SWIFT
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Swift Interface Requirements Document

Version 3.3

September 9, 2002

CHANGE DISPOSITION AND REVISION

Revision/Change Number	Description	Effective Date
N/A	Initial Release (Version 1.0)	August 9, 1999
1.1	Review comments incorporated.	March 17, 2000
1.2	Second review version.	June 6, 2000
1.3	Third review version.	August 4, 2000
1.4	Fourth review version.	August 21, 2000
2.0	Review version.	November 29 2000
2.0	Updated to provide changes as discussed at the Swift CCB on 12/20/00. Approved under CCR-014.	December 20, 2000
3.0	Incorporated changes from the following CCR's 410.4-15, 410.4-19, 410.4-20 (WAIVER), 410.4-25, 410.4-28, 410.4-30, 410.4-31, 410.4-56, 410.4-57 and 410.4-58	August 23, 2001
3.1	Incorporated changes from the following CCR's 410.4-50, 410.4-59	September 27, 2001
3.2	Incorporated changes from the following CCR's 410.4-70, 410.4-74, 410.4-83, 410.4-85	December 13, 2001
3.3	Incorporated changes from the following CCR's 410.4-125,410.4-114, 410.4-113, 410.4-112 (see CCR for waiver), Sections renumbered to increase detail on subparagraph numbering (no change bars used). Incorporated minor typos	August 20, 2002 September 9, 2002

TABLE OF CONTENTS

TABLE OF FIGURES

TABLES

1 Introduction

This Interface Requirements Document (IRD) defines both the interfaces and the interface requirements between the Swift Instruments and the Swift spacecraft bus, the Swift instruments and the Optical Bench, the Optical Bench and the spacecraft, the BAT, XRT and UVOT instruments themselves, the Swift spacecraft and GSE and the Swift spacecraft and Flight Operations

The interface between the spacecraft and launch vehicle shall be documented in the Launch Vehicle ICD, which is prepared by the launch vehicle vendor.

This is a configuration-controlled document and any changes require the approval of the Project Manager through a Configuration Change Board (CCB) process.

1.1 General Definitions

Observatory	Interchangeable with Spacecraft. Defined as the satellite which includes both Spacecraft Bus and Instrument Module
Spacecraft	Interchangeable with Observatory. Defined as the satellite which includes both Spacecraft Bus and Instrument Module
Spacecraft Bus	Provided by Spectrum-Astro. The S/C Bus provides the interface structure to the launch vehicle, avionics, and systems required to support the Instrument Module.
Instrument Module	Consists of the Optical bench, XRT, UVOT, BAT, and their associated electronic boxes and harnesses. Note that instrument electronic boxes mounted to the spacecraft are not part of the instrument module. Spacecraft provided components are mounted to the optical bench and the XRT.
Optical Bench	Consists of the structure plate which provides support to the instruments, as well as the flexures which interface the plate to the S/C Bus structure.
Qualification Tests	Tests intended to demonstrate that the test item will function within performance specifications under simulated conditions more severe than those expected from ground handling, launch, and orbital operations. Their purpose is to uncover deficiencies in design and method of manufacture. They are not intended to exceed design safety margins or to introduce unrealistic modes of failure. The

	design qualification tests may be to either "prototype" or "protoflight" tests levels.
Acceptance Tests	The verification process that demonstrates that hardware is acceptable for flight. It also serves as a quality control screen to detect deficiencies and, normally, to provide the basis for delivery of an item under terms of a contract.
Protoflight Hardware	Flight hardware of a new design; it is subject to a qualification test program that combines elements of prototype and flight acceptance verification; that is, the application of design qualification test levels and flight acceptance test duration's.
Prototype Hardware	Hardware of a new design; it is subject to a design qualification test program; it is not intended for flight.
Follow-on Hardware	Hardware built in accordance with a design that has been qualified either as prototype or as protoflight hardware; follow-on hardware is subject to flight acceptance test program.
Flight Hardware	Hardware to be used operationally in space. Flight level testing indicates acceptance level testing.
Limit Level	The maximum expected flight level.
Performance Verification	Determination by test, analysis, or a combination of the two that the payload element can operate as intended in a particular mission; this includes being satisfied that the design of the payload or element has been qualified and that the particular item complies with the design and is ready for flight operations.
BAT	The Burst Alert Telescope consists of a telescope assembly, several electronic boxes, and interconnecting harness.
UVOT	The UV/Optical Telescope consists of a telescope assembly, several electronic boxes, and interconnecting harness.
XRT	The X-ray Telescope consists of a telescope assembly, one electronic box, interconnecting harness, and a heatpipe/radiator.

2 Applicable Documents and Precedence

The following documents of the exact issue shown form a part of this document to the extent specified herein. In the event of conflict between documents referenced herein and the content of this document, the contents of the Swift SRD shall take precedence, followed by the Swift MRD; for all other documents, the contents of this document shall be considered a superseding requirement.

Swift Science Requirements Document (SRD) – 410.4-SPEC-0005

Swift Mission Requirements Document (MRD) – 410.4-SPEC-0004

Swift Safety, Reliability & Quality Assurance Program - 410.4-SPEC-0001.

Outgassing Data for Selecting Spacecrafts Materials, NASA Reference Publication 1124, Revision 3, September 1993.

General Environmental Verification Specification for STS and ELV Payloads, Subsystems, and Components, GEVS-SE, January 1990

NSI document 15-01-422 "Analysis Procedure for Spreader Bar Lift Stability"

Design Criteria for Controlling Stress Corrosion Cracking, MSFC-SPEC-522

Eastern and Western Range Safety Requirements, EWR 127-1

Kennedy Space Center Safety Practices Handbook, KHB 1710.2 Rev. D

NASA Safety Policy and Requirements Document, NHB 1700.1

Flight Programmable Gate Array Design Guidelines, 561-PG-8700.2.1

NASA-STD-8739.7 Electrostatic Discharge Control

NASA STD 5005 Ground Support Equipment

GSFC 5405-048-98, Vol. 1 & 2, December 1998, GSFC Mechanical Systems Center (MSC) Safety Manual

NSS/GO 1740.9, NASA Safety Standard for Lifting Devices and Equipment

3 Mechanical Interfaces

3.1 General

The BAT, UVOT and XRT shall be mounted to the Optical Bench. In addition, various spacecraft components listed in Table 1 shall be mounted to the Optical Bench. Two Star Trackers shall be mounted to the XRT forward tube. The Optical Bench is the responsibility of GSFC.

Table 1 shows the locations, volumes, and provider of components separately mounted to the optical bench or spacecraft bus. Figure 1 gives the overall volume restrictions for the Instrument Module. Table 1 and Figure 1 represent maximum volumes.

ITEM	LOCATION	HARDWARE PROVIDER
BAT Telescope Assembly	Optical Bench	GSFC
UVOT Telescope Assembly	Optical Bench	PSU
XRT Telescope Assembly	Optical Bench	PSU
BAT Image Processor A	Spacecraft	GSFC
BAT Image Processor B	Spacecraft	GSFC
BAT Power Supply	Spacecraft	GSFC
UVOT Digital Electronics Module A	Optical Bench	PSU
UVOT Digital Electronics Module B	Optical Bench	PSU
XRT electronics box	Spacecraft	PSU
Star Tracker (2)	XRT	Spectrum Astro
IRU Assembly	Optical Bench	Spectrum Astro
1553 Couplers (2)	Optical Bench	Spectrum Astro
CSS Assembly (2)	Optical Bench	Spectrum Astro
Hemispherical Antenna Assembly (2)	Optical Bench	Spectrum Astro

Table 1 Component Location and Provider

The exact dimensions of the hardware will be contained in the detailed MICDs listed in Table 2.

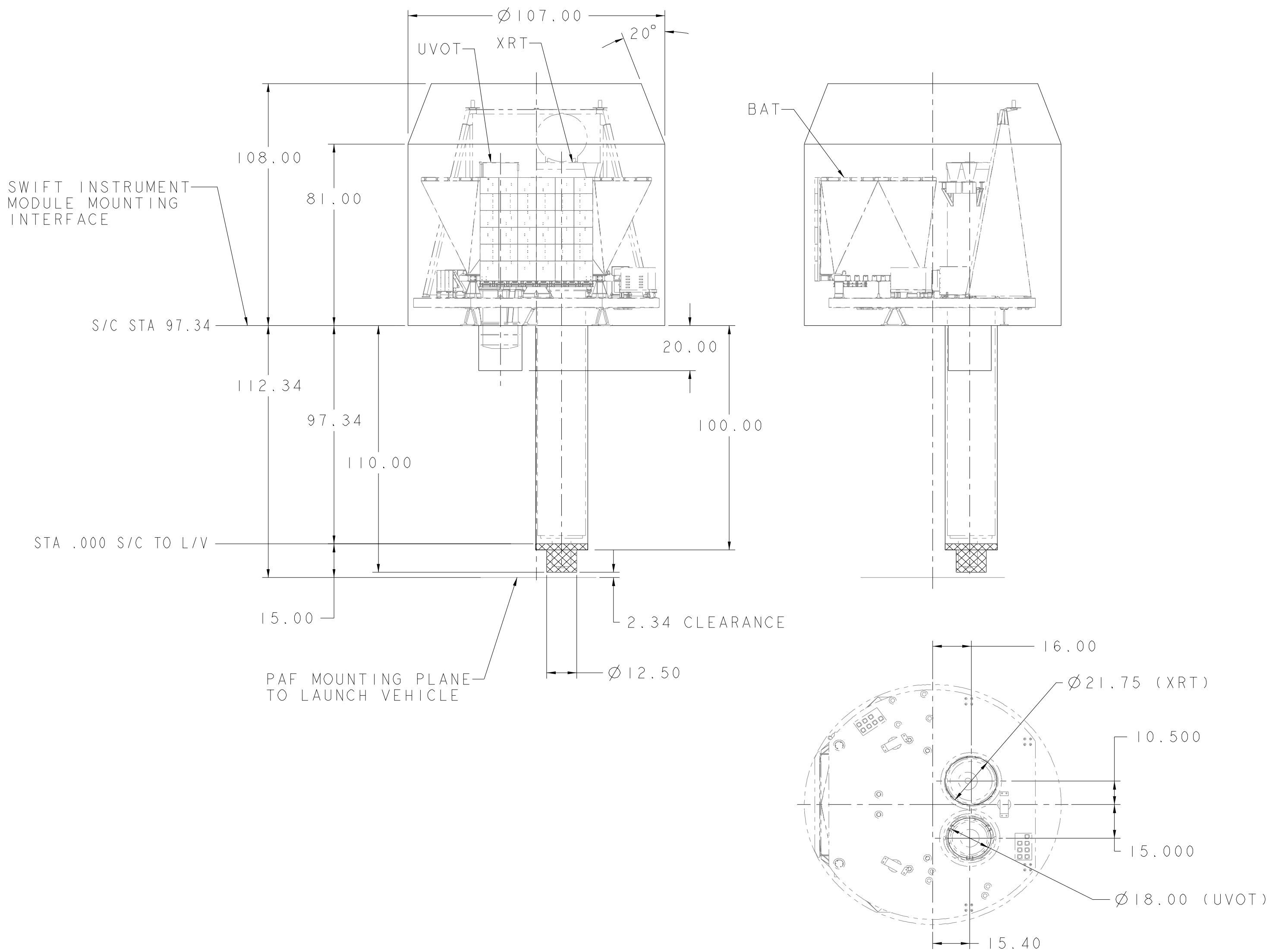

Figure 1 Instrument Module Mechanical Envelope (For reference only – interfaces controlled by drawings 2045136, ICD-220649, and ICD-220650)

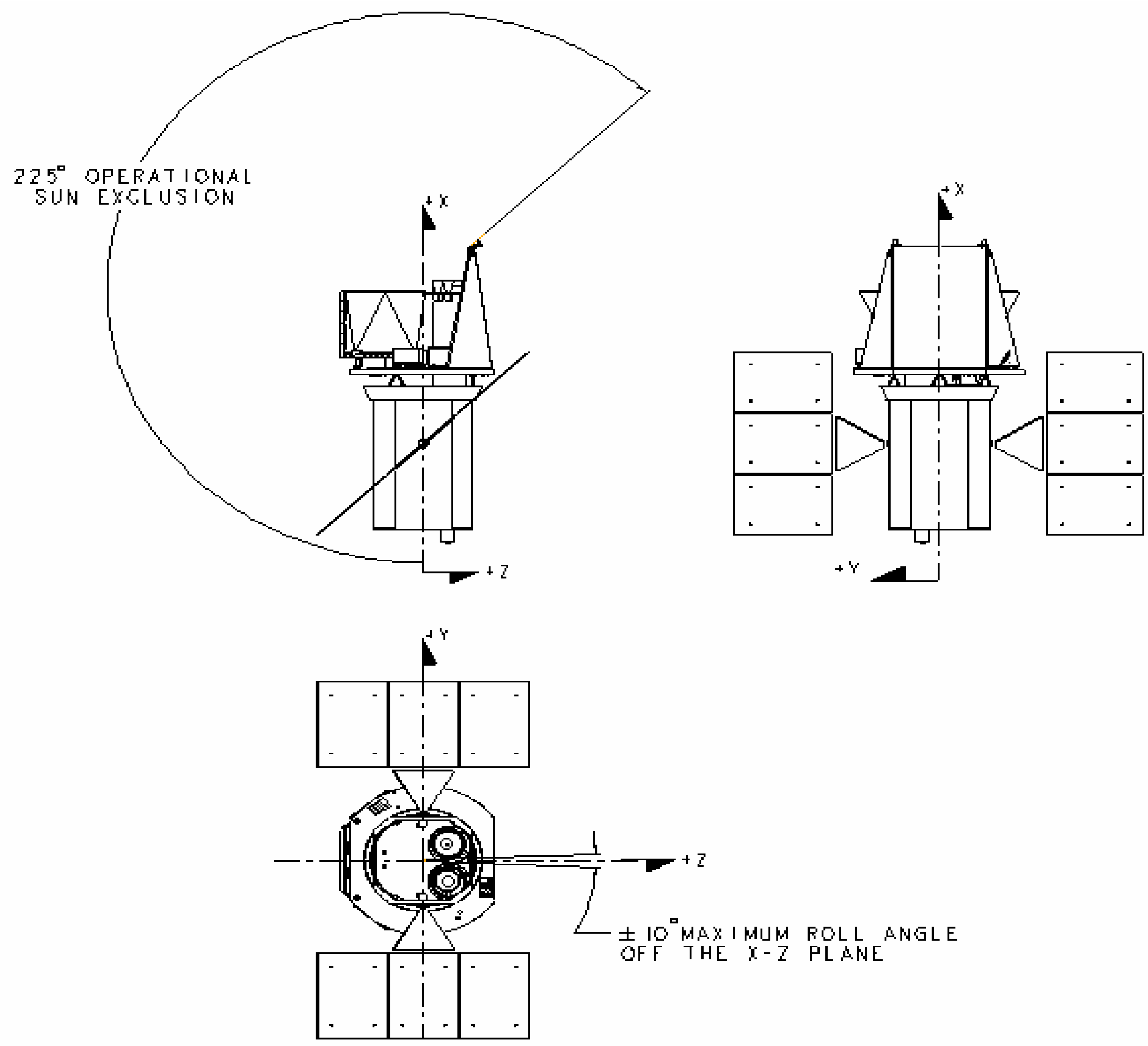

Figure 2 Instrument Sun Avoidance Angles

3.2 Clear Fields of View

3.2.1 Instrument fields-of-view shall be defined in corresponding MICDs. Each instrument's FOV shall be unobstructed. Instrument bright object/RAM avoidance angles are defined in section 8.1 for both operational and safe-hold modes.

3.2.2 NFI aperture doors shall not impinge on the FOV of the other instruments or the star trackers.

3.2.3 The star trackers have a glint-free FOV of 25˚ (half-cone angle), which must remain unobstructed at all times.

3.3 Instrument Mounting to the Optical Bench

3.3.1 The optical bench shall support the UVOT, XRT, and BAT telescopes.

3.3.2 The optical bench shall also accommodate the UVOT electronics.

3.3.3 The BAT Field of View shall be canted away from the UVOT and XRT by no more than 9 to allow for an unobstructed field of view.

3.3.4 In general, instrument to optical bench interfaces shall be mechanically isolated; i.e., kinematic or semi-kinematic coupling. GSFC shall provide the instrument flexure mounting system.

3.3.5 Any surface above the UVOT aperture must be optically diffuse and black.

3.3.6 The BAT Field of View shall be canted away from the UVOT and XRT by no more than 9˚ to allow for an unobstructed field of view.

3.3.7 The harness run from the UVOT electronics box to the telescope interface connector shall be less than 1.5 meters in length.

3.4 Optical Bench Mounting to the S/C Bus

3.4.1 GSFC shall provide a flexure mounting system with the optical bench to interface with the spacecraft bus.

3.4.2 The spacecraft shall provide a ring or plate to interface to the flexure mount. The current spacecraft bus is an aluminum structure, and the optical bench is made of composites.

3.4.3 The spacecraft/Optical Bench interface shall be maintained with a co-planarity of 0.003" on orbit.

3.5 Spacecraft Components Mounted to the Instrument Module

A star tracker assembly, two hemispherical antennas, two CSSs and an IRU assembly are mounted to the instrument module.

Spectrum Astro shall provide the associated bracketry and mounting hardware.

3.5.1 Spacecraft Components Mounted to the Optical Bench

3.5.1.1 The IRU assembly, consisting of three IRUs, mounting bracket, and radiator is mounted to the optical bench.

3.5.1.2 Spectrum Astro shall provide the mounting hardware. Mounting location and orientation is defined in MICD, drawing number 2045135.

3.5.2 Spacecraft Components Mounted to the Sunshade

Two omni antennas, two Coarse Sun Sensors (CSSs), and two 1553 couplers are mounted on the Sunshade. Fields of view are documented in the MICD, drawing number 2045138.

3.5.3 Spacecraft Components Mounted to the XRT

3.5.3.1 Two star trackers and their mounting plate/radiator are mounted onto flexure brackets that are mounted off the XRT upper tube.

3.5.3.2 Spectrum Astro shall supply mounting hardware for the trackers and radiator to flexure I/F.

3.5.3.3 GSFC shall supply mounting hardware from the flexure brackets to the XRT upper tube I/F. Fields of view are defined in the MICD, drawing number 2045141.

3.6 Instrument Components Mounted to the S/C Bus

3.6.1 The XRT electronics must be mounted on the spacecraft bus such that the interconnecting harness to the XRT detector is less than 1.6 m.

3.6.2 The BAT Image Processors and BAT Power Supply Box shall be mounted on the spacecraft bus, as close to the optical bench as possible such that the interconnecting harnesses to the BAT Telescope are less than 5 m.

REQ	TITLE	DRAWING #	RESPONSIBILITY
3.7.1	XRT to Optical Bench MICD	2045136	GSFC
3.7.2	XRT Electronics Box to Spacecraft MICD	IM-220652	Spectrum Astro
3.7.3	XRT Radiator & Heat Pipe to Spacecraft MICD	IM-220650	Spectrum Astro
3.7.4	XRT Radiator and Heat Pipe to Spacecraft ICD	B1832	Swales
3.7.5	UVOT to Optical Bench MICD	2045137	GSFC
3.7.6	UVOT Electronics MICD	2045139	GSFC
3.7.7	BAT Image Processors to Spacecraft MICD	IM-220651	Spectrum Astro
3.7.8	BAT to Optical Bench MICD	2045199	GSFC
3.7.9	BAT Power Supply Box to Optical Bench MICD	IM-220655	Spectrum Astro
3.7.10	Star Tracker Bracket to XRT and Star Tracker MICD	2045141	GSFC
3.7.11	IRU Bracket to Optical Bench MICD	2045135	GSFC
3.7.12	Course Sun Sensor and Hemispherical Antennae to Optical Bench MICD	2045138	GSFC
3.7.13	Instrument Module to Spacecraft MICD	IM-220649	Spectrum Astro

Table 2 MICD List

3.7 Mechanical Interface Control Drawings (MICDs)

MICDs as indicated in Table 2 shall be developed for each separately mounted instrument component and for the Instrument Module assembly. A list of required MICDs and responsibilities is also shown in Table 2.

The MICDs shall contain, as a minimum, the information as listed below.

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

3.8 Design Criteria for Instrument Components

These design criteria apply to the optical bench, instruments, and electronic boxes. Beyond the criteria within this section, all components shall be designed to withstand the environments defined in section 7.2 – Environments, with margins as defined in the following section.

(GEVS 2.4.1: …The test-verified model shall then be used to predict the maximum expected load for each critical loading condition, including handling and transportation, vibroacoustic effects during lift-off, insertion into final orbit, orbital operations, thermal effects during landing, etc., as appropriate for the particular mission…

Normally, the design and verification of payloads shall not be burdened by transportation and handling environments that exceed stresses expected during launch, orbit, or return. Rather, shipping containers shall be designed to prevent the imposition of such stresses. To verify this, a documented analysis shall be prepared on shipping and handling equipment to define the loads transmitted to flight hardware. When transportation and handling loads are not enveloped by the maximum expected flight loads, the transportation and handling loads shall be included in the set of limit loads.)

3.8.1 Minimum Factors and Margins of Safety

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

- FS Yield = 1.25
- FS Ultimate = 1.4

3.8.1.2 Margins of safety (MS) shall be positive for both yield and ultimate stress calculations.

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

3.8.2 Stress Analyses and Mathematical Models

3.8.2.1 A detailed NASTRAN finite element model (FEM) of each instrument shall be developed and kept current by the instrument's developer.

3.8.2.2 The model should be modified and correlated to match test data, as it becomes available.

3.8.2.3 Stress analysis shall be performed on all structural and non-structural components for each instrument and remote electronics box. This analysis should be used to calculate margins of safety and the results should be properly documented for reviews and audit purposes.

3.8.2.4 A combined Instrument Module model shall be assembled and maintained by GSFC and transferred to Spectrum Astro for coupled loads analyses.

3.8.3 Hardware Qualification of all flight hardware shall be achieved through a combination of analysis and testing to protoflight levels. All structure worthiness shall be demonstrated through detailed stress and dynamic analysis. Although it is not the preferred method, strength qualification of metallic flight structure by means of analysis only is an option with the use of the following no-test factors used for analysis FS Yield=1.6 FS Ultimate=2.0.

3.8.3.1 Qualification of all flight hardware shall be achieved through a combination of analysis and testing to protoflight levels.

3.8.3.2 All structure worthiness shall be demonstrated through detailed stress and dynamic analysis.

3.8.4 Acceleration Design Load

Instrument acceleration design loads are defined at their respective c.g. and are paralled to the spacecraft coordinate axes shown in Figure 4.

3.8.4.1 BAT Instrument

EVENT	PROTOFLIGHT LEVEL		FLIGHT LEVEL	
	Axis	Level	Axis	Level
Liftoff/Airloads	X	±4.6 g's	X	±3.7 g's
	Y	±4.7 g's	Y	±3.8 g's
	Z	±4.6 g's	Z	±3.7 g's
	RX	±38.3 rad/sec^2	RX	±30.6 rad/sec^2
	RY	±74.3 rad/sec^2	RY	±59.4 rad/sec^2
	RZ	±18.0 rad/sec^2	RZ	±14.4 rad/sec^2
MECO	X	±10.4 g's	X	±8.3 g's
	Y	±0.5 g's	Y	±0.4 g's
	Z	±0.5 g's	Z	±0.4 g's
	RX	±5.4 rad/sec^2	RX	±4.3 rad/sec^2
	RY	±19.9 rad/sec^2	RY	±15.9 rad/sec^2
	RZ	±3.4 rad/sec^2	RZ	±2.7 rad/sec^2

The loads shall be applied simultaneously and in all combinations for each event.

Table 3 Acceleration Design Loads for the BAT Instrument

3.8.4.2 XRT Instrument

EVENT	PROTOFLIGHT LEVEL		FLIGHT LEVEL	
	Axis	Level	Axis	Level
Liftoff/Airloads	X	±4.0 g's	X	±3.2 g's
	Y	±4.3 g's	Y	±3.4 g's
	Z	±4.5 g's	Z	±3.6 g's
	RX	±34.1 rad/sec^2	RX	±27.3 rad/sec^2
	RY	±22.1 rad/sec^2	RY	±17.7 rad/sec^2
	RZ	±39.8 rad/sec^2	RZ	±31.8 rad/sec^2
MECO	X	±10.3 g's	X	±8.2 g's
	Y	±0.4 g's	Y	±0.3 g's
	Z	±1.0 g's	Z	±0.8 g's
	RX	±4.3 rad/sec^2	RX	±3.4 rad/sec^2
	RY	±17.1 rad/sec^2	RY	±13.7 rad/sec^2
	RZ	±6.1 rad/sec^2	RZ	±4.9 rad/sec^2

The loads shall be applied simultaneously and in all combinations for each event.

Table 4 Acceleration Design Loads for the XRT Instrument

3.8.4.3 UVOT Instrument

EVENT	PROTOFLIGHT LEVEL		FLIGHT LEVEL	
	Axis	Level	Axis	Level
Liftoff/Airloads	X	±4.3 g's	X	±3.4 g's
	Y	±4.1 g's	Y	±3.3 g's
	Z	±4.0 g's	Z	±3.2 g's
	RX	±33.5 rad/sec^2	RX	±26.8 rad/sec^2
	RY	±40.8 rad/sec^2	RY	±32.6 rad/sec^2
	RZ	±48.1 rad/sec^2	RZ	±38.5 rad/sec^2
MECO	X	±10.3 g's	X	±8.2 g's
	Y	±0.3 g's	Y	±0.2 g's
	Z	±0.9 g's	Z	±0.7 g's
	RX	±4.0 rad/sec^2	RX	±3.2 rad/sec^2
	RY	±14.3 rad/sec^2	RY	±11.4 rad/sec^2
	RZ	±16.9 rad/sec^2	RZ	±13.5 rad/sec^2

The loads shall be applied simultaneously and in all combinations for each event.

Table 5 Acceleration Design Loads for the UVOT Instrument

3.8.4.4 Instrument Module

EVENT	PROTOFLIGHT LEVEL		FLIGHT LEVEL	
	Axis	Level	Axis	Level
Liftoff/Airloads	X	±3.6 g's	X	±2.9 g's
	Y	±3.8 g's	Y	±3.0 g's
	Z	±3.6 g's	Z	±2.9 g's
	RX	±36.3 rad/sec^2	RX	±29.0 rad/sec^2
	RY	±35.1 rad/sec^2	RY	±28.1 rad/sec^2
	RZ	±23.3 rad/sec^2	RZ	±18.6 rad/sec^2
MECO	X	±10.3 g's	X	±8.2 g's
	Y	±0.4 g's	Y	±0.3 g's
	Z	±0.5 g's	Z	±0.4 g's
	RX	±5.5 rad/sec^2	RX	±4.4 rad/sec^2
	RY	±10.3 rad/sec^2	RY	±8.2 rad/sec^2
	RZ	±3.3 rad/sec^2	RZ	±2.6 rad/sec^2

The loads shall be applied simultaneously and in all combinations for each event.

Table 6 Acceleration Design Loads for the Instrument Module

3.8.4.5 SWIFT Observatory

EVENT	PROTOFLIGHT LEVEL		FLIGHT LEVEL	
	Axis	Level	Axis	Level
Liftoff/Airloads	Thrust	±3.5 g's	Thrust	±2.8 g's
	Lateral	±3.5 g's	Lateral	±2.8 g's
MECO	Thrust	±10.1 g's	Thrust	±8.1 g's
	Lateral	±0.4 g's	Lateral	±0.3 g's

The loads shall be applied simultaneously and in all combinations for each event.

Table 7 Acceleration Design Loads for the SWIFT Observatory

3.8.4.6 Instrument Remote Electronics Boxes

EVENT	PROTOFLIGHT LEVEL		FLIGHT LEVEL	
	Axis	Level	Axis	Level
ALL	Thrust	±15.0 g's	Thrust	±12.0 g's
	Lateral	±15.0 g's	Lateral	±12.0 g's

The loads shall be applied in thrust and lateral directions.

Table 8 Acceleration Design Loads for Instrument Remote Electronics Boxes

3.8.5 Instrument Minimum Frequency Requirement

3.8.5.1 The design of the instruments shall be such that the fundamental resonance of the first structure mode of an individual instrument shall be a minimum of 50 Hz (XRT, BAT, UVOT) 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.

3.8.5.2 For instruments not meeting 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.

3.8.6 XRT Cold Finger Interface Load

The XRT cold finger adapter plate/heat pipe assembly shall not impose loads onto the XRT cold finger greater than those shown in Table 9. Maximum thermal loads are operational loads and include all thermal effects on the heat pipes, radiator, and spacecraft bus. Maximum launch loads are mechanical design loads and include conditions due to all environmental effects, as well as relative displacement between the XRT cold finger and the spacecraft bus.

DESCRIPTION	Max Thermal	Max Launch
M1 (in-lbs)	140	442
M2 (in-lbs)	7	241
V1 (lbs)	22	48
V2 (lbs)	1	24
AXIAL (lbs)	11	24
TORQUE (in-lbs)	3	25

Table 9 XRT Cold Finger Interface Maximum Design Loads

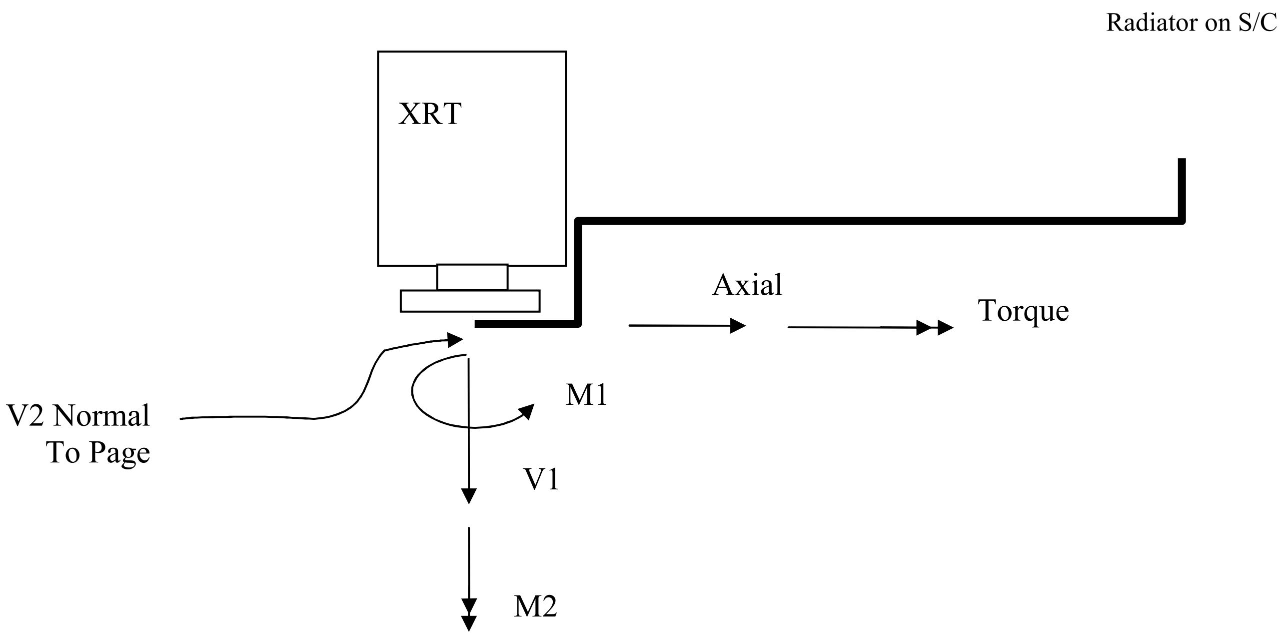

Figure 3 XRT Cold Finger Interface Load Component Definition

3.9 Accessibility

3.9.1 The spacecraft shall provide for access to any instrument component within 48 hours of written notification to do so.

3.9.2 The instrument module shall be designed such that removal of an instrument from the optical bench (prior to integration to the LV) shall not require removal of any adjacent instruments.

3.9.3 Instrument accessibility requirements for red/green tag items, calibration sources, purging and cooling GSE shall be shown in the instrument MICDs.

3.10 Electrical Bonding

3.10.1 GSFC shall provide grounding straps with the instrument module that provide a resistance of 10 milli-ohms or less from the chassis of each component to the spacecraft structure.

3.10.2 For instrument electronics boxes mounted on the spacecraft structure, the component's baseplate shall be constructed to provide a bonding resistance of 2.5 milliohms or less from the chassis of each component to the spacecraft structure. A grounding strap may be used for thermally isolated components, as long as it provides a resistance of 10 milliohms or less from the chassis of the component to the spacecraft structure.

3.11 Mass Properties

3.11.1 Coordinate System

Instrument and spacecraft coordinate systems are shown in Figure 4 and Figure 5 for the Swift observatory. All coordinate systems are right-handed. Orientations shown include representation for the S/C, star trackers (ST), gyros, BAT, XRT, UVOT, and launch vehicle.

Notes: In general, the origin in the out-of-plane axis is at the component mounting I/F plane (specified in appropriate MICDs).

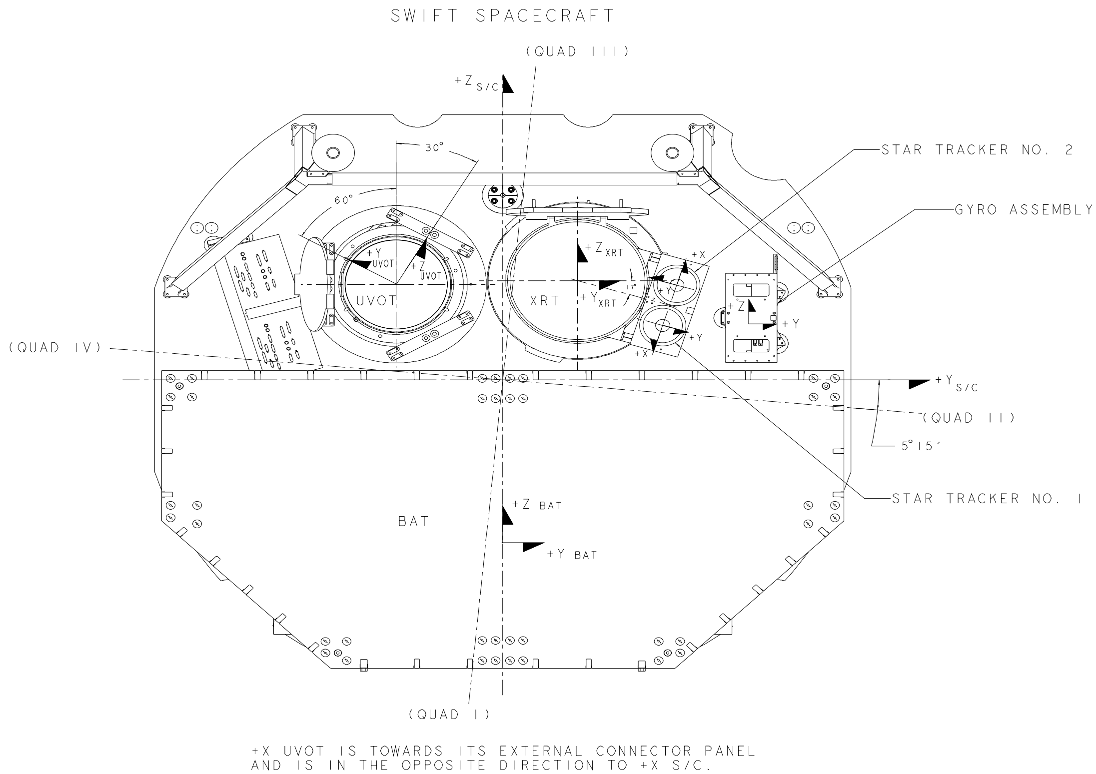

Figure 4 Swift Spacecraft and Component Coordinate Systems, Top View

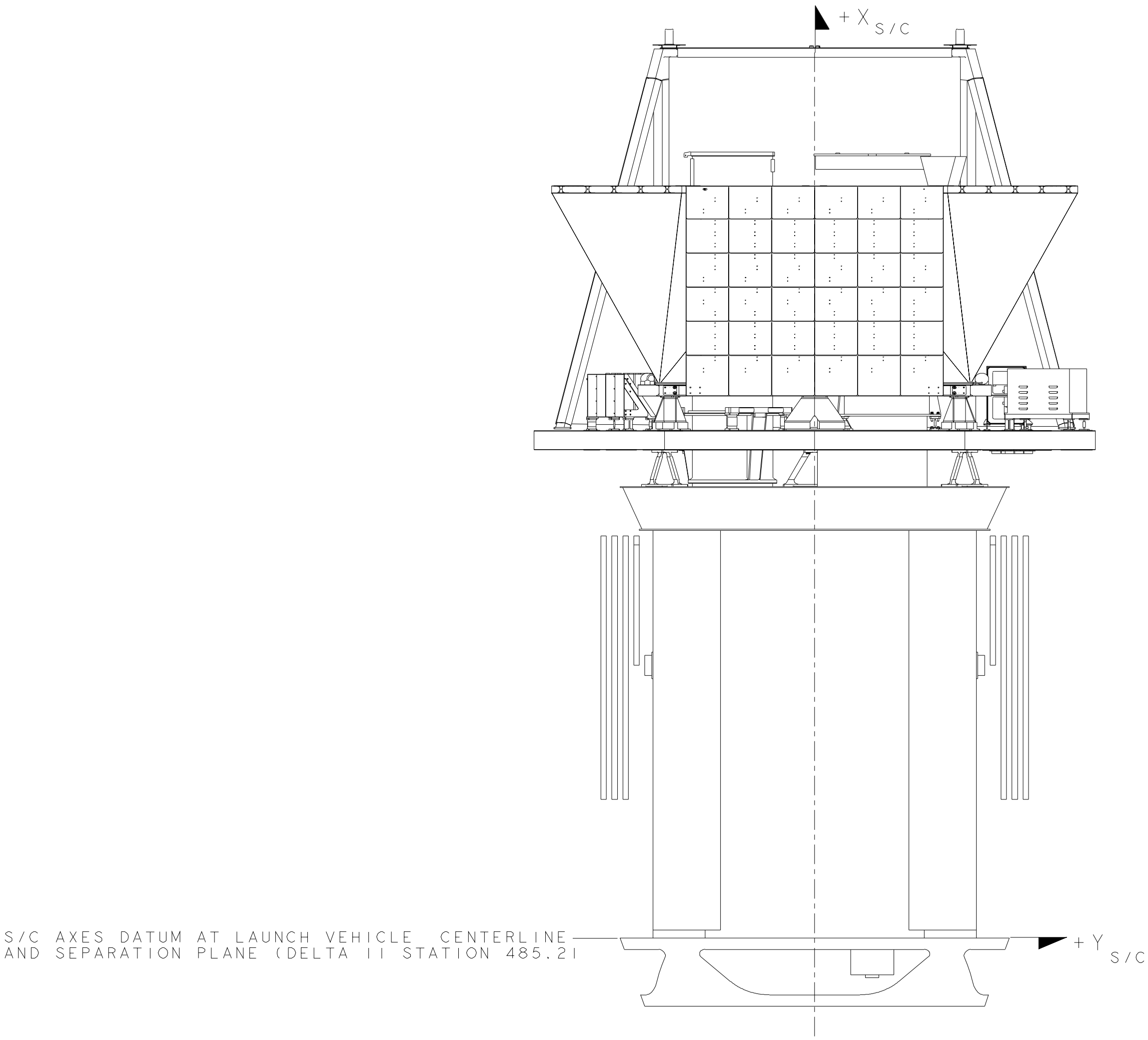

Figure 5 Swift Spacecraft Coordinate System, Side View

3.11.2 Mass

Table 10 lists the maximum allocation for instrument and optical bench mass. These numbers are not to be exceeded. Components separately mounted to the optical bench or spacecraft bus are listed along with the total subsystem (instrument) allocation. All harnesses are included except those supplied by Spectrum Astro (i.e., those below the optical bench). Harnesses above the optical bench are supplied by GSFC and the harness between the XRT CCD Camera and XRT electronics box mounted on the spacecraft bus are also included. The ACS mass includes two CSSs, two star trackers, two IRUs and harness above the OB connector plate. Each mass number is to be tracked separately and maintained within its sub-allocation. Current best estimates for the mass of all components listed shall be reported monthly to the Swift Systems Manager. All mass shall be reported in kilograms.

	SUBSYSTEM	COMPONENT	MASS (kg)
3.11.2.1	BAT	Telescope Assembly	299
3.11.2.2		Image Processor A	8.5
3.11.2.3		Image Processor B	8.5
3.11.2.4		Power Supply	31
3.11.2.5		BAT TOTAL	347
3.11.2.6	XRT	Telescope Assembly	190
3.11.2.7		Electronics Box Assembly	18
3.11.2.8		XRT TOTAL	208
3.11.2.9	XRT HRS	XRT HRS TOTAL	11
3.11.2.10	UVOT	Telescope Assembly	91
3.11.2.11		Digital Electronics Module A	12
3.11.2.12		Digital Electronics Module B	12
3.11.2.13		UVOT TOTAL	115
3.11.2.14	Optical Bench	Optical Bench TOTAL	181
3.11.2.15	Spacecraft bus components mounted on IM	TOTAL (includes Star Tracker Assembly, IRU Assembly, 2 Hemisperical Antenna Assemblies, 2 Coarse Sun Sensor Assemblies, 1553 Couplers, Cabling)	30

Table 10 Mass Allocation

3.11.3 Center of Mass

The center of mass of the Instrument Module shall be defined on the Instrument Module to spacecraft MICD, drawing number ICD-220649.

3.11.4 Mass Moment of Inertia

The mass moments of inertia of the Instrument Module shall not exceed the values specified in Table 11.

Ixx	458
Iyy	1165
Izz	1118

Table 11 Instrument Module Moments of Inertia (kg-m^2)

4 Thermal Interfaces

4.1 General

Thermal ICDs (TICDs) shall be generated for the instrument module and separate components, as listed in Table 12. These TICDs shall include and define: interface temperatures, radiative and conductive requirements, footprints and heat flow characteristics, thermal control coatings and equivalent sink temperatures, thermal blankets, heater sizing criteria and approximate locations, approximate temperature sensor locations, etc. A list of required TICDs is shown in Table 12 along with party responsible for the drawing. In general, hardware providers are responsible for the procurement and installation of all thermal hardware. One exception is survival temperature sensors, which shall be provided by the spacecraft, and installed by the instrument and optical bench hardware providers. Other exceptions are described in the following paragraphs.

	TITLE	DRAWING #	RESPONSIBILITY
4.1.0.1	XRT Radiator to Spacecraft TICD	IM-223892	Spectrum Astro
4.1.0.2	XRT Electronics to Spacecraft TICD	IM-223891	Spectrum Astro
4.1.0.3	XRT to Optical Bench TICD	2046594	GSFC
4.1.0.4	UVOT Electronics TICD	2046597	GSFC
4.1.0.5	UVOT to Optical Bench TICD	2046595	GSFC
4.1.0.6	BAT Power Supply to TICD	IM-223890	GSFC
4.1.0.7	BAT Image Processors to Spacecraft TICD	IM-223889	Spectrum Astro
4.1.0.8	BAT to Optical Bench TICD	2046596	GSFC
4.1.0.9	Star Tracker Bracket to XRT and Star Tracker TICD	2046600	GSFC
4.1.0.10	IRU Bracket to Optical Bench TICD	2046599	GSFC
4.1.0.11	Instrument Module to Spacecraft TICD	IM-223893	Spectrum Astro

Table 12 Thermal Interface Control Drawing List

4.1.1 Final flight MLI shall be the responsibility of GSFC for the BAT and XRT instruments, and the UVOT DEMs.

4.1.2 The UVOT Telescope module shall be delivered to IM integration with flight MLI in place.

4.2 Instrument Module Internal Thermal Interfaces

Requirements in this section apply to the GSFC-supplied Instrument Module.

4.2.1 All instruments and instrument components shall be radiatively and conductively isolated as much as possible from the optical bench, the spacecraft bus, and each other.

4.2.2 Flexures with low thermal conductance shall be utilized for conductive isolation.

4.2.3 MLI shall be used for radiative isolation.

	ITEM	OPERATIONAL LIMITS	SURVIVAL LIMITS
4.2.6.1.	OB-BAT Telescope interface flexures	0° to 20°C	-20 to +60°C
4.2.6.2.	BAT - DAP I/F	0 to 20°C	-20 to +50°C
4.2.6.3.	BAT Image Processors	-10° to +50°C	-20° to 60°C
4.2.6.4.	BAT Power Supply	-10° to +50°C	-20° to 60°C
4.2.6.5.	OB-XRT I/F flexures	+8° to +16°C	-20 to +60°C
4.2.6.6.	XRT OBIF	18±1°C	+5° to 55°C
4.2.6.7.	XRT Electronics Box	-10 to + 40°C	-20 to + 50°C
4.2.6.8.	XRT - Cold Finger	-150 to -39°C	-150 to +50°C
4.2.6.9.	OB-UVOT I/F flexures	+10 to +18°C	-20 to + 60°C
4.2.6.10.	UVOT Telescope InterfaceFlange	+19.5±0.5°C	-35 to +55°C
4.2.6.11.	UVOT Electronics Box (DEM)	-10 to +50°C	-15 to +60°C
4.2.6.12.	XRT Heat Rejection System (HRS) – CheaterPlate	-150 to -41°C	-150 to +50°C
4.2.6.13.	XRT HRS - Flexure Interface on Radiator	-150 to -40°C	-150 to +50°C
4.2.6.14.	Spacecraft - XRT Radiator Flexures	-25 to +30°C	-35 to +40°C
4.2.6.15.	Spacecraft - XRT Heat Pipe Flexures	-25 to +30°C	-35 to +40°C
4.2.6.16.	Star Trackers	-5 to +45°C	-15 to +55°C
4.2.6.17.	IRU	- 0 to +50°C	-11 to +59°C
4.2.6.18.	CSS	-40 to +75°C	-150 to +100°C
4.2.6.19.	Hemispherical Antennas	-120 to +100°C	-140 to +120°C

Table 13 Component Temperature Limits, Degrees Centigrade

4.2.4 Conducted heat flow during operational mode shall be less than 2 watts from each instrument to the optical bench.

4.2.5 Conducted heat flow during survival (safehold) mode shall be less than 5 watts between each instrument and the optical bench.

4.2.6 XRT and BAT radiators are located on the –Z side of the spacecraft (cold side). Spacecraft pointing constraints for sun avoidance are defined in section 8.1

4.2.7 Table 13 lists the operational and survival temperature limits for instrument components.

4.2.8 Qualification temperature limits shall be ±10°C beyond the worst case predicted operational temperatures for passively controlled components.

4.2.9 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 control set point. For temperature exposures beyond the 5°C margin required, instrument performance does not need to meet specifications.

4.2.10 Developers shall verify that each component will reach its operational temperature range during initial operations or after a safehold.

4.3 Instrument Module to Spacecraft Bus Thermal Interfaces

4.3.1 The spacecraft bus shall maintain an interface to the optical bench that is "adiabatic", i.e., conductive heat flow is minimized by utilizing low thermal conductance mounting methods, and radiative heat transfer is minimized by using multi-layer insulation (MLI) between the spacecraft and optical bench.

4.3.2 Conductive and Radiative Interfaces

4.3.2.1 Conductive heat flow across the optical bench/spacecraft interface shall be less than 5 watts during operational and survival modes.

4.3.2.2 Radiative interface requirements are specified in the TICDs listed in Table 12.

4.3.3 The spacecraft interface ring (or plate) bulk temperature range during operational modes shall be maintained within +/-30°C from the average bulk temperature at which on orbit calibration of the NFI boresight is performed.

4.3.4 The spacecraft side of the spacecraft-to-optical bench interface shall be maintained within a temperature range of -20 to +40°C during operations and -30°C to 50°C in the survival mode.

4.3.5 Additional thermal requirements, mechanical requirements and co-planarity requirements are in section 3.4.

4.4 Thermal Control Hardware Provisions

4.4.1 Heaters

4.4.1.1 Operational and survival heaters, heater controllers and thermostats on the instruments are the responsibility of the instrument suppliers, with the following exception. UVOT survival heaters and thermostats are the responsibility of GSFC

4.4.1.2 Operational and survival heaters, heater controllers and thermostats on OB-mounted spacecraft components are the responsibility of Spectrum Astro. Switching of power to survival heaters is the responsibility of the spacecraft.

4.4.1.3 For GSFC provided radiators, GSFC shall provide survival heaters and thermostats.

4.4.1.4 Thermostatically controlled operational and 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).

4.4.2 Temperature Sensors

4.4.2.1 Temperature sensors used to monitor instrument health are shown in Table 14.

	ITEM	TEMPERATURE SENSOR ALLOCATION
4.4.2.1.1.	BAT Telescope	6
4.4.2.1.2.	UVOT Telescope	3
4.4.2.1.3.	XRT Telescope	3
4.4.2.1.4.	UVOT-DEM A	1
4.4.2.1.5.	UVOT-DEM B	1
4.4.2.1.6.	XRT Electronics	1
4.4.2.1.7.	BAT Image Processors	2
4.4.2.1.8.	BAT Power Supply	1
4.4.2.1.9.	Optical bench	7
4.4.2.1.10.	Unallocated	0
4.4.2.1.11.	TOTAL	25

Table 14 Instrument Temperature Sensor Allocation

4.4.2.2 Temperature sensor locations shall be indicated in the subsystem TICDs.

4.4.2.3 Spectrum Astro shall provide and monitor temperature sensors.

4.5 Design Parameters

Design values of environmental constants to be used for thermal analysis are shown in Table 15.

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

Table 15 Design Values of Environmental Constants

4.6 Thermal Analysis

4.6.1 Thermal analysis models of each instrument, including associated electronic boxes, shall be provided by the respective instrument team.

4.6.2 Thermal analysis models of the Star Trackers/radiator and IRU Assembly, antennas, and CSSs shall be provided by Spectrum Astro.

4.6.3 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. All modes of operation should be defined.

4.6.4 A combined instrument module thermal analysis shall be performed by GSFC, and the instrument module model shall be delivered to Spectrum Astro for an integrated observatory thermal analysis. The IM thermal model shall be used to predict instrument interface temperatures for all mission phases, including all testing scenarios.

4.6.5 Each instrument team shall be responsible for prediction of their instrument's internal temperatures during testing, and for analysis of thermal testing data for verification of proper internal thermal control.

4.6.6 The thermal design of each instrument shall be validated by an instrument thermal balance test, and the thermal model shall be correlated with the thermal balance test data.

4.7 System Level Thermal Test

4.7.1 Spectrum Astro shall have primary responsibility for the system-level thermal vacuum test and shall lead test planning and test execution.

4.7.2 During the tests, the responsible thermal control engineer for each instrument shall be on site and available, if needed.

5 Electrical Interfaces

5.1 General

Electrical interfaces shall be documented in the ICDs indicated in Table 16. The power allocations for the instruments are shown in Table 19. These numbers are orbital average power and peak power. They represent the total power (including contingency) consumed by each instrument.

	ICD	Spectrum Astro ICD NUMBER
5.1.1.	Instrument Module to Spacecraft	1143-EI-Y22363
5.1.2.	UVOT to Spacecraft	1143-EI-Y22364
5.1.3.	XRT to Spacecraft	1143-EI-Y22365
5.1.4.	BAT to Spacecraft	1143-EI-Y22366

Table 16 Spacecraft – to – Instrument ICDs

5.2 Power Interfaces

5.2.1 Power Bus Conditions

a) All components on the Swift observatory shall be designed to operate normally, and without degradation, given the power bus conditions specified below.
b) All instruments shall be able to survive an instantaneous removal of power. This protects against inadvertent switching on the ground, as well as emergency operations on-orbit.

5.2.1.1 Steady-State Voltage

A steady-state voltage within the range of +24 volts DC to +35 volts DC, including harness losses, shall be available on all primary power inputs (operational and survival modes) to components, as measured at the instrument connector. Ripple and transients will be superimposed as stated in the following paragraphs.

NOMINAL VOLTAGE AT BOX INPUT	RANGE
+32 VDC	+24 to +35 VDC

Table 17 Steady State Bus Voltage Characteristics

5.2.1.2 Ripple

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

Table 18 Spacecraft Bus Ripple Characteristics

Ripple on the Spacecraft bus shall be less than 1.0 Volts peak-to-peak over the frequency range of 1 Hz to 10 MHz, and less than 0.5V peak-to-peak for frequencies over 10 MHz, at the power input.

5.2.1.3 Turn-On Transients (In-Rush Current)

5.2.1.3.1 Instrument Total Transient In-rush current limits shall not exceed 250% of maximum steady state (MSS) current. Duration shall be less than 50 milli-seconds. Turn-on transient limit is shown in Figure 6.

5.2.1.3.2 During turn-on and turn-off the spacecraft power switch controls the rise and fall time of output voltage to be between 50 and 200 micro-seconds.

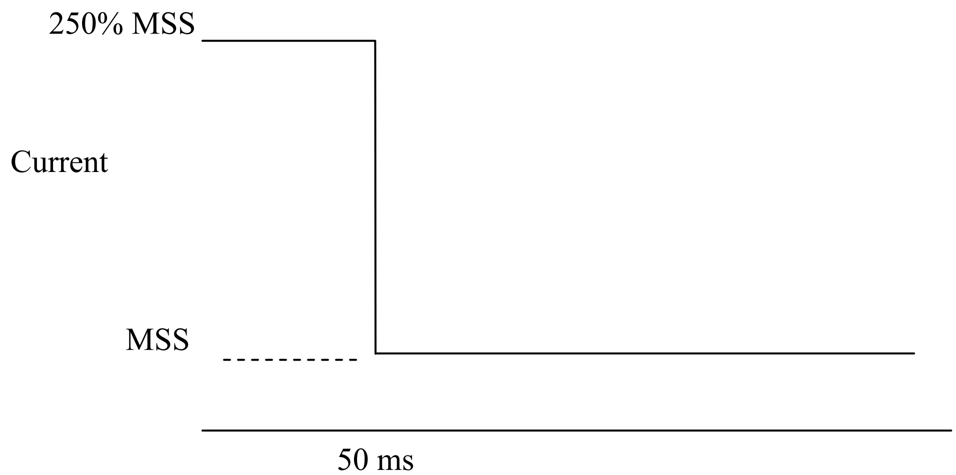

Figure 6 Instrument Turn-on Transient Limits

5.2.1.4 Abnormal Transients

5.2.1.4.1 Susceptibility to bus transients: All subsystems shall be designed not to be damaged by any Voltage in the range of -1 to +40 VDC for up to 500 milliseconds applied to the power input during anomalistic operations.

5.2.1.4.2 All subsystems shall be designed to prevent damage due to polarity reversal of the input power.

5.2.1.5 Turn-Off Transients

5.2.1.5.1 The peak voltage of transients induced on the power service, when the instruments are switched off shall not exceed +40 V, nor fall below -1 V.

5.2.1.5.2 When sub-switching is performed within an instrument, transients induced on the power service to that instrument during turn-off shall not exceed +/-3 V.

5.2.1.6 Common Mode Noise

During all normal operating modes, a component shall not produce common mode Voltage exceeding 100 mV peak-to-peak (50 mV goal). Measurements to verify compliance with this requirement shall be made between:

Power (+28) and component chassis;
Power return and component chassis;
Signal Ground and Chassis.

5.2.1.7 Over-Current Protection

The spacecraft shall provide protection of the Spacecraft power system by providing over-current protection devices on each instrument power connection.

5.2.2 Instrument Power and Switching Requirements

Instrument power and switching requirements are shown in Table 19. These numbers represent the instrument allocations, including contingency. These power numbers are not to be exceeded. Current best estimates of power are to be reported monthly to the Swift Systems Manager.

		ORBIT AVERAGE POWER (WATTS, OAP)	PEAK POWER (WATTS)
	BAT		
5.2.2.1.	BAT Total - Operational	385	536
5.2.2.2.	BAT Total - Survival	119	200
	UVOT		
5.2.2.3.	UVOT Total - Operational	125	220
5.2.2.4.	UVOT (TM Only) Survival	100	175
	XRT		
5.2.2.5.	XRT Total - Operational	135.0	300.0
5.2.2.6.	XRT Total - Survival	100.0	291.0
	Optical Bench		
5.2.2.7.	OB Total - Operational	50.0	91
5.2.2.8.	OB Total – Survival (includes UVOT DEM surv. Htrs)	55	93

Table 19 Instrument Power Requirements

5.3 Signal Interface

5.3.1 Data Interface

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

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

5.3.1.3 The instruments shall have 4 remote terminal addresses on the 1553 bus: BAT, UVOT/DPU, UVOT/ICU and XRT. The remote terminal addresses shall be defined in the 1553 ICD.

5.3.1.4 The spacecraft bus controller shall be the only bus controller on the MIL-STD-1553 bus.

5.3.1.5 The spacecraft shall accommodate variable length packets in CCSDS packet telemetry format transmitted over the MIL-STD-1553 interface. Note that it is acceptable to use variable size packets for telemetry data that is to be processed by ITOS. However, any telemetry packets that require real-time display by the ITOS ground system terminals must be of fixed length.

5.3.1.6 The spacecraft shall support communication between instruments, and shall define this interface in the 1553 ICD. The detailed command and telemetry formats for Swift shall be listed in the Swift Telemetry and Command Handbook.

5.3.2 Data Rates

The instrument daily average and peak data rate limits are listed in Table 20. Rates include CCSDS overhead, and are driven by the downlink capacity to the ground station.

	INSTRUMENT	AVERAGE SCIENCE TELEMETRY RATE	HOUSEKEEPING RATE	PEAK RATE
5.3.2.1.	BAT	42.9 kbps	2.6 kbps	187.5 kbps
5.3.2.2.	UVOT/DPU	7.0 kbps	0.5 kbps	62 kbps
5.3.2.3.	UVOT/ICU	0	0.5 kbps	2 kbps
5.3.2.4.	XRT	3.9 kbps	0.5 kbps	64 kbps

Table 20 Instrument average and peak data rates.

5.3.2.1 The spacecraft shall provide storage for the instrument data (science and housekeeping) and also downlink the instrument housekeeping during ground contacts (e.g., for XRT, the spacecraft shall store 4.4 kbps (3.9+0.5) while telemetering the 0.5 kbps of housekeeping during ground contacts).

5.3.2.2 The spacecraft shall also provide a means to retain a minimum of 2 hours of instrument housekeeping for trouble-shooting, in case of spacecraft safehold (when the instrument and solid-state recorder is powered off).

5.3.2.3 The instrument 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.

5.3.2.4 During ground test (e.g., I & T), modifications to the 1553 bus controller table shall be permitted to facilitate a particular instrument's checkout (e.g., increase UVOT's science telemetry poll rate to 150 kbps).

5.3.3 Time Interface

5.3.3.1 The spacecraft shall be capable of correlating onboard time to within 200 μs of UTC and maintaining onboard time to within 1 ms of UTC for a 24 hour period.

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

5.3.3.3 The MOC shall be responsible for measuring the spacecraft time error and uploading UTCF adjust commands to maintain spacecraft UTC as necessary.

5.3.3.4 The spacecraft shall transmit time to all instruments once every second.

Spacecraft time and Universal Time Correlation Factor shall be transmitted over the 1553 bus and be valid at the next 1 pulse per second epoch. The time accuracy error budget is given in Table 21.

	ERROR SOURCE	MAXIMUM ALLOWABLE ERROR (μS)	REQUIREMENT ON:
5.3.3.4.1.	Ground Station Time Stamp Error	40	Ground System
5.3.3.4.2.	Ephemeris Error (30 km)	100	Ground System
5.3.3.4.3.	Spacecraft Oscillator and Electronics Latencies (includes oscillator offset, oscillator temperature drift, time stamp uncertainties)	160	Spacecraft
	Total (RSS)	193	
	Requirement	<200	

Table 21 Time Accuracy Error Budget

5.3.3.5 Maximum relative time tag errors for instrument science products and spacecraft ancillary (ACS) data shall be as shown in Table 21 (e.g., BAT, UVOT & XRT Timing Mode products time-tagged with identical times have relative errors as indicated in Table 22).

		TIME TAG ERROR
5.3.3.5.1	BAT Data	0.1 ms
5.3.3.5.2	XRT Timing Mode Data	10 ms
5.3.3.5.3	UVOT Data	20 ms
5.3.3.5.4	S/C Ancillary Data (ACS)	5 ms

Table 22 Allowable Instrument Relative time Error

5.3.3.6 A redundant “hard-line” 1 pulse-per-second (pps) interface shall be provided to each instrument remote terminal.

5.3.3.7 Maximum skew on the hard-line 1 pps shall be <1 microsecond. The details of how time requirements relative to instruments are implemented are addressed in the 1553 ICD and Instrument Module ICD.

5.3.4 Other Interfaces

5.3.4.1 Active Analog Telemetry

No active analog telemetry monitoring is required by the instruments.

5.3.4.2 Passive Analog Telemetry

Spacecraft shall provide for monitoring of IM Temperature Sensors, as defined in section 4.4, Table 14.

5.3.4.3 Discrete Telemetry

Spacecraft C&DH shall monitor the following instrument sensors:
a) XRT Door Sensor (4micro-switches).
b) UVOT Door Sensor (4micro-switches).

5.3.4.4 Pulse Commands (Switched 28V service)

Spacecraft shall provide 2 pulse signals for two HOP-actuated NFI telescope covers for a total of 4 services. A 28V pulse of less than 1 ampere and 10 minutes duration is required.

5.4 Test Connectors

All test connector locations shall be shown in the appropriate MICD.

5.5 Observatory Grounding, Interfacing Power Distribution, and Shielding

In order to assure adequate performance of internal and external spacecraft electrical interfaces, this section imposes specific requirements relating EMC/EMI, electrical grounding, electrical interfacing, power distribution, and shielding.
The specific EMC/EMI, grounding, interfacing, power distribution, and shielding requirements contained in this section support the following design goals:
- An equipotential spacecraft
- Low conducted and radiated emissions within system cabling.
- High transient noise immunity on interface circuits associated with system cabling.
- Standard interface designs
- Electrostatic discharge prevention and safeguards.

5.5.1 Grounding

The general objective of the electrical grounding specifications is to ensure that all electrical circuits, whether power, digital, or analog signal, have access to suitable grounds or signal return paths which shall not contribute significantly to noise or otherwise interfere with the operation of the Observatory. The best way to achieve this is to produce an equipotential spacecraft surface, through the reduction of potentials acquired from the ambient plasma and currents flowing in the structure. Proper Spacecraft electrical grounding requires attention to structure grounding (electrical bonding) and circuit grounding. No part of the structure shall carry power return current by design.

5.5.1.1 Equipment and Structure Grounding

All chassis, structure, and metal elements shall be interconnected to the spacecraft structural ground system, either directly or by use of bond straps as specified in section 3.10. The BAT Mask with its 54,000 Pb tiles is excluded from this requirement (BAT mask will be enclosed in a Germanium coated black Kapton MLI cover to dissipate electrical charge build up). To support the above stated requirements, the materials and construction methods for spacecraft assemblies, subassemblies, chassis, subchassis and other components shall be such that electrical properties of the Spacecraft structure are maintained throughout the service life of the Spacecraft. Preparation of metal-to-metal surfaces for electrical bonding purposes shall be made in accordance with MIL-B-5087B, paragraph 3.1.4 or equivalent.

5.5.1.2 Power Return and Grounding

5.5.1.2.1 Primary power returns shall be isolated from signal returns and chassis by at least 1 MegaOhm at DC.

5.5.1.2.2 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 470nF.

5.5.1.3 Circuit Grounding

The first purpose of grounding is to maintain an equipotential ground plane available to all circuits as an electrical point of reference. The second purpose of grounding is to ensure that no significant voltage exists between circuit return and structure.

5.5.1.3.1 All circuitry interconnecting semiconductors, capacitors, resistors, transformers, and other electronic components shall be referenced to secondary return.

5.5.1.3.2 A single point grounding method shall be used for each instrument 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.

5.5.1.3.3 All instrument chassis shall be tied to the spacecraft chassis with a resistance of less than 10 milliohms.

5.5.1.4 Ground Tree

The ground trees provide grounding for circuit commons within the subsystems and for interface circuit returns. The spacecraft and instrument scheme shall documented in the ICDs listed in Table 16.

5.5.1.5 Thermal Blankets

5.5.1.5.1 There shall be at least one ground point for all layers for every square meter of MLI blanket surface.

5.5.1.5.2 The edges of the blanket shall be bound with material having a conductive outer side, which is bonded to the blanket ground points.

5.5.1.5.3 Each blanket ground point shall be connected to the nearest practical point on the structure, with a minimum length ground wire having a resistance less than 0.25 ohms.

5.6 Spacecraft/Instrument Module Harness Shielding

Shielding shall be provided to lines where protection from RFI is indicated. Shielding shall be documented in EICDs, which shall be approved by representatives from both sides of the interface.

5.7 Harness Requirements

5.7.1 General

5.7.1.1 All interconnects from the instrument module to the spacecraft shall be routed through an interface connector plate(s) on the optical bench, excluding the RF coaxial cable runs up to the hemispherical antennas mounted on the sunshade.

5.7.1.2 Instrument harnesses completely contained within the instrument module shall be the responsibility of GSFC. GSFC shall provide an optical-bench-mounted harness between spacecraft components and the optical bench interface connector plates. An Optical Bench EICD shall provide connector descriptions and contact designations.

5.7.1.3 Spacecraft to Instrument Module harness is the responsibility of Spectrum Astro. A spacecraft EICD shall provide connector descriptions and contact designations.

5.7.1.4 The harness which connects the XRT Focal Plane Assembly to the XRT electronics box mounted on the spacecraft bus shall be provided by PSU.

5.7.1.5 The wiring harness which connects the XRT electronics to the Instrument Module connector interface, shall be provided by Spectrum Astro.

5.7.1.6 That section of harness from the Instrument Module interface to the XRT forward structure (above the optical bench), shall be provided by GSFC.

5.7.2 Optical Bench Harness Requirements

5.7.2.1 Harness lengths and wire counts within instrument harnesses shall be documented in EICDs.

5.7.2.2 Harness for spacecraft components mounted on the OB shall be independent of all instrument wiring, and shall be provided by GSFC.

5.7.2.3 Connectors shall be used on the optical bench assembly to allow the removal of any instrument or the entire Instrument Module assembly without the de-integration of the wiring harness.

5.7.2.4 Connectors for IM temperature sensor and survival heater wiring shall be documented in EICDs.

5.7.3 Connectors

5.7.3.1 The Instrument Module and instrument electronics mounted to the spacecraft bus shall provide Spectrum Astro with 3 mating connectors to each flight connector that interfaces to the spacecraft harness.

5.7.3.2 Spectrum Astro shall provide GSFC with 3 mating connectors for each spacecraft component flight connector that interfaces to the OB harness.

6 Software Interfaces

6.1 GRB and Pre-Planned Target Observation Strategy

The goal of Swift is to detect and observe GRBs as early as possible for a specified period of time. This means that it is desirable to observe a newly detected GRB whenever "safe" and the pre-planned target when deemed "not safe". The following is meant to describe the current science observation strategy, from which requirements will be derived. It is not meant to be a detailed description of all transactions needed to support desired Swift observations. The strategy is summarized in Figure 7.

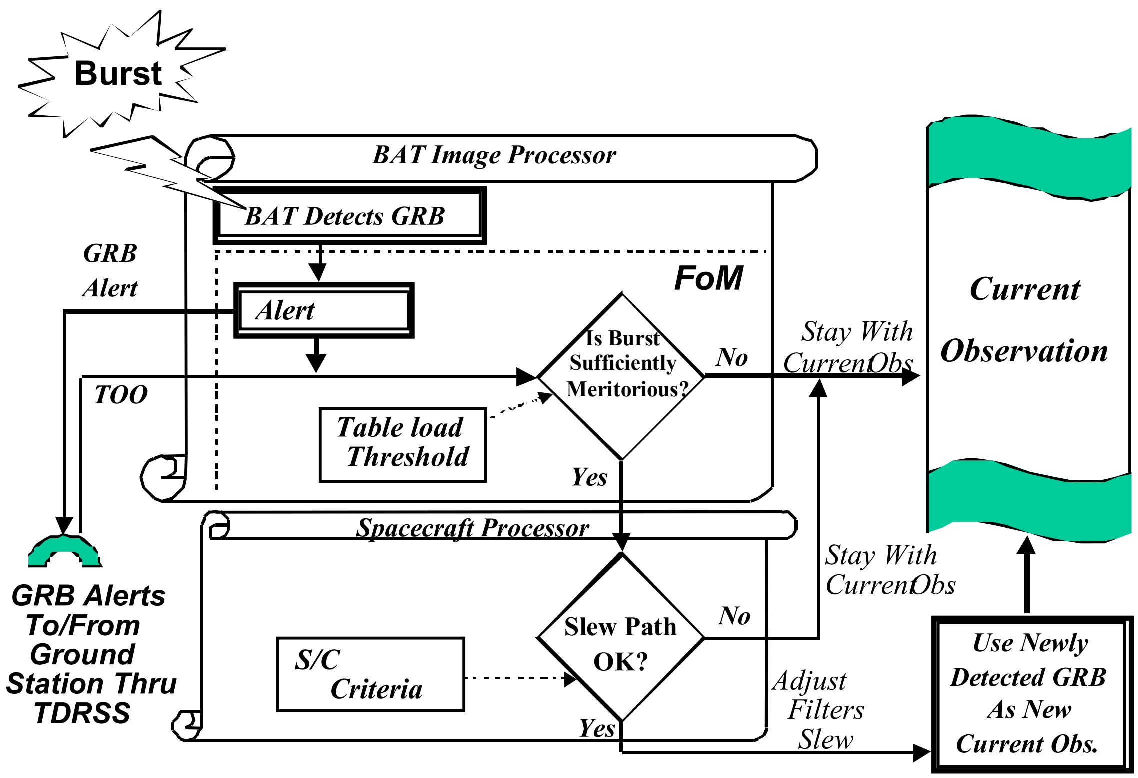

Figure 7 Burst Alert Flow

The baseline operation concept includes the uploading of pre-planned observations at a pre-defined time of day, five (5) days a week. The pre-planned observations will be stored and managed by the spacecraft stored command processor (SCP) and will provide a means of performing multiple observations without ground commands. A major benefit of the Swift mission is its ability to quickly detect & slew to a newly detected gamma-ray burst (GRB). When a GRB is detected by the BAT, an alert and a subsequent location telemetry message is sent to the ground (via TDRSS) and to the other instruments. Once the BAT determines the location of the GRB, the FoM will coordinate between observing the newly detected GRB & the pre-planned targets, using a merit value comparison. Preplanned targets have ground assigned merit values and newly detected GRBs will be assigned merit values onboard. If the FoM determines that the new target is more meritorious, it will send the spacecraft a request to slew. If the spacecraft deems that it is safe, it will slew to the target, pending verification that the UVOT has safed itself. The spacecraft will provide a look-ahead of how much time the target can be safely viewed before constrained. As the spacecraft slews, it will provide slew status to all instruments (e.g., slewing, within 10', settled). The FoM will continue to manage observations, checking when the new target will violate pointing constraints and when the next pre-planned target is scheduled. When the new target is constrained, the FoM will attempt to follow the pre-planned observations (by requesting spacecraft slews). As a part of the coordination, the FoM will monitor and provide observing information (e.g., target ID, past observation time) at the beginning of a new observation to each instrument. If the spacecraft deems that it is not "safe" to slew to the new target, it will notify the FoM with the projected time of when the new target will be viewable. The FoM will in-turn coordinate the observations so that it will request a spacecraft slew when the new target is viewable. A newly detected GRB will be observed for a specified amount of time. Note that though the pre-planned observations are stored and maintained in the spacecraft, all observations are routed through the FoM (e.g., a slew to a pre-planned target at noon will be routed at noon to the FoM first). This allows the FoM to "inhibit" a pre-planned target slew if an automated target of higher merit is being observed.

6.1.1 Following are requirements that support autonomous observations of newly detected GRBs:

The spacecraft shall accept slew requests from the FoM:

6.1.1.1. If the spacecraft can safely slew to the requested target, it shall execute the slew and provide a message giving the time when target is no longer visible.
6.1.1.2. Note: the spacecraft shall not execute the slew until it has received a message from the UVOT that it has been safed. Note: for all slews, the spacecraft shall handshake to safe the UVOT prior to slew execution. If the UVOT does not reply to the safing message, within a specified time, the spacecraft shall take the following actions:
6.1.1.3. For slews to preplanned or automated targets, the spacecraft shall abort the slew, and generate the TDRS event message indicating the error.
6.1.1.4. For slews to a safe pointing position, the spacecraft shall power down the UVOT, slew to the safe pointing position, and generate TDRS event message indicating the error.
6.1.1.5. In all cases, the spacecraft shall ensure safety of the observatory by meeting observatory pointing constraints.
6.1.1.6. If the UVOT becomes inoperable, the requirement by the spacecraft to verify UVOT safety prior to executing a slew shall be capable of being overridden by ground command.

6.1.2 If the spacecraft cannot safely slew to the requested target, it shall stay on the current target and provide a message giving the time that the target will be safe to view.

6.1.3 The spacecraft shall accept a request from the FoM to slew to a "safe" pointing location. This safe location is to be determined by the spacecraft & is intended to be a backup pointing position without putting the spacecraft into "spacecraft safehold".

6.1.4 The spacecraft shall provide a means for messages to be routed between instruments, allowing each instrument to be aware of observation activities. For example, though messages like the initial BAT burst alert & a request to slew are intended for specific destinations, it may be useful to route a copy to all instruments.

6.1.5 The spacecraft shall provide RT to RT messaging with a maximum round-trip time of 500 ms (from when a message is made available in the source RT shared memory to when it is written in the destination RT shared memory).

6.1.6 The spacecraft shall provide the status of a spacecraft slew to all instruments (per IRD Table 22. – i.e., "maneuvering to target", "within 10' of target", "settled on target").

6.1.7 In the event the current target begins to violate constraints, the spacecraft shall attempt to avoid "safehold by slewing to a "safe pointing location.

6.1.8 Note that once a slew has started, the spacecraft shall accept no other slew commands until the "slew settled" status has been issued.

6.1.9 The spacecraft shall be responsible for all observation safety functions.

6.1.10 The spacecraft shall be capable of receiving target of opportunity (ToO) commands from TDRSS and routing them to the FoM.

6.2 Spacecraft Observation Related Command Telemetry Services

6.2.1 Table 23 indicates the spacecraft services provided in response to either the occurrence of certain conditions or messages that are associated with science observations. These services result in either commands issued to Swift's instruments or telemetry provided to the TDRSS link.

6.2.2 In addition to the messages listed in Table 23, the spacecraft shall have the capability to downlink spacecraft and instrument housekeeping information through TDRSS.

Spacecraft Provided Services						
	On Condition	**When S/C Receives**	**S/C Service**	**Commands to Instruments**	**Telemetry to TDRSS**	**Purpose / Comment**
6.2.1.1.	At 1 Hz		S/C clock time telecommand	X		Time distribution and synchronization
6.2.1.2.	At 5 Hz rate		Send attitude information	X		Provides ancillary data to instruments (e.g. Long, Lat, 3-axes s/c attitude)
6.2.1.3.	Whenever instrument are powered on		The S/C shall provide commanding to instrument at a 20 hz rate, including ACS messages, time messages, ground/stored/spacecraft commands & inter-instrument commands.	X		Support general operations
6.2.1.4.	Whenever instruments are powered on		1. The S/C shall poll each instrument 5 times a second for an inter-instrument command of up to 62 bytes 2. When an inter-instrument command is retrieved, forward to one or all other instruments within 500 ms (details of message timing for multiple inter-instrument commands are discussed in the 1553 ICD) 3. The S/C shall buffer up to one seconds worth of inter-instrument commands	X		Support observations
6.2.1.5.		A S/C slew request command from FoM	1. If target not constrained, provide "OK to slew" message, with the estimated time until target is constrained. S/C shall verify UVOT safed prior to slewing. 2. If target constrained, provide "Not OK to slew" message, with estimated time when requested target will no longer be constrained.	X	X	Support nominal & autonomous observations
6.2.1.6.		A S/C slew request command to new target from FoM	Set programmable timeout in seconds for response from UVOT to S/C safing message.	X		Provides for safe slew to target
6.2.1.7.		A S/C slew inquiry from FoM	S/C shall reply with either an “OK to slew” or “Not OK to slew” message, but shall not execute a slew to the specified target	X		This shall be a polling mechanism available for the FoM. There is an option for the UVOT to use the slew request to safe itself & this is a separate mechanism to inquiry w/o triggering UVOT safing.
6.2.1.8.	When s/c is slewing		S/C shall provide the following status during slews: 1. slewing 2. within 10’ of target 3. settled on target	X		Support science operations
6.2.1.9.		A UVOT safed command message from UVOT	The s/c can now slew to target	X		Provides for UVOT safety
6.2.1.10.	10 seconds prior to S/C entering constraint		S/C shall send message to FoM indicating S/C will enter constraint in 10 seconds	X		If FoM does not select a new target in 5 seconds, the s/c shall track to a safe attitude.

Spacecraft Provided Services						
	On Condition	**When S/C Receives**	**S/C Service**	**Commands to Instruments**	**Telemetry to TDRSS**	**Purpose / Comment**
6.2.1.11.		A telemetry packet from an instrument destined for TDRSS	S/C shall: 1. send messages down TDRSS link at downlink rate as specified in MRD 2. send messages in order of receipt, 3. buffer up to 96KB kbytes of TDRSS messages 4. manage the TDRSS link (e.g., synchronization/lock, hemispheric antenna hand-overs, TDRSS hand-overs). The following are example TDRSS telemetry packets (not intended to be complete list): 1) BAT alert, 2) BAT position, 3) BAT lightcurve, 4) XRT position, 5) UVOT finding chart, 6) XRT spectrum, 7) XRT image, 8) FoM will/will not request slew to target, 9) S/C will/will not slew to target, 10) significant s/c or instrument events		X	Support GRB observations & other immediate alert conditions.
6.2.1.12.		Return to planned attitude timeline command from ground ops	Ground (MOC) shall send message informing instruments that it is safe to resume operations	X		Allows for return back to operations after entering safe pointing or safehold.
6.2.1.13.	S/C Entering Safehold		Within 60 seconds of spacecraft entering safehold, the spacecraft shall generate a TDRSS notification message to the ground.		X	
6.2.1.14.	Once S/C determines it is going to a safe attitude		The spacecraft shall send a message through TDRSS indicating that the s/c is going to a safe attitude. The spacecraft shall also provide to the FoM status indicating s/c is going to safe attitude.		X	Used in support of onboard management of operation by FoM

Field definition:

- *On Condition* – This field denotes that on a certain condition (e.g., s/c safehold), the s/c shall provide the services as described in that row.
- *When S/C Receives* – This field denotes that when the s/c receives this message (e.g., a telemetry packet from an instrument destined for TDRSS), the s/c shall provide the services as described (e.g., send messages down TDRSS link at downlink rate as specified in MRD).
- *S/C Service* – This field denotes what services the s/c is required to provide (e.g., at SAA entry, the s/c shall send a telecommand indicating SAA entry to all instruments).
- *Cmd to Instr* – This field denotes that the message describes in the “S/C Service” field is to be a telecommand to all instruments.
- *Tlm to TDRSS* – This field denotes that the message describes in the “S/C Service” field is to be a telemetry packet sent down through the TDRSS link.
- Purpose/Comment – This field denotes the purpose of the service or a comment about the service.

Table 23 Spacecraft Services

7 Environmental Interfaces

7.1 Ground Operations and Handling

7.1.1 Instrument and Payload Checkout

7.1.1.1 Upon delivery for optical bench integration, each instrument shall perform a comprehensive performance test to ensure that instrument has survived shipment and all performance requirements are being met.

7.1.1.2 The same test shall be performed 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).

7.1.1.3 A copy of each instrument's CPT shall be provided to Spectrum Astro 3 months prior to IM delivery.

7.1.2 Mechanisms

Except for the Solar Array Deployment and Drive mechanisms, all flight mechanisms shall be capable of being operated on the ground in horizontal or vertical orientations to support ground testing.

7.1.3 Protective Covers (Ground Use)

7.1.3.1 Shall be compatible with contamination requirements.

7.1.3.2 Shall be easily removable in test/launch configurations.

7.1.3.3 Shall employ tethered hardware.

7.1.4 Alignment Cube Covers

7.1.4.1 Shall be compatible with contamination requirements.

7.1.4.2 Shall be easily removable in test/launch configurations.

7.1.4.3 Shall employ tethered hardware.

7.1.5 External calibrations sources

7.1.5.1 Shall be compatible with contamination requirements.

7.1.5.2 Shall be easily removable in test/launch configurations.

7.1.5.3 Shall employ tethered hardware.

7.1.6 Contamination Purge

XRT and UVOT require a purge through T=0 launch. See Section 10 for further discussion.

7.1.7 Electrostatic Discharge Control

7.1.7.1 The Swift mission shall be handled in accordance with the requirements of NASA-STD-8739.7, Electrostatic Discharge Control.

7.1.7.2 Many of the Spacecraft subsystems contain parts that are sensitive to Electrostatic Discharge (ESD). These parts can be damaged or destroyed if they are exposed to ESD. In order to protect the flight hardware from ESD, all personnel must have current ESD certification. Personnel within one meter of flight hardware or the flight structure (including the Swift spacecraft bus, Swift instruments (BAT, XRT, UVOT) and the Optical Bench, must be electrically grounded using wrist straps. These wrist straps should have load resistors greater than 200 kiloohms and less than one megaohm in series from the wearer to the ground point. In addition, to help protect the flight hardware from ESD damage, access to flight hardware by unauthorized personnel should be restricted.

7.2 Environments

Flight hardware shall be designed to survive the following environments. Expected environmental test requirements shall be defined in the Swift Verification Plan and Environmental Specification.

7.2.1 Pressure Profiles

Instruments and electronic boxes shall be designed to withstand the pressure profile shown in Figure 8 without any degradation in performance.

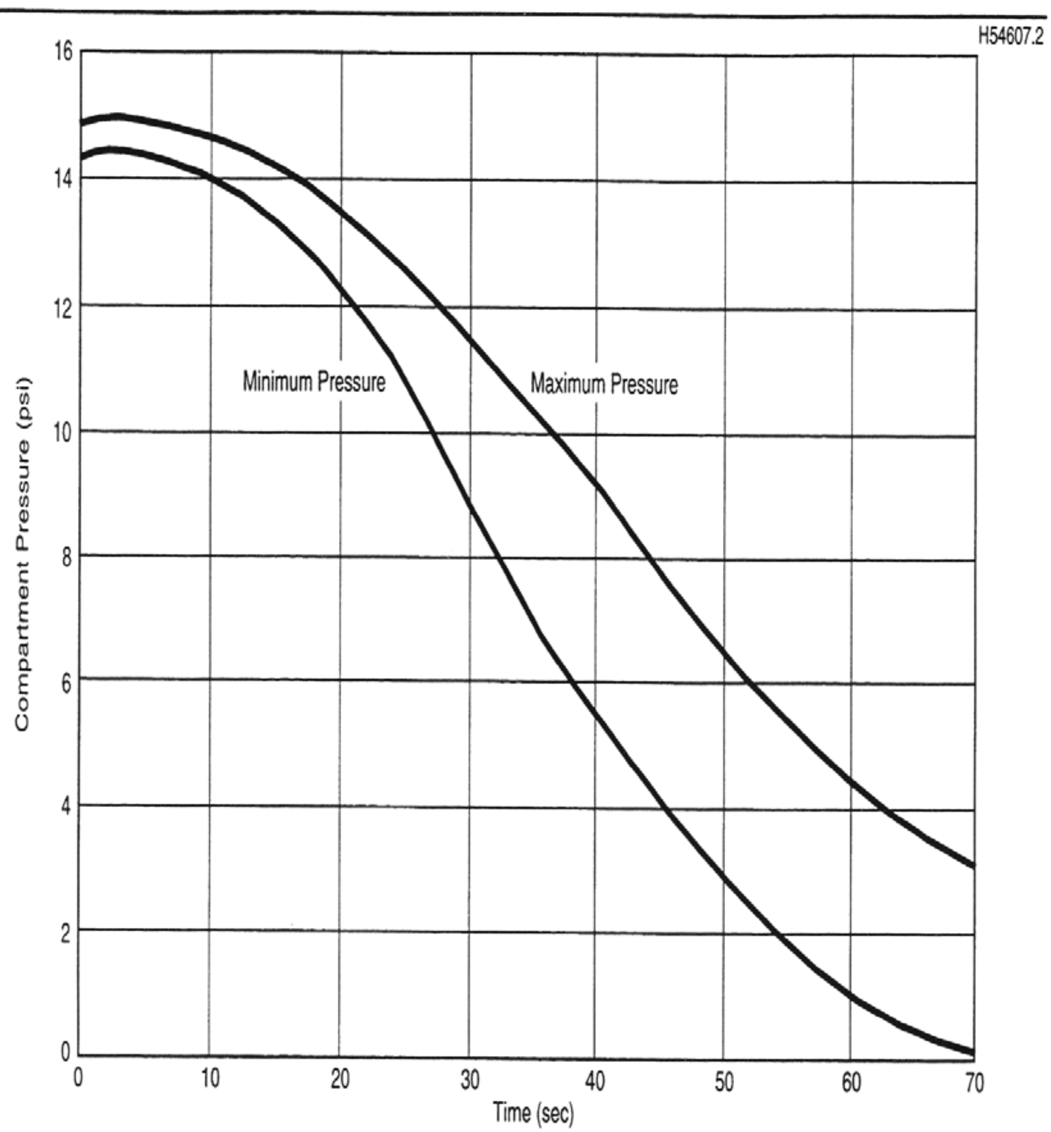

Figure 8 Delta II Payload Fairing Compartment Absolute Pressure Envelope

7.2.2 Acoustic Environment (Instruments and Remote Electronics Boxes)

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**
Test Duration: 1 minute		

Table 24 Acoustic Environment (Instruments and Remote Electronics Boxes)

7.2.3 Vibration Environment

7.2.3.1 BAT and XRT Instruments

PROTOFLIGHT LEVEL				FLIGHT LEVEL		
Axis	Freq(Hz)	Level		Axis	Freq(Hz)	Level
	20	0.01 g^2/Hz		All	20 - 2000	0.01 g^2/Hz
	20 – 50	+2.3 dB/oct				
All	50 – 800	0.02 g^2/Hz		Overall Level = 4.45 grms		
	800 - 2000	-2.3 dB/oct		Duration = 1 min/axis		
	2000	0.01 g^2/Hz				
Overall Level = 5.65 grms Duration = 1 min/axis						

Table 25 Vibration Environment (BAT and XRT Instruments)

7.2.3.2 UVOT Instrument

PROTOFLIGHT LEVEL				FLIGHT LEVEL		
Axis	Freq(Hz)	Level		Axis	Freq(Hz)	Level
	20	0.026 g^2/Hz			20	0.013 g^2/Hz
	20 – 50	+1.2 dB/oct			20 – 50	+1.2 dB/oct
All	50 – 800	0.038 g^2/Hz		All	50 – 800	0.019 g^2/Hz
	800 - 2000	-1.2 dB/oct			800 - 2000	-1.2 dB/oct
	2000	0.026 g^2/Hz			2000	0.013 g^2/Hz

Table 26 Vibration Environment (UVOT Instrument)

Overall Level = 8.15 grms
Duration = 1 min/max

Overall Level = 5.76 grms
Duration = 1 min/max

7.2.3.3 Instrument Remote Electronics Boxes

PROTOFLIGHT LEVEL				FLIGHT LEVEL		
Axis	Freq(Hz)	Level		Axis	Freq(Hz)	Level
	20	0.026 g^2/Hz			20	0.013 g^2/Hz
	20 – 50	+6 dB/oct			20 – 50	+6 dB/oct
All	50 – 800	0.16 g^2/Hz		All	50 – 800	0.08 g^2/Hz
	800 - 2000	-6 dB/oct			800 - 2000	-6 dB/oct
	2000	0.026 g^2/Hz			2000	0.013 g^2/Hz

Table 27 Vibration Environment (Instrument Remote Electronics Boxes)

Overall Level = 14.1 grms
Duration = 1 min/max

Overall Level = 10.0 grms
Duration = 1 min/max

7.2.4 Sine Sweep Vibration

7.2.4.1 Instruments (BAT, XRT, and UVOT)

Thrust Axis

Protoflight Level			Flight Level		
Frequency (Hz)	Level (G, 0-peak)	Sweep Rate (oct/min)	Frequency (Hz)	Level (G, 0-peak)	Sweep Rate (oct/min)
5-6.3	0.5 in-D.A.	4	5-6.3	0.4 in-D.A.	4
6.3-25	1	4	6.3-25	0.8	4
25-30	1	1.5	25-30	0.8	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 Level			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	1.75	4	15-25	1.4	4
25-30	1.75	1.5	25-30	1.4	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.

Table 28 XRT Sine Sweep Vibration Specifications

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	3.5	1.5	30-35	2.8	1.5
35-42	3.5	4	35-42	2.8	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
25-35	1.5	1.5	25-35	1.2	1.5
35-40	1	4	35-40	0.8	4
40-50	1	4	40-50	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.

Table 29 BAT Sine Sweep Vibration Specifications

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.

Table 30 UVOT Sine Sweep Vibration Specifications

7.2.4.2 Instrument Remote Electronics Boxes

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

Table 31 Sine Sweep Vibration (Instrument Remote Electronics Boxes) All Axes

7.2.4.3 Observatory

Thrust Axes

PROTOFLIGHT LEVEL		
Freq(Hz)	Level (g, 0-pk)	Rate
5 – 15	0.25	4 oct/min
15 – 20	0.60	4 oct/min
20 – 25	0.25	4 oct/min
25 – 35	0.25	1.5 oct/min
35 - 50	0.25	4 oct/min

Table 32 Sine Sweep Vibration (Observatory Thrust Axis)

Lateral Axis

PROTOFLIGHT LEVEL		
Freq(Hz)	Level (g, 0-pk)	Rate
5 – 17	0.25	4 oct/min
17 – 25	0.50	4 oct/min
25 – 35	0.70	1.5 oct/min
35 – 45	0.40	4 oct/min
45 - 50	0.20	4 oct/min

Table 33 Sine Sweep Vibration (Observatory Lateral Axis)

7.2.5 Pyroshock Environment

7.2.5.1 Shock Response Spectrum (Instruments and Remote Electronics Boxes)

ALL AXES				
Protoflight Level			Flight Level	
Q=10			Q=10	
Freq (Hz)	Shock Response Spectrum (g's)		Freq (Hz)	Shock Response Spectrum (g's)
200	53		200	38
200 – 400	+12 dB/oct		200 – 400	+12 dB/oct
400 – 1250	210		400 – 1250	150
1250 – 1600	+7 dB/oct		1250 – 1600	+7 dB/oct
1600 - 4000	280		1600 - 4000	200
Apply shock pulse per axis.				

Table 34 Shock Response Spectrum (Instruments and Remote Electronics Boxes)

7.2.5.2 Shock Response Spectrum (Instruments and Remote Electronics Boxes)

ALL AXES				
Protoflight Level			Flight Level	
Q=10			Q=10	
Freq (Hz)	Shock Response Spectrum (g's)		Freq (Hz)	Shock Response Spectrum (g's)
200	161		200	115
200 – 630	+7.7 dB/oct		200 – 630	+7.7 dB/oct
630 – 800	700		630 – 800	500
800 – 1250	+9.3 dB/oct		800 – 1250	+9.3 dB/oct
1250 - 4000	1400		1250 - 4000	1000
Apply shock pulse twice per axis.				

Table 35 Shock Response Spectrum (Items With a Mounting Interface with 60cm of S/C Separation Plane)

7.2.6 Electromagnetic Environment

7.2.6.1 All instruments shall meet the requirements of MIL-STD-461, Rev. C, with levels specified in GEVS-SE and tailored in the Swift EMI/EMC Test Plan.

7.2.6.2 The spacecraft shall perform the conducted emissions testing at the instrument power bus and provide the data to the instrument teams and the Swift Project Office.

7.2.6.3 The spacecraft shall meet the conducted emissions requirements of MIL-STD-461, Rev. C, with levels specified in GEVS-SE at the instrument power interface.

7.2.7 Magnetic Properties

A list and description of permanent magnets and ferro-magnetic materials shall be compiled for each instrument component.

7.2.8 Natural Charged Particle Radiation

7.2.8.1 Radiation Environment

The Swift mission will be exposed to trapped particles consisting of protons, electrons, and relatively low-energy heavy ions. Also, low levels of very high-energy heavy ions of galactic origin are able to penetrate through the magnetosphere to the level of the Swift orbit.

7.2.8.2 Total Ionizing Dose (TID)

All observatory hardware shall be designed to survive space radiation, with the addition of local shielding, for the required mission lifetime. The observatory shall meet the total dose requirements based on the total dose-depth curves identified in Figure 9. This curve was generated based on the expected normal and solar flare electron and protons environments and does not include any radiation design margin.

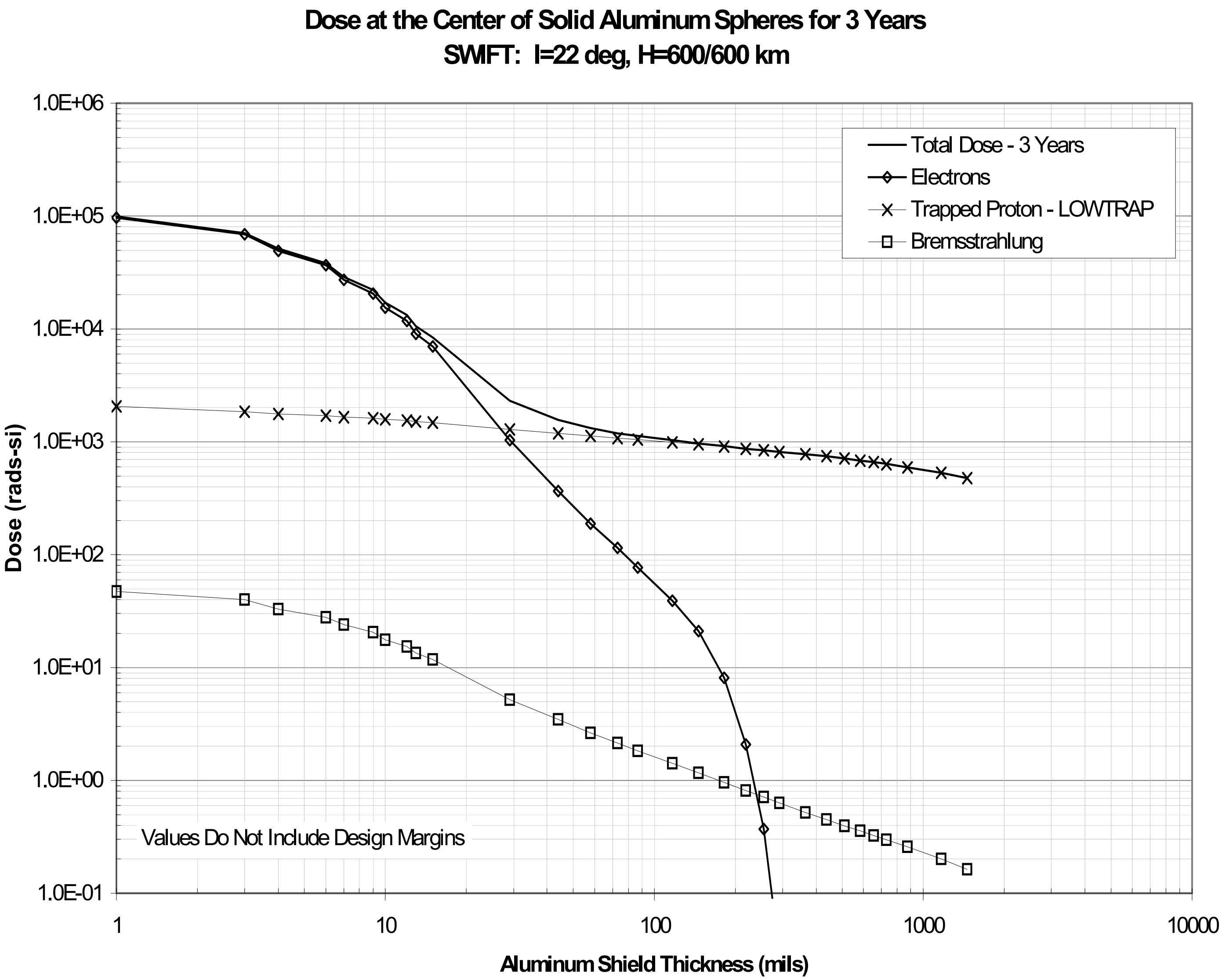

Figure 9 Total Dose-Depth Curves for the Swift Environment

For 100 mils of equivalent aluminum shielding, the top-level dose requirement is 2.2K rads (Si) for a three year mission. These dose estimates do include a “x2” design margin, which is the minimum recommended margin. A larger design margin may be required for commercial parts with large “in-lot” variation in radiation response and for devices that are sensitive to enhanced low dose rate effects and/or displacement damage. It is recommended, but not required, that CMOS devices selected have an additional design margin of “x2” and that linear bipolar devices have an additional design margin of “x7” due to low dose rate effects.

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.

7.2.8.3 Single Event Effects (SEE)

7.2.8.3.1 Observatory hardware shall be designed so that no SEE may cause permanent damage to a system or subsystem.

7.2.8.3.2 Electronic components shall be designed to be immune to SEE induced functional anomalies that require ground intervention to correct.

7.2.8.3.3 SEE capabilities for each electronic part shall be reviewed to prevent the failure of any component due to heavy ions or protons.

7.2.8.3.4 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.

7.2.8.3.5 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.

7.2.8.3.6 As a goal, observatory parts shall have a Linear Energy Transfer (LET) latchup threshold of 80 MeV*cm^2/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.

7.2.8.3.7 If a part is not immune to SEUs, analysis for SEU rates and effects must take place based on the Let$_{th}$ of the part as indicated in Table 36.

PART/DEVICE THRESHOLD	ENVIRONMENT TO BE ASSESSED
$LET_{th}>37$ MeV*cm^2/mg	No analysis required*
10 MeV*cm^2/mg$<LET_{th}<$37MeV*cm^2/mg	Cosmic Ray
$LET_{th}<10$ MeV*cm^2/mg	Cosmic Ray, Trapped Protons, Solar Flare

*Analysis may be required if using significant quantities of a particular part

Table 36 Analysis Requirements for Non-immune Parts

7.2.9 Radioactivity

This section shall be used to describe the radioactive calibration sources to be used during observatory level integration and test, as well as internal instrument sources used for flight.

7.2.9.1 The XRT has five internal flight Fe55 sources, with an activity of less than 10 micro-curies each, for a total of less than 50 micro-curies.

7.2.9.2 No external calibration sources shall be required during instrument module or observatory level integration and test.

7.2.9.3 The BAT has an internal ^{241} Am radioactive calibration sources with a total activity of less than 300 nanocuries.

8 Pointing and Alignment

8.1 Viewing Constraints

8.1.1 Viewing Constraints-Instrument Boresights

8.1.1.1 Instrument viewing constraints related to instrument safety during spacecraft safehold are as shown in Table 37. Instruments are assumed to be powered off.

8.1.1.2 Once safehold has triggered, the observatory shall meet the requirements of Table 38 within 10 minutes.

AVOIDANCE FROM LOS FOR INSTRUMENT SAFETY	SUN	EARTH LIMB	MOON	RAM
UVOT	20°	None	None	5°
XRT	20°	None	None	5°
BAT	None	None	None	None

Table 37 Instrument Health and Safety Viewing Constraints

8.1.1.3 The UVOT and XRT shall have one-time deployable doors to protect the instruments from the sun during launch and early-orbit operations. While the NFI aperture doors are closed, there are no instrument pointing constraints.

AVOIDANCE FROM LOS FOR INSTRUMENT OPERATIONS TO MAINTAIN INSTRUMENT PERFORMANCE	SUN	EARTH LIMB	MOON	RAM
UVOT	45°	30°	30°	5°
XRT	45°	20°	20°	5°
BAT	None	None	None	None

Table 38 Instrument Operational Viewing Constraints to Maintain Instrument Performance

8.1.1.4 Instrument operational viewing constraints related to performance are shown in Table 38. When the instruments are powered on, the spacecraft shall meet all of the constraints of Table 38.

8.1.2 Viewing Constraints-Instrument Radiators

8.1.2.1 While settled on target, the sun shall be maintained within an angle of ±10° from the spacecraft X-Z plane.

8.1.2.2 There shall be no direct solar illumination of the BAT or XRT thermal radiators while the observatory is settled on the target. During slews the sun may impinge on the XRT and BAT thermal radiators for no more than 5 minutes per orbit.

8.2 Pointing

8.2.1 Definitions

8.2.1.1 Pointing Control

Pointing Control is the accuracy to which each instrument's boresight is placed on the target. Errors include internal instrument errors as well as optical bench and spacecraft pointing and alignment errors.

8.2.1.2 Pointing Knowledge

The accuracy to which the position of the target is known. This error includes internal instrument errors, as well as spacecraft ACS errors.

8.2.1.3 Jitter

Jitter is the short term pointing control error. It contributes to errors in both pointing and control and knowledge. Jitter is caused by disturbances that occur above the controlled bandwidth of the spacecraft ACS, as well as sensor noise. Jitter is defined for the Swift mission as the 3σ excursion from the nominal pointing direction over any 10-second time period.

8.2.1.4 Placement

Placement refers to the co-alignment achieved on-orbit. Errors here include launch shift, g-release, ground alignment errors and thermal distortion. The critical requirement here is for the co-alignment of XRT and UVOT. The intent is to ensure that the UVOT FOV falls entirely within the XRT FOV.

8.2.2 Requirements

8.2.2.1 Slewing

8.2.2.1.1 The spacecraft shall accommodate any sequence of otherwise valid targets provided the sum of the slew angles for maneuvers between targets does not exceed 500 degrees per orbit. The slew angle of a maneuver is the great circle distance between the initial and final targets. The spacecraft is not required to reject maneuver requests that exceed the required total slew capability.

8.2.2.1.2 The spacecraft shall also be able to accommodate at least one automated target per orbit in addition to the pre-planned targets. The automated target can be generated by either the BAT or the MOC.

8.2.2.1.3 The spacecraft shall accommodate a maneuver to the automated target and a maneuver to return to the pre-planned sequence of targets at any time such maneuvers do not violate observing constraints. The spacecraft is not required to reject maneuver requests for additional automated targets.

8.2.2.1.4 In response to a ToO burst alert message which results in slews from 50° to 180°, the settling time shall be less than 270 seconds.

8.2.2.1.5 For pre-planned observations, slew times can be up to twice as long.

8.2.2.2 Pointing Control

8.2.2.2.1 Once settled, the instrument LOS shall be controlled to within 3 arc minutes (each axis pitch, yaw), 3sigma of the commanded value. Roll control is 4.5 arc minutes, 3 sigma.

8.2.2.2.2 Requirement during slew: Once the BAT has detected a burst, the burst shall be maintained within the BAT's FOV throughout the remainder of the slew.

8.2.2.3 Pointing Knowledge

8.2.2.3.1 Target LOS shall be known to better than 5.0 arc seconds, 3 sigma each axis pitch and yaw, 1.5 arc minute (3 sigma) in roll. The allocation of this requirement is defined in the Swift MRD, 410.4-SPEC-0004

8.2.2.3.2 Requirements during slews: The accuracy of the attitude knowledge while slewing shall be 1 arc minute, 3 sigma, each, in pitch and yaw, and 2.5 arc minutes, 3 sigma in roll. Rationale: to allow the BAT to continue imaging the burst during slews.

8.2.2.4 Jitter

Once settled the spacecraft pointing shall be stable to better than 1 arc second (pitch and yaw) over any 10 second period. Once settled the spacecraft pointing shall be stable to better than +/- 1.2 arc minute (3 sigma) in roll over any 1000 second period.

8.2.2.5 Placement

8.2.2.5.1 The optical bench shall provide the inter-instrument alignment and stability. A major objective of the optical bench is to maintain alignment between the star trackers (STs), XRT, and UVOT.

8.2.2.5.2 To maintain FOV overlap between the XRT and UVOT, the boresights of the two instruments must be held in co-alignment through ground operations, launch, and on-orbit effects to better than 210 arcseconds. The budget for NFI absolute co-alignment is shown in Table 39.

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

Table 39 NFI FOV Overlap

UVOT boresight to XRT boresight stability shall be maintained on orbit to within 12 arc seconds, 3 sigma. The error budget for this reqirement is listed in Table 40.

	UVOT boresight to XRT boresight stability	Allocation	
		RSS(Pitch, Yaw)	
		arc seconds, 3 sigma	
	Error Source		
8.2.2.5.2.12	XRT/UVOT calibration	1.4	
8.2.2.5.2.13	XRT centroiding error	1.4	From MRD EB3
8.2.2.5.2.14	XRT BS to XRT OB Interface stability	2	Includes XRT HRS effects
8.2.2.5.2.15	XRT OB Interface to UVOT OB Interface stability	6	Includes XRT HRS effects
8.2.2.5.2.16	UVOT OB Interface to UVOT BS stability	1	
8.2.2.5.2.17	XRT Harness effects	0.5	
	Total = RSS(1,2)+3+4+5+6	11.5	
	Requirement	12	

Table 40 UVOT/XRT Co-alignment Stability

8.2.2.5.3 The relative alignment between the UVOT, XRT, and ST shall be determined, to the levels defined in the Swift MRD, 410.4-SPEC-0004 approximately 1 month post launch by on-orbit calibration using celestial sources.

8.2.2.5.4 The average boresight between the UVOT, XRT, and STs shall be referred to as the NFI boresight.The BAT shall be co-aligned/measured to the defined NFI boresight to within 3 arc minutes on the ground. This alignment shall be measured during on-orbit calibrations to an accuracy of better than 3 arc minutes to calibrate out initial alignment, G-unloading, and launch shifts. Thermal and other long-term variations (between calibrations) of the BAT OB interface relative to the NFI OB interfaces occurring on orbit from any source shall be less than 1.0 arc minutes.

8.2.2.6 ACS Information Required On-orbit

8.2.2.6.1 All instruments shall be provided an attitude solution as described in section 6, which is accurate to 1.0 arc minutes during slews and to the level defined in the Swift MRD, 410.4-SPEC-0004 while settled on target.

8.2.2.6.2 UVOT and XRT require a pointing status message that indicates that the NFI boresight is at 10 arc minutes from the target, as listed in Table 23.

8.2.2.6.3 During normal operations, including during slews, attitude updates are provided to the instruments at a 5 Hz rate and are stored at a 0.1 Hz rate for later download. More detailed attitude information required for science processing shall be stored by the instruments within their science data.

8.2.2.6.4 Attitude and location information provided by the spacecraft to the instruments shall be in the form of a RA/DEC/ROLL, plus observatory latitude and longitude.

8.2.3 Measuring Alignment

8.2.3.1 Ground Alignment Requirements

Instruments and ACS components to be aligned as part of IM integration will be delivered with external optical references. Offsets of instrument/component boresight/coordinate systems with respect to its optical reference shall be delivered to GSFC.

Requirements for the ground placement and placement knowledge are listed in Table 41.

		Reference	Placement RSS(pitch, yaw)	Knowledge Error of Placement
8.2.3.1.1	BAT	NFI Boresight	1 degree	5 arc sec
8.2.3.1.2	XRT	UVOT	40 arc sec	5 arc sec
8.2.3.1.3	ST (2)	XRT Boresight	1 arc min	5 arc sec
8.2.3.1.4	IRU Assy	ST	1 arc min	10 arc sec
8.2.3.1.5	CSS on IM (2)	ST	2 deg	2 deg
8.2.3.1.6	Antennas on IM (2)	SC X-axis	5 deg	5 deg

Table 41 Ground Alignment Requirements

8.2.3.2 Alignment cube size, quality and location shall be specified on respective MICDs.

8.2.3.3 The UVOT and XRT cubes shall be plainly visible from the top of the instrument. The BAT, IRU, and star tracker alignment reference surfaces shall be plainly visible from the top and one side of the instrument. More than one cube can be utilized to meet the alignment cube visibility requirement.

8.2.3.4 The optical bench shall have one or more optical cubes installed to allow alignment shifts to be localized to a particular instrument.

8.2.3.5 Externally mounted alignment cubes shall have flight covers.

8.2.3.6 GSFC will provide the UVOT external reference and provide for measuring its alignment relative to the UVOT internal reference.

9 Ground Support Equipment

9.1 General

ITOS, the Integrated Test and Operations System, is a suite of computer software for controlling a satellite. See http://sunland.gsfc.nasa.gov/~tcw/ITOS/ for more information.

9.1.1 Spacecraft and observatory 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 Operations.

9.1.2 GSE shall be compatible with CCSDS versions as specified in IRD Section 11.

9.2 Mechanical GSE

Any 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.

9.2.1 Lifting Sling

In general, lifting slings shall be designed per NSS/GO 1740.9 to show positive margins using factors of safety (FOS) of 3 on yield and 5 on ultimate with respect to the design working load. Lifting slings shall be proof tested to a factor of twice the design working load. The flight hardware interface/attachment points shall use a tested FOS of 1.25 yield and 1.4 ultimate (untested FOS of 1.6 yld and 2.0 ult).

9.2.1.1 Instrument Module Lifting Sling

9.2.1.1.1 The instrument module shall provide a lifting sling capable of lifting the instrument module or the observatory.

9.2.1.1.2 The lift sling shall be designed to be stable for all lifting scenarios and satisfy NSI document 15-01-422 “Analysis Procedure for Spreader Bar Lift Stability”.

9.2.1.1.3 The sling shall be configured such that it can be installed and removed without disassembly.

9.2.1.2 Instrument Lifting Slings

9.2.1.2.1 Instrument shall provide lifting slings which accommodate a vertical integration onto the Optical Bench.

9.2.1.2.2 The 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”.

9.2.1.3 Handling Fixtures/Dollies

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

9.2.1.3.2 Stability analysis shall be performed on fixtures/dollies to verify turnover and move operations are safe.

9.2.1.3.3 Positive margins of safety shall be shown using factors of safety of 3 on yield and 5 on ultimate with respect to the design working load.

9.2.1.3.4 Fixture/dollies shall be proof loaded to twice the design working load.

9.3 Instrument EGSE

Instrument providers shall provide a list of their EGSE to the Project Office by mission CDR.

9.4 Spacecraft EGSE

9.4.1 The EGSE shall utilize the same grounding scheme as the spacecraft.

9.4.2 No single or double fault in the EGSE or its wire-harness shall cause damage to the spacecraft.

9.4.3 The spacecraft EGSE shall support orderly shutdown within 20 minutes, without damage to the spacecraft, instruments or EGSE in the event of unanticipated interruption of GSE AC power.

9.5 Spacecraft Simulators

9.5.1 Spectrum Astro shall provide 3 spacecraft interface simulators which meet the following general requirements:

a) Hi-Fidelity 1553 Bus Controller Simulation (as documented in the Product Functional Specification for the Spacecraft Simulator, Spectrum Astro 1143-EW-S20787).
b) Packet Commanding and Telemetry Interface
c) 1 PPS per IM ICD
d) ITOS User Interface

9.5.2 GSFC shall provide 3 power simulators.

9.6 Instrument Module Mechanical Interface Simulator

GSFC shall provide an IM simulator which matches the mechanical interface, mass, and center of gravity of the flight IM.

9.7 Instrument Components Mechanical Interface Simulator

Instrumenters shall provide an electronics box simulator which matches the mechanical interface and mass of all spacecraft bus mounted flight components.

10 Contamination

10.1 General

10.1.1 The instruments, spacecraft, and optics bench shall be designed to minimize contamination to and from external sources before, during, and after launch. They should also accommodate access for removal of pre-launch contamination.

10.1.2 The instrument providers shall develop contamination control plans (CCPs) which shall be approved by the Swift Project.

10.1.3 The spacecraft manufacturer and Optical Bench shall develop individual contamination control implementation plans (CCIPs) that account for all the contamination requirements specified in the instrument (CCPs) and submit for approval by the Swift Project.

10.1.4 Spacecraft (including solar arrays) to instrument and instrument cross-contamination shall be controlled in compliance with the overall Swift Contamination Control Master Plan, Document 410.4-PLAN-0003.

10.2 Venting

10.2.1 Instrument and spacecraft vent locations and paths shall be provided to the Swift Project and defined in the applicable contamination control plan.

10.2.2 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 Covers

10.3.1 Contamination-sensitive surfaces, which require protective covers during I&T and pre-launch activities, shall be defined in the applicable CCP or CCIP.

10.3.2 The hardware provider shall furnish any protective covers required. The covers must be compatible with the Observatory contamination control requirements specified in 410.4-PLAN-0003. Temporary protective covers must be easily removed for tests and launch configurations.

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

10.4 Purges

UVOT and XRT shall specify their purge requirements in the applicable contamination control plans. The purge port locations 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.

10.5 Integration and Test Environments

10.5.1 To minimize particulate contamination during integration and testing, assembled flight hardware shall be maintained in a clean environment equivalent to Class 10,000. 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.

10.5.2 The instruments and spacecraft must be able to withstand temperatures between 15-20°C and relative humidity levels between 30-50%. In addition:

a) XRT and UVOT require Class 1000 clean rooms for operations in which mirrors are exposed or the cryostat door is open.
b) XRT and UVOT require Class 10,000 clean rooms and purges for operations in which mirrors are covered.
c) XRT and UVOT shall be double or triple bagged and purged when conditions exceed Class 10,000.

10.5.3 The acoustic and vibration test facilities at GSFC are not Class 10,000 facilities. Precautions shall be taken to minimize instrument and Observatory surface cleanliness levels.

10.5.4 The thermal vacuum chamber during Observatory level thermal vacuum and thermal balance testing shall be run as a Class 10,000 clean room for pre-test and post-test operations.

10.5.5 The XRT and 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.

10.6 Outgassing

There shall be negligible degradation of instrument 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.

10.6.1 Spacecraft and instrument non-metallic materials shall be screened using ASTM E 595-93 data. The materials shall not have a total mass loss (TML) of 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.

10.6.2 Spacecraft to instrument contamination and instrument cross contamination shall be controlled in accordance with the Swift Contamination Control Master Plan, Document 410.4-PLAN-0003.

10.7 Parts and Subassemblies Bake-out

10.7.1 Thermal vacuum bake-out of instrument and spacecraft 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 instrument certification requirements specified in the applicable contamination control plan. The parameters (e.g., verification method, temperature, test duration, pressure) of such back-outs must be individualized depending on materials used, the fabrication environment, and the established contamination allowance.

10.7.2 The bake-out parameters shall be documented in the individual instrument or spacecraft Contamination Control Plan. It is highly recommended that all subassembly bake-outs be monitored with temperature controlled quartz crystal microbalances (TQCMs).

10.8 Instrument and Observatory Contamination Certification Requirements

In order to minimize cross contamination between the instruments and observatory sensitive surfaces, each instrument, the spacecraft bus, and the optical bench, regardless of its contamination sensitivity, must meet the following minimum cleanliness requirements.

10.8.1 Particulate Contamination

The external surfaces of the instruments, spacecraft, and optical bench shall be 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 visually inspected with a high intensity white and black light from a distance of 15 to 30 cm (6-12 inches). These surfaces shall be free of visible particles. Particles shall be removed as specified by the hardware provider.

10.8.2 Molecular Contamination

At delivery, the external surfaces of the instruments, spacecraft bus, and optical bench shall be verified to be less than +2.0 mg/0.1 m^2 . This shall be done using a Solvent Wash method. A small representative section of the instrument'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 instrument of spacecraft provider.

10.8.3 Outgassing

10.8.3.1 The instruments, spacecraft (including solar arrays), and optical bench shall have undergone assembly bakeouts, if applicable, to preclude cross-contamination during the Swift Observatory Thermal Vacuum and Thermal Balance tests and on-orbit operations. An Observatory system level outgassing rate will be measured during these test.

10.8.3.2 These outgassing levels shall be specified in the Swift Contamination Control Master Plan, Document 410.4-PLAN-0003.

10.8.3.3 The instruments, spacecraft, and optical bench shall provide interfaces, which allow verification of the outgassing rate using a Temperature-Controlled Quartz Crystal Microbalance (TQCM).

10.9 Cleaning Requirements

10.9.1 The instrument support team shall be responsible for cleaning their respective instrument during Optical Bench integration, IM activities, Observatory integration and testing and launch site activities.

10.9.2 The spacecraft support team shall be responsible for cleaning the spacecraft and solar arrays during integration and testing and launch site activities.

11 Operational Interfaces

11.1 Ground Communications

11.1.1 For ground station communications, the spacecraft shall downlink telemetry data at 2.25 Mbps, and receive command data at 2kbps, including all overhead.

11.1.2 For TDRSS communications, the spacecraft shall support downlinking of telemetry at up to 8 kbps, with a minimum of 1 kbps, and receipt of command data at 125 bps.

11.1.3 The spacecraft shall use CCSDS Version 2 (Advanced Orbiting Systems) Virtual Channel Data Units (VCDUs) for the transfer frames, etc., and CCSDS Version 1 source packets for telecommands.

11.2 On-Board Data Recording

11.2.1 The spacecraft and instruments generate housekeeping telemetry packets that are recorded on-board for later transmission to the ground, and are transmitted in real-time during contacts with the ground. These science and instrument housekeeping packets are merged into the observatory housekeeping stream.

11.2.2 The instruments also generate higher rate science and engineering packets that are recorded on-board, separate from the observatory housekeeping packet stream. These packets are never transmitted to the ground in real-time.

11.2.3 The spacecraft shall provide the ability to store all instrument housekeeping, science, and engineering data in 4 separate virtual recorders that can be individually controlled and monitored by the ground. The determination of which data is routed to which virtual recorder shall be determined on-board by CCSDS application ids.

11.2.4 Instrument housekeeping data shall be routed for real-time downlink as well as for storage and playback. Instrument science/engineering data shall be routed for storage and playback only.

11.2.5 The storage allocation for all virtual recorders shall at a minimum meet the combined average data rates for each instrument for 24 hours. The storage allocation for each virtual recorder assigned to an individual instrument shall at a minimum meet the average data rates for that instrument for 24 hours. Real time instrument housekeeping data requirements are specified in section 5.3.2. Additional detail is provided in the MIL Standard 1553 Bus ICD.

11.3 Recorder Playback

11.3.1 The spacecraft shall playback data from each virtual recorder over a separate virtual channel.

11.3.2 All real-time housekeeping data shall be sent to the ground on a single CCSDS virtual channel as the highest priority transmission (i.e., not affected by the dumping of housekeeping or science/engineering data).

11.3.3 The spacecraft shall downlink stored housekeeping data with a higher priority than stored science data.

11.3.4 Virtual recorder dump status shall provide adequate information for the ground to determine the completeness of the dumps and request frame selectable retransmissions of stored data by virtual channel. The spacecraft shall provide at a minimum the following frame-level information on the status and progress of the virtual recorder dumps, separately for each virtual recorder, in the real-time housekeeping data: telemetry storage enable status, downlink enable status, number of stored frames, last read frame pointer, last write frame pointer, downlink read frame pointer, downlink frames remaining, and total frames downlinked beginning with transmitter turn-on.

11.3.5 The spacecraft shall provide the ability for the ground to retransmit any stored data that was not received successfully on the initial downlink (i.e., full or partial redump).

11.3.6 The spacecraft shall provide an independent playback command buffer for each virtual recorder. The playback command buffer shall contain both playback and redump commands. Buffered playback/redump commands shall be prioritized based on the order in which the commands were issued. The spacecraft shall execute each buffered playback/redump command when the previous playback/redump operation completes. Playback completion shall be determined as follows: for new data (no playback command previously issued), playback shall complete when the read pointer equals the write pointer at the start of the playback; for redumps, playback shall complete when the number of frames requested for the redump has been dumped. All buffered playback and redump commands for a virtual recorder shall be flushed with a transponder off sequence or a virtual recorder playback stop command.

11.4 Operations Considerations

The observatory shall be capable of carrying out a normal sequence of science observations without ground commands for 72 hours.

Appendix A. Acronym List

ACS	Attitude Control System
ASTM	American Society for Testing and Materials
BAT	Burst Alert Telescope
C&DH	Command and Data Handling
c.g.	center of gravity
CCD	Charge Coupled Device
CCSDS	Consultative Committee for Space Data Systems
CCU	Charge Control Unit
COTS	Commercial Off the Shelf
CSS	Coarse Sun Sensor
CVCM	Collected Volatile Condensable Materials
D.A.	Double Amplitude
dB	decibel
DEM	Digital Electronics Module
DOF	Degrees Of Freedom
DPU	Data Processing Unit
DWG	drawing
EGSE	Electrical GSE
EICD	Electrical ICD
ELV	Expendable Launch Vehicle
FEM	Finite Element Model
FoM	Figure of Merit
FOV	Field of View
FS	Factor of Safety
GCN	GRB Coordinates Network
GEVS-SE	General Environmental Verification Specification for STS and ELV Payloads, Subsystems, and Components
GLAST	Gamma ray Large Area Space Telescope
GRB	Gamma Ray Burst
grms	Gravity root mean square
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
Hz	Hertz
HRS	Heat Rejection System
I&T	Integration and Test
I/F	Interface
ICD	Interface Control Drawing
ICU	Instrument Control Unit
IIRD	Instrument Interface Requirements Document
IM	Instrument Module
IMU	Inertial Measurement Unit
IRU	Inertial Reference Unit

ITOS	Integrated Test and Operations System
Kbps	kilo-bits per second
LOS	Line of Sight
Mbps	Mega-bits per second
MCS	Mechanical Systems Center
MECO	Main Engineer Cut Off
MICD	Mechanical Interface Control Drawing
MLI	Multi-Layer Insulation
MOC	Mission Operations Center
MS	Margin of Safety
MSS	Maximum Steady State
N/A	Not Applicable
NASTRAN	NASA Structural Analysis
NCC	Network Control Center (GSFC)
NEC	National Electric Code
NFI	Narrow Field Instruments
NFPA	National Fire Protection Association
NTE	Not To Exceed
OB	Optical Bench
oct	octave
Pa	Pascals
PDU	Power Distribution Unit
PFS	Product Functional Specification
pps	pulse per second
PSU	Pennsylvania State University
QVCM	Quarts Crystal Microbalance
RLG	Ring Laser Gyro
RT	Remote Terminal
S/C	Spacecraft
SAA	South Atlantic Anomaly
ST	Star Tracker
STS	Space Transportation System
TBC	To Be Confirmed
TBD	To Be Determined
TBR	To Be Reviewed
TDRSS	Tracking and Data Relay Satellite System
TICD	Thermal ICD
TID	Total Ionizing Dose
TML	Total Mass Loss
ToO	Target of Opportunity
UTC	Universal Time Coordinated
UVOT	UV/Optical Telescope
WSC	White Sands Complex
XRT	X-ray Telescope