MAR]" (MRD 4.2.1).

3.1.17 Quality Assurance

The developer shall meet the requirements for workmanship, failure reporting, and reviews as specified in the MAR (MRD 4.2.2).

3.1.18 Safety Assurance

The developer shall plan and implement a system safety program as specified in the MAR (MRD 4.2.3).

3.1.19 Design Assurance

The developer shall plan and implement parts, materials, reliability, and software assurance programs as specified in the MAR (MRD 4.2.4).

3.1.20 Verification Assurance

The developer will conduct a verification program to ensure that systems meet their specified performance requirements (MRD 4.2.5).

3.1.21 Nonconformance Documentation and Control

The developer shall provide a program for nonconformance documentation and control as specified in the MAR (MRD 4.2.6).

3.1.22 Interface Requirements

The developer shall provide a system that meets the requirements of the "Swift Interface Requirements Document [IRD]," 410.4-ICD-0001 (MRD 4.3).

3.1.23 GRB Message Timing Allocations

Swift subsystems shall be designed to meet the timing requirements as specified in the Burst Alert Timing Budget [refer to Section 13.2 of this document] (MRD 4.5).

3.1.24 Observatory Command & Telemetry Database

The UVOT team shall provide inputs to the spacecraft team who shall define and manage the contents of the observatory telemetry and command database. This database shall be used through I&T, and transitioned to the MOC prior to launch. (MRD 4.10.10).

3.1.25 Flight Software Updates

The UVOT shall support the capability to update the onboard flight software post-launch (MRD 4.11.16).

3.1.26 Flight Software Maintenance

The UVOT providers shall maintain facilities and expertise for the development and validation of Swift instrument flight software updates and the maintenance of instrument flight software for the duration of the mission. (MRD 4.11.17).

3.1.27 Telemetry

The UVOT shall move up to 960 bytes of UVOT telemetry for each transfer over the 1553 bus resulting in a peak SC transfer capability 64 kbps. (MRD EB1 field definitions).

3.2 UVOT Instrument Requirements

3.2.1 Radiation Environment

All parts of the UVOT shall be designed to survive in a 600 km, 22 degree inclination orbit radiation environment for a minimum mission life of 2 years, including a 30-day on-orbit checkout (IRD 7.2.8.2, MRD 4.1.5). The goal for designed radiation survivability is defined by PSU as less than 2% degradation in performance as compared to the performance at 30-day on-orbit checkout.

3.2.2 GRB Position

Using the burst location provided by the BAT, a parameterized source list of objects within an 8.0′ x 8.0′ window will be generated. This window size provides a sufficient field-of-view to include the GRB (the

BAT error circle is 8.0′) and supply enough stars in the field to accurately determine the GRB position. The source list shall be provided to the C&DH in t ≤ 270 s after a BAT trigger (MRD-3.2.6).

3.2.3 Detection Limit

The UVOT shall have a source detection limit of mB = 24.0 in a white light filter in 103 s [MRD-3.4.2]. A source detection limit of mB = 24.0 at the 5σ confidence level, for an A star spectrum in a white light filter in 103 s, has already been demonstrated by the XMM-OM.

3.3 Additional UVOT Requirements

Additional UVOT instrument level requirements have been added either due to XMM-OM heritage or to enhancements necessary to the UVOT.

3.3.1 Broadband Images

The UVOT shall provide broadband images to facilitate the calculation of redshifts in the 1.5 ≤ z ≤ 3.5 range.

3.3.2 UV Grism Spectral Range

The spectral range of the UV grisms will be 1700 - 3000 Å.

3.3.3 Optical Grism Spectral Range

The spectral range of the Optical grisms will be 3000 - 6000 Å.

3.3.4 Spatial Resolution

The UVOT should demonstrate a spatial resolution of < 0.75 arcsec at 4000 Å.

3.3.5 Field-of-View

The UVOT should demonstrate a full field of view of ≥ 22.6′ across the diagonal. This is easily determined using the 16.0′ x 16.0′ sides of the detector.

3.3.6 Spatial Distortion

The UVOT should demonstrate a spatial distortion in the field of view of less than 3%.

3.3.7 Initial Photon Capture

The UVOT should provide an imaging mode that allows the first 150 s of UV/optical photon events to be stored in memory as they arrive.

3.3.8 Time Resolution

The minimum time resolution of UVOT images should be 10.8 ms, determined by the CCD frame time.

3.3.9 Autonomous Safing

The UVOT shall have a safe function that autonomously protects the detector from bright sources (MV<=8) in all science modes.

3.3.10 Brightness Limit

The limiting UVOT bright magnitude is $m_V = 8.0$. Therefore, the UVOT should not observe GRBs with any objects in the field-of-view over this limiting magnitude. In all other cases the UVOT will observe the GRB regions, whether an optical counterpart exists or not.

3.3.11 Minimum Science

The minimum science required by the UVOT (based on the Phase A Report) is 17.0′ x 17.0′ exposures in event mode during the settling phase, an 8.0′ x 8.0′ image mode finding chart, a 17.0′ x 17.0′ image mode using the visible grism, during a 17.0′ x 17.0′ image mode using the UV grism, & sixty 8.0′ x 8.0′ image mode planned targets.

4. INSTRUMENT DESCRIPTION

This section describes the overall Hardware and Software architecture of the UVOT.

4.1 Hardware Description

The UVOT consists of 5 units:

1) One Telescope Module (TM) containing:

- The UV/optical telescope
- Two blue photon counting detectors, one prime and one redundant
- Two filter wheel mechanisms
- The dichroic mechanism
- Two power supplies & electronics

2) Two Digital Electronics Modules (DEMs), one prime and one cold redundant; each one containing:

- Data processing electronics
- Instrument control electronics
- DEM chassis and power supply electronics

3) Two Interconnecting Harness Units (IHUs), one prime and one redundant connect the TM and the two DEMs.

A schematic of the UVOT is shown in Figure 4-1 Instrument Schematic; the instrument H/W configuration is shown in Figure 4-2 Instrument Configuration.

4.1.1 Telescope Module

The optical train consists of a 300 mm clear aperture Ritchey-Chretien telescope with a primary f/ratio of f/2.0 increasing to f/12.72 after the secondary. The baffle system consists of an external baffle that extends beyond the secondary mirror; an internal baffle lining the telescope tube between the primary and secondary mirrors; and primary/secondary baffles surrounding the secondary mirror and the hole at the center of the primary mirror.

The dichroic mechanism selects either the prime or redundant optical path. The dichroic mirror reflects the beam through the filter wheel In order to flatten the intrinsically curved focal plane the front surface of the detector window is concave (thinner at the center), and the filters are weakly figured.

Two filter wheels, one for each blue detector, carries 7 filters, 2 grisms, a focal expander and a blocked position. The grisms offer limited spectral resolution (~1 nm/pix). Two grisms are required to cover the full spectral range. The focal expander provides a 4x increase in image scale, to f/54 in the blue, to provide diffraction-limited images. This reduces confusion problems and permits the reaching of fainter limiting magnitudes at the center of the field of view. The focal expander does not operate at UV wavelengths because of the limitation of transmission optics over a wide wavelength range. The gain in resolution from the magnifier will be realized only with a greater stability in the S/C pointing than currently specified. Simulations suggest that this will be achieved; however the use of the magnifier is not to be regarded as a driver for the AOCS performances.

The prime and redundant detectors operate in a wavelength range between 170 and 600 nm. These are photon-counting devices, based on a micro-channel plate intensifier. The photosensitive surface is an S20 photo-cathode with an active area of 24 mm in diameter and a field of view of 24 arcmin on the diagonal. The detector format will be 2048 x 2048 pixels with each pixel ~9.6 µm square (the precise dimension depends on the curvature of the detector window and filter elements). There will be commandable stimulation of the detector for calibration purposes.

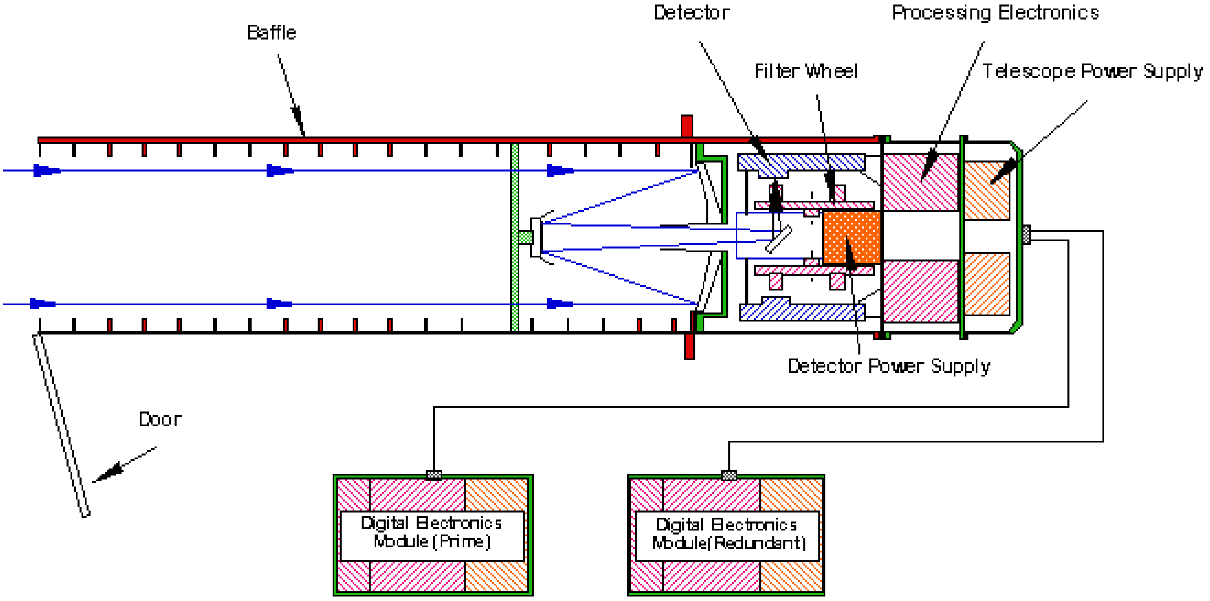


Figure 4-1 Instrument Schematic

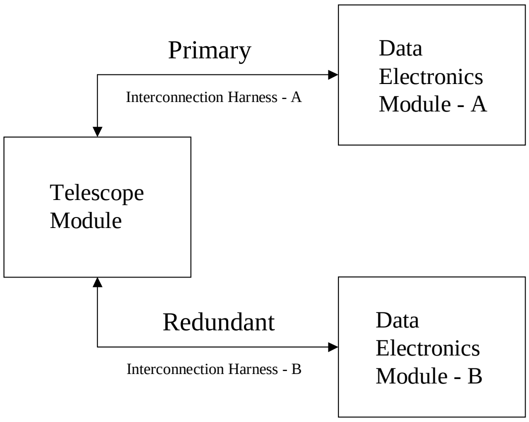


Figure 4-2 Instrument Configuration

4.1.2 Digital Electronics Module

There are two identical DEMs, one being redundant to the other. Each DEM will consist of three electronic units: instrument control unit (ICU), data processing unit (DPU), and a power supply module. Within each DEM are two complete backplanes one for the ICU and one for the DPU. The ICU exercises overall control over the instrument and is responsible for interfacing to the S/C. The DPU is responsible for accepting the data from the detectors, compensating for S/C drift, and accumulating and packaging the data before passing it on to the S/C for transmission. The power supply module is a single module that provides two completely separate secondary power supplies: one for the ICU and one for the DPU.

4.1.3 Interconnecting Harness

The two IHUs connect the two DEMs to the TM.

4.2 Mechanical Design

4.2.1 Telescope Unit Mechanical Design

The overall Telescope Module configuration is shown in Figure 4-1.

The TM can be divided into a number of sub-modules. This type of concept enables considerable assembly, integration, and test of the blue module and telescope to take place independently. It also means that interfaces are minimized and optical alignment eased. The tube of the TM has an external mounting flange, which connects to the optical bench (OB).

The primary and secondary mirrors in the telescope are made from Zerodur. Focus is maintained by the intrinsically thermally stable invar metering structure between the primary and secondary mirrors. However, some degree of fine focusing is possible by local heating, if necessary.

The structural tubes behind the primary mirror house the detectors, mechanisms and their associated electronics on two bulkheads (see Figure 4-3). The first bulkhead serves as the optical bench for the blue module with detectors, filter wheels, and a dichroic mechanism on its forward face and electronics on its rear. The blue detectors are separated by 180º about the optical axis. This optimizes the use of the limited space behind the primary mirror. The structural integrity of the blue detectors is aided by bracing them to a central square column carrying the dichroic mechanism. The second bulkhead carries the TMPSU, which contains the motor drive circuits for the three mechanisms, and the external connector panel.

4.2.2 Digital Electronics Module Mechanical Design

There are two identical DEMs, one being redundant to the other. These are mounted, separately from the TM, on the S/C optical bench. Both units are box structures. Inside each unit there are a number of modules that mate with a motherboard. The modules consist of printed circuit cards held in frames.

4.2.3 Mechanisms

There are four mechanisms in the TM: two blue filter wheel mechanisms, a dichroic mechanism, and an aperture door mechanism.

The two blue filter wheel mechanisms are identical and fully redundant. Each one carries seven filters, one blocked position, two grisms, and a focal expander. Each wheel rotates on a stub axle, which is in turn mounted on a base plate. A stepper motor, also mounted on the base plate, drives the wheel round. Both base plates are firmly bolted to flat faces on the square central column surrounding the dichroic mechanism. Figure 4-4 shows the design of the filter wheels.

The dichroic mechanism, driven by a stepper motor, comprises a cylinder that can rotate around the axis of the incident beam. The dichroic itself is mounted on one end of the cylinder. Figure 4-5 shows the design of the dichroic mechanism.

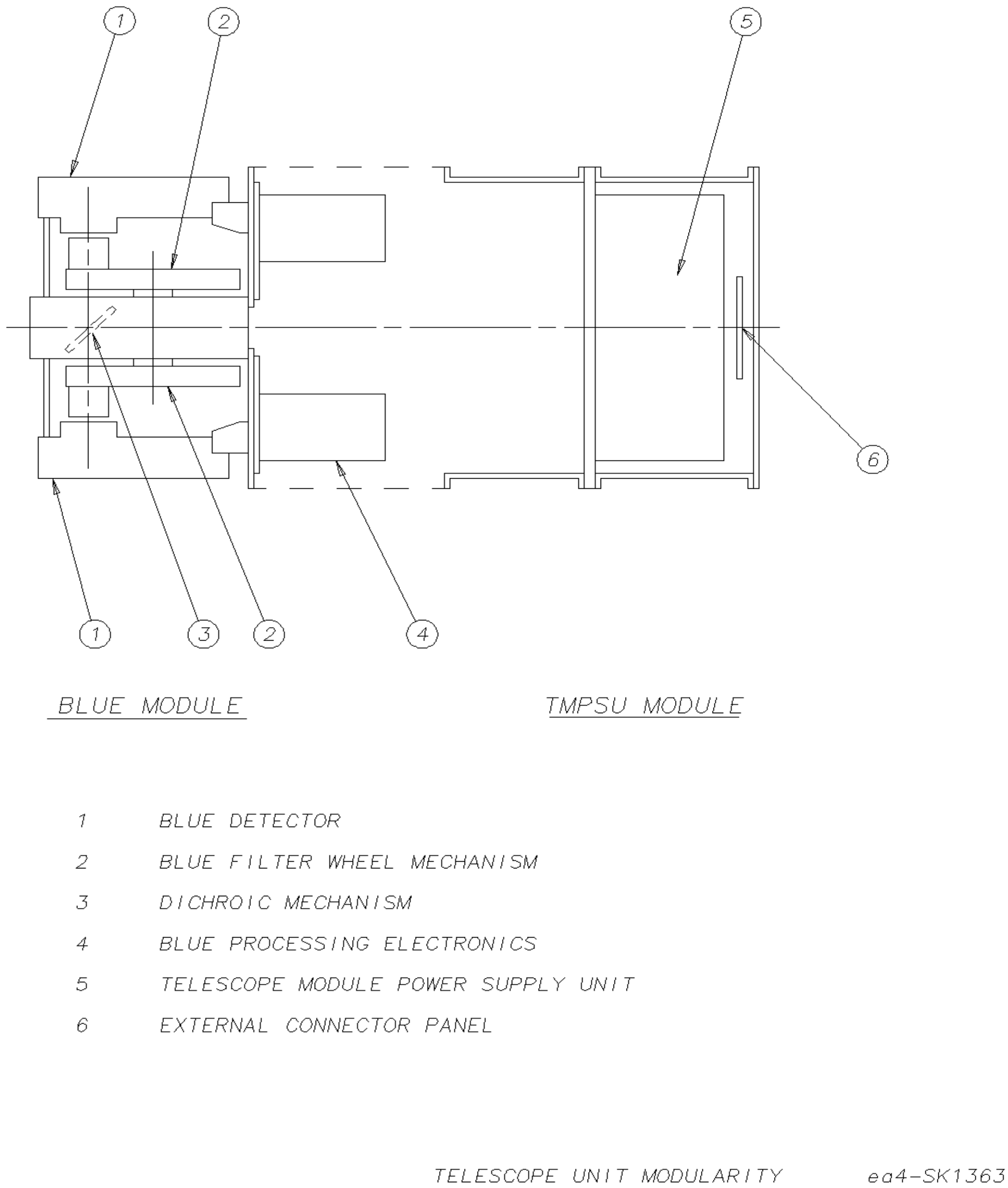


Figure 4-3 Telescope Unit Modularity

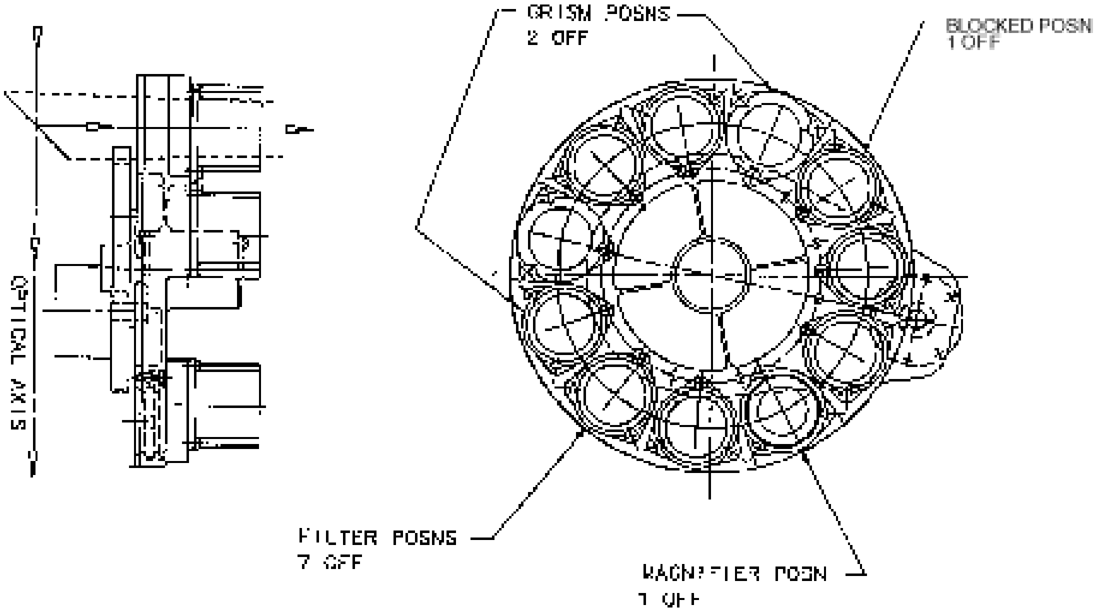


Figure 4-4 Filter Wheel Mechanism

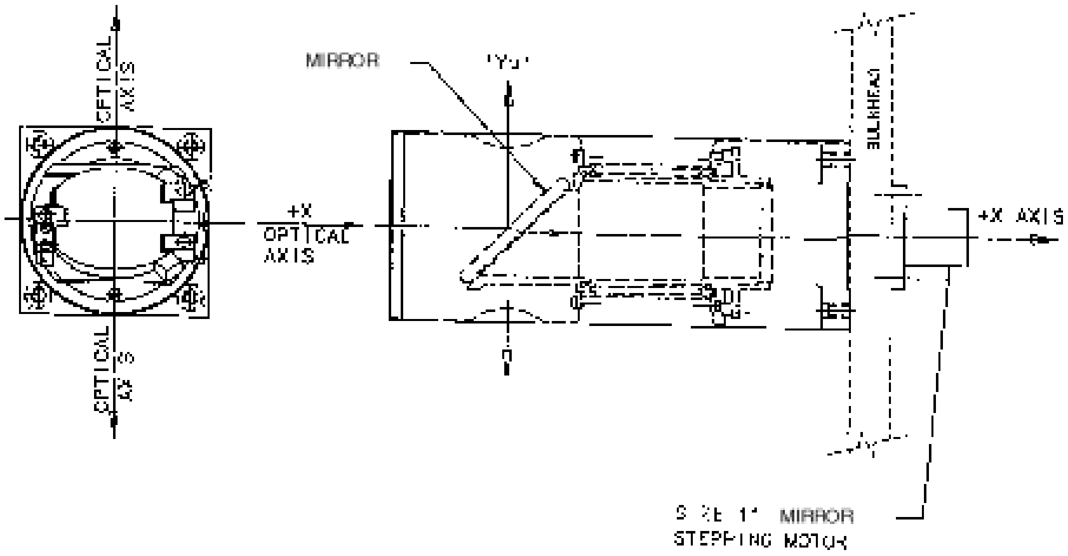


Figure 4-5 Dichroic Mechanism

4.3 Thermal Design

The thermal design of the TM is constrained by the requirements that the TM mounting flange must be controlled to ±0.5°C of its nominal temperature (currently 19.5°C) to minimize the heat flux exchanged between it and the spacecraft OB, and that the telescope optics bay must remain at a constant temperature during telescope operation to maintain the separation between the primary and secondary mirrors (see section 6.1).

In addition to these special requirements, there are standard requirements on the thermal design of the instrument in order to safeguard the operation of the electronics in both the TM and the DEM.

Thermal control will be active in the TM and passive in the DEMs.

4.4 Electrical Design

The UVOT instrument consists of three electronic units:

- The TM
- DEM Prime
- DEM Redundant

At any time during instrument operation one of the two DEMs will be switched on and will perform digital data processing and telemetry formatting in addition to instrument supervisory control. Figure 4-6 illustrates the configuration of the major external interfaces for power, data, and control. Primary and redundant power is routed directly to the TM. The two DEMs are powered separately one from the primary bus and one from the redundant. The 1553 bus carries uplink and downlink data from and to the active DEM. Between the two DEMs and the telescope there are two types of digital links; the data capture interface (DCI) and the Instrument Control Bus (ICB). The data capture interface carries detector data from the telescope to the active DEM where it is then processed for telemetry. Monitoring and control of the electronics inside the telescope are performed via the other link, the ICB, which is redundant and under command of the active DEM.

The telescope module is a cold redundant photon counting detector system. Figure 4-7 illustrates the configuration of the major internal electrical interfaces. Primary power is converted by the TMPSU into regulated secondary rails to power the TM electronic subsystems. An ICB interface within the TMPSU controls the dichroic mirror and filter wheel stepper motors. Primary power is also switched to control focus heaters. The Blue Camera Head (BCH) contains the CCD and CCD read out electronics. The Image Intensifier is biased by the High Voltage Unit (HVU). The HVU contains three separately commandable supplies. Data from the BCH is taken by the Blue Processing Electronics (BPE) and processed. The dark current value per row is latched and subtracted from the data. Data is validated and events centroided to increase image resolution. The data is FIFO buffered for transmission to the DPU via the Data Capture Interface. The BPE also contains an ICB bus interface to control BPE and other TM control functions.

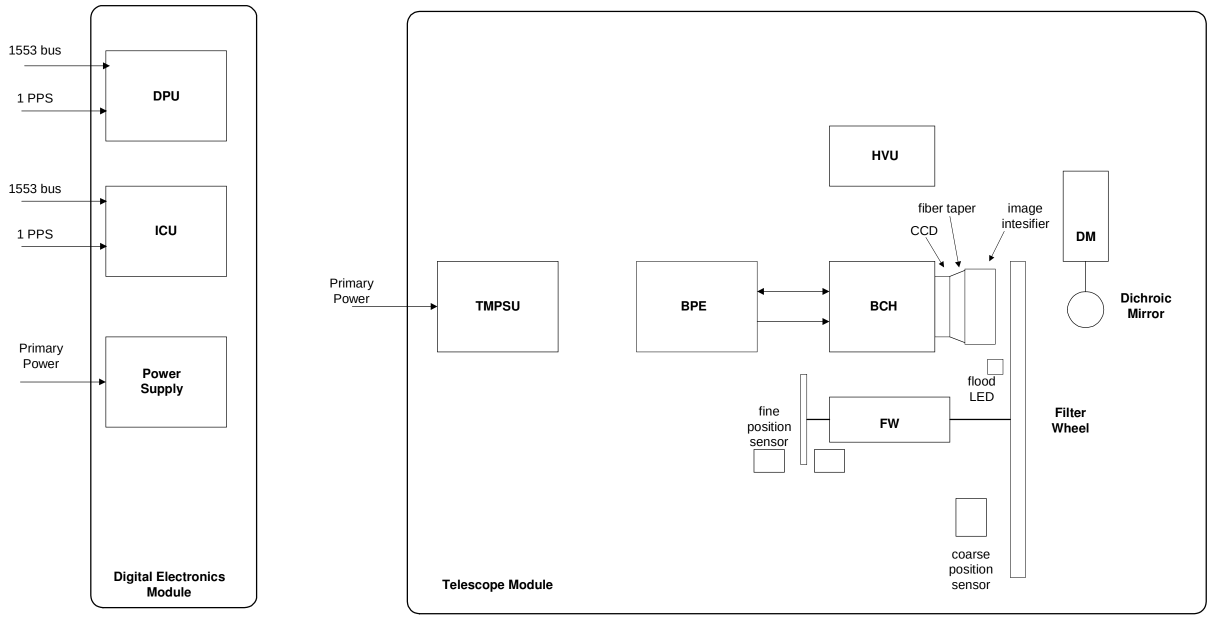


Figure 4-6 UVOT Electrical Interfaces to the Spacecraft

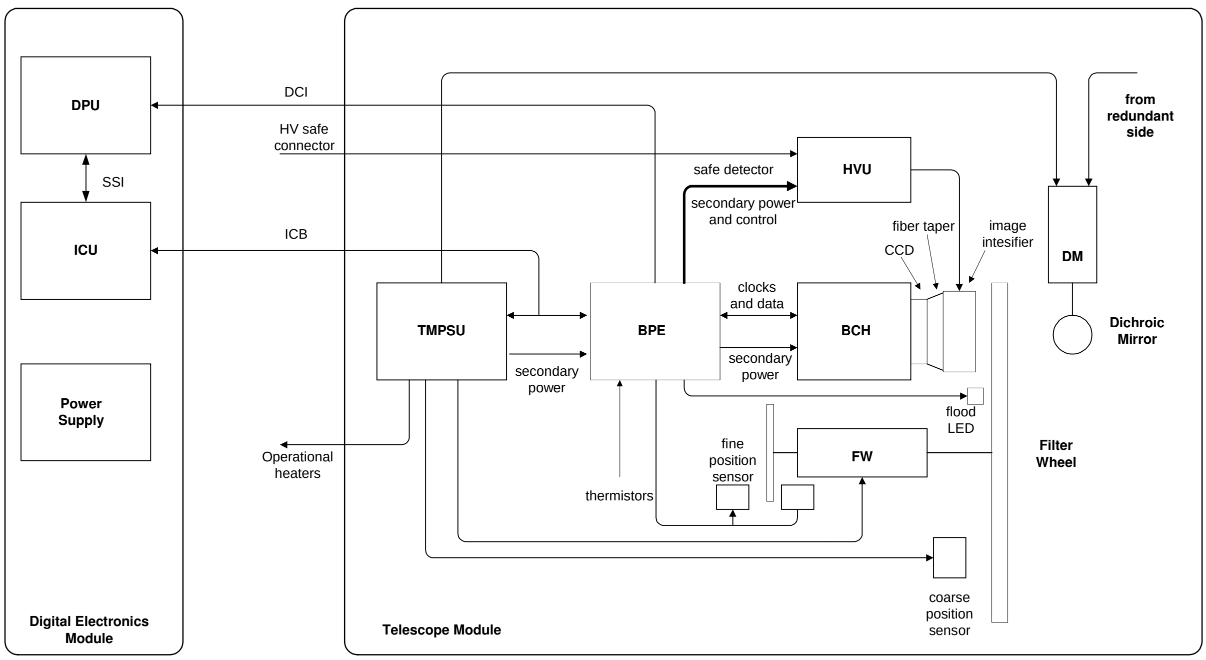


Figure 4-7 UVOT Internal Electrical Interfaces

The blue detector processing electronics are physically combined with the electronics to receive thermistor and filter wheel fine position sensors. They share the same ICB connections and are manufactured and tested as a single module.

Each detector will carry a low-intensity flood illumination source. This can be activated by S/W control and has been incorporated in order to provide for flat field calibration of detectors. This corrects for the detector response on small scales. The sources will not be uniformly bright on large scales and their stability is not guaranteed: therefore they will not be useful for absolute flux calibration of the detectors. However, they will be useful in providing an indication of the operational status of the detector. The source will be located on the detector camera head in such a way that the light can be reflected off the rear of the blocked filter when it is selected. This surface will be treated to provide the appropriate non-specular reflective characteristics. The source will be activated by command to the respective detector via the ICB.

The internal structure of each DEM is illustrated in Figure 4-8, showing the three electronic units: the DPU, the ICU, and power supply module. The ICU is responsible for overall control of the UVOT instrument. It receives commands from and reports health and status to the Spacecraft via the 1553 bus and takes appropriate autonomous action based on these commands. This includes setting up the TM via the ICB interface and the DPU via the SSI interface. The DPU performs all data processing of the science data. Science data is delivered to the DPU via the data capture interface, a high-speed three wire synchronous serial interface that is a one-way pipe from the TM to the DPU. Once the science data is processed it is transmitted to the spacecraft via the 1553 bus. The DEM power supply module contains an independent power supply for the ICU and another for the DPU. Each power supply conditions the +28V input voltage to provide secondary voltages of +3.3Vdc, +5Vdc and +/- 12Vdc. The DEM has the capability to time-tag data to a resolution of 10 msec. The ICU and DPU will independently synchronize to Spacecraft time using the 1PPS signal and the 1553 bus time broadcast.

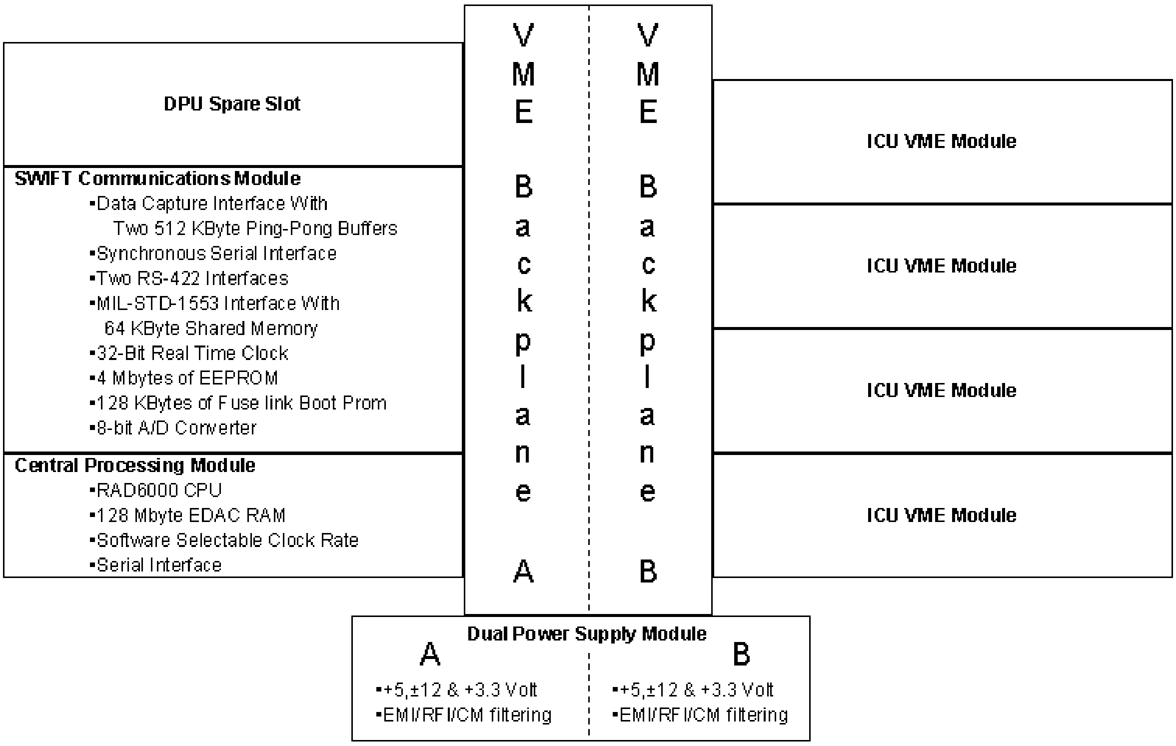


Figure 4-8 DEM Block Diagram

4.5 Redundancy Concept

The instrument has two redundant electronic chains from the spacecraft interface up to and including the dichroic stepper motor windings.

Power for the DEM and the detector electronics are separate. Main and redundant power are used separately to supply the two DEMs with switching provided by the spacecraft. Only one DEM will be active at any time. Primary power is routed to drive the prime converter inside the TM; redundant power is routed to the redundant converter. The outputs of the converters are routed to the blue electronics, including high voltage units.

Control interfaces are bi-directional. There is one control bus for each detector chain. The power supply is controlled as two separate modules: each blue detector is a separate module. Any module that is powered will receive commands and send responses via its control bus.

4.6 Instrument Software

Both the ICU and the DPU contain flight software (FSW). The following sections briefly describe the functions of the ICU and DPU FSW. For a full description of flight software, please see the Swift Gamma Ray Burst Explorer Software Requirements Specification for the UVOT DPU, SwRI document

03691-DPUSRS-01. If discrepancies exist between this document and the Swift Gamma Ray Burst Explorer Software Requirements Specification for the UVOT DPU, the Swift Gamma Ray Burst Explorer Software Requirements Specification for the UVOT DPU shall be followed.

4.6.1 ICU Software

The ICU FSW controls the telescope and overall instrument functions. The ICU monitors and controls Telescope Module (TM) high voltage power, thermal control, 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) which contains pre-loaded Relative Time Sequences (RTS). Each RTS contains sequences of commands which establish the instrument configuration. An observation is carried out by executing a selected RTS based on the identification of a target of interest by the Figure of Merit (FoM). The ICU produces periodic housekeeping telemetry which is reported to the spacecraft over the MIL-STD-1553B (1553) interface [IRD 5.3.2]. A local copy of the spacecraft clock is maintained which is used to timestamp the data packets, which are formatted as Consultative Committee for Space Data Systems (CCSDS) Source Packets.

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

1. Receive and execute telecommands from the spacecraft and other instruments.
2. Monitor the instrument status and report housekeeping to the spacecraft [IRD 5.3.2].
3. Configure the instrument by switching parts of the instrument on or off.
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.
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 [MRD 4.11.17].
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.

4.6.2 DPU Software

The DPU FSW is primarily a data processing slave for the UVOT Instrument under control of the ICU. The DPU reports status to, and receives control commands from, the ICU over the SSI. The DPU receives the raw detector events and timing data from the telescope over the serial Data Capture Interface (DCI). The volume of this science data exceeds the UVOT telemetry allocation, so the DPU employs histogramming and lossless data compression to reduce the amount of data transmitted to the spacecraft over the 1553 interface. A local copy of the spacecraft clock is maintained which is used to timestamp the data packets, which are formatted as Consultative Committee for Space Data Systems (CCSDS) Source Packets.

The DPU FSW is written in C and assembly language and executes on the RAD6000 processor. The DPU FSW has the following primary functions:

1. Receive science data in the form of detector (photon) events from the telescope, histogram the events, optionally compress the data, and relay it to the Spacecraft Control Unit (SCU) in the form of CCSDS Source Packets.
2. Collect science data in the form of raw time-tagged detector events from the telescope.
3. Rapidly produce a Finding Chart following a GRB for use by ground-based observatories.
4. Receive commands from the ICU which establish the current mode and exposure time.
5. Communicate status information to the ICU in the form of Data Alert messages.
6. Transmit detailed housekeeping data to the spacecraft over the 1553 interface.
7. Provide the capability to uplink new FSW code modules [MRD 4.11.17].
8. Receive a time message from the spacecraft and synchronize the local copy of the spacecraft clock.

While the primary product of the DPU is histogram images, the DPU FSW processes detector events in various ways depending upon the current science or engineering mode, as controlled by the ICU (refer to Section 4.8 - Instrument States and Modes).

4.7 Ground Support Equipment

The following sections summarize the necessary electrical, mechanical, and optical ground support equipment (GSE) which will be employed in the development, test, and operation of the UVOT.

4.7.1 Electrical Ground Support Equipment

The Electrical Ground Support Equipment (EGSE) supports three primary functions:

- Commanding and housekeeping display,
- Interface simulation, and
- Science data analysis.

All units will have internal power supplies that can be operated from a 120 V, 60 Hz or from a 220/240 V, 50 Hz supply.

4.7.1.1 Commanding and Housekeeping Display

Test and operation of the UVOT instrument requires a system with a user interface which facilitates instrument commanding, housekeeping telemetry display, and automated test scripting. The Swift mission has standardized on the Integrated Test and Operations System (ITOS) for instrument checkout, integration and test, and on-orbit operations. ITOS provides commanding, real-time housekeeping display, command/test scripting, and data archiving functionality. The ITOS system executes on a UNIX platform (Sun™ or Linux). Automated command scripting is implemented in the systems test and operations language (STOL).

4.7.1.2 Interface Simulators

Interface simulators are required to facilitate the testing of individual instrument components prior to the integration of the entire instrument, and prior to integration of the instrument with the spacecraft. The following table summarizes the required interface simulators.

Table 4-1 Required Interface Simulators

Name and Description	**Source**	**Needed By**		
		Qty	**Organization**	**Date**
Name: Interim Spacecraft Data Interface Simulator Platform: Sun™ Workstation Description/Use: Provides early spacecraft 1553 data interface testing and interfaces instrument to ITOS.	SwRI	1 1	MSSL SwRI/PSU	Aug. 18, 2000 Aug. 1, 2000
Name: Spacecraft Simulator Platform: Unknown Description/Use: Provides high-fidelity spacecraft 1553 and power interface testing, and interfaces instrument to ITOS.	Spectrum Astro	1 1	MSSL SwRI/PSU	(Needed as soon as possible; anticipate June 2001)
Name: Data Capture Interface Simulator Platform: PC/AT Description/Use: Provides playback of detector events over the DCI to facilitate DPU hardware and software testing.	MSSL	1	SwRI	Aug. 1, 2000
Name: SSI Interface Simulator Platform: PC Description/Use: Provides ability to transmit data over SSI for SSI hardware interface testing.	MSSL (card and software only)	1	SwRI	Aug. 1, 2000
Name: Instrument Control Unit Simulator Platform: PC Description/Use: Simulates portions of the ICU and provides protocol translation between the SSI and 1553 interfaces to facilitate DPU software testing.	MSSL	1 1	SwRI PSU	Sept. 15, 2000 Nov. 30, 2000

4.7.1.3 Science Data Analysis

To verify the scientific performance of the instrument, a science data analysis system is required. The Science Data Analysis Terminal (SDAT) provides the capability to convert raw data packets produced by UVOT into science data products for display and analysis. The SDAT will be based on a Sun™ workstation running UNIX with an X-Windows based graphical user interface (GUI). The SDAT software will be based on the IDL™ analysis package. The SDAT obtains Level Zero files containing CCSDS Source Packets from the ITOS via a standard Ethernet (TCP/IP) interface.

For the purpose of the SDAT, data can be classified as image, time series, or spectral (from grisms). For each type, the SDAT will read or write the data from disk or magnetic tape, display the data on the workstation screen and produce hardcopies of images and graphics output. The SDAT provides the capability to manipulate, model and analyze the data. Each of the above will be performed in a user-friendly manner by using the IDL widgets. Buttons and sliders will be provided to give the user control of the data representation (e.g. color tables, contrast, axis ranges and labels, etc.). Archived files will be able to be selected from a list.

4.7.2 Mechanical and Optical Ground Support Equipment

No specific OGSE will be provided for the TM to support internal alignment. If necessary, shims should be provided and fitted by the spacecraft contractor to align the TM with respect to the other instruments.

No reference cubes or OGSE are needed for the DEM.

MGSE will be supplied to aid handling, mounting, and alignment of the TM and two DEMs for pre-delivery activities at MSSL. Some existing MGSE will also be made available at the test facility and spacecraft integration site.

For transportation, the TM will be double bagged and part filled with dry N_2 . Once unpacked from its container, the spacecraft will provide, fit and monitor a purge gas supply to the TM, which is flow rate controlled.

4.8 Instrument States, Modes, and Operational Concepts

The following sections describe the overall function of the instrument, including operational concepts and instrument states and modes.

4.8.1 Operational Concepts

<u>There are no UVOT initiated conditions that directly influence the operation of other instruments, the OB, or the SC.</u> The UVOT Instrument consists of the Telescope, the Instrument Control Unit (ICU), and the Data Processing Unit (DPU). The ICU controls the operation of the UVOT. The DPU serves as a data processing slave to the ICU. The ICU controls the activities of the DPU using commands transmitted over a synchronous serial interface (SSI), and the DPU reports progress and status to the ICU over the same interface. The UVOT contains a 256x256 CCD array which detects the arrival of photons. The

UVOT is designed such that the arrival of a photon in a given CCD pixel can be further resolved to a location within an 8x8 sub-pixel array using a centroiding process. The arrival of photons is reported to the DPU in 24-bit detector events which contain either x and y coordinates of the photon within the resulting 2048x2048 image area, or engineering information. Science and engineering data are compressed using a loss-less compression algorithm and transmitted to the spacecraft in the form of CCSDS Source Packets over the MIL-STD-1553B interface.

4.8.1.1 In-Orbit Checkout and Calibration Concept

In-orbit checkout and calibration will be carried out using Relative Time Sequences (RTSs) loaded into the ICU deferred command store. These will be developed during ground integration and test prior to launch.

4.8.1.2 Observational Concepts

In normal science operation, the Swift observatory conducts a series of pre-planned observations loaded into the Figure of Merit (FoM) processor. The UVOT is notified of a target of interest by the FoM, and in response, the UVOT invokes a specific pre-loaded RTS stored in the ICU deferred command store [IRD 11.4]. Each RTS defines a sequence of one or more science and engineering exposures using selected filters. In Image Mode, the DPU histograms detector events into a positional array of 24-bit elements over a specified integration time. In Event Mode, the position and arrival time of individual photons is stored. Additional engineering modes result in alternate detector event formats and methods of processing.

It is anticipated that pre-planned observations may be interrupted by a GRB an average of once per day. When the Burst Alert Telescope (BAT) detects a GRB, UVOT is notified of the event within one second of the GRB trigger. If the FoM determines the GRB to have merit for observation, a request to slew will be transmitted to UVOT. In response, the UVOT will suspend any pre-planned observation, enter Slew State by setting the detector cathode to 0 V, and notify the spacecraft that it is ready for slew. While the spacecraft slews, the UVOT will begin moving the filter wheel to select the shortest wavelength UV filter (UVW2). The spacecraft will transmit a message when it is within 10 arcmin of the target position. In response, UVOT will enter Science State and begin collecting Event Mode data for the duration of the slew settling time (approximately 35 seconds). The UVOT is notified once the spacecraft has settled on target, at which time the UVOT begins a 100 second exposure using the V filter. The science software collects both Image Mode and Event Mode data during this exposure and the resultant image becomes the finding chart for the GRB. Because of telemetry constraints in the real-time downlink, the finding chart is processed onboard into a source list containing the 32 brightest objects. This information is transmitted immediately via the Tracking and Data Relay Satellite System (TDRSS). On the ground, the finding chart image is reconstructed and posted to the GRB Coordinate Network (GCN).

The ICU contains a Deferred Command Store (DCS) which is stored in EEPROM. It consists of

1. A set of parameterized RTSs that perform basic operations on UVOT (e.g. move filter wheel, specify a window configuration, choose guide stars etc).
2. Several higher-level RTSs that call the above RTSs to perform a series of standardized exposures using various instrument configurations. They can also be parameterized.

Upon receipt of a message indicating we have slewed to, or are settling upon, a target, the DCS runs one of the high-level RTSs associated with the target. The RTS ID could be supplied as a parameter in the message or via a separate uploaded table in the DCS that 'maps' target IDs to stored sequences.

The higher-level RTSs will incorporate 'milestones'. It is anticipated that the milestones will be located at the start of each exposure. The time already spent on a target should be supplied as a parameter to the 'at target' message. Therefore should an observation be interrupted by a constraint, upon return to that target the associated RTS can be restarted at the next milestone consistent with the time spent in the interruption. Additional parameters could also be supplied in the same message and applied to the RTS.

4.8.2 Instrument States

The UVOT has eight powered states: Initial, Basic, Safe, Configure, Science, Engineering, Slew, and South Atlantic Anomaly (SAA). The following diagram illustrates the states and transitions between them.

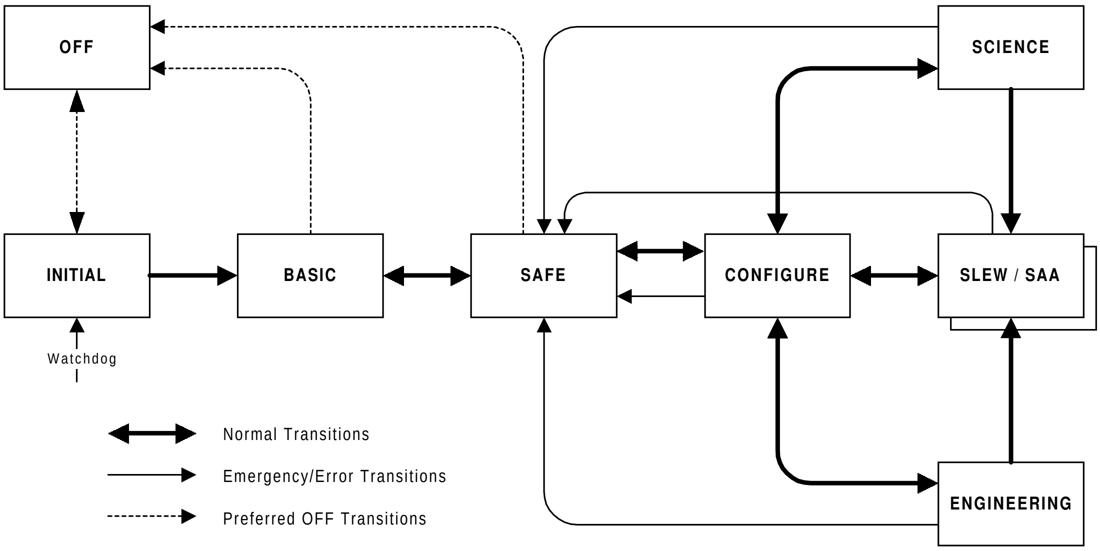


Figure 4-9 UVOT State Transition Diagram

Notes relevant to the various states are listed below. The effects on the various UVOT components are described in a table following the diagram.

<u>Off State</u>. The transitions to the OFF state are controlled by the spacecraft, and therefore could occur at any time. However, to prevent damage to the detector, 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.

<u>Initial State</u>. ICU Basic code is copied from ROM code into RAM and switches automatically to the Basic state. The DPU performs a self-check and flight software is copied from EEPROM into RAM and booted automatically.

Basic State. 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, a request is sent to the spacecraft to turn it off. The ICU Watchdog is enabled. The DPU Heartbeat Watchdog is enabled. ICU EEPROM code can be reloaded or executed. DPU EEPROM code is running. All subsequent modes are run from EEPROM code.

Safe State. The ICU ensures that the TM 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.

Configure State. The experiment configuration is specified (except dichroic) by command.

Science State. 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. GRB or planned non-engineering observations are performed. Flood LED level must be zero. The full area of the detector must be enabled.

Engineering State. 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. Enabled area of the detector may not include the full detector.

Slew State. 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. If necessary, a suitable filter, including blocked, is selected. The $V_{cathode}$ is set to zero to protect the instrument.

SAA State. The V_{mcp23} is set to 70% and the $V_{cathode}$ is set autonomously to zero. The filter wheel is moved to the blocked position.

			OFF	INITIAL	BASIC	SAFE	CONFIGURE	SCIENCE	ENGINEERING	SLEW	SAA
DEM	ICU	State	Off	Initial	Basic	Operational	Operational	Operational	Operational	Operational	Operational
DEM	ICU	Telecommand	Off	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
DEM	ICU	Telemetry	Off	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
DEM	DPU	State	Off	Initial	Idle	Idle	Idle	Event Processing	Event Processing	Idle	Idle
DEM	DPU	Telecommand	Off	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
DEM	DPU	Telemetry	Off	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
DEM	DPU	Data Acquisition	Off	No	No	No	No	Yes	Yes	No	No
TM	Electro-nics	Main Power	Off	Off	Off	On	On	On	On	On	On
TM	Electro-nics	Detector High Voltage	Off	Off	Off	Off	Commandable	Operational	Operational	Vmcp23 = 100% Vcathode = 0V	Vmcp23 = 70% Vcathode = 0V
TM	Electro-nics	Detector Electronics	Off	Off	Off	On	On	On	On	On	On
TM	Electro-nics	Thermal	Off	Off	Off	Closed Loop	Closed Loop	Closed Loop	Closed Loop	Closed Loop	Closed Loop
TM	Electro-nics	Flood LED	Off	Off	Off	Off	Off	Off	Commanded Level	Off	Off
TM	Electro-nics	Events to DPU via DCI	Off	No	No	No	No	Yes	Yes	No	No
TM	Mechan-isms	Filter Wheel: Position	Off	Unchanged	Unchanged	Blocked	Commanded Position	Commanded Position	Commanded Position	Moving	Blocked
TM	Mechan-isms	Filter Wheel: Position Sensors	Off	Off	Off	Available	Available	Available	Available	Available	Available
TM	Mechan-isms	Dichroic Mechanism	Off	Unchanged	Unchanged	Commandable	Unchanged	Unchanged	Unchanged	Unchanged	Unchanged

Table 4-2 UVOT Operating States

4.8.3 Science and Engineering Modes

The UVOT has multiple Science and Engineering modes. These modes determine:

- What types of events are produced by the detector,
- How detector events are processed by the DPU, and
- What science and engineering data packets are produced by the DPU?

4.8.3.1 Science Modes

The Science Modes are described in the following table. Note that full auto-safing is enabled in all of the Science Modes [IRD 6.1]. Image Mode and Event Mode can be run simultaneously. The data volume is reduced by specifying science windows, i.e., this means that data is processed and transmitted only for a small subsection of the entire detector area. Each mode can define its own unique science window.

Table 4-3 Science Modes

Mode and Description	Entered On	Setup	Activities and Data Products
Event Mode The purpose of Event Mode is to collect individual photon events and provide high-resolution timing information. During slew settle, raw detector events are collected over the full 16 x 16 arcmin FOV. When the telescope is on target, the event list is reduced to relevant events defined by the Event Mode science window. The event list is compressed and transmitted to the ground.	Receipt of "Notification of slew within 10' of target" (new GRB observations only), Pre-planned command, or Ground command	ICU ensures correct filter element selected ICU ensures detector cathode on ICU ensures detector in science mode ICU selects exposure time ICU ensures BPE configured to send events ICU commands DPU to Event Mode with a specified science window	Collect events Filter events based on Event Mode science window Compress event list Produce Event Packet(s)
Image Mode The purpose of Image Mode is to produce drift-corrected images of the target of interest during GRB and pre-planned observations. In Image Mode, detector events are collected, shifted, and histogrammed for a specified integration time. A finding chart will be produced for new GRBs. An $8' \times 8'$ image is created from which is derived a parameterized source list. This list is transmitted to the ground in real-time via TDRSS. All images (including the finding chart) are compressed and transmitted with regular science telemetry during routine ground station contact.	Receipt of "Notification of slew settle" (new GRB observation), Pre-planned command, or Ground command	ICU ensures correct filter element selected ICU ensures detector cathode on ICU ensures detector in science mode ICU selects exposure time ICU ensures BPE configured to send events UVOT commands DPU to Image Mode with a specified science window	Generate image by collecting, drift correcting, and histogramming events for specified integration time Filter events based on Image Mode science window Compress data Produce Image Packet(s) If Finding Chart selected: Extract list of bright sources (this includes position and a 5pix $\times$ 5pix source image) Compress list Produce Parameterized Finding Chart Packet

4.8.3.2 Engineering Modes

The Engineering Modes are described in the following table. Note that full auto-safing is enabled in all Engineering Modes except Channel Boundary Mode. In Channel Boundary Mode, auto-safing is partially disabled due to the need to receive events in the center of the detector only. An Engineering Mode cannot be run simultaneously with Image Mode, Event Mode, or other Engineering Modes.

Table 4-4 Engineering Modes

Mode and Description	Entered On	Setup	Activities and Data Products
Full-Frame Engineering Mode The purpose of Full-Frame Engineering Mode is to monitor the health of the detector and to locate hot spots and dead pixels. This mode can use high resolution (all pixels) or low-resolution imaging (2^Nx2^N pixel binning).	Pre-planned command, or Ground command	ICU selects filter element (normally blocked) ICU ensures detector cathode on ICU ensures detector in science mode ICU ensures full-window on detector ICU commands flood LED level ICU selects exposure time and high/low resolution imaging ICU ensures BPE configured to send events ICU commands DPU to Full-Frame Engineering Mode	Collect and histogram events for specified integration time Compress data Produce Full-Frame Engineering Image Packet
Raw Event List Engineering Mode The purpose of Raw Event List Engineering Mode is to diagnose problems with the detector by collecting all events over a specified length of time and transmitting the raw events to the ground.	Pre-planned command, or Ground command	UVOT setup according to ground-commanded configuration ICU selects exposure time ICU ensures BPE configured to send events ICU commands DPU to Raw Event List Engineering Mode	Collect events for specified integration time Compress data Produce Raw Events Packet
Channel Boundary Engineering Mode The purpose of Channel Boundary Mode is to derive the optimum channel boundary settings from a flat field. This mode is used in conjunction with the “m/n engineering” mode of the detector which corrects for the non-uniformity of the image intensifier.	Pre-planned command, or Ground command	ICU selects blocked filter element ICU ensures detector cathode on ICU ensures detector in engineering m/n mode ICU configures detector window ICU commands flood LED level ICU selects exposure time ICU ensures BPE configured to send events ICU commands DPU to Channel Boundary Engineering Mode	Collect and histogram events for specified integration time Derive channel boundaries Reload detector channel boundaries Compress image data Produce Channel Boundary Data Packet and M, N Psuedo-Image Packets

Mode and Description	Entered On	Setup	Activities and Data Products
Centroiding Confirmation Engineering Mode The purpose of Centroiding Confirmation Engineering Mode is to determine the validity of derived channel boundaries. The full 2048x2048 field is divided into 8x8 sub-images, each of 256x256 centroided (by 8) pixels. These sub-images are then modulo binned to produce a set of 8x8 pixels pseudo-images. The images are column (y axis) ordered, as are the pixels within them.	Pre-planned command, or Ground command	ICU selects blocked filter element ICU ensures detector cathode on ICU ensures detector in science mode ICU ensures full-window on detector ICU commands flood LED level ICU selects exposure time ICU ensures BPE configured to send events ICU commands DPU to Centroiding Confirmation Engineering Mode	Collect and histogram events for specified integration time Produce centroiding confirmation data sub-images Compress psuedo-image data Produce Centroiding Confirmation Pseudo-Image Packets
Intensifier Characteristics Engineering Mode The purpose of Intensifier Characteristics Engineering Mode is to produce a pulse-height histogram to assess detector health and performance.	Pre-planned command, or Ground command	ICU selects blocked filter element ICU ensures detector cathode on ICU ensures detector in event height mode ICU ensures full-window on detector ICU commands flood LED level ICU selects exposure time ICU ensures BPE configured to send events ICU commands DPU to Intensifier Characteristics Engineering Mode	Collect and histogram events for specified integration time Compress histogram data Produce Intensifier Characteristics Packet

5. MECHANICAL INTERFACES AND REQUIREMENTS

5.1 Identification Code

The UVOT units shall be uniquely identified by the instrument unit codes listed in Table 5-1.

Table 5-1 Instrument Unit Identification Codes

Code	Instrument Unit	# Of Units
TM	Telescope Module	1
DEM-1	Digital Electronics Module (Prime)	1
DEM-2	Digital Electronics Module (Redundant)	1
IHU-1	Interconnecting Harness Unit (between TM & DEM-A)	1
IHU-2	Interconnecting Harness Unit (between TM & DEM-B)	1

The complete H/W configuration with the total number of units is shown in Figure 4-2.

5.2 Location Requirements

The UVOT TM and DEMs shall be mounted to the Optical Bench as documented in Mechanical Interface Control Documents (MICDs) 2045137 and 2045139, respectively.

The UVOT coordinate system shall be as shown in Figures 4 and 5 of the IRD (410.4-ICD-0001). All coordinate systems are right-handed. (In general, the origin in the out-of-plane axis is at the component mounting I/F plane).

5.3 Dimensional Requirements

All units are restricted to the dimensions listed the corresponding MICDs. The maximum dimensions are reproduced in Table 5-2 for convenience. If any discrepancy exists between Table 5-2 and the corresponding MICD, the MICD shall be followed [IRD-3.1]. The maximum IHU length is also specified in Table 5-2 [IRD-3.3.7].

Table 5-2 Instrument Unit Dimensional Requirements

Unit	**Footprint (mm x mm)**	**Height (mm)**	**Harness Length (m)**
TM	∅519 mm	2150	
DEM-A	300 x 240	220	
DEM-B	300 x 240	220	
IHU-A	NA		< 1.5
IHU-B	NA		< 1.5

5.4 Alignment Requirements

5.4.1 NFI Co-Alignment

Through ground operations, launch, and orbit, the boresights of the XRT and UVOT must be held in co-alignment to better than 210 arcseconds. The budget for NFI absolute co-alignment is shown in Table 5-3.

Table 5-3 NFI Co Alignment Requirements

		Arc seconds
		RSS (Pitch, Yaw)
Ground Alignment - Measurement Errors		
	XRT IF/XRT BS	15
	UVOT IF/UVOT BS	15
Ground Alignment - Placement Errrors		
	UVOT IF/XRT IF	40
Launch Effects - g release		
	XRT IF/XRT BS	15
	UVOT IF/UVOT BS	15
	UVOT IF/XRT IF	20
Launch Effects - Vibration		
	XRT IF/XRT BS	30
	UVOT IF/UVOT BS	30
	UVOT IF/XRT IF	30
Launch Effects - Pressure Release		
	XRT IF/XRT BS	5
On-orbit Stability - From Table 40		
	XRT BS/UVOT BS	12
	TOTAL (SUM, RSS(Vib))	189
	Requirement	210

5.4.2 TM Alignment

The TM shall be delivered fully aligned internally. To allow alignment as part of IM integration, the UVOT will be delivered with external optical reference/alignment cube(s) provided by GSFC. The UVOT alignment cube(s) shall be plainly visible from the top of the instrument. Offset of the UVOT boresight/coordinate system with respect to its optical reference cube(s) shall be delivered to GSFC.

On-orbit, post-calibration errors in alignment between the UVOT and XRT interface planes shall be maintained to within 12 arcsec, 3σ due to all on-orbit effects [IRD-8.2.2.5].

5.4.3 DEM and IHU Alignment

The DEMs and IHUs have no specific alignment requirements.

5.5 Interface Control Drawings

Table 5-3 defines mechanical interface drawings for the UVOT and the organizations responsible for them [IRD-3.7].

Table 5-3 UVOT Interface Control Documents

Drawing Number	Issue	Rev.	Title	Responsible Organization
2045137	-	-	TM-OB MICD	GSFC
A1/5278/300	-	-	UVOT ICD	MSSL
2045139	-	-	DEM-OB MICD	GSFC
2046597	-	-	DEM ICD	GSFC

The MICDs shall contain, as a minimum:

a) Identification
b) Indicate nomenclature, part number, and location of identification.
c) Envelope and Overall Package Dimension indicate footprint size, shape, and dimension.
d) Surface Finish/Coatings External surfaces only.
e) Mounting Surface: Flatness/Coplanarity
f) Materials Used
g) Thickness of Mounting Flange
h) Mounting Holes:Location, size, and tolerance.
i) GSE Handling Points: Location, size, and tolerance. Access zones to support testing (i.e., sources required for calibration, etc) can be indicated here also.
j) Mass in kilograms and approximate c.g.
k) Electrical Grounding Provisions
l) Connectors : Interface and test, location, type, keying, and ID.
m) Optical Reference Surfaces: Alignment cube/reference mirror surfaces, size, and location if applicable.
n) Fields of View (FOV): Include instrument and radiator FOVs.

o) Thermal Blanket: Show thermal blanket locations and associated hardware.
p) Instrument accessibility requirements for red/green tag items, calibration sources, purging, and cooling GSE.
q) The UVOT and spacecraft coordinate systems.

5.6 Instrument Allocated Mass

The mass allocated to the UVOT is shown in Table 5-4. The mass allocated to the TM includes the mass for the IHUs. The total mass shall not be exceeded [IRD-3.11.2].

Table 5-4 UVOT Mass Allocation

Unit	Mass (kg)
TM (including IHUs)	91
DEM-1	12.0
DEM-2	12.0
UVOT Total	115.0

Mass numbers (in kg) for each component shall be tracked separately and the current best estimates for the mass of all components shall be reported monthly to the Swift Systems Manager.

5.7 Design Criteria

The design criteria in this section (5.7) apply to the TM, DEMs, & IHUs. Beyond the criteria within this section, all components shall be designed to withstand the environments defined in Section 8 Environmental Requirements, with margin, as defined in the following sub-section [IRD-3.8].

5.7.1 Moving Parts

The UVOT shall contain four moving parts; a telescope door, two filter wheels, and a beam steering mirror. The Not To Exceed (NTE) attributes of a telescope door, filter wheels, and beam steering mirror are listed below and shall not be exceeded.

5.7.1.1 Telescope Door

The attributes of the UVOT telescope door are listed below and shall not be exceeded.

a. Range of motion: 0 to 257^{o} (+12°,-0°) (see MICD 2045137)
b. Velocity: 500 degrees/s (NTE)
c. Angular Momentum: 0.85 N-m-sec (NTE)
d. Release impulse: 17 N-m-sec (NTE)

5.7.1.2 Filter Wheels

The two filter wheels shall be controlled by the UVOT instrument and shall operate mutually exclusive to each other. The attributes of each UVOT Filter Wheel are listed below and shall not be exceeded.

a. Range of motion: 360° Unidirectional Rotation
b. Velocity: 1.5 radians/sec (NTE)
c. Angular Momentum: 1E-2 N m s (NTE)

5.7.1.3 Beam Steering Mirror

The UVOT Beam Steering Mirror shall be used in event of a failure, and will direct received imagery to the redundant processing electronics within the UVOT telescope. The attributes of the UVOT Beam Steering Mirror moving parts are listed below and shall not be exceeded.

a. Range of motion: 180° Bidirectional Rotation
b. Velocity: 0.3 radians/sec (NTE)
c. Angular Momentum: 1E-4 N m s (NTE)

5.7.2 Minimum Factors of Safety

UVOT mechanical design shall analytically be proven capable of withstanding the specified limit (flight level) load times the appropriate factor of safety (FS) without failure [IRD-3.8.1.1].

FS Yield = 1.25 Tested/1.6 Untested
FS Ultimate = 1.4 Tested/2.0 Untested

If strength qualification of metallic flight structure by means of analysis (rather than another method) is chosen, the following no-test factors shall be used for analysis FS Yield=1.6 FS Ultimate=2.0.

5.7.3 Minimum Margins of Safety

Margins of safety (MS) shall be positive for both yield and ultimate stress calculations [IRD-3.8.1].

- MS = [allowable material strength / max. working stress x FS] - 1 > 0

5.7.4 Stress Analyses and Mathematical Models

The UVOT team shall develop and keep current a detailed NASTRAN finite element model (FEM) of the UVOT. As test data becomes available, the UVOT FEM shall be modified and correlated to match data. Stress analysis shall be performed on all structural and non-structural components for the TM and DEM. This analysis should be used to calculate margins of safety and the results should be properly documented for reviews and audit purposes [IRD-3.8.2].

5.7.5 H/W Qualification

UVOT flight hardware shall be qualified through a combination of analysis and testing to protoflight levels. UVOT flight hardware structure worthiness shall be demonstrated through detailed stress and dynamic analysis. [IRD-3.8.3].

5.7.6 Acceleration Design Loads

5.7.7 TM Acceleration Design Loads

The UVOT Instrument acceleration design loads are defined at the center of gravity of the TM and are parallel to the spacecraft coordinate axes shown in Figure 4 of the IRD and are listed in Table 5 of the IRD (410.4-ICD-0001). [IRD-3.8.4.3].

Table 5-5 TM Acceleration Design Loads

Event	Proto-flight Level	
	Axis	Level
Liftoff/Air loads	X	±4.3 g's
	Y	±4.1 g's
	Z	±4.0 g's
	RX	±33.5 rad/sec^2
	RY	±40.8 rad/sec^2
	RZ	±48.1 rad/sec^2
MECO	X	±10.3 g's
	Y	±0.3 g's
	Z	±0.9 g's
	RX	±4.0 rad/sec^2
	RY	±14.3 rad/sec^2
	RZ	±16.9 rad/sec^2

Apply thrust and lateral levels simultaneously and in all combinations for each event.

5.7.7.1 DEM Acceleration Design Loads

The UVOT DEM acceleration design loads are defined at the center of gravity of the DEM and are parallel to the spacecraft coordinate axes shown in Figure 4 of the IRD and are listed in Table 8 of the IRD (410.4-ICD-0001). [IRD-3.8.4.6].

Table 5-6 DEM Acceleration Design Loads

Event	Proto-flight Level

	Axis	Level
All	Thrust	±15.0 g’s
	Lateral	±15.0 g’s

Levels are applied independently in thrust and lateral directions.

5.7.8 Stiffness Requirements

The design of the UVOT shall be such that the fundamental resonance of the first structure mode shall be a minimum of 50 Hz when analytically fixed at the instrument to optical bench flexure interface with the appropriate Degrees of Freedom (DOF) constrained so as to represent the flexure behavior. If the UVOT does not meet the specified minimum frequency requirement, a modal survey test shall be conducted to verify all significant modes below 50 Hz. The agreement between test and analysis frequencies shall be within 5 percent. Mode shape comparisons shall be required via cross-orthogonality checks using the test modes, the analytical modes, and the analytical mass matrix. The cross-orthogonality matrix shall have diagonal terms that are greater then 0.9 and off-diagonal terms that are less than 0.1.

Resonances of internal items (e.g. PCBs, CCD benches, etc.) should be higher than 200 Hz to avoid coupling with the inputs from the launcher.

5.8 Clear Fields of View

The UVOT field-of-view shall be unobstructed once on-orbit operations begin. No part of the UVOT (including the aperture door) shall impinge on the FOV of the other instruments or the star trackers (which have a glint-free FOV of 25 (half cone angle)). [IRD-3.2].

5.9 Instrument Mounting to the Optical Bench

The UVOT Instrument shall be removable from the optical bench (prior to integration to the LV) without requiring the removal of any adjacent instruments. Any structure above the UVOT aperture must be optically diffuse and black [IRD-3.3].

5.10 Pointing Performance

In order for the jitter compensation technique to operate successfully, the jitter of the S/C should not exceed more than one blue detector pixel in a guiding frame time. The pixel size is 0.5 arcsec and nominally the guide frame period is 10 seconds. This gives rise to the requirement that the pitch and yaw of the S/C should be within 0.5 arcsec at timescales of 10 seconds and less, for 95% of the active observing time. For the purposes of this discussion, this has been translated to a 95% tolerance of ±0.25 arcsec single axis. The stability is different for different timescales, and the above figure can be relaxed for longer timescales. At the two-minute timescale, a ±3 arcsec 95% tolerance is adequate. At longer timescales, this can be relaxed even further. It should be noted that once settled, the spacecraft pointing requirement is to be stable to better than 1 arcsec (pitch and yaw) over any 10 sec period [IRD-8.2.2.4]. It is anticipated that the S/C will provide 0.1 arcsec (pitch and yaw) over any interval [Phase-A Report].

The pointing performance required is given in Table 5-7 and shown graphically in Figure 5-1.

Table 5-7 Pointing Performance Requirements

Timescale (s)	**Tolerance (arcsec, 95% single axis)**
1.0E-01	0.25
1.0E+00	0.25
1.0E+01	0.25
1.0E+02	2.50
1.2E+02	3.00
1.0E+03	30.00
1.0E+04	30.00
3.6E+04	30.00
1.0E+05	30.00

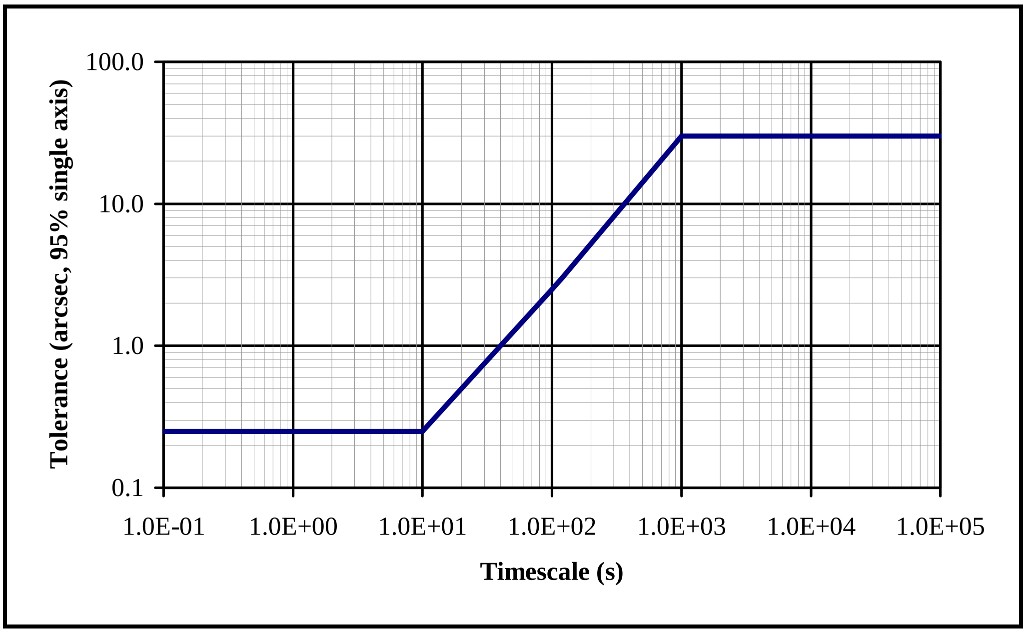


Figure 5-1 Pointing Performance Requirements

Given the processing and memory resources of the DPU, it is not feasible to resample the detector pixel grid on a finer scale in order to compensate for the spacecraft rotation. The spacecraft rotation is therefore calculated, but no roll-correction is made to the time slices of the images before summing. The spacecraft roll therefore has the effect of causing blur at large distances from the center of roll, which can be specified to the tracking algorithm.

Intrinsically the upper limit of the blue detector exposure time is set by the time it takes to saturate the number of bits (24) in the image store. This would be 6.5 x 10^4 s, or 18 hours, at 250 counts/sec/pix, equivalent to the duration of the active portion of the orbit at the maximum counting rate. Because the telemetry requirement occurs only at the end of the exposure, long exposures make efficient use of the telemetry bandwidth available to the UVOT. At present the roll specification limits the exposure time to ~3600 s, depending on the characteristics of the roll. Further improvements to the roll translate directly into more efficient use of the telemetry bandwidth, allowing the acquisition of larger images or data at a higher time resolution, and images with higher spatial resolution at their boundaries.

In order to achieve high time resolution on selected areas of the field of view while at the same time fitting within the guaranteed telemetry bandwidth, the high time resolution windows have to be spatially restricted. For the current specification of the absolute pointing, it is clear that for all non-interactive observations it will be necessary to provide an image recognition algorithm within the instrument in order to center the image within the small windows. Such an algorithm has been written and tested and has been shown to be robust. Entries from the Hubble Space Telescope guide star catalog are uplinked at the same time as the observing sequence commands.

6. THERMAL INTERFACES AND REQUIREMENTS

Thermal Interface Control Documents (TICDs) shall be developed for thermal interfaces between the UVOT and the Optical Bench. TICD 2046595 and 2046597 shall define the thermal interfaces between the TM and the Optical Bench and the DEMs and the Optical Bench, respectively. The TICDs shall include and define, as a minimum:

a) Interface temperatures
b) Radiative and conductive requirements
c) Footprints and heat flow characteristics
d) Thermal control coatings and equivalent sink temperatures
e) Thermal blankets
f) Heater sizing criteria and approximate locations
g) Approximate temperature sensor locations
h) Radiative Interfaces.

6.1 Temperature Limits in Space Environment

The UVOT shall operate in and survive the temperature ranges specified in the Swift Interface Requirements Document [410.4-ICD-0001], section 4.2. Each component of the UVOT shall reach their operational temperature ranges during initial operations or after a safehold. Additionally, the TM optics bay must remain at a constant temperature during telescope operation to maintain the separation between the primary and secondary mirrors.

The UVOT shall be compatible with the FMH profile of the Delta II launch vehicle shown in Figure 6-1 and will not be damaged when subjected to FMH of 0.1 Btu/ft2-sec (1135 w/m2) or less.

Table 6-1 Temperature Limits in Space Environment

Unit	**Operational (°C)**		**Minimum**	**Non-Operational(°C)**	
	Min	**Max**	**Switch-on (°C)**	**Min**	**Max**
Flexures	+10	+18	-20	-20	+60
TM (IF)	+19	+20	-10	-10	+55
DEMs	-10	+50	-15	-15	+60

6.2 Temperature Limits in Laboratory Environment

6.2.1 Operational Limits in Laboratory Environment

Unless amended by the individual product functional specification or source control drawing, the UVOT shall be designed to operate when the UVOT Telescope Interface Flange and the UVOT DEMs/IHUs are within the temperature ranges of +0°C to +25°C, and - 10°C to +40°C, respectively, at ambient pressure. All units should be designed for operation over extended periods of time to facilitate integration and test activities. *The UVOT shall not be operated when exposed to environments outside these ranges at ambient pressure*. These limits are also found in Table 6-2.

6.2.2 Non-Operational Limits in Laboratory Environment

Unless amended by the individual product functional specification or source control drawing, the UVOT shall be designed to survive when the UVOT Telescope Interface Flange and the UVOT DEMs/IHUs are within the temperature ranges of -5°C to +50°C, and - 10°C to +55°C, respectively, at ambient pressure. These limits are also found in Table 6-2.

Table 6-2 Temperature Limits in Laboratory Environment

Unit	**Operating (°C)**		**Minimum**	**Non-Operating (°C)**	
	Min	**Max**	**Switch-on (°C)**	**Min**	**Max**
TM	+0*	+25*	-5	-5	+50
DEMs	-10	+40	-10	-10	+55
IHUs	-10	+40	-10	-10	+55

*Optical performance will be degraded in this wider operating range.

6.3 Environmental Requirements During Ground Storage & Transportation

The environmental requirements placed upon the UVOT during ground storage and transportation is listed in Table 6-3. All components of the UVOT shall be designed to survive such an environment unpowered, unless amended by the individual product functional specification or source control drawing.

Table 6-3 Environmental Requirements During Storage & Transportation

Max Temperature	+20°C
Min Temperature	+15°C
Max Rel. Humidity	50%
Min Rel. Humidity	30%

6.4 *Temperature Bake-Out Limits*

The temperature bake-out absolute limit for the UVOT TM is +72°C, for a maximum period of 24 hours with the exception of the Image intensifier tube and the optics. If the temperature of the optics bay exceeds +72°C, the detector window seal will fail.

6.5 *Thermal Qualification*

Qualification temperature limits will be ±10°C beyond the worst case predicted temperatures for passively controlled components. Telescope components such as detectors, mirrors, etc. that are heater controlled to specific operational temperatures require qualification to a minimum of +/–5°C beyond the highest and lowest control setpoint. For temperature exposures beyond the 5°C margin required, instrument performance does not need to meet specifications [IRD 4.2]. Table 6-4 lists the operational and survival temperature limits for instrument components.

Table 6-4 Component Temperature Limits

ITEM	Worst Case Predicted Temps/Setpoints	Qualification Limits
UVOT telescope interface	+19 to +20°C	+14 to +25°C
UVOT telescope assembly	−10 to +25°C	−35 to +55°C
UVOT telescope baffle tubes	+2 to +20°C	−35 to +55°C
UVOT telescope tube	+19.5 to +20.5°C	−35 to +55°C
UVOT DEMs	−10 to +50°C	−20 to +60°C

6.6 Temperature Sensors

The UVOT shall have 21 analog temperature sensors, 16 allocated to the UVOT, and 5 allocated to the spacecraft. The spacecraft sensors shall function regardless of the power state of the UVOT, while the UVOT sensors shall be active when the UVOT is powered on. Three of the spacecraft sensors shall be placed on the UVOT Telescope Module, and one sensor shall be placed on each DEM. UVOT temperature sensor locations shall be documented in the UVOT to S/C ICD (1143-EI-Y22364). A description of the UVOT temperature sensors and their locations are listed in Table 6-5 [IRD-4.4.2].

Table 6-5 Temperature Sensors

Unit	Sensor Read-out S/C	Sensor Read-out UVOT	Location	Type
TM	3*	16	Refer to UVOT TICD #2046595	S/C: YSI44908 UVOT: YSI44908
DEMs	2	--	--	S/C: YSI44908

*S/C powered sensors, procured by Spectrum Astro for the FM model & integrated by the UVOT.

6.7 Heaters

The UVOT utilizes two heater systems to allow consistent optical and electrical performance and to ensure instrument survival.

6.7.1 UVOT Operational Heaters

The UVOT Operational heaters provide thermal control of the Instrument while the Instrument is powered. The heaters are powered and controlled by the Instrument. A description of the UVOT heaters and their locations are listed in Table 6-6. The UVOT team shall be responsible for the procurement and installation of all operational thermal hardware.

6.7.2 UVOT Survival Heaters

UVOT survival heaters are provided to protect the Instrument whether the Instrument is powered or not. If power is removed from the UVOT, the instrument will no longer be controlling its thermal environment and will begin to cool down. When the local temperature drops below the set point of each survival heater, that heater shall turn on thermostatically. Survival heaters shall be located on each UVOT DEM according to the UVOT Electronics To OB MICD (2046597), and on the UVOT Telescope Tube according to UVOT Telescope To OB MICD (2046595). Survival heaters, survival heater harnesses, and thermostatic controllers shall be provided by GSFC and installed by the UVOT team. UVOT survival heaters shall be sized for 27V (at instrument interface) with a duty cycle of 80%, worst case cold conditions (flight predict with no temperature margin). The duty cycle of the UVOT survival heaters varies depending on environment but shall not exceed the Orbit Average Power (OAP) listed in Table 5-2 of the UVOT to S/C ICD (1143-EI-Y22364). Two pairs of wires shall carry the A-side service for the primary survival heaters and two pairs of wires shall carry the B-side service for the secondary survival heaters via IMP11 on Disconnect Panel 1 of the OB. The UVOT survival heaters shall be continuously powered by the SC power bus.

Table 6-6 Heaters

Unit	Device Power		Location	Type
	S/C	UVOT		
TM	1*	8	Refer to UVOT TICD #2046595	S/C: Minco Kapton Heater UVOT: Kapton Heater
DEMs	--	--	--	--

*S/C powered heater, provided & integrated by the UVOT.

6.8 Thermal Control Requirements

6.8.1 Mounting Point Temperature Difference

The temperature difference between any two mounting points of the interface flange of the TM should not exceed 0.5°C.

6.8.2 Thermal Rate of Change

The temperature rate of change at the TM temperature reference point should not exceed 1.0°C/hr.

6.9 Thermal Links & Heat Flow

Conducted heatflow during survival (safehold) mode shall be less than 5 Watts between the UVOT and the Optical Bench. A description of the thermal interfaces is found in Figure 6-1.

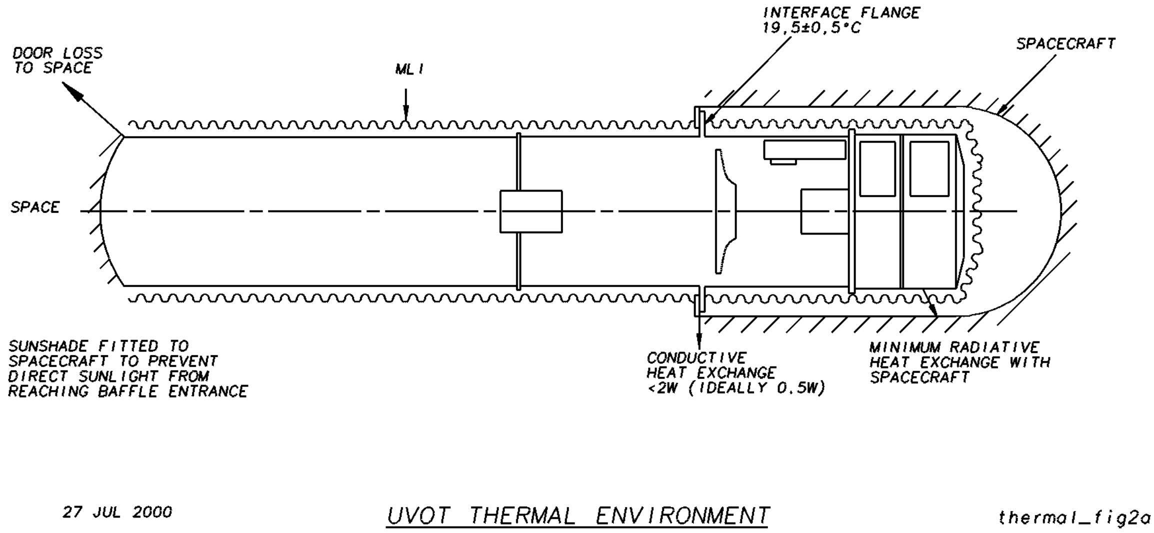


Figure 6-1 TM Thermal Links Schematic

6.10 Thermal Analysis

A thermal analysis model of the UVOT, including the associated DEMs, shall be provided to the project. Thermal mathematical models should be provided in SINDA format if possible; however, as a minimum, each model shall include a complete description of nodes, their thermal mass, conductive and radiative couplings, and heat dissipation locations including heaters and thermostatic control characteristics if applicable. Also, all modes of operation should be defined.

The thermal design of the UVOT shall be validated by a UVOT thermal balance test, and the thermal model shall be correlated with the thermal balance test data.

6.11 Thermal Design Parameters

Design values of environmental constants to be used for thermal analysis are shown in Table 6-7.

Table 6-7 Design Values of Environmental Constants

Environmental Constants	MINIMUM	MAXIMUM
Solar Constant (W/m^2)	1287	1419
Albedo	0.25	0.35
Earth Emitted Infrared Radiation (W/m^2)	208	265

6.12 Multilayer Insulation

The UVOT Telescope Module shall be delivered to IM integration with flight Multilayer Insulation (MLI) in place. Flight MLI for the UVOT TM shall be the responsibility of PSU.

6.13 Payload Fairing Requirements

The UVOT shall survive the environmental conditions inside the Payload Fairing of the Launch Vehicle (LV). Thus, the UVOT shall be compatible with an air conditioning temperature range of 55°F to 70°F at the inlet to the PLF and a flowrate of 42.5 m^3/min inside the PLF during prelaunch activities until launch. The UVOT shall also be compatible with the PLF thermal environment shown in Figure 9-1 and the temperature profile shown in Table 9-2 of the IM to S/C ICD (1143-EI-Y22363).

7. ELECTRICAL INTERFACES AND REQUIREMENTS

A system level block diagram outlining Electrical interfaces for the UVOT (including harness lengths / wire counts, shielding, IM temperature sensors, spacecraft and UVOT grounding scheme, and survival heater wiring connectors) shall be documented in the UVOT to Spacecraft ICD (1143-EI-Y22364).

All interconnects from the UVOT to the spacecraft shall be routed through an interface connector plate(s) on the Optical Bench (OB). These connections shall include power, commands, and telemetry.

The UVOT to Instrument Module harness and the Instrument Module to DEMs harness shall be the responsibility of GSFC. GSFC shall provide an optical-bench-mounted harness between spacecraft the TM / DEMs and the optical bench interface connector plates. An Optical Bench EICD shall provide connector descriptions and contact designations.

Flight harnesses connecting the UVOT to the optical bench shall use connectors on the optical bench assembly to allow removal of the TM or the DEMs, and also to allow removal of the entire Instrument without the de-integration of the wiring harness.

7.1 Electrical Resources Required from S/C

The UVOT shall conform to the Electrical Interface specifications as listed in the Spectrum Astro ICD 1143-EI-Y22364. The UVOT electronics input power receive circuitry shall be as shown in Figure 5-8 through Figure 5-10 of the UVOT to S/C ICD (1143-EI-Y22364). A summary of the electrical resources required by the UVOT from the S/C is found in Table 7-1.

Table 7-1 Summary of Electrical Resources Required from S/C

Parameter	Signal Type	Basic Requirement[1]	Redundancy	
			circuit	line
Power	+28 V DEM power[2]	1	X	X
	+28 V DEM power return	1	X	X
	+28 V TM power[2]	1	X	X
	+28 V TM power return	1	X	X
	heater power	1	X	X
	heater power return	1	X	X
Data	ICU 1553 interface	1	X	X
	DPU 1553 interface	1	X	X
	analog channels (double ended)	0		
	analog channels return (double ended)	0		
	relay status monitor	0		
	relay status monitor return	0		
Telecommands	High level on/off commands	0		
	High level on/off commands return	0		
Temperature[3]	Temperature sensor	2	X	X
	Temperature sensor return	2	X	X
HOP	High Output Parafin	1	X	X

[1]Basic requirement: number of functions without redundancy.
[2]Instrument power switching is executed in the S/C power subsystem.
[3]See Section 6.6.

Directing diodes in the UVOT shall be used to prevent power from flowing back into the EPS from the UVOT electronics should both the primary and redundant switches for the UVOT instrument be closed at the same time. Directing diodes are not needed for the UVOT survival heaters, as they are physically redundant.

7.1.1 TM Operating Power

SC power shall be used for power converters located in the UVOT TM processing electronics and for thermostatically controlled survival heaters.

7.1.2 DEM Operating Power

SC power shall be used for power converters located in the UVOT DEMs. The two DEMs shall operate mutually exclusive to each another.

7.1.3 Door Operating Power

The UVOT door release mechanism shall use SC power.

7.2 Power Budget

The following power and switching requirements shall be met by the UVOT. Refer to Table 19 in the Swift Interface Requirements Document [IRD 5.2.2]. Current best estimates of utilization of power allocation are to be reported monthly to the Swift Systems Manager.

Table 7-2 UVOT Power Requirements

UVOT	ORBIT AVERAGE POWER (WATTS, OAP)	PEAK POWER (WATTS)
UVOT Total - Operational	125	220
UVOT (TM Only) - Survival	100	175

7.3 Power Bus Conditions

The UVOT shall be designed to operate normally, and without degradation, given the power bus conditions specified below and in section 5.2.1 of the Swift Interface Requirements Document [GSFC-730-SWIFT-IRD] (summarized in table 7-3). The UVOT shall be able to survive an instantaneous removal of power up to 10 times without being damaged, protecting against inadvertent switching on the ground as well as emergency operations on-orbit. [IRD 5.2.1].

Table 7-3 Power Bus Conditions

Parameter	Value
Steady State Input Voltage	+32 V_{DC} (Nominal)
Input Voltage Range	+24V_{DC} to +35V_{DC} [IRD 5.2.1.1]
	No damage or degradation when powered at all voltages lower than 27 volts for an indefinite period of time without
Unpowered Service Power Distribution	Voltage on unpowered circuit < 0.3 volts during operation.
Input Ripple Voltage	<1.0V_{p-p}, for frequencies between 1Hz to 10 MHz [IRD 5.2.1.2]
	<0.5V_{p-p}, for frequencies > 10 MHz [IRD 5.2.1.2]
Turn-On Transients (In-rush Current)	< 250% of maximum steady state with duration less than 50mS See [IRD 5.2.1.3]
	the rise and fall time of input voltage is between 50 and 200 micro-seconds during turn-on and turn-off of the spacecraft power.
Abnormal Transients	-1V_{DC} < V < +40V_{DC} for up to 500 mS No damage due to polarity reversal of the input power [IRD 5.2.1.4]
Turn-off voltage transients	-1V_{DC} to +40V_{DC} [IRD 5.2.1.5]
	Transients induced on the power service to that instrument during turn-off shall not exceed +/-3 V.
Common Mode Noise	<100 mV peak-to-peak (50 mV goal) during all normal operating modes. Measurements shall be made between: Power (+28) and component chassis; Power return and component chassis; Signal Ground and Chassis.
Over-Current Protection	There shall be over-current protection devices on each instrument power connection to protect the Spacecraft power system.
Note: The UVOT will not be required to perform as specified during these conditions. The UVOT is required to withstand these conditions without sustaining damage.	

7.3.1 Steady State Input Voltage

Nominal Steady State input voltage for the UVOT instrument shall be +32 volts DC, available on all primary power inputs (operational and survival modes).

7.3.2 Input Voltage Range

The UVOT shall operate normally when provided steady-state voltage within the range of +24 volts DC to +35 volts DC, including harness losses, on all primary power inputs (operational and survival modes), as measured at the instrument connector. The UVOT instrument shall be capable of being powered at all voltages lower than 27 volts for an indefinite period of time without damage or degradation.

7.3.3 Unpowered Service Power Distribution

The voltage present on any switch powering a unit intended to be unpowered (cold spare) shall be less than 0.3 volts during operation of the UVOT instrument.

7.3.4 Input Ripple Voltage

The UVOT shall operate normally when ripple on the Spacecraft bus is less than 1.0 Volt peak-to-peak over the frequency range of 1 Hz to 10 MHz at the power input. The UVOT shall operate normally when ripple on the Spacecraft bus is less than 0.5V peak-to-peak for frequencies over 10 MHz at the power input.

The total contribution to ripple on the Spacecraft bus caused by the UVOT shall not exceed 0.1 V peak-to-peak.

Table 7-4 Input Ripple Voltage

VALUE	FREQUENCY RANGE
1.0 Volts	1 Hz to 10 MHz
0.5 Volts	>10MHz

7.3.5 Turn-On Transients (In-rush Current)

All UVOT electronic power is supplied through converters incorporating active inrush current limiting except the operational heaters that are powered by opto-isolated switched primary power. Each converter shall be designed to limit inrush currents to those defined in Table 5-1.

The UVOT shall operate normally when the Total Transient In-rush current does not exceed 250% of maximum steady state (MSS) current for less than 50 milliseconds as shown in Figure 7-1.

The UVOT shall operate normally when the rise and fall time of input voltage is between 50 and 200 micro-seconds during turn-on and turn-off of the spacecraft power.

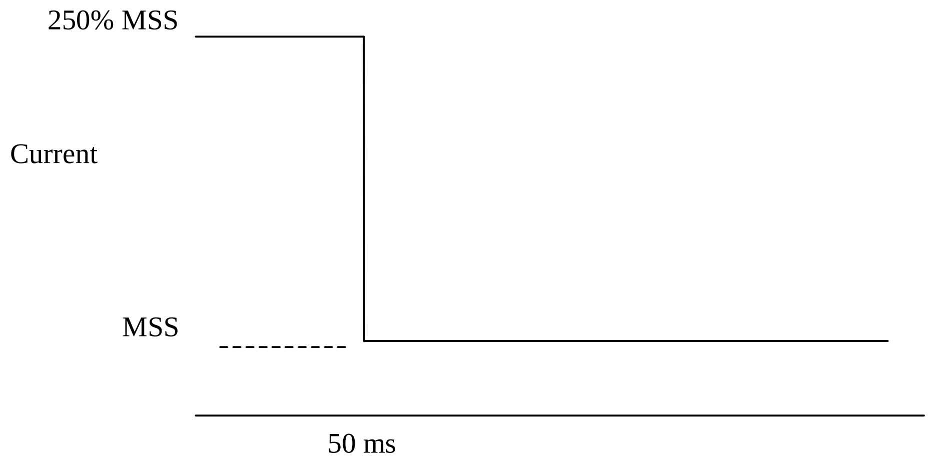


Figure 7-1 Instrument Turn-on Transient Limits

7.3.6 Abnormal Transients

The UVOT shall not be damaged and shall operate normally when voltage in the range of - 1 to +40 VDC for up to 500 milliseconds is applied to the power input during anomalistic operations. The UVOT shall operate normally and not be damaged due to polarity reversal of the input power.

7.3.7 Turn-Off Voltage Transients

UVOT induced voltages, produced by load switching, shall be within the range of +40 to -1 V. These voltage surges shall decay to within 1 volt of steady state voltage in less than 5 ms. Verification measurements shall be made at the remote box harness connector or at the IM harness connector. The UVOT shall operate normally when the peak voltage of transients induced on the power service, when the UVOT is switched off do not exceed +40 V, nor fall below - 1 V.

The UVOT shall operate normally as long as transients induced on the power service to the UVOT during turn-off do not exceed +/-3 V when sub-switching is performed within the UVOT instrument.

7.3.8 Common Mode Noise

During all normal operating modes, the UVOT shall not produce Common Mode Voltage exceeding 100 mV peak-to-peak (50 mV goal) between:

a) Power (+28) and TM chassis;
b) Power (+28) and DEM chassis
c) Power return and TM chassis;
d) Power return and DEM chassis;
e) Signal Ground and TM chassis;
f) Signal Ground and DEM chassis.

Measurements to verify compliance with this requirement shall be made.

7.3.9 Over-Current Protection

There shall be over-current protection devices on each instrument power connection to protect the Spacecraft power system.

7.4 Power Shutdown sequence

While the UVOT instrument shall be able to survive a limited number of instantaneous power removals, the normal power off sequence for the UVOT is to respond to an imminent power removal 1553 command by safing the instrument within 3 minutes after the command was sent. This 3 minute delay will allow the following to occur:

a) 20 seconds for filter wheel to get to block;
b) 10 seconds cathode voltage control;
c) 100 seconds for MCP1 voltage control;
d) 30 seconds for MCP23 voltage control;
e) 10 seconds housekeeping.

The UVOT specific requirements related to power shutdown notification shall be as documented in the IM to S/C ICD (1143-EI-Y22363).

7.5 Grounding

In order to assure adequate performance (and conformance with the grounding scheme applied to XMM) of internal and external spacecraft electrical interfaces, The follow design goals are necessary:

- An Equipotential spacecraft and Optical Bench.
- Low conducted and radiated emissions from system cables.
- High noise immunity on interface circuits associated with system cabling.
- Electrostatic discharge prevention and safeguards.

The SC to UVOT interfaces shall accommodate design features to dissipate SC and payload charge build up.

In addition, the materials and construction method of the UVOT chassis, structure, and metal elements shall be such that electrical properties of the UVOT are maintained throughout the service life of the mission.

The overall UVOT system grounding shall be as shown in Figure 5-9 of the IM to S/C ICD (1143-EI-Y22363). The UVOT grounding system is described in Section 5.5 of the UVOT to S/C ICD (1143-EI-Y22364).

7.5.1 Bonding and structure grounding

The UVOT TM requires a ground strap with a resistance of 10 mΩ or less from the chassis of the TM to the spacecraft structure. The UVOT DEMs shall be thermally isolated from the IM, thus the DEMs require a ground strap with a resistance of 10 mΩ or less from the chassis of the DEM to the spacecraft structure.

7.5.2 Grounding and isolation

The requirements for isolation of returns are as follows:

a) No part of the structure shall carry power return current by design. Each unit will establish a secondary reference [IRD-5.5.1].
b) UVOT Primary power returns shall be isolated from signal returns and chassis by at least 1 MegaOhm at DC.
c) Primary power returns should be isolated from secondary power lines by at least 1Mohm minimum.
d) All circuitry interconnecting semiconductors, capacitors, resistors, transformers, and other electronic components shall be referenced to secondary return.

7.5.3 Surface Conductivity

The outer surfaces exposed to space should be conductive (R<10kOhms/square cm) in order to avoid differential charge build up resulting in a static discharge.

7.5.4 Single Ended Signal Interfaces

Single ended signal interfaces should be avoided between units when reasonable.

7.5.5 Differential Interface Signals

Differential interface signals should use a dedicated return conductor (twisted pair) with the return isolated from chassis. The differential interface receiver circuit should provide > 10Ω isolation from chassis ground.

7.5.6 Digital Signal Interfaces

Digital signal interfaces with fundamental frequencies ≥ 5 MHz or rise times of ≤ 60 ns should use controlled impedance transmission lines such as coax and twisted shielded pairs. The shield should be grounded to chassis at both ends and at convenient midpoints.

7.5.7 Analog Telemetry Sensors

Passive bi-level, relay, and passive analog telemetry sensors will be isolated from chassis by ≥ 50kΩ (with 1MΩ as a goal).

7.5.8 RF Signals

RF signals will use coaxial cables with the outer shield grounded to chassis at both ends.

7.5.9 Harness Shields

All UVOT harnesses shall be properly shielded. In addition, power and signal (data) lines shall be routed in separately shielded cables within each harness. Shielding shall be provided to lines where protection from RFI is indicated. All 1553 bus leads/connectors shall be shielded, Trompeter-type "Twinax" threaded style in accordance with MIL-STD-1553B. Shielding used for all non-1553 interconnections shall use MIL-STD-461C as a guide.

7.5.9.1 Twisted Pair Shielding

Wire shields should cover the twisted pair or twisted group rather than individual wires.

7.5.9.2 Current in Shield

No shield should intentionally carry current except for coax cables used with RF signals.

7.5.9.3 Shield Grounding

Circuit shields should normally be grounded to the equipment case at each end. The preferred method of grounding shields is through a conductive backshell that makes good electrical contact to the equipment case. In special cases, noisy or noise sensitive signals may be individually shielded, with the shield terminated to signal ground at the source end only. Overall shields should be used over cable bundles for additional protection and shall also be grounded to equipment case at each end.

7.5.10 Primary Power Grounding

Primary power returns shall be referenced to spacecraft chassis at a designated spacecraft power single point ground (IRD 5.5.1.3).

7.5.11 Secondary Power Grounding

A single point grounding method shall be used for the UVOT and the spacecraft bus. Single point ground means that all secondary return paths shall be isolated from structure except where they all meet at a single location within each instrument or spacecraft bus and where the signal ground is connected to chassis. Thus, secondary power, inherently isolated from primary power by DC-DC converters or isolation transformers, and routed external to the equipment, shall be grounded to the structure at one point. Normally, this point will be the equipment case containing the secondary power supply. The properly bonded mounting surface of an equipment case is considered to be a single point. In the event that a secondary power source is only used by one subsystem, that subsystem design may designate the single-point ground location at the source or at any one load. Care should be taken to isolate signal, command, and control lines such that separate, independently grounded power supply returns will not be inadvertently interconnected.

Components with single ended interfaces should not have secondary returns tied to chassis, in order to avoid ground offsets. In such cases, secondary returns shall be referenced to spacecraft chassis at a designated spacecraft signal single point ground. A signal should not generate more than 1 milliamp of chassis current, with a design goal of zero chassis current.

Capacitive coupling to chassis ground on both sides of a DC-DC power converter to provide a short return path for currents generated by stray capacitance inside the converter is permissible where it does not conflict with other requirements in this section. Capacitance shall not exceed 4.7 nF.

7.5.12 Thermal Blankets

The UVOT MLI shall be grounded to the UVOT structure according to the following requirements:

a) There shall be at least one ground point for all layers for every square meter of MLI blanket surface.
b) Each MLI blanket ground point shall be connected to the nearest practical point on the UVOT structure, with a minimum length ground wire having a resistance less than 0.25 ohms.
c) The edges of the MLI blanket shall be bound with material having a conductive outer side, which is bonded to the blanket ground points.

8. TELECOMMANDS AND TELEMETRY

The UVOT shall be controlled through a combination of digital, bilevel, and power control commands.

The UVOT shall accept commands originating from the following sources:

a) Real-time commands uplinked from the ground
b) Data upload from the ground
c) Stored commands from the SC stored command queues
d) Generated by the SC bus software

The UVOT shall utilize the MIL-STD-1553B, Digital Time Division Command/Response Multiplex Data Bus as the primary commanding, control, and telemetry interface. UVOT bilevel inputs shall be as documented in the UVOT to S/C ICD (1143-EI-Y22364). There shall be no analog inputs to the UVOT with the exception of UVOT power, see Section 5.3 of the UVOT to S/C ICD (1143-EI-Y22364).

The following sections specify the UVOT telecommanding requirements, and then describe the primary UVOT telecommands needed to control the instrument. Except as noted, each requirement applies to both the ICU and the DPU.

8.1 Telecommands

8.1.1 Door Commanding

Once the outgassing rate is sufficiently low the UVOT telescope door shall be opened on ground command using High Output Paraffin (HOP) actuators. The UVOT door latch shall be actuated by one of 2 pulse signals for the HOP actuator. A 28V pulse of less than 1 ampere and 10 minutes duration is required. The commands are listed in Sections 5.1.2 and 6 of the UVOT to S/C ICD (1143-EI-Y22364) and summarized below:

a) The UVOT Latch Actuation Primary command causes actuation of the UVOT telescope door latch primary actuator from the A-side of the SC bus.
b) There shall be two (2) bilevel commands sent to the UVOT payload for telescope door latch release. These commands are categorized as critical commands and require extra steps to be taken by the ground operators in order to be sent.
c) Both telescope door latch release commands shall not be issued simultaneously.
d) The UVOT shall accomodate two bilevel inputs consisting of a primary and secondary actuator for the telescope door latch.
e) The primary telescope door latch actuator shall interface to the SC A-side electronics only.
f) The secondary telescope door latch actuator shall interface to the SC B-side electronics only.
g) Within the latch, the primary actuator shall be wired in series with a micro-switch that will cut off power to the actuator upon latch release.
h) The secondary actuator in each latch shall be wired directly to the Power Distribution Unit (PDU) with no micro-switch to cutoff power automatically.
i) The UVOT receive circuitry for the bilevel interface shall be as shown in Figure 5-6 of the IM to S/C ICD (1143-EI-Y22363).

8.1.2 Telecommands Requirements

8.1.2.1 Telecommand Interface and Format

All data shall be passed to/from the spacecraft and between instruments using a MIL-STD-1553 bus formatted as CCSDS Source Packets. The UVOT shall communicate across the 1553 interface according to the procedures and with command formats set forth in the Swift 1553 Bus Protocol Interface Control Document (Spectrum Astro 1143-EI-S19121), also referenced to in this document as the 1553 ICD. The UVOT shall have two remote terminal address on the 1553 bus: UVOT/DPU and UVOT/ICU. The UVOT shall not be configured as a bus controller on the 1553 bus.

The UVOT 1553 commands shall contain at least 10 bytes and may contain multiple 62 byte (31 word) messages transferred in a Consultative Committee For Space Data Systems (CCSDS) Packet over the 1553B bus to the UVOT payload.

8.1.2.2 Telecommand Rate

The UVOT shall be capable of receiving telecommands over the 1553 interface at a rate of 20 commands per second.

8.1.3 Telecommands Description

The UVOT shall be capable of receiving the standard telecommands (observatory messages) documented in the Swift 1553 Bus Protocol Interface Control Document [1143-EI-S19121], and in the Swift Interface Requirements Document [GSFC-730-SWIFT-IRD].

8.1.3.1 ICU Telecommands

The UVOT requires a number of telecommands to control and configure the instrument. The ICU is commanded via the spacecraft 1553 interface. ICU commands are required as follows:

Table 8-1 ICU Commands

Application/Interface	Function/Component	
ICU Control	State Memory Load/Dump Deferred Command Store	Telemetry Watchdog Timer Instrument Safing
Science Observations	Observatory Messages Relative Time Sequences	Science Plan/Target List
Telescope Module	Detector Digital Electronics Instrument Control Bus Dichroic Mechanism	Detector Analog Electronics Filter Wheel Telescope Heaters
DPU Interface	SSI Configuration Accept and Forward DPU Commands	DPU Heartbeat Watchdog
Spacecraft Interface	Clock Message Telemetry Transfer Rate	Attitude Message Test/Null Command

8.1.3.2 DPU Telecommands

The DPU is commanded via the spacecraft 1553 interface and the ICU SSI. DPU commands are required as follows:

Table 8-2 DPU Commands

Application/Interface	Function/Component	
DPU Control	State Memory Load/Dump	Telemetry Data Compression
Science/Engineering Observations	Mode	Exposure Configuration
Spacecraft Interface	Clock Message Telemetry Transfer Rate	Attitude Message Test/Null Command

8.1.4 Observatory Messaging

The UVOT shall receive spacecraft-broadcast time once every second. This redundant "hard-line" 1 pulse-per-second (pps) interface is provided at UVOT/DPU and UVOT/ICU remote terminals.

Refer to the Onboard Operational Messaging Interface Document and the Swift Telemetry Format Standards Document.

8.2 Telemetry

The following sections specify the UVOT telemetry requirements, and then list and describe the UVOT housekeeping, science, and engineering telemetry produced by the instrument. Except as noted, each requirement applies to both the ICU and the DPU.

8.2.1 Telemetry Requirements

8.2.1.1 ACS Information

UVOT shall receive attitude and location information from the spacecraft in the form of a RA/DEC/ROLL, plus observatory latitude and longitude. The UVOT shall receive attitude updates at a rate of 5 Hz.

8.2.1.2 Telemetry Interface and Format

The UVOT shall provide FOUR types of telemetry: REAL-TIME HOUSEKEEPING, TDRSS, HIGH-PRIORITY SCIENCE, AND LOW-PRIORITY SCIENCE. UVOT data shall be handled via the 1553B bus under the control of the 1553 Bus Controller (BC) as described in the Swift 1553 Bus ICD (1143-EI-S19121). UVOT science data shall be handled via the 1553B bus under the control of the 1553 Bus Controller (BC) as described in the Swift 1553 Bus ICD (1143-EI-S19121). The UVOT and spacecraft team shall develop a MIL-STD-1553 schedule table implementing this telemetry allocation as well as the commanding/inter-instrument messaging required to support mission goals. The UVOT shall be polled over the 1553 bus for telemetry by the BC at a 9 Hz rate for the DPU and at a 1 Hz rate for the ICU.

8.2.1.3 Door Telemetry

The UVOT shall have three bilevel outputs, a monitor for the telescope door latch plus two hinge monitors. When the door is opened, the micro-switches shall change state grounding the signals to a logic low via the SC supplied secondary return to indicate that the door is open. The door position signal identification and required characteristics shall be as listed below:

a) Signal Name:
    a. UVOT Latch Telemetry
    b. UVOT Door Telemetry Primary
    c. UVOT Door Telemetry Secondary
b) Signal Type: Discrete bilevel
c) Signal Logic: Positive
d) High Level: 5 Vdc nominal (4.5 Vdc min, 5.5 Vdc max) (Door Closed)
e) Low Level: 0.0 Vdc minimum, 0.5 Vdc maximum (Door Open)
f) Load Current: 0.5 mA nominal (.75 mA max)
g) Pulse Width: N/A
h) Rise and fall times: Non-critical.

The UVOT Door Sensor (4 micro-switches) shall be monitored by Spacecraft C&DH.

8.2.1.4 ICU Telemetry Rates

The UVOT (ICU) shall produce a maximum average science telemetry rate, housekeeping data rate, and peak data rate of 0, 0.5, and 2 kilobits per second, respectively.

8.2.1.5 DPU Telemetry Rates

The instrument daily average and peak data rate limits are listed below. Rates include CCSDS overhead, and are driven by the downlink capacity to the ground station. The UVOT (DPU) shall produce a maximum average science telemetry rate, housekeeping data rate, and peak data rate of 7.0, 0.5, and 62 kilobits per second, respectively.

8.2.1.6 Memory Dump Telemetry

The UVOT shall implement the standard Swift memory dump telemetry packet format as described in document 03691-DPUSDS-01, Software Design Specification for the UVOT DPU for the Swift Gamma Ray Burst Explorer.

8.2.2 Telemetry Description

The following sections list the required housekeeping telemetry parameters and science/engineering data products.

8.2.2.1 Housekeeping Telemetry

The following table lists the required health and status parameters which must be reported in UVOT housekeeping. For each parameter, the system state(s) and minimum rate at which the parameter must be reported is indicated.

Table 8-3 Parameter Reporting Frequency

State of Health Parameter	Minimum Reporting Frequency
Instrument Time	10 seconds
Currents and Voltages	10 seconds
High Voltage Status	10 seconds
Temperatures	10 seconds
Heater Power Status	10 seconds
Positions of Moveable Mechanics	10 seconds
Packet Counts	10 seconds
Errors (count and last error code)	10 seconds
States and Modes	10 seconds
Tracking Status	10 seconds

Deferred Command Store Status	10 seconds
Commands (count and last command)	10 seconds

The following table lists the planned housekeeping data packets to be produced by the UVOT instrument.

Table 8-4 Housekeeping Data Packets

Name and Description	Pkt Type	Produced By	Pre-Compressed Data Size	Packet Frequency	Compress Data
ICU State of Health Packet Contains ICU periodic state of health data	HK	ICU	Fixed 230 bytes	Once every 3 seconds or once every 10 seconds	No
ICU Log Packet Contains a log of significant activities, echoed commands, and errors.	HK	ICU	Variable Maximum of 230 bytes	Event-driven	No
ICU Telemetry Management Packet Contains a report on the enable/disable status of the various telemetry packets	HK	ICU	Fixed 96 bytes	On command	No
ICU Memory Dump Packet Contains the results of a commanded ICU memory dump	HK	ICU	Variable Multiple packets of maximum of 958 bytes for non-RT dump packet, maximum of 230 bytes for RT dump packet	On command	No
DPU Startup Packet Contains a comprehensive set of parameters describing the state of the DPU at boot time.	HK	DPU	Fixed	At boot up or on command	No
DPU State of Health Packet Contains DPU periodic state of health data	HK	DPU	Fixed Maximum of 230 bytes	Once every 10 seconds	No
DPU Log Packet Contains a log of significant activities and errors.	HK	DPU	Variable Maximum of 230 bytes	Event-driven	No
DPU Command Echo Packet Contains a log of echoed commands.	HK	DPU	Variable Maximum of 230 bytes	Event-driven	No
DPU Memory Dump Packet Contains the results of a commanded ICU memory dump	HK	DPU	Variable Maximum of 958 bytes for non-RT dump packet, maximum of 230 bytes for RT dump packet	On command	No

8.2.2.2 Science and Engineering Telemetry

The following table lists the science and engineering data packets to be produced by the UVOT instrument, and the approximate pre-compressed size of each. The UVOT anticipates an average 2:1 compression ratio for image packets (non-image packets may realize less compression since the compression algorithm is optimized for images).

Table 8-5 UVOT Science and Engineering Packets

Name and Description	Pkt Type	Produced By	Pre-Compressed Data Size	Packet Frequency	Compress Data
Event Packet Contains raw time-tagged events	Sci	DPU	Variable Maximum of 763MB of 4-byte events for a 1000s exposure at 200,000 events per second, split into multiple packets not larger than 8192 bytes	Multiple per observation	Yes
Image Packet	Sci	DPU	Variable Maximum of 16 MB of data per full-frame image exposure, split into multiple packets not larger than 8192 bytes (TBR)	Multiple per observation	Yes
Parameterized Finding Chart Packet Contains a list of sources described by x/y position and a 5x5 counts matrix	Sci	DPU	Variable Maximum of 16 kbits	One per GRB	Yes
Full-Frame Engineering Image Packet	Eng	DPU	Fixed Total of 16MB of data per full-frame image exposure, split into multiple packets not larger than 8192 bytes	One per Full-Frame Engineering exposure	Yes
Raw Events Packet	Eng	DPU	Variable	One per Raw Event Engineering exposure	Yes
Channel Boundary Data Packet	Eng	DPU	Fixed Eighteen 16-bit values for a total of 36 bytes	One per Channel Boundary Engineering exposure	Yes
M, N Pseudo Image Packet	Eng	DPU	Fixed Two images (x and y), each of size 262,144 bytes, split into multiple packets not larger than 8192 bytes	Multiple per Channel Boundary Engineering exposure	Yes
Centroiding Confirmation Pseudo-Image Packet	Eng	DPU	Fixed Total of 16,384 bytes split into multiple packets not larger than 8192 bytes	Multiple per Centroiding Confirmation Engineering exposure	Yes
Intensifier Characteristics Pseudo-Image Packet	Eng	DPU	Fixed 1024 bytes	One per Intensifier Characteristics Engineering exposure	Yes

8.3 Telecommand Electrical Interface Circuits

The UVOT shall have two types of serial inputs: 1553 and 1Hz timing pulse. The UVOT shall have two types of serial outputs (inputs for the IM); 1553, and RS-422 1Hz timing pulse outputs. The UVOT receive circuitry for the 1 Hz Timing Pulse shall be as shown in Figure 5-4 and Figure 5-5 of the UVOT to S/C ICD (1143-EI-Y22364).

8.3.1 1553 Bus Interface

The UVOT receive circuitry for the 1553B data bus shall be as shown in Figure 5-2 and Figure 5-3 of the UVOT to S/C ICD (1143-EI-Y22364). The 1553 bus cabling shall be coupled to terminal using transformer coupling as described by MIL-HDBK-1553B (not direct coupling). Receiver terminal components shall be of the same type or equivalent to insure compatibility.

The DPU will provide MIL-STD-1553B bus signals as identified in Table 8-6 .

Table 8-6 MIL-STD-1553B Data Bus Signal Identification

#	Function Name	Signal Type
1	1553 A TxRx+	MIL-STD-1553B – A Primary Data +
2	1553 A TxRx-	MIL-STD-1553B – A Primary Data -
3	1553 B TxRx+	MIL-STD-1553B – B Primary Data +
4	1553 B TxRx-	MIL-STD-1553B – B Primary Data -

8.3.2 Aperture Door Sensors

The UVOT circuitry for the Telescope Door Position Sensor Circuitry shall be as shown in Figure 5-7 of the IM to S/C ICD 1143-EI-Y22363.

8.3.3 S/C Powered Temperature Sensors Interface

The S/C powered thermistors will conform to the *Swift Instrument Module ICD* 1143-EI-Y22363 section 5.2.3.

9. ENVIRONMENTAL REQUIREMENTS

Testing shall use as guidelines MIL-STD-1540D, "Test Requirements for Space Vehicles", dated 10 October 1982, and MIL-HDBK-343, "Design, Construction, and Testing Requirements for One-of-a-Kind Space Equipment," dated 1 February 1986.

In Addition, the UVOT shall be capable of withstanding the flight environments and test levels defined in the following sections:

a) Section 11 of the IM to S/C ICD (1143-EI-Y22363)
b) Section 11 of the UVOT to S/C ICD (1143-EI-Y22364)
c) Section 7.2 of the SWIFT IRD (410.4-ICD-0001)

9.1 Static Loads

UVOT's components (TM and DEMs) shall be capable of withstanding static loads defined in Table 11-1. Instrument acceleration design loads are defined at their respective Center of Gravity (CG) and are parallel to the SC coordinate axes shown in Figures 3 and 4 in Section 3.11.1 of the IM to S/C ICD (1143-EI-Y22363). The loads shall be applied simultaneously and in all combinations for each event. These loads may be revised following the preliminary and final design loads cycle analysis performed by the Launch Vehicle (LV) contractor.

The Quasi Static Loads for the UVOT instrument at the component level are encompassed by the static loads defined in Table 11-1.

9.2 Pressure Profiles

The UVOT shall be designed to survive (unpowered) the Delta II 2420 Payload Fairing Compartment Absolute Pressure Envelope (shown in Figure 8 of the IRD (410.4-ICD-0001) and Figure 11-2 of the IM to S/C ICD (1143-EI-Y22363)) without any degradation in performance. The UVOT shall be unpowered during the transition from atmospheric pessure at ground (T=0) to atmospheric pessure in orbit.

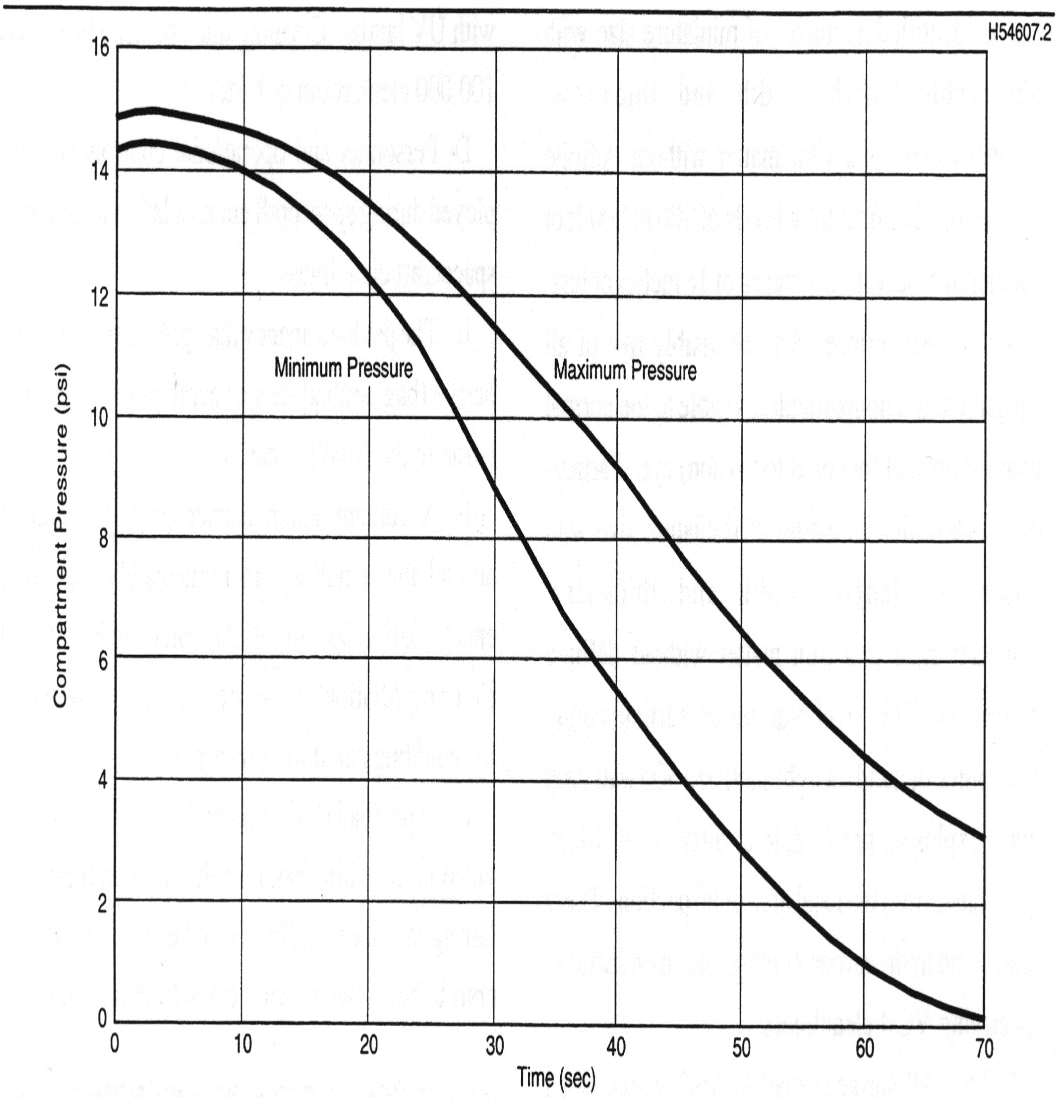


Figure 9-1 Delta II Payload Fairing Compartment Absolute Pressure Envelope

9.3 Acoustic Environment

The UVOT shall be designed to survive (unpowered) the Swift acoustic environment shown in Table 24 of the IRD (Table 11-9 of 1143-EI-Y22363) and Table 8-1, for the test duration of 1 minute, without any degradation in performance [IRD-7.2.2]. Acoustic tests shall be performed based upon an analysis of the design.

Table 9-1 Swift Acoustic Environment

One-Third Octave Center Frequency (Hz)	**Protoflight Level (dB) RE: 0.00002 Pa**	**Flight Level (dB) RE: 0.00002 Pa**
31.5	120.5	117.5
40	123.5	120.5
50	127.5	124.5
63	129.0	126.0
80	129.5	126.5
100	130.5	127.5
125	131.0	128.0
160	131.0	128.0
200	131.5	128.5
250	132.5	129.5
315	133.5	130.5
400	132.5	129.5
500	129.5	126.5
630	126.0	123.0
800	123.0	120.0
1000	121.0	118.0
1250	119.5	116.5
1600	118.0	115.0
2000	117.5	114.5
2500	117.0	114.0
3150	116.0	113.0
4000	114.5	111.5
5000	112.5	109.5
6300	108.0	105.0
8000	104.0	101.0
10000	101.0	98.0
Overall Level	**141.8**	**138.8**

9.4 Thermal Vacuum Test Requirements

The Instrument level thermal vacuum test will comprise separate vacuum testing of the TM and the DEMs.

The UVOT team shall be responsible for prediction of the UVOT's internal temperatures during testing, and for analysis of thermal testing data for verification of proper internal thermal control.

During system level thermal tests, the UVOT thermal control engineer shall be on site and available, if needed.

9.4.1 TM Thermal Vacuum Test Requirements

The TM shall be verified to perform at operating temperatures from +14°C to +25°C, and at operating pressures of less than or equal to 10^{-5} Torr for at least six complete cycles. The unit under test shall dwell at the target temperature for a minimum of 4 hours at each extreme before the applicable test is performed. In addition, one cold soak "turn on" shall be performed and one hot soak "turn on" shall be performed.

9.4.2 DEM Thermal Vacuum Test Requirements

The DEM shall be verified to perform as specified herein at operating temperatures from -20°C to +50°C for six complete cycles. The unit under test shall dwell at the target temperature for a minimum of 2 hour at each extreme before the applicable test is performed. In addition, one cold soak "turn on" shall be performed and one hot soak "turn on" shall be performed. Functional tests shall be performed during transition. All thermal vacuum tests shall be performed as specified herein at operating pressures of less than or equal to 10^{-4} Torr.

9.5 Shock Environment

The UVOT shall be shall be capable of withstanding the shock pulse generated by the LV and transmitted by the SC structure as shown in Section 11.6.1 of 1143-EI-Y22363 and in Table 34 of the IRD.

The UVOT shall be capable of withstanding the shock produced by the SC when the solar arrays and lower antenna booms are released.

The UVOT shall be capable of withstanding the shock pulse generated by the XRT telescope door and camera door releases as defined in Section 4.7 of the XRT ICD (1143-EI-Y22365).

The UVOT shall be capable of withstanding the shock pulse generated by the UVOT telescope door release as defined in Section 4.7 of the UVOT to S/C ICD (1143-EI-Y22364).

The UVOT shall withstand a 280 g shock environment across the entire frequency range at the IM interface.

9.6 Random Vibration Test Requirements

The Instrument level random vibration testing shall be performed via separate testing of the TM and the DEMs.

9.6.1 TM Random Vibration Test Levels

<u>The TM shall be designed to survive (unpowered) the Random Vibration Environment described in Table 8-2 (see also Table 26 of the IRD and Table 11-2 of the UVOT to S/C ICD (1143-EI-Y22364)).</u>

Table 9-2 TM Vibration Environment

Axis	Proto-flight Level	
	Freq (Hz)	Level
All	20	0.026 g^2/Hz
	20-50	+1.2 dB/oct
	50-800	0.038 g^2/Hz
	800-2000	-1.2 dB/oct
	≥ 2000	0.026 g^2/Hz
Overall Level	8.15 grms	
Duration	1 min/max	

9.6.2 DEM Random Vibration Test Levels

<u>The DEMs shall be designed to survive (unpowered) the Random Vibration Environment described in Table 8-3 (see also Table 27 of the IRD and Table 11-2 of the UVOT to S/C ICD (1143-EI-Y22364)).</u>

Table 9-3 DEM Vibration Environment

Axis	Proto-flight Level	
	Freq (Hz)	Level
All	20	0.026 g^2/Hz
	20-50	+6 dB/oct
	50-800	0.16 g^2/Hz
	800-2000	-6 dB/oct
	> 2000	0.026 g^2/Hz
Overall Level	14.1 grms	
Duration	1 min/max	

9.7 Sine Sweep Vibration Requirements

The Instrument level vibration testing shall be performed via separate testing of the TM and the DEMs.

9.7.1 TM Sine Sweep Vibration Test Levels

The TM shall be designed to survive (unpowered) the Sine Sweep Vibration Environment described in Table 8-4 (see also Table 30 of the IRD, Tables 11-3 and 11-4 of the UVOT to S/C ICD (1143-EI-Y22364), and Tables 11-7 and 11-8 of the IM to S/C ICD (1143-EI-Y22363)).

Table 9-4 TM Sine Vibration Environment

Thrust Axis

PROTOFLIGHT			FLIGHT LEVEL		
Frequency (Hz)	Level (G, 0-peak)	Sweep Rate (oct/min)	Frequency (Hz)	Level (G, 0-peak)	Sweep Rate (oct/min)
5-7.7	0.5in-D.A.	4	5-7.7	0.4in-D.A.	4
7.7-25	1.5	4	7.7-25	1.2	4
25-30	1.5	1.5	25-30	1.2	1.5
30-35	4.5	1.5	30-35	3.6	1.5
35-42	4.5	4	35-42	3.6	4
42-50	1.5	4	42-50	1.2	4

Lateral Axis

PROTOFLIGHT			FLIGHT LEVEL		
Frequency (Hz)	Level (G, 0-peak)	Sweep Rate (oct/min)	Frequency (Hz)	Level (G, 0-peak)	Sweep Rate (oct/min)
5-10.2	0.75in-D.A.	4	5-10.2	0.6in-D.A.	4
10.2-15	4	4	10.2-15	3.2	4
15-25	1.5	4	15-25	1.2	4
25-30	1.5	1.5	25-30	1.2	1.5
30-35	1	1.5	30-35	0.8	1.5
35-50	1	4	35-50	0.8	4

Note: Notching at critical resonant frequencies shall be permitted so as to not to exceed 1.25 times flight limit levels for protoflight testing and 1.0 times flight limit levels for flight testing based on the Delta II/Swift coupled loads analyses.

9.7.2 DEM Sine Sweep Vibration Test Levels

The DEMs shall be designed to survive (unpowered) the Sine Sweep Vibration Environment described in Table 8-5 (see also Table 31 of the IRD, Table 11-3 and 11-4 of the UVOT to S/C ICD (1143-EI-Y22364), and Table 11-6 of the IM to S/C ICD (1143-EI-Y22363)).

Table 9-5 DEM Sine Vibration Environment

All Axes

PROTOFLIGHT LEVEL			FLIGHT LEVEL		
Freq(Hz)	Level (g, 0-pk)	Rate	Freq(Hz)	Level (g, 0-pk)	Rate
5 – 12.5	0.63 in D.A.	4 oct/min	5 – 12.5	0.5 in D.A.	4 oct/min
12.5 – 25	5.0	4 oct/min	12.5 – 25	4.0	4 oct/min
25 – 35	5.0	1.5 oct/min	25 – 35	4.0	1.5 oct/min
35 – 50	5.0	4 oct/min	35 - 50	4.0	4 oct/min

9.8 EMI/EMC and ESD Requirements

The UVOT shall meet the requirements of MIL-STD-461, Rev. C, with levels specified in GEVS-SE and section 11 of the IM to S/C ICD (1143-EI-Y22363), and tailored in the Swift EMI/EMC Test Plan.

(CE0l) Conducted Emissions, Power & Interconnecting Leads, Low Frequency (30 Hz - 15 kHz)

(CE03) Conducted Emissions, Power and Interconnecting Leads (15 kHz - 50 MHz)

(CE06) Antenna Conducted Emissions

(CE07) Conducted Transient Emissions

(CS01) Conducted Susceptibility, Power Leads (30 Hz - 50 kHz)

(CS02) Conducted Susceptibility, Power Leads (50 kHz - 400 MHz)

(CS03/4/5) Conducted Susceptibility, Intermodulation, Harmonics, Spurious tests

(CS06) Conducted Susceptibility, Spikes, Power Leads (+28 V pulse at 10 μsec, 10 pps)

(RE0l) Radiated Emission, Magnetic Field (30 Hz - 50 kHz)

(RE02) Radiated Emissions, Electric Field (14kHz - 10 GHz)

(RS01) Radiated Susceptibility, Magnetic Field (30Hz - 100kHz)

(RS03) Radiated Susceptibility, Electric Field (14 kHz - 10 GHz)

Payload components tested to earlier or later revisions of MIL-STD-461 shall be evaluated on a case-by-case basis for determination if delta testing per the requirements of 461C is required.

When the UVOT is integrated with the S/C, EMC testing shall consist of a self-compatibility test, a LV compatibility test, and a range compatibility test. That is, if the UVOT does not detect a change in performance measurements when the Swift SC is operated in its modes of operation, then the SC will be considered compatible with the UVOT. If the SC bus does not detect a change in its performance measurements when the UVOT is operated in its modes of operation, then the UVOT will be considered compatible with the SC bus. When these two conditions have been sucessfully demonstrated, observatory self compatibility shall have been met. The observatory must not interfere with the LV or range nor will it be adversely affected by LV or range activities.

9.8.1 Radiated Susceptibility Requirements

The analog processing chain is most sensitive in the 10 kHz – 20 MHz range.

The UVOT shall meet the radiated electric susceptibility requirements of RS02 and RS03 (10 KHz. to 10 GHz.) with levels from GEVS-SE, the launch environment, and the SC transmitters defined in Table 11-2 and Table 11-3 of the IM to S/C ICD (1143-EI-Y22363). In addition, the range contribution to the pad 17 environment of 20 V/m across all frequencies shall be used for test purposes.

9.8.2 Radiated Emission Requirements

The UVOT shall meet the radiated emissions requirements of RE02 with limits from GEVS-SE tailored per Table 11-1 and shown in Figure 11-1 of the IM to S/C ICD (1143-EI-Y22363) with the exception of the SC and LV transmitters fundamental frequencies defined in Table 11-2 and Table 11-3 of the IM to S/C ICD (1143-EI-Y22363A).

Table 9-4 Frequency Plan for Component Emission

Components	**Frequency Range**
	< 0.1 Hz
Heater Switching	< 0.1 Hz
	100 Hz – 1 kHz
Stepper Motor Drive	Will be driven with the 1st few pulses ramping up to ~ 420 Hz & ramp down at the end of the movement
	100 kHz – 1 MHz
ICB – 3M Screened Cable	125 – 500 kHz
Clock	500 kHz
Data	250 kHz & 125 kHz
Converters for HV	200 kHz
Main Power Converters	65.5 kHz
	1 – 10 MHz
Digital Clocks	1 – 10 MHz
Inside Boxes	1, 2.5, 4, 5, 8, & 10 MHz
Data I/F	5 MHz
Data	2.5 MHz
CCD Clock	10 MHz
	10 – 20 MHz
Crystal Oscillator	16 & 20 MHz

9.8.3 Magnetic Requirements

The UVOT shall minimize the use of ferromagnetic materials.

9.8.3.1 Magnetic Susceptibility

The UVOT shall tolerate a 100 milligauss field without degradation. In addition, the UVOT shall tolerate magnetic fields less than 3 Gauss at the CCD.

9.8.3.2 Magnetic Field Generation

The UVOT shall not exceed a DC dipole moment greater than 1 Am^2. In addition, The magnetic field generated by UVOT above DC shall be less than 1 milligauss at 1 meter from either the focal plane electronics or a UVOT DEM.

The UVOT shall be tested in accordance with MIL-STD-461C for magnetic fields generated by the payload.

9.8.4 Electrostatic Discharge (ESD)

The UVOT shall be handled in accordance with the requirements of NASA-STD-8739.7, Electrostatic Discharge Control, including:

a) All personnel working on or within 1 meter of UVOT Flight hardware must have current Electrostatic Discharge (ESD) certification. Exceptions must be accompanied by person with current ESD certfication and must be approved by Instrument Lead.
b) Personnel within one meter of UVOT flight hardware must be electrically grounded using wrist straps having load resistors greater than 200 kiloohms and less than one megaohm in series from the wearer to the ground point.
c) To help protect the flight hardware from ESD damage, access to UVOT flight hardware by unauthorized personnel should be restricted.

In addition, all components should be designed using best practices to minimize susceptibility to ESD damage in ground handling and on-orbit operations. In all cases, signals at component interfaces should include reasonable protection against damage due to ESD or accidental connection to a potentially damaging signal or ground. MIL-STD-1686 or an approved substitute will be used as a guideline for handling of ESD-sensitive components.

9.9 Radiation Exposure Design Requirements

The UVOT shall be designed to withstand the total ionizing dose environment during and after exposure to the space radiation environment defined herein. The space radiation environment is specified to be from trapped protons and electrons, solar flare events, and the cosmic ray background for an orbit with mean altitude between 600 km and inclination of 22 degrees. The space radiation environment is tabulated in Table 8-4 and illustrated in Figure 9 of the IRD for the mission lifetime plus required margin. Parts that do not meet the predicted total dose requirement (including the minimum design margin) shall be identified and reviewed by the Swift Radiation engineer. If spot shielding is required to reduce the dose rate of a part, the Swift Radiation engineer shall review and approve the use of these spot shields on a case-by-case basis.

9.9.1 Total Ionizing Dose

The UVOT shall be designed to withstand the total ionizing dose environment illustrated in Figure 8-2 and tabulated in Table 8-5.

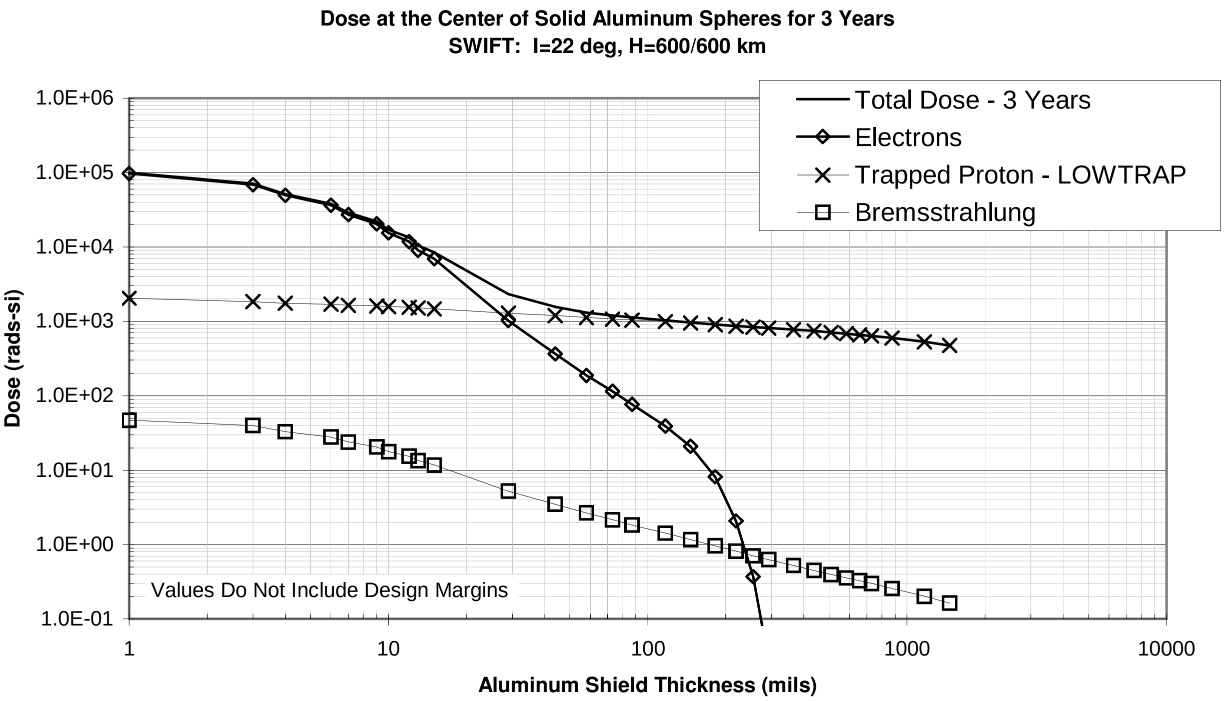


Figure 9-2 Radiation Dose Depth Curves

Table 9-5 Dose Depth Values

Thickness	Total Dose
1 mils	1.0 e +05
10 mils	2.0 e +04
100 mils	1.0 e +03
1000 mils	4.0 e +02

9.9.2 Single Event Effects (SEE)

The single event effects of interest are Single Event Upset (SEU), Single Event Latchup (SEL), Single Event Burnout (SEB), and Single Event Gate Rupture (SEGR). System level requirements with respect to SEE are as follows (IRD 7.2.8.3):

a) The UVOT shall be designed such that no single event effect can cause permanent damage to a system or subsystem
b) SEE capabilities for each electronic part shall be reviewed to prevent the failure of any component due to heavy ions or protons.
c) Electronic components of the UVOT shall be designed to be immune to SEE induced functional anomalies that require ground intervention to correct.
d) Except for radiation degradation, any effects SEUs have on component operations shall be temporary and correctable by automatic reset or ground command. Also, any design circuit using a device which exhibits Single Event Upsets (SEUs) shall be capable of recovering from such upsets without degradation to the functionality of the circuit, the instrument, or any other subsystem of the spacecraft. If a part is not immune to SEUs, analysis for SEU rates and effects must take place based on the LETth of the part as indicated in Table 36 of the IRD.
e) For any part that is not immune to Single Event Latchup (SEL), or any other potentially destructive conditions, protective circuitry must be added to eliminate the possibility of damage and verified by analysis or test.
f) In evaluating parts for latch-up, selected parts should have a Linear Energy Transfer (LET) latchup threshold of 80 MeV*cm2/mg. The Swift Radiation engineer shall be notified if any parts are selected with a latchup threshold lower than this; analysis and latchup mitigation techniques shall be required.

9.9.3 Single Event Effects Environments

Parts will be selected based on the integral particle flux environments defined by the following:

1) Trapped protons;

2) Cosmic ray background environment (CREME M = 4);

3) Adams 90% worst case flare environment (CREME M = 7);

4) And, August 1972 (King) flare environment (CREME M = 9).

The integral particle flux as a function of particle LET is illustrated in Figure 8-3. The particle flux for each case (M = 4, 7, and 9) includes the component due to trapped protons. In determining SEU effects on the system, a factor of safety of two shall be applied to the evaluation of the upset rate.

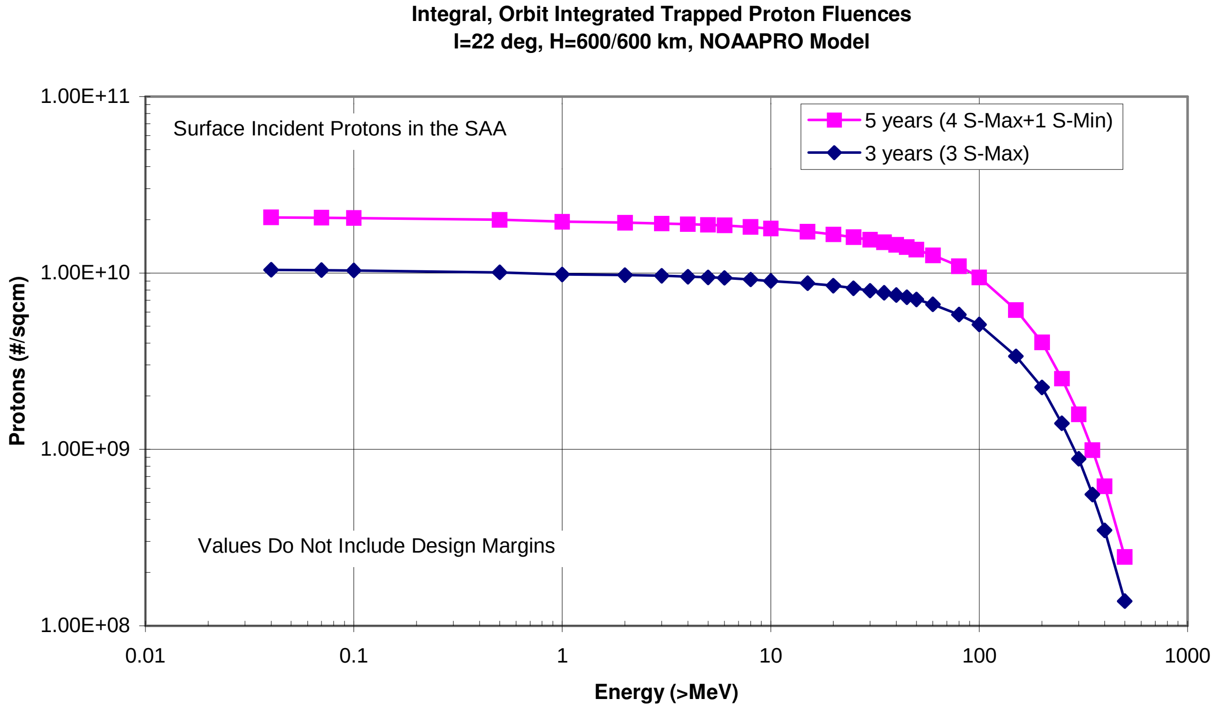


Figure 9-3 Integral Particle Flux vs. LET

9.9.4 Radiation Testing

When adequate test data is not available, testing shall be performed as identified below.

9.9.4.1 Total Dose Testing

Should total dose testing be required due to lack of data or inadequate design margins, total dose testing should be performed using MIL-STD-883, TMl019.4 as a guide. Sample size will be five parts for test and one control sample. Test criteria include the following: a dose rate of less than 10 rads/s shall be used; an anneal test shall be done for MOS technologies; the part should be tested to 150 percent of the expected incident total dose; and the bias conditions shall closely match the flight conditions. A statement of work (SOW) or test plan shall be generated prior to performing each test.

9.9.4.2 SEE Testing

Should SEE testing be required, it should be performed using ASTM F1192-88 as a guide.

10. TRANSPORTATION, HANDLING, CLEANLINESS, AND PURGING REQUIREMENTS

The TM and DEMs are ESD sensitive items. No person without current ESD training shall be allowed to work within 1 meter of the UVOT or its components.

10.1 Transportation Requirements

10.1.1 TM Transportation Requirements

A special transport container will be made available for the UVOT TM.

10.1.2 DEM and IHU Transportation Requirements

Standard containers will be made available for both the DEMs and IHUs.

10.2 Handling Requirements

10.2.1 TM Handling Requirements

The TM is an optical instrument requiring careful handling. Because of its mass, the TM will be supplied with three holes in its mounting flange for eye bolts to facilitate lifting.
Whenever possible the TM must remain inside its transportation container, double bagged. Outside of the transportation container, the TM shall be oriented within its MGSE so that it is facing downwards. At no stage shall the TM be supported at any point except at its mounting interface. At all times except when absolutely necessary the instrument end cap and any other caps should be retained in place until the final stages of integration. Such caps will be marked with red tags.

10.2.2 DEM and IHU Handling Requirements

The DEMs and IHUs have no special handing requirements other than ESD and contamination requirements.

10.3 Contamination Requirements

The UVOT team shall develop a contamination control plan (CCP) which shall be approved by the Swift Project. The UVOT support team shall be responsible for cleaning the UVOT during Optical Bench integration, IM activities, Observatory integration and testing and launch site activities. The UVOT shall be designed to minimize contamination to and from external sources before, during and after launch. The UVOT should also accommodate access for removal of pre-launch contamination

There shall be negligible degradation of UVOT performance due to self-contamination from outgassed materials or due to contamination from materials used on the spacecraft. Silicone materials, known to be a high UV absorber, should not be used on the spacecraft or instruments unless approved by Swift project contamination control engineering.

10.3.1 TM Contamination Requirements

The cleanliness requirements for the TM must be severe for the TM to reach its full potential sensitivity, particularly in the UV. The sensitivity will be degraded in two ways:

1) Attenuation by molecular contaminants;

2) Scattered background contributed by particulate contamination (dust).

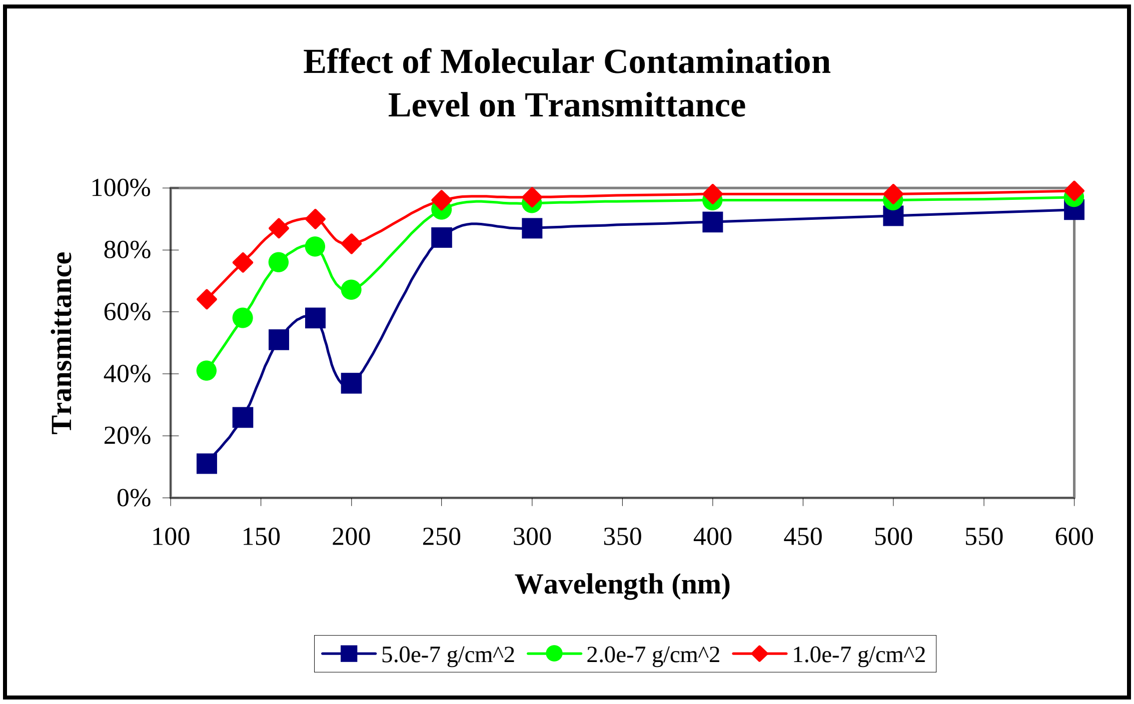
The effect of the molecular contamination can be seen in Table 9-1 and Figure 9-1 Molecular Contamination Effects Over Transmittance. In order for the sensitivity to be degraded by less than 20% over the wavelength range 170 nm to 600 nm, a total absorption coefficient ≤ 10^{-7} g/cm^2 at end of life is required.

The effects of scattering by particulate contamination and micro-roughness in the optics are severe because of the extremely low background in the space environment and the modest baffle length available on the TM. The fraction of the scattering budget to be assigned to particulate contamination is 50%. The cleanliness of the optical surfaces is 300 ppm in order to comply with the envelope of the permitted bi-directional reflectance distribution function of the contaminated surface.

Table 10-1 Molecular Contamination Effects Over Transmittance

Wavelength (nm)	Absorption Coefficient (1/(ng/cm^2))	Contamination level (g/cm^2)		
		5.0e^{-7}	2.0e^{-7}	1.0e^{-7}
120	0.000500	11%	41%	64%
140	0.000300	26%	58%	76%
160	0.000150	51%	76%	87%
180	0.000120	58%	81%	90%
200	0.000220	37%	67%	82%
250	0.000040	84%	93%	96%
300	0.000030	87%	95%	97%
400	0.000025	89%	96%	98%
500	0.000020	91%	96%	98%
600	0.000015	93%	97%	99%

Figure 10-1 Molecular Contamination Effects Over Transmittance



In order to minimize the effect of these contaminants, careful choice of materials will be exercised and close attention paid to outgassing paths and handling and cleanliness procedures during integration and before launch. Materials that may be deleterious or present a cross-contamination hazard shall undergo additional screening using the methodologies described in ASTM-E1559-00. These results must be reviewed and the Swift Contamination Engineering Manager or designee must approve use on the SC or UVOT.

10.3.2 Covers

Contamination-sensitive surfaces which require protective covers during I&T and pre-launch activities, shall be defined in the applicable CCP or CCIP. The covers must be compatible with the Observatory contamination control requirements specified in 410.4-PLAN-0003. The UVOT team shall furnish any protective covers required. Temporary protective covers must be easily removed for tests and launch configurations.

Practical extension of these statements yield the following requirements:

a) The UVOT GSE Aperture cover shall be compatible with Observatory contamination control requirements.
b) The UVOT GSE Aperture cover must be easily removed for tests and launch configurations.
c) The UVOT GSE Aperture cover shall employ tethered hardware.
d) The High-voltage safety plug shall be compatible with Observatory contamination control requirements.
e) The High-voltage safety plug must be easily removed for tests and launch configurations.
f) The High-voltage safety plug shall employ tethered hardware.

g) The GSE Alignment cube cover shall be compatible with Observatory contamination control requirements.
h) The GSE Alignment cube cover must be easily removed for tests and launch configurations.
i) The GSE Alignment cube cover shall employ tethered hardware.

10.3.3 DEM and IHU Contamination Requirements

The DEMs and IHUs have no special cleanliness requirements other than those levied by the project.

10.3.4 Purging Requirements

The UVOT team shall specify purge requirements in the UVOT CCP. The purge port locations and interfaces shall be defined and approved by the Swift Project to ensure compatibility with Observatory I&T and pre-launch activities. Detailed purge information including the flow rates and purity levels, can be found in the Swift Contamination Control Master Plan, Document 410.4-PLAN-0003.

10.3.4.1 TM Purging Requirements

The TM trickle purge will be supplied by a purge MGSE through the baffle tube so that the purge flow is first to the telescope, then the blue detector bay before reaching the remainder of the unit. After the instrument end cap is removed for the closing of the UVOT door, purge must be re-established so that the flow is, as before, first through the telescope section. The TM should be purged continuously by trickle purge until as late as is feasible; if possible continuing after integration within the spacecraft shroud, and broken only at launch.

The S/C contractor will be responsible for providing and monitoring of the purge MGSE and its correct operation. Logging of the monitoring activities and of the purge gas quality on a regular basis will be a requirement.

10.3.4.2 DEM and IHU Purging Requirements

The DEMs and IHUs have no purge requirements.

10.3.5 Integration and Test Environments

To minimize particulate contamination during integration and testing, assembled flight hardware must be maintained in a clean environment. When the UVOT is not being worked on or tested, it must be properly protected from contamination using covers and clean approved bagging material. Additional information on UVOT contamination requirements can be found in the UVOT Contamination Control Plan (SWIFT-UVOT-003).

To ensure a proper contamination controlled environment, the integration facilities for the SC and UVOT shall be maintained in accordance with MIL-STD-1540D and as specified in the UVOT Contamination Control Plan, SWIFT-UVOT-003.

10.3.6 Outgassing and Venting

The UVOT shall be manufactured using low outgassing materials. UVOT non-metallic materials shall be screened using ASTM E 595-93 data. The materials shall not have a total mass loss (TML) in vacuum of no greater than 1% and the total collected volatile condensable materials (CVCM) shall be less than 0.1%. Additional information is contained in test procedure ASTM E 595-93. Materials, which will be used on or around contamination-sensitive components, may require additional testing. This additional testing shall provide data, which may allow the use of certain materials with additional environmental exposure. These outgassing levels shall be specified in the Swift Contamination Control Master Plan, Document 410.4-PLAN-0003.

UVOT vent locations and paths shall be provided to the Swift Project and defined in the applicable contamination control plan. Venting paths shall be reviewed by GSFC contamination engineering personnel to ensure that the spacecraft or instrument contamination sensitive surfaces shall not be affected by venting effluents from other hardware.

10.3.7 Parts and Subassemblies Bake-out

Thermal vacuum bake-out of UVOT MLI, wire harnesses, and other parts or subassemblies with high initial outgassing characteristics shall be performed before final assembly to limit self contamination and facilitate compliance with the certification requirements specified in the UVOT CCP (SWIFT-UVOT-003), and SC Bus Contamination Control Implementation Plan For Swift (1143-EP-I24358). The parameters (e.g., verification method, temperature, test duration, pressure) of such bake-outs must be individualized depending on materials used, the fabrication environment, and the established contamination allowance. The bake-out parameters shall be documented in the UVOT Contamination Control Plan. It is highly recommended that all subassembly bake-outs be monitored with temperature controlled quartz crystal microbalances (TQCMs). An Observatory system level outgassing rate will be measured during these test.

10.3.8 Contamination Certification Requirements

In order to minimize cross contamination between the instruments and spacecraft sensitive surfaces, the UVOT must meet the minimum cleanliness requirements listed in the UVOT Contamination Control Plan (SWIFT-UVOT-003). The Contamination Control Engineer will certify that the UVOT has met the requirements in the UVOT Contamination Control Plan (SWIFT-UVOT-003). Spacecraft (including solar arrays) to UVOT and UVOT cross-contamination shall be controlled in compliance with the overall Swift Contamination Control Master Plan, Document 410.4-PLAN-0003.

10.4 Potential Hazards

The UVOT instrument contains three potential hazards: telescope door release, heat pipes, and high voltage power. UVOT hazards shall be further defined in Section 10 of the UVOT to S/C ICD (1143-EI-Y22364). All UVOT hazards shall be compliant with EWR-127-1 requirements

10.4.1 Telescope Door Release

A redundant High-Output Paraffin (HOP) actuator located on the UVOT shall cause the release of the telescope door. Upon actuation, the door will swing open. The characteristics of the door can be found in Section 5.7.1.1 (see also section 4.1.1 of the UVOT to S/C ICD (1143-EI-Y22364) and the UVOT Telescope Assembly To Optical Bench MICD (2045137)).

10.4.2 Heat Pipes

Anhydrous ammonia is used in the UVOT heat pipes to transport thermal energy from the electronics portion of the UVOT to the radiator portion. The UVOT heat pipes shall be designed, manufactured, and tested to MIL-STD 1522A.

10.4.3 High Voltage Power

The optical sensitivity of the UVOT is achieved through the use of a PMT. The PMT requires high voltage to operate. The high voltage power operates at 6000 volts peak. The maximum current supplied at 6000 volts is 66 uA providing a maximum of 400 mW. As a precaution, permission from the I&T manager shall be required to remove the UVOT safe plug and to physically touch the observatory when the UVOT instrument high voltage power is enabled.

11. GROUND AND FLIGHT OPERATION REQUIREMENTS

11.1 Ground Operations

11.1.1 Ground Support Equipment

UVOT GSE shall use a Unix-based version of ITOS during I&T; the scripting language is STOL. Swift-specific information in the GSE system shall be moved to the ITOS system used for flight operations. UVOT GSE shall be compatible with CCSDS versions as specified in IRD section 11.

11.1.1.1 Instrument Lifting Slings

The UVOT shall provide lifting sling(s) which accommodate a vertical integration onto the Optical Bench. Lifting slings shall be designed to be stable for any lifting scenario per NSI document 15-01-422 “Analysis Procedure for Spreader Bar Lift Stability”. UVOT lifting slings shall be designed to show positive margins using factors of safety of 3 on yield and 5 on ultimate with respect to the design working load. UVOT lifting slings shall be proof tested to a factor of twice the design working load.

11.1.1.2 Handling Fixtures/Dollies

All fixtures and dollies designed to support the UVOT in a clean enviroment shall be compatible with operation in a class 10,000 clean room. Use of hydraulics to actuate mechanisms shall be avoided.

UVOT Handling Fixtures/Dollies shall be designed to show positive margins using factors of safety of 3 on yield and 5 on ultimate with respect to the design working load. UVOT Handling Fixtures/Dollies shall be proof tested to twice the design working load. Stability analysis shall be performed on fixtures/dollies to verify turnover and move operations are safe.

11.1.2 Covers

All non-flight covers, such as protective covers, shall be marked as red tag items and will be removed prior to flight.

11.1.3 Integration and Test Environments

To minimize particulate contamination the UVOT shall be maintained in a clean environment equivalent to Class 10,000 or better. When the instruments or spacecraft are not being worked on or tested, they shall be properly protected from contamination using covers and clean approved bagging material.

In addition, the following requirements apply:

a) The UVOT requires Class 1000 (per FED-STD-209) clean rooms for operations in which mirrors are exposed.
b) The UVOT requires Class 10,000 (per FED-STD-209) clean rooms and purges for operations in which mirrors are covered.
c) The UVOT shall be double or triple bagged and purged when conditions exceed Class 10,000 per FED-STD-209.

11.1.3.1 Acoustic and Vibration Testing Environments

The UVOT shall be bagged and purged according to the UVOT CCP during acoustic and vibration tests at GSFC as those facilities are not maintained to Class 10,000 levels.

11.1.3.2 Thermal Vacuum and Thermal Balance Testing Environment

During all thermal vacuum and thermal balance testing and during pre-test and post-test operations, the thermal vacuum chamber shall be run as a Class 10,000 clean room.

The UVOT shall provide interfaces, which allow verification of the outgassing rate using a Temperature-Controlled Quartz Crystal Microbalance (TQCM).

The UVOT telescope doors shall not be opened in thermal vacuum until the Temperature Controlled Quartz Crystal Microbalance (TQCM) and the residual gas analyzer (RGA) show an acceptable contamination level in the chamber. The acceptable limits shall be determined by contamination analyses and will be documented in the applicable test plan. The chamber shall be backfilled with clean dry nitrogen gas.

11.1.4 Contamination

11.1.4.1 Molecular Contamination

At delivery, the external surfaces of the UVOT shall be verified to be less than +2.0 mg/0.1 m2 . This shall be done using a Solvent Wash method. A small representative section of the UVOT's exterior shall be washed with a solvent and the residue shall be collected and analyzed. The solvent wash test shall be performed by GSFC contamination personnel under the supervision of the UVOT team.

11.1.4.2 Particulate Contamination

At delivery, the external surfaces of the UVOT shall be verified to be less than Level 400 per MIL-STD-1246. Individual particulate contamination requirements shall be verified using standard tape lift procedures. Surfaces which cannot be verified by tape lift, shall be free of visible particles when visually inspected with a high intensity white and black light from a distance of 15 to 30 cm (6-12 inches). Particles shall be removed as specified by the hardware provider.

11.1.5 Launch Site Requirements

Payload requirements regarding the launch campaign at the factory and launch site, including facility, Ground Support Equipment (GSE) HW, and software interfaces, shall be provided and included in the Launch Vehicle (LV) to Observatory ICD provided by Boeing and entitled Swift Mission Specification (MDC01H0041) and the Spacecraft and Observatory Integration and Test Plan (1143-ET-I24530).

11.1.6 Assembly, Integration and Verification

A successful UVOT Long functional Test Procedure (ULFT) is required upon delivery for optical bench integration, to ensure that the UVOT has survived shipment and all performance requirements continue to be met.

A successful ULFT is required at the instrument module level of assembly prior to observatory level integration. This test shall include simultaneous operation of all instrument module electronics (instruments and OB-mounted spacecraft components).

After integration in the S/C a successful Short Functional Test (SFT) or a successful ULFT are required in order to monitor the health of the instrument and to check the S/C interfaces. Providing the High Voltage is off (plug is in), both tests will be safe to execute with or without cooling to the radiator, in air or in vacuum, and with the instrument end-cap or the UVOT door open or closed. The tests will use the internal flat field flood lamps on each detector.

11.2 Flight Operations

The alignment cube mounted external to the UVOT tube shall have a flight cover.

Table 10-1 summarizes the UVOT instrument modes during flight operations.

Table 11-1 UVOT Flight Operation States

Mission Status	**Permitted State(s)**
LEOP	OFF
Switch-on	INITIAL, BASIC
Slew	SLEW
Perigee	SAFE
Eclipse	OFF
Loss of communication to the OBDH	SAFE
AOCS Alert	SAFE
Science Exposure	SAFE, CONFIGURE, ENGINEERING, SCIENCE, SAA
Diagnostic	SAFE, CONFIGURE, ENGINEERING, SCIENCE
Calibration	SAFE, CONFIGURE, ENGINEERING, SCIENCE
South Atlantic Anomaly	OFF, INITIAL, BASIC, SAFE, SAA

11.2.1 Avoidance Angles

The UVOT shall have a one-time deployable door to protect the instrument from the sun during launch and early-orbit operations. The UVOT shall have no instrument pointing constraints while the aperture door is closed. After the door is opened, The UVOT must avoid pointing too close to a bright object or in the direction of flight. UVOT bright object/RAM avoidance angles are defined in section 11.2.2 for both operational and safe-hold modes. Table 11-2 summarizes the UVOT avoidance angles during flight operations.

Table 11-2 UVOT Flight Avoidance Angles

Source	**Angles**	**State**	Comments
Sun limb	> 45°	Mode commandable	1) No direct sunlight to reach telescope baffle entrance 2) Inside of spacecraft door black and if possible with baffle vanes 3) Careful attention to scattering sources on spacecraft
	< 45°	Safe Mode	Safe mode triggered by spacecraft command on OBDH bus and, as backup, by internal monitoring signal. Transition will take 10 sec.
Earth limb	> 30° < 30°	Mode Commandable Safe Mode	Safe mode triggered by internal monitoring signal. Transition will take 10 sec.
Moon limb	> 30° < 30°	Mode Commandable Safe Mode	Safe mode triggered by internal monitoring signal. Transition will take 10 sec.

The UVOT shall be considered in a safe state if it is both powered off and if the observatory is meeting the viewing constraints related to instrument safety as shown in Table 11-2. In addition, the UVOT shall exhibit no degradation of performance when the instrument is powered on, while the observatory is meeting the viewing constraints related to instrument performance as shown in Table 11-2.

11.2.2 Violation of the Sun Avoidance Angle Constraint

The UVOT should be designed to survive limited exposure to the Sun and Earth while in Safe Mode. Safe mode will be triggered by S/C command on the OBDH bus and, as backup, by internal monitoring signal on the blue detector.

11.2.3 Calibration

In order to define requirements for acquiring fields, the calibration and verification phase of the mission will include measures to examine the pointing directions of the UVOT. Constraints on positioning targets will include the measured offsets between UVOT and XRT, the blank ribs in the XRT images, orientation of the detectors with respect to CCD charge transfer directions, bad spots in the performance on any instrument, etc. With time, mission analysis should also reveal the likely thermal changes that may impact the co-alignment of the detectors, and this may need to be considered in the choice of pointing direction for field acquisition. Should an element of the blue detector system fail, it is understood that the redundant system will be employed. Should this occur well into the mission, the requirement to perform a new set of calibration observations will impede the other instrument operation efficiency. Hence it is suggested that the normal calibration and verification phase include some minimal observations with the redundant system to ensure confidence that initiation of the redundant system observations can be made with little distraction (e.g. pointing offsets, optimal focuses, etc., are known). Contingency plans for using normal star fields, based on accumulated experience with the primary system, for calibrating the redundant system will be considered.

In-orbit calibrations will include both internal stimulation to test functionality and individual performance parameters, and astronomical calibrations to determine sensitivities, resolutions, and spatial distortions.

Spatial distortions may be mapped by observing a number of well-separated point sources of known position. This allows a measurement of the distortion as a coarse function of position.

An internal source will be used to illuminate the detectors to obtain a calibration flat field. This need not necessarily be flat, only constant in spatial distribution from one simulation to the next. It will be variable in coarse intensity steps. This field will be used also to recalculate the centroiding lookup table in the blue detector from time to time.

Calibration against astronomical standards will require a wide range of measurements if the full dynamic range is to be confidently mapped. This will not necessarily entail more than a few special pointing directions.

11.2.4 Early Operations

During launch the instrument will be off. In order to move the mechanisms in their reference position, switch-on of the instrument should occur before the UVOT door is opened. This will result in the instrument moving through the INITIAL state and into BASIC state, where basic checks on the health of the instrument can be made. Execution of a 3rd stage load will then be permitted, moving the instrument into SAFE mode. After sufficient outgassing has occurred, further transitions can be made to CONFIGURE and ENGINEERING states in order to check operations using the simulator on the inside of the UVOT door. Performance will not be nominal because the passive radiator at the front of the baffle will not be operating.

12. DELIVERABLES

All parties shall meet the schedule for UVOT deliverables, etc. given in Table 17-1 of the UVOT to S/C ICD (1143-EI-Y22364)

UVOT shall provide a list and description of permanent magnets and ferro-magnetic materials for each instrument component.

Three months prior to IM delivery, the UVOT team will provide a copy of the ULFT to Spectrum Astro

UVOT shall provide a list of EGSE to the Project Office by mission CDR.

The UVOT instrument compliance to requirements shall be addressed at the UVOT Integration Readiness Review.

12.1 Engineering Model

12.1.1 TM Engineering Model

No Engineering Model of the TM shall be provided.

12.1.2 DEM Engineering Model

An engineering module of the Swift Communications Module and a Breadboard RAD6000 shall be delivered to Penn State University from SwRI for Software development.

12.2 Flight Model

One full set of units will be delivered. Prior to delivery the flight model units will be subjected to the full acceptance and verification test program as defined in section TBD.

12.2.1 TM Flight Model

One full flight Telescope Module.

12.2.2 DEM Flight Model

12.2.2.1 ICU Flight Model

One primary and one redundant ICU shall be provided.

12.2.2.2 DPU Flight Model

One primary and one redundant DPU shall be provided

12.2.2.3 Chassis Flight Model

One primary and one redundant DEM Cabinet shall be provided

12.2.3 IHU Flight Model

One primary and one redundant IHU shall be provided.

12.3 MGSE

MGSE will be supplied to allow safe transportation and storage of each FM unit. Any UVOT mechanical ground support equipment (MGSE) that will be utilized at the launch site (planned or contingent) shall satisfy the design criteria of EWR 127-1, Range Safety Document.

12.4 EGSE

EGSE will be provided to allow verification of proper electrical operation.

12.5 OGSE

No OGSE will be supplied.

12.6 Flight Spare Models

12.6.1 Flight Spare TM

No flight spare model will be supplied at unit level.

12.6.2 Flight Spare DEMs

12.6.2.1 Flight Spare DPU

No flight spare unit will be provided. The following Spare modules shall be provided:

- 1 P/S Module
- 1 SCM Module

12.6.2.2 Flight Spare ICU

No flight spares shall be provided.

12.6.2.3 Flight Spare Cabinet

No flight spare cabinet shall be provided

12.6.3 Flight Spare IHU

No flight spare unit for IHU will be delivered.

13. VERIFICATION

Details of UVOT Verification can be found in the Verification Matrix For The Swift UltraViolet Optical Telescope (SWIFT-UVOT-002A).