410.4-SPEC-0004

# Swift Mission Requirements Document

Version 2.4

November 14, 2002

NASA Goddard Space Flight Center

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## CHANGE DISPOSITION AND REVISION

| REVISION/ CHANGE NUMBER | DESCRIPTION | EFFECTIVE DATE |
|---|---|---|
| 1.0 | Original Release with Spacecraft Contract | 22-Jul-99 |
| 2.0 | Incorporated changes CCRs 410.4-9, 410.4-12 and 410.4-13 | 09-Jan-01 |
| 2.1 | Incorporated changes CCR 410.4-25 AND CCR 410.4-27 | 28-Jun-01 |
| 2.2 | Incorporated changes from CCRs 410.4-67, 68, 82 | 09-Oct-01 |
| 2.3 | Incorporated changes from CCR 410.4-97 | 26-Feb-02 |
| 2.4 | Incorporated changes from CCR 410.4-111 | 14-Nov-02 |
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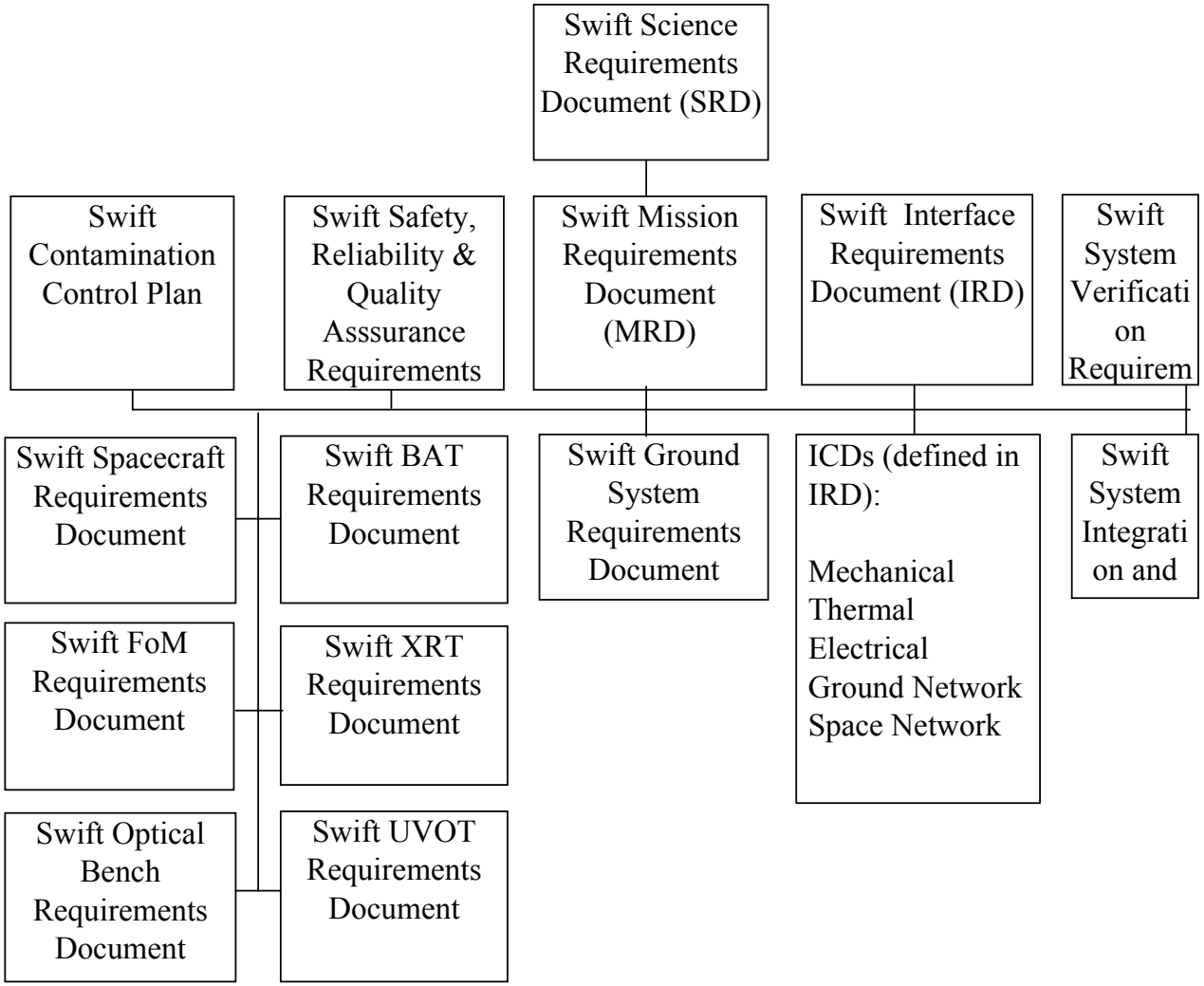
# Swift Project Level Documents



# Swift Mission Requirements Document

| | | Functional | Value | Source | Comments | Element/ Subsystem |
|---|---|---|---|---|---|---|
| 1 | **Introduction** | | | | | |
| 1.1 | **Scope** | This document establishes the science and mission requirements for the Swift Mission. Section 2 contains applicable documents, including the document hierarchy. Section 3 contains the science requirements. Section 4 contains the derived and programmatic mission requirements on the Swift Project, instruments, spacecraft , mission operations, and ground segment. | | | | |
| 1.2 | **Mission Objectives** | Swift is an observatory designed to provide multi-wavelength observations of gamma-ray bursts. The powerful combination of onboard telescopes (gamma-ray, X-ray, and UV/optical) and the capability to slew to a gamma-ray burst (GRB) position within 10s of seconds make Swift the ideal mission for unraveling the gamma-ray burst mystery. In particular Swift will:<br><br>- Probe the sites and nature of GRB progenitors<br>- Explore the local environment near GRBs<br>- Pioneer the use of GRBs as probes of the early Universe<br>- Provide a sensitive all-sky hard X-ray survey<br><br>This is accomplished through a complementary set of co-aligned telescopes. The Burst Alert Telescope (BAT) operating from 15-150 keV provides the primary GRB trigger and an all-sky hard X-ray survey. The BAT has a large field-of-view (2 sr half-coded). The X-Ray Telescope (XRT) allows extended spectral coverage from 0.3 – 10 keV and provides 5 arcsec positions. Positional information down to 0.3 arcsec is then calculated through the observations of the UV & Optical Telescope (UVOT) which is sensitive from 170-650 nm. | | | | |
| 2 | **Applicable Documents** | | | | | |

# Swift Mission Requirements Document

| | | Functional | Value | Source | Comments | Element/ Subsystem |
|---|---|---|---|---|---|---|
| | Document Hierarchy | Unless otherwise stated in this document, all inconsistencies shall be resolved in the following order:<br>1. Swift Science Requirements Document<br>2. Swift Mission Requirements Document<br>3. Swift Interface Requirements Document<br>4. Swift Safety, Reliability and Quality Assurance Requirements<br>5. Swift Verification Plan and Environmental Specifications | | | | |
| 3 | **Science Requirements** | | | | | n/a |
| 3.1 | GRB database with good statistics | | | | | n/a |
| 3.1.1 | | Number of GRBs detected per year by BAT [1] | > 150 [2] | SRD 1.1 | | BAT |
| 3.1.2 | | Capability to efficiently detect short (<0.1 s) and long (100 s) GRBs by BAT (burst trigger requirement) [3] | | SRD 1.2 | | BAT |
| 3.1.3 | | Low energy threshold to discover soft GRBs by BAT (keV) | < 15 [4] | SRD 1.3 | | BAT |
| 3.1.4 | | GRB detection sensitivity by BAT (improvement rel. to BATSE) | > 5X [5] | SRD 1.4 | | BAT |
| 3.1.5 | | Percentage of newly detected GRBs with XRT/UVOT follow-up [6] | > 80 | SRD 1.5 | | FoM, GND |
| 3.1.6 | | Number of afterglow observations with >5000 s duration [1] | > 100 | SRD 1.6 | | GND |

| Swift Mission Requirements Document | | | | | | |
|---|---|---|---|---|---|---|
| | | **Functional** | **Value** | **Source** | **Comments** | **Element/ Subsystem** |
| 3.1.7 | | Partially-coded FOV size for detecting rare GRBs by BAT (sr) | > 2.0 [7] | SRD 1.7 | | BAT |

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|---|---|---|---|---|---|---|
| 3.1.8 | | Percent deadtime for BBOY for BAT [8] | < 20 | SRD 1.8 | | BAT |
| 3.1.9 | | Capability to produce good (~5 arcmin) positions even for BBOY by BAT | | SRD 1.9 | | BAT |
| 3.1.10 | | Percentage of events stored on-board for highest fluence burst of year by BAT [9] | > 95 | SRD 1.10 | | BAT |
| 3.2 | Rapid identification of counterparts | | | | | n/a |
| 3.2.1 | | GRB rapid position time available on the ground from BAT (s) | < 20 [10] | SRD 2.1 | MRD 4.5 - GRB Message Timing Allocations | BAT, FoM, S/C, GND, GCN |
| 3.2.2 | | GRB rapid position absolute accuracy by BAT (arcmin) | < 5 [11] | SRD 2.2 | MRD 4.6 - BAT GRB Position Error Budget | BAT, S/C, OB, XRT |
| 3.2.3 | | GRB X-ray position time available on the ground from XRT (s) | < 100 [12] | SRD 2.3 | MRD 4.5 - GRB Message Timing Allocations | XRT, FoM, S/C, GND, GCN |
| 3.2.4 | | GRB X-ray position absolute accuracy by XRT (arcsec) | < 5 [13] | SRD 2.4 | MRD 4.7 - XRT GRB Position Error Budget | -XRT, S/C |
| 3.2.5 | | GRB optical finding chart time available on the ground from UVOT (s) | < 270 [14] | SRD 2.5 | MRD 4.5 - GRB Message Timing Allocations | UVOT, S/C, GND, GCN |
| 3.2.6 | | GRB optical finding chart position accuracy for relative astrometry (arcsec) | < 0.3 [15] | SRD 2.6 | | UVOT |
| 3.2.7 | | GRB rapid spacecraft slew time for 80% of slews less than 50° | < 75 [16] | SRD 2.7 | | S/C |
| 3.3 | Measure distances (redshifts) for GRBs | | | | | n/a |
| 3.3.1 | | GRB X-ray energy resolution by XRT (eV at 6 keV at launch +3 yrs) | < 400 [17] | SRD 3.1 | | XRT |
| 3.3.2 | | GRB UV/optical resolving power by UVOT GRISM ( $\lambda/\Delta\lambda$ at 300 nm for V<17) | > 300 | SRD 3.2 | | UVOT |

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| | | Functional | Value | Source | Comments | Element/ Subsystem |
|---|---|---|---|---|---|---|
| 3.4 | Study GRB lightcurve evolution | | | | | n/a |
| 3.4.1 | | GRB X-ray integral sensitivity by XRT from 0.2–10 keV ($10^{-14}$ erg cm$^{-2}$ s$^{-1}$ in $10^4$ s) | < 2 [18] | SRD 4.1 | | XRT |
| 3.4.2 | | GRB UV/optical sensitivity by UVOT (blue magnitude in 1000 s with open filter) | > 24 [19] | SRD 4.2 | | UVOT |
| 3.4.3 | | Long wavelength limit to cover optical band by UVOT (nm) | 600 | SRD 4.3 | | UVOT |
| 3.4.4 | | Short wavelength limit to cover UV band by UVOT (nm) | 170 | SRD 4.4 | | UVOT |
| 3.4.5 | | Total number of minutes of data storage capability before and after a GRB by BAT (min) | > 10 | SRD 4.5 | | BAT |
| 3.4.6 | | Capability to modify automated on-board observing program | | SRD 4.6 | | FoM, GND |
| 3.4.7 | | Prompt upload capability for GRBs & transients discovered by other missions | | SRD 4.7 | | FoM, GND |
| 3.4.8 | | Observing program upload capability for follow-up observations of GRBs & transients | | SRD 4.8 | | FoM, GND |
| 3.4.9 | | Continuous monitoring of hard X-ray lightcurve during GRB observation by BAT, including slew | | SRD 4.9 | | BAT |
| 3.5 | Hard X-ray survey | | | | | n/a |
| 3.5.1 | | Hard X-ray survey sensitivity by BAT (mCrab at high galactic latitude in 1 yr. at 20 keV) | < 0.6 [20] | SRD 5.1 | | BAT |
| 3.5.2 | | Hard X-ray survey uniformity by BAT (ksec per yr exposure for minimum point on sky) | >1000 | SRD 5.2 | This is a goal, not a requirement. | BAT, GND |

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| | | Functional | Value | Source | Comments | Element/ Subsystem |
|---|---|---|---|---|---|---|
| 3.5.3 | | Hard X-ray average detector energy resolution (keV at 60 keV at launch +2 years) | < 7 [21] | SRD 5.3 | | BAT |
| 3.5.4 | | High energy limit to cover hard X-ray diffuse peak by BAT (keV) | > 120 | SRD 5.4 | | BAT |
| 3.6 | Transient observations | | | | | n/a |
| 3.6.1 | | Hard X-ray transient detection sensitivity by BAT (mCrab at high galactic latitude in 1 day at 20 keV) | < 20 | SRD 6.1 | | BAT |
| 3.6.2 | | Sky coverage for transient monitoring by BAT (% of sky covered per day) | | SRD 6.2 | Goal is >80% | BAT |
| 3.6.3 | | Bright X-ray source intensity capability by XRT (Crab) | > 15 | SRD 6.3 | | XRT |
| 3.6.4 | | Ground system reaction time to ToO's (hrs) [22] | < 2 | SRD 6.4 | | FoM, GND |
| 3.7 | Data quality and mission success | | | | | n/a |
| 3.7.1 | | Absolute time accuracy reconstructed on-ground (ms) | < 0.2 | SRD 7.1 | Sub-allocation required | S/C, GND |
| 3.7.2 | | Absolute time accuracy on-board (ms) | < 1.0 | SRD 7.2 | | |
| 3.7.3 | | Time tagging accuracy relative to spacecraft clock by BAT (ms) | < 0.1 | SRD 7.3 | | BAT |
| 3.7.4 | | Time tagging accuracy relative to spacecraft clock by XRT (ms) [23] | < 10 | SRD 7.4 | | XRT |
| 3.7.5 | | Time tagging accuracy relative to spacecraft clock by UVOT (ms) [24] | < 20 | SRD 7.5 | | UVOT |
| 3.7.6 | | Spacecraft position knowledge reconstructed on ground (km) | < 30 | SRD 7.6 | | GND |
| 3.7.7 | | Spacecraft position knowledge on board (km) | < 50 | SRD 7.7 | | |

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|---|---|---|---|---|---|---|
| | | **Functional** | **Value** | **Source** | **Comments** | **Element/ Subsystem** |
| 3.7.8 | | End-to-end data loss (%) [25] | < 10 | SRD 7.8 | Sub-allocation required | All |
| 3.7.9 | | Observing efficiency outside SAA (%) | >80 | SRD 7.9 | | |
| 3.7.10 | | Mission life (yr) | > 2 [26] | SRD 7.10 | | All |

| Swift Mission Requirements Document | | | | | | |
|---|---|---|---|---|---|---|
| | | **Functional** | **Value** | **Source** | **Comments** | **Element/ Subsystem** |

NOTES:
1. Range of GRBs per year is due to range of possible longN-logS extrapolations below BATSE threshold.
2. Phase A Report Fact Sheet
3. Phase A Report Fact Sheet p. 12
4. Phase A Report Fact Sheet, modified from 10 keV to 15 keV
5. Phase A Report Fact Sheet
6. Assuming only GRBs available within instrument and pointing constraints
7. Phase A Report Fact Sheet (error in Phase A: baseline fully-coded is ~1.5 sr, not 2.5 sr in Phase A; baseline partially-coded is 2.5 sr.)
8. BBOY = Brightest Burst Of Year = 68 photons/cm^2-s in 10-150 keV range
9. Highest fluence burst of year = 4x10^6 photons in 10-150 keV range
10. Phase A Report Fact Sheet, modified from 12 s to 20 s. From GRB trigger to end of GCN processing time.
11. Phase A Report Table 3.1.5.4(b), 99% confidence radius assuming 8 sigma BAT detection (p. 18)
12. Phase A Report Fact Sheet, modified slightly from 96 s to 100 s
13. Phase A Report Table 3.1.5.4(b), 99% confidence radius, for 0.2-15 Crab X-ray brightness
14. Phase A Report Table 3.1.5.4a, assuming UVOT observation is allowed by constraints
15. Phase A Report Fact Sheet
16. Phase A Report Fact Sheet, modified from 60 s to 75 s. Up to 160 s may be needed for the worst case roll maneuvers required.
17. Phase A Report p. 66
18. Phase A Report Fact Sheet
19. Phase A Report Fact Sheet
20. Phase A Report p. 14
21. Phase A Report Figure 1.2.2(a)
22. Reaction time from receipt of data indicating an exceptionally interesting transient to the upload of a new observing program
23. Timing mode data
24. Event mode data
25. Applies separately to TDRSS and Malindi data.

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26. Phase A Report p. 3. Modified from 3 to 2 years at meeting with OSS Board of Directors on Nov. 28, 2001.

| Swift Mission Requirements Document | | | | | | |
|---|---|---|---|---|---|---|
| | | **Functional** | **Value** | **Source** | **Comments** | **Element/ Subsystem** |
| 4 | **Mission Requirements** | | | | | n/a |
| 4.1 | **Launch/orbit/lifetime** | | | | | n/a |
| 4.1.1 | Launch Vehicle | The observatory shall be launched on a Delta class launch vehicle. | | Project | | LV |
| 4.1.2 | Launch Site | The observatory shall be launched from the Eastern Test Range (ETR) | | Project | | LV |
| 4.1.3 | Launch Date | The launch date shall be no later than September 30, 2003. | | Project | Original MRD 1.2 stated June 30, 2003 as launch date. | LV, All |
| 4.1.4 | Launch Window | There are no launch window requirements driven by scientific requirements. | | Project | Original MRD 1.3 | LV |
| 4.1.5 | Mission Lifetime | Swift shall be designed for a mission lifetime of 2 years, which includes a 30 day on-orbit checkout. | >=2 years | SRD 7.10 | Original MRD 1.1 | All |
| 4.1.6 | Autonomous Operations | The mission shall be designed for autonomous operations for at least 72 hours without human intervention. | | Project | | All |
| 4.1.7 | Orbit Altitude | | 600 km ±20 km | Project | Mission design shall not preclude operations within these altitudes. Original MRD 1.4 says altitude must be less than 600 km. | LV |
| 4.1.8 | Orbit Inclination | | 22°+1/ -7° | Project | Mission design shall not preclude operations within these inclinations. Origianl MRD 1.5 says inclination must be less than 28.5°. | LV |

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|---|---|---|---|---|---|---|
| | | **Functional** | **Value** | **Source** | **Comments** | **Element/ Subsystem** |
| 4.2 | **Safety, Reliability & Quality Assurance Requirements** | | | | | n/a |
| 4.2.1 | **Performance Assurance Implementation Plan** | The developer shall provide a quality plan in accordance with the requirements of 410.4-SPEC-0001 "Swift SR&QA Requirements (MAR)." | | 410.4-SPEC-0001 | | Instruments, FoM, OB, S/C |
| 4.2.2 | Quality Assurance | The developer shall meet the requirements for workmanship, failure reporting, and reviews as specified in the MAR. | | 410.4-SPEC-0001 | | Instruments, FoM, OB, S/C |
| 4.2.3 | Safety | The developer shall plan and implement a system safety program as specified in the MAR. | | 410.4-SPEC-0001 | | Instruments, FoM, OB, S/C |
| 4.2.4 | Design Assurance | The developer shall plan and implement parts, materials, reliability, and software assurance programs as specified in the MAR. | | 410.4-SPEC-0001 | | Instruments, FoM, OB, S/C |
| 4.2.5 | Verification | The developer will conduct a verification program to ensure that systems meet their specified performance requirements. | | 410.4-SPEC-0001 | | All |
| 4.2.6 | Nonconformance Documentation and Control | The developer shall provide a program for nonconformance documentation and control as specified in the MAR. | | 410.4-SPEC-0001 | | Instruments, FoM, OB, S/C |
| 4.3 | **Interface Requirements** | The developer shall provide a system which meets the requirements of 410.4-ICD-0001, the Swift Interface Requirements Document (IRD). | | Project | | All |
| 4.4 | **Reserved** | | | | | |

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| | | **Functional** | **Value** | **Source** | **Comments** | **Element/ Subsystem** |
| 4.5 | **GRB Message Timing Allocations** | Swift subsystems shall be designed to meet the "End-to-End" Timing Requirements as specified in EB1 - Burst Alert Timing Budget [1] | See EB1 - Swift Burst Alert Timing Budget | SRD 2.1<br>SRD 2.3<br>SRD 2.5<br>Project | | All |
| 4.6 | **BAT GRB Position Error Budget** | Swift subsystems shall be designed to meet requirements as specified in EB2 - BAT GRB Position Error Budget | See EB2 - BAT GRB Position Error Budget | SRD 2.2 | | BAT, OB, S/C |
| 4.7 | **XRT GRB Position Error Budget** | Swift subsystems shall be designed to meet requirements as specified in EB3 -XRT GRB Position Error Budget | **See EB3- XRT GRB Position Error Budget** | SRD 2.4 | | XRT, OB, S/C |
| 4.8 | **Reserved** | | | | | n/a |
| 4.9 | **Figure of Merit Performance Requirements** | | | | | n/a |
| 4.9.1 | Time Delay Due to FoM Processing | The FoM shall minimize time delay to slew to a new burst (design goal is <0.4 seconds for FoM processing). | See EB1 - Swift Burst Alert Timing Budget | SRD 2.1 | | FoM |

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| | | **Functional** | **Value** | **Source** | **Comments** | **Element/ Subsystem** |
| 4.9.2 | Observing efficiency | The FoM will not significantly degrade the observation of GRB afterglows by Swift. The predicted number of XRT afterglow photons shall be greater than 80% of the total predicted for an optimally efficient system. | | SRD 1.5 | This requirement will be verified by analysis. | FoM |
| 4.9.3 | Multi-orbit Observations | The FoM shall allow for multi-orbit automated observations of new BAT source locations to maximize the NFI observing efficiency during the critical early phase of the afterglow. | | SRD 1.5 | | FoM |
| 4.9.4 | Maximize Observing Time | The FoM shall allow for maximizing the observing time devoted to the uploaded program whenever an automated target is not being observed. | | SRD 1.5 | | FoM |
| 4.9.5 | Automated Termination of Observations | The FoM shall allow for automated termination of automated observing of a target at the completion of a predetermined observing strategy | | SRD 1.5 | | FoM |
| 4.9.6 | Override Automated Observations via Upload | The FoM shall allow for pre-specified uploaded observations to override automated observations | | SRD 1.5 | | FoM |
| 4.9.7 | Uploaded Automated Observations | The FoM shall allow for automated observations triggered by TDRSS commands | | SRD 1.5 | | FoM |
| 4.9.8 | Override Automated Observations | The FoM shall allow for the current automated target to override new GRBs based on input from the instruments. | | SRD 1.5 | | FoM |

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|---|---|---|---|---|---|---|
| | | **Functional** | **Value** | **Source** | **Comments** | **Element/ Subsystem** |
| 4.9.9 | Override Automated Observations via NFI Input | The FoM shall allow for extension of the automated observing time based on input from the NFIs. | | SRD 1.9 | This is not a requirement on the NFIs. | FoM |

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| 4.9.10 | Adjustment of Observing Time | The FoM shall allow for adjustment of the fraction of observing time allocated to the automated and uploaded programs for extended automated observations | | SRD 4.7 | | FoM |
| 4.9.11 | Termination of Observations by TDRSS | The FoM shall allow for termination of automated target observations by command from the ground. | | SRD 1.5 | | FoM |
| 4.9.12 | Accommodate New Observing Strategies | The FoM shall allow for a workable mechanism to implement new automated observing strategies after launch. | | SRD 1.5 | | FoM |
| 4.9.13 | Disable Slew Requests | The FoM shall have the capability to disable slew requests to the S/C by command. | | SRD 4.6 | | FoM |
| 4.10 | **Spacecraft Performance Requirements** | | | | | n/a |
| 4.10.1 | **Interface Requirements** | The spacecraft bus shall meet the interface requirements as specified in the Swift Interface Requirements Document (410.4-ICD-0001) | | Project | Original MRD 2.1 | S/C |
| 4.10.2 | **Mass** | Spacecraft Bus mass shall not exceed 660.0 kg. | | Project | Original MRD 2.2 Includes spacecraft components mounted to the optical bench | S/C |
| 4.10.3 | **Mass Margin** | This section was deleted per CCR 410.4-82 | | Project | Original MRD 2.3 | S/C |

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| 4.10.4 | **Power** | Spacecraft Bus solar array shall produce 2215 W (EOL), orbit average power, for the orbit specified above. | | Project | Original MRD 2.4 | S/C |
| 4.10.5 | **Bus Power** | Spacecraft Bus subsystems (not including battery charging) shall consume no more than 450 W, orbital average power, including contingency. | | Project | Original MRD 2.5 | S/C |
| 4.10.6 | **Power Margin** | Bus Power Contingency of 47.4 Watts (included in the 450 W above) shall be sub-allotted for spacecraft bus use only. Spectrum shall manage the allotted power contingency internally and will provide to the Swift Team the current best estimate of bus power on a timely basis. | | Project | Original MRD 2.6 | S/C |
| 4.10.7 | **Bus Data Volume** | Downlinked spacecraft bus housekeeping shall have a real-time telemetry rate of less than 45 kbps, and an average daily stored telemetry rate of less than 1 kbps. | | Project | Original MRD 2.7 was at 400 Mbits/day. | S/C |
| 4.10.8 | **Link Margins - STDN** | Spacecraft and RF ground station design shall provide RF link margins of at least 3dB on all downlinks, and at least 5dB on all command uplinks. | | Project | | S/C, GND |
| 4.10.9 | **Link Margins - TDRSS** | Spacecraft shall provide RF link margins of at least 1dB on all TDRSS downlinks, and at least 1dB on all TDRSS command uplinks. Link margins shall be calculated using the Communication Link Analysis and Simulation System (CLASS) at GSFC. | | Project | | S/C, GND |

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| 4.10.10 | **Command & Telemetry Database** | The spacecraft shall define and manage the contents of the observatory telemetry and command database, with required inputs from the instrument teams. The database shall be used through I&T, and transitioned to the MOC prior to launch. | | Project | | S/C, GND, BAT, XRT, UVOT |
| 4.10.11 | **Spacecraft Epoch Time** | The spacecraft clock shall represent the elasped time in sections from the beginning of calendar year 2001. | | Project | | S/C,GND |
| 4.11 | **Ground System** | | | Project | | n/a |
| 4.11.1 | **Compatibility with I&T operations.** | The MOC shall use a telemetry and command processing system that is compatible with the system used for observatory I&T. | | Project | | GND |
| 4.11.2 | **Command & Telemetry Data base Ingest** | The ground segment shall have the capability to ingest, validate and use the observatory telemetry and command data base provided by the spacecraft vendor. | | Project | | GND |
| 4.11.3 | **Command & Telemetry Database** | The MOC shall maintain the flight Command & Telemetry database based on the observatory I&T database. | | Project | | S/C, GND, BAT, XRT, UVOT |
| 4.11.4 | **Level 0 Processing** | The MOC shall receive the raw science telemetry data from the observatory , generate the associated quick-look and production level 0 science data products, and deliver them to the Swift Data Center. | | Project | | GND |
| 4.11.5 | **History Log and Data Retrieval** | The MOC shall maintain a history log of all commands sent to the observatory, a log of telemetry completeness, and have the capability to retrieve the data as needed for analysis. | | Project | | GND |

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| 4.11.6 | **Autonomous Burst Alert Message Processing** | The MOC shall provide the capability to autonomously receive and process alert messages from the observatory , including Burst Alert Messages and spacecraft alert messages. | | Project | | GND |
| 4.11.7 | **Operations** | The Mission Operations Center (MOC) shall have the capability to support mission operations 24 hours per day, 7 days per week. | | Project | After the early orbit operational checkout is complete (approximately 30 days), planned staffing of the MOC is 8 hours a day, 5 days a week. | GND |
| 4.11.8 | **Automated Operations - Command and Telemetry** | The MOC shall support fully automated ground station pass execution, including command uploads and playback of recorded data. | | Project | | GND |
| 4.11.9 | **Automated Operations - Health and Safety** | The MOC shall have the capability to autonomously determine satellite and instrument health & safety status through automated housekeeping data analysis. | | SRD 2.2 | | GND |
| 4.11.10 | **Automated Operations - Paging Operators** | The MOC shall have the capability to autonomously page an operator for satellite or instrument emergencies or other mission operations anamolies, such as a missed ground station pass during the off-shift. | | Project | | GND |
| 4.11.11 | **Deleted** | | | | | |
| 4.11.12 | **Automated Operations - Manual Override** | The MOC shall have the capability to process and display real-time housekeeping and engineering telemetry and to generate and transmit real-time commands. | | Project | | GND |

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| 4.11.13 | **Recovery from Ground System Failures** | The MOC shall have the capability to recover from any internal hardware failure and return to operations within 12 hours. | | Project | | GND |
| 4.11.14 | **Flight Dynamics Functions** | After launch and early orbit operations, the MOC shall perform all flight dynamics functions required to support the Swift mission, including attitude determination and orbit analysis . | | Project | | |
| 4.11.15 | **Spacecraft Clock Maintanence** | The ground segment shall maintain knowledge of the spacecraft clock to within 0.2 milliseconds of UTC. | | SRD 7.1 | | GND |
| 4.11.16 | **Flight Software Updates** | The spacecraft, instrument, and ground segment shall support the capability to update the onboard flight software post-launch. | | Project | | S/C, GND, BAT, XRT, UVOT |
| 4.11.17 | **Flight Software Maintenance - Instruments** | The instrument providers shall maintain facilities and expertise for the development and validation of Swift instrument flight software updates and the maintenance of instrument flight software for the duration of the mission. | | Project | | BAT, XRT, UVOT |
| 4.11.18 | **Spacecraft Mission Planning** | The MOC shall perform all spacecraft mission-planning and scheduling functions. | | SRD 7.1 | | GND |
| 4.11.19 | **Instrument Operational Planning** | The MOC shall perform instrument operational mission planning and scheduling functions. | | Project | | GND |
| 4.11.20 | **ToO Processing** | The MOC shall support the receipt and processing of Target of Opportunity requests from the science community. | | Project | | GND |

| Swift Mission Requirements Document | | | | | | |
|---|---|---|---|---|---|---|
| | | **Functional** | **Value** | **Source** | **Comments** | **Element/ Subsystem** |
| 4.11.21 | **Command Checking** | The MOC shall verify all command uploads against resource constraints prior to uplink to the spacecraft. | | Project | | GND |
| 4.11.22 | Orbit Determination - Early Orbit Operations | Tracking and orbit determination for launch and early orbit shall be provided by the launch service provider. This should include a predicted state vector pre-launch and an actual insertion vector provided to the MOC within TBD minutes after final seperation. | | Project | | LV |
| 4.11.23 | Orbit Determination | The MOC shall provide the capability to generate orbit ephemeris data to an accuracy of 30 km. | | ~~SRD 7.5~~ SRD 7.6 | | GND |
| 4.11.24 | System Security | The ground segment shall provide system security to ensure that only authorized personnel can access system capabilities (such and spacecraft commanding) and mission-critical data. | | Project | | GND |
| 4.12 | **Communications** | | | Project | | na |
| 4.12.1 | Data Volume | The Swift ground segment shall provide sufficient RF communications coverage with the spacecraft to downlink all recorded telemetry data (up to 5.23 Gbits per day). | | SRD 7.5 | Data volume does not include RF communications overhead. | GND |
| 4.12.2 | CCSDS Protocols | Ground and flight communication systems shall be compatible with CCSDS Version 1 COP-1 commanding and CCSDS Advanced Orbiting Systems (AOS) telemetry protocols. | | Project | | S/C, GND |

# Swift Mission Requirements Document

| | | Functional | Value | Source | Comments | Element/ Subsystem |
|---|---|---|---|---|---|---|
| 4.12.3 | Bit Error Rate | The average end-to-end bit error rate of data provided to the Swift Data Center shall not affect more than TBD% of the data packets. This applies to both Malindi and TDRSS data separately. | | Project | | GND |
| 4.12.4 | Primary Link | Swift shall utilize S-band in STDN mode for primary space/ground communications (uplink & downlink). S-band communications shall be possible regardless of the spacecraft attitude. | | Project | | GND, S/C |
| 4.12.5 | Burst Alert Link | For alert messages, Swift shall utilize TDRSS when safe. Link shall be capable of least a 1 kbps data rate, including all communications overhead. | | Project | | GND, S/C |
| 4.12.6 | Burst Alert Link - Distribution | The ground segment shall provide the capability to receive alert messages from the observatory via the SN, process them, and distribute them to the science community. | | SRD 7.6 | | GND |
| 4.12.7 | ToO Communications | For alert messages from the ground, Swift shall utilize TDRSS MA Forward services, scheduled and provided using the existing TDRSS capabilities. Link shall be capable of least a 125 bps data rate, including all communications overhead. | | Project | | GND, S/C |
| 4.12.8 | Uplink data rate | The Swift uplink in STDN mode shall be capable of at least a 2 kbps data rate, including all communications overhead. | | Project | | GND, S/C |

| Swift Mission Requirements Document | | | | | | |
|---|---|---|---|---|---|---|
| | | **Functional** | **Value** | **Source** | **Comments** | **Element/ Subsystem** |
| 4.12.9 | Downlink Data Rate | The Swift science data playback downlink shall be capable of at least 2.25 Mbps data rate, including all communications overhead. | | Project | | GND, S/C |
| 4.12.10 | Real-time Housekeeping Downlink Rate | The Swift real-time housekeeping (HK) telemetry downlink shall be capable of at least 42 kbps data rate, including 4.1 kbps of instrument HK. | | Project | | GND, S/C |
| 4.12.11 | Ground System Coordination | The MOC shall be responsible to coordinate all operationally-related data communications between the ground stations, and supporting remote facilities. | | Project | | GND |

NOTES:
1. The subsystem allocated times shown in table EB-1 are for budgetary purpose used to show how the end-to-end timing requirements are met.

# EB1 - GRB Alert Data Products Timing Requirements

| | EB1.1 | EB1.2 | EB1.3 | EB1.4 | EB1.5 | EB1.6 | EB1.7 | EB1.8 | EB1.9 | |
|---|---|---|---|---|---|---|---|---|---|---|
| **SRD source** | | **SRD2.1** | | | **SRD2.3** | | **SRD2.5** | | | |
| **Data Product =>** | **GRB Alert** | **BAT Position** | **FoM Will/Will Not Observe** | **S/C Will/Will Not Observe** | **XRT Position** | **BAT Light-curve** | **UVOT Finding Chart** | **XRT Spectrum** | **XRT Image** | **Flow** |
| **Message Size (In Bytes)** | ***≤ 58*** | ***≤ 92*** | ***≤ 68*** | ***≤ 68*** | ***≤ 60*** | ***≤ 2150*** | ***≤ 2000*** | ***≤ 2200*** | ***≤ 680*** | **Instrumen** |
| **Estimated No. of Telemetry Packets** | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 3 | 1 | **(info only)** |
| **Estimated No. of Telemetry Frames** | 1 | 1 | 1 | 1 | 1 | 21 | 19 | 21 | 7 | **(info only)** |
| **All Time Based Off Burst Trigger** | | | | | | | | | | |
| **BAT GRB Location/ FoM Slew Request (s)** | | 6.0 | 6.2 | 6.2 | 6.2 | 6.2 | 6.2 | 6.2 | 6.2 | **BAT/foM** |
| **BAT/FoM to C&DH, ACS Slew Check & Request to Safe UVOT (s)** | 0.4 | 0.4 | 0.4 | 0.8 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | **S/C** |
| **UVOT Safing (s)** | | | | | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | **UVOT** |
| **UVOT Reply to C&DH (s)** | | | | | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | **S/C** |
| **Spacecraft slew/settle (s)** | | | | | 75.0 | | 75.0 | 75.0 | 75.0 | **S/C** |
| **Instrument Processing (s)** | | | 2.0 | 2.0 | 5.0 | 115.0 | 150.0 | 200.0 | 7.0 | **Instrumen** |
| **Instrument to C&DH (s)** | | | | | 0.3 | 0.5 | 1.4 | 0.8 | 0.4 | **S/C** |
| **C&DH to Transponder (s)** | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.8 | 0.8 | 0.8 | 0.5 | **S/C** |
| **S/C to TDRSS Initial Delay (s)** | 9.0 | 4.0 | 3.0 | 4.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | **S/C** |
| **Swift to WSC @ 1 kbps (s)** | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 22.8 | 20.8 | 22.8 | 8.5 | **S/C** |
| **WSC processing (s)** | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | **Ground Sy** |
| **WSC to GCN (s)** | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | **Ground Sy** |
| **GCN Processing (s)** | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.5 | 0.5 | 0.5 | **GCN** |
| **Allocated Total Times (s)** | 15.5 | 16.5 | 17.7 | 19.1 | 95.0 | 151.2 | 260.4 | 311.8 | 103.8 | |
| **End-to-End Timing Requirement (s)** | **20** | **20** | **70** | **70** | **100** | **200** | **270** | **1200** | **1200** | |
| Margin (Time) | 4.5 | 3.5 | 52.3 | 50.9 | 5.0 | 48.8 | 9.6 | 888.2 | 1096.2 | |
| Margin (%) | 29% | 21% | 295% | 266% | 5% | 32% | 4% | 285% | 1056% | |

GRB Alert Data Products Timing Requirements enumerates the key science data products and the timing requirement for each to be received at the GCN. The timing breakdowns denote the current estimates for each step in order to show how the overall time requirement is met. The "Flowdown" field denotes the responsible organization for each step. Note that additional usage of the TDRSS link is planned spacecraft emergencies, and, on a non-interference basis, observatory state-of-health telemetry.

**Field definitions:**

• Message Size (In Bytes) – This field denotes the message size of the data product, including CCSDS packet telemetry header (~12 bytes) for each packet.
• Estimated No. of Telemetry Packets – This field denotes the number of telemetry packets that will be used to downlink the data product. If a data product is greater than 958 bytes, it must be broken down into smaller packets of less than or equal to 958 in order to be transferred from the instrument to the C&DH.
• BAT GRB Location/ FoM Slew Request & UVOT Safing –
• For the GRB Alert & the BAT Position – this field denotes the time allocated for the BAT to locate the GRB and make the position packet available to the C&DH on the 1553 bus.
• For all other data products - this field denotes the time allocated for the BAT to locate the GRB and includes 0.4 seconds for the FoM to request a slew. Note that this is the time allocated for the FoM to transfer the slew request to the C&DH. Note that This time should also be sufficient for the UVOT to safe itself.
• BAT/FoM to C&DH – This denotes the time allocated to transferring the message to the C&DH.
• Spacecraft slew/settle – This field denotes the time allocated for the spacecraft to slew 50 degrees & settle on a target. Note that this time begins when the s/c receives the slew request from the Figure of Merit.
• Instrument Processing – This field denotes the time allocated for an instrument to generate the data product.
• Instrument to C&DH – This field denotes the time allocated to transfer the data product from the instrument to the C&DH.
• C&DH to Transponder – This field denotes the time allocated for the C&DH, once it has received it from the instruments, to forward the data product to the transponder.
• S/C to TDRSS Initial Delay – This field denotes the time allocated for the worst case initial delay to synchronize & lock up with TDRSS. The nominal delay is expected to be less than 0.5 seconds.
• Swift to WSC @ 1 kbps – This denotes the time allocated to downlink the data product to WSC at a 1 kbps rate.
• WSC Processing – This field denotes the time allocated to process the message at WSC before transferring to the GCN.
• WSC to GCN – This field denotes the time allocated to transfer the message from WSC to the GCN.
• GCN Processing – This field denotes the time allocated to process the message at the GCN.
• Allocated Total Times – This field denotes the sum of all allocation times.
• End-to-End Timing Requirement – This field denotes the top level science end-to-end time requirement for each data product.
• Margin (Time) – This field denotes the margin (in time) for each data product.
• Margin (%) – This field denotes the margin (in %) and is calculated as [margin in time]/[allocated total times].

# EB2 Coarse Position Error Budget

| | | BAT Position Error | | |
|---|---|---|---|---|
| | Error Source | Pitch, Yaw | Subsystem | Comment |
| | | arcmin, 3σ, each | | |
| EB2.1 | BAT Internal Alignment | 2.00 | BAT | |
| EB2.2 | BAT Centroiding Error | 4.00 | BAT | |
| EB2.3 | BAT/ST Alignment (Thermal) | 1.00 | OB, XRT | Optical Bench requirement, roll alignment same |
| EB2.4 | ACS Pointing Knowledge-Roll Error Effect | 1.65 | S/C | 1.5 arcmin ACS knowledge results in 1.65 arc min position error at the edge of the BAT FOV |
| EB3.5 | ACS Pointing Knowledge-Pitch, Yaw | 0.05 | S/C | |
| | TOTAL (RSS) | 4.87 | | |
| | REQUIREMENT | 5.00 | | |
| | Margin (RSS) | 1.13 | | |

# EB3 XRT GRB Position Error Budget

| | | Pitch, Yaw | Subsystem |
|---|---|---|---|
| | | arcsec, 3s, each | |
| EB3.1 | XRT Internal Alignment Error | 1.5 | XRT |
| EB3.2 | XRT Centroiding Error | 1 | XRT |
| EB3.3 | XRT/ST Boresight Cal | 1 | XRT, S/C |
| EB3.4 | XRT/ST Alignment (Thermal) | 1 | XRT, S/C |
| EB3.5 | ACS Pointing Knowledge | 3 | S/C |
| EB3.6 | Radiator-induced Misalignment | 1 | |
| | TOTAL (RSS) | 3.9 | |
| | Requirement | 5.0 | |
| | Margin (RSS) | 3.1 | |

Notes:
EB3.1 includes pointing errors caused by CCD heat pipe forces transmitted to the XRT tube, as well as distortions from the mounting interface with the Optical Bench.

The addition of a Telescope Alignment Monitor (TAM) may eliminate some or all of EB3.1, EB3.4. It would also add EB3.6 - TAM residual error.