NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER

Figure of Merit Flight Software Requirements Document 410.4-SPEC-0002

Version 1.2

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REVISION HISTORY

Version 1.0	12/15/00	July/August comments incorporated Revised per updated operations concept Update science requirements from MRD
Version 1.1	5/11/01	Incorporate 1/25/01 FoM Peer Review comments Incorporate requirement refinements since initial version
Version 1.2	2/05/02	Incorporate Version 1.1 FoM SRS review redlines and Subsequent requirement updates

Specific Version 1.2 updates and requirements modified as follows :

- Updated Target Id definitions to match terminology outlined in Frank Marshall 'Target_Id' memo, dated June 2001. Replaced description of 32 bit FoM_Track_Id consisting of a 16 bit Target_Id and Observation Number with 32 bit Observation Number consisting of 24 bit Target_Id and 8 bit Observation Segment.
- Modified FoM initialization to show separate maximum observing time limits for GRB and ToO type targets.
- Provided additional detail regarding GRB merit input instrument and merit weight value data types, and the specific equation used by FoM. (Reqs FM111.6, 111.7, 111.8)
- Split higher level requirements with several requirements into multiple lower level requirements to facilitate test planning.
- Added further details regarding command processing (Reqs in FM160, FM 170 sections)
- Rewrote observing time parameter requirement to make clearer. (Req FM132)
- Provided further details on Slew, AT, and PPT Scheduling inhibit capabilities (Req FM140, 160.04 - 160.07, 160.16. 160.17)
- Added requirements in Command processing section for XRT Position Update and Spacecraft Slew Abort commands (Reqs FM160.22, 160.23)
- Corrected errors in the description of what the AT Abort command should do (Req FM169.10)
- Section 4, 'Add On Functions', updated to indicate no post launch capabilities to be added.
- Appendix A, 'FoM Science Requirements Traceability', updated
- An 'ReqObserveSecs' field will be added to PPT target requests (modifies Onboard Operational Messaging Interface Document which specifies command formats)
- PPT request provided 'ObserveSecs' values will be used in lieu of Spacecraft Slew Reply provided Observe Secs values for PPT target Next_Observation_Info messages. (Req FM122.1, FM122.1.2 -4)
- Added SC_Slew_Abort and PPT_Target_Error messages to be downlinked via TDRSS (Req 180.06 & 180.07).
- Changed GRB and TOO default maximum observation times from 6000 to 10,000 seconds (FM013, FM018)
- Corrected references to Observation_Number to reflect proper ordering of subfields (ie, Observation_Segment, followed by Target_ID)
- Changed mission life description to reflect new baseline of studying ~300-600 bursts over 2 years (Section 2.1)

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1 OVERVIEW

1.1 Scope

This document defines the requirements for the Swift Figure of Merit (FoM) flight software.

1.2 Applicable Documents

410.4-SPEC-0004	Swift Mission Definition and Requirements Document (Version 1.4 - October 10, 2000)
410.4-ICD-0001	Swift Interface Requirements Document (Version 2.0 - October 25, 2000)
410.4-ICD-0006	Onboard Operational Messaging Interface Document (Version 1.02 - August 2001)

1.3 Acronyms

ACK	Acknowledgement
BAT	Burst Alert Telescope
Candidate_AT	Candidate Automated Target
FoM	Figure of Merit
FoM_AT	Figure of Merit Automated Target
FoM_PPT	Figure of Merit Preplanned Target
FSW	flight software
GRB	gamma ray burst
ms	milliseconds
NACK	Non-Acknowledgement
NFI	Narrow Field Instruments
PPT	Preplanned Target
RA/Dec	Right Ascension/Declination
SAA	South Atlantic Anomaly
Scheduled_AT	Scheduled Automated Target
Scheduled_PPT	Scheduled Preplanned Target
ToO	Target of Opportunity
TBD	to be determined
TBR	to be resolved
UVOT	Ultra-Violet Optical Telescope
XRT	X-Ray Telescope

2 BACKGROUND

2.1 Introduction

The unique capability that distinguishes Swift from all other astrophysics missions is the requirement to autonomously slew the spacecraft to acquire the newly discovered GRBs within the field of view of the Narrow-Field Instruments. The scientific premium on rapid acquisition is so high as to preclude ground control of the slew request, so the Swift spacecraft must include an onboard Figure-of-Merit (FoM) decision process to enable an entirely automated response to unplanned slew requests

The Swift MIDEX mission is the first-of-its-kind observatory for multi-wavelength transient astronomy. Its goal is to determine the origin of gamma ray bursts (GRBs) and to use bursts to probe the early universe. Swift will exploit newly discovered GRB afterglow characteristics to make a comprehensive study of approximately 300-600 bursts over 2 years.

Compared to current and planned missions, Swift will provide an order of magnitude more identified GRB events per year, 2-3 orders of magnitude better positions, and a 500-fold improved response time to study afterglow in the X-ray and optical bands. For 30% of the bursts, the afterglow observations will start while the GRB is still in progress.

In order to achieve a 500-fold increase in response time, the Swift Burst Alert Telescope (BAT) instrument will detect GRBs and the spacecraft will autonomously slew to point the X-Ray Telescope (XRT) and Ultra-Violet Optical Telescope (UVOT) instruments at the GRB position. Swift will observe new GRBs as soon as possible and for as long as is necessary to achieve the science goals.

2.2 Figure of Merit Software Context

The Figure of Merit (FoM) is the onboard instrument flight software (FSW) used to coordinate the observations of preplanned and autonomous targets. The FoM is hosted within the BAT instrument processor but is considered a Swift mission function. Nominally, Swift follows a preplanned observation plan. Meanwhile, the BAT FSW continuously processes event data from the BAT detectors in order to detect GRBs. Following burst detection, the BAT FSW will determine the position of the burst. Given the burst position, and other relevant parameters, the FoM FSW will determine whether the newly detected burst warrants preemption of the current preplanned observation. Given the desire to slew to the new burst, the FoM will request the spacecraft slew to the new position. The FoM is the “glue” that coordinates all observations, in order to achieve the overall science goals.

2.3 Science Observation Strategy

The science observing strategy is implemented by scheduling observations via three methods: (1) A preplanned observing program with pre-planned targets, (2) Automated observations of targets detected by the BAT and (3) Ground uploaded targets of opportunity (ToO) . The metric for success is the predicted number of XRT afterglow photons will be greater than 80% of the total predicted for an optimum observing program. The FoM design & requirements as defined in this document has been validated to meet the 80% requirement through Robin Corbet's simulations. As the Swift mission progresses with discoveries made after launch, further optimizations of the observing strategies are also expected to conform to this efficiency requirement.

2.3.1 Uploaded Observing Program

An uploaded timeline of preplanned observations is generated on the ground by the science team. A timeline covering the planned observations for up to 7 days may be uploaded to Swift on a daily basis, up to five times per week. The uploaded timeline has a merit value assigned to each observation. The Swift spacecraft is responsible for storing & forwarding the uploaded timeline commands to the FoM at the time specified in the upload. The FoM will determine whether to forward the observation commands back to the spacecraft for immediate execution or to delay the uploaded observation in order to continue observing an automated target.

Nominally, the preplanned target will be passed back to the spacecraft as a request to slew to target command. In the condition that there is an automated target of higher merit than the preplanned target, the automated target will continue to be observed and the preplanned target will be held until either the automated target observation is complete or when the automated target is not viewable due to constraints. Preplanned observation can start anytime from original start time until the time of the next preplanned observation. For example, if "observe target A" is scheduled for noon, and "observe target B" is scheduled for 1PM, then "observe target A" can be started anytime between noon and 1PM.

2.3.2 FoM Autonomous Observations

The BAT surveys the sky by pointing at locations controlled by the preplanned stored program. When the BAT detects an event rate increase that matches its burst trigger criteria, a notification is sent to the ground via TDRSS. The BAT FSW determines a location for the newly detected burst. The burst location is sent to the FoM and to the ground via TDRSS. The FoM evaluates the merit of the newly detected burst against the merit of the current observation (i.e. either the preplanned target or a previously detected automated target). If justified by the merit, the FoM requests the spacecraft to pre-empt the current observation in order to slew to and observe the new burst.

At launch, autonomous observations will have a default observation duration to observe GRB afterglows (value to be baselined at launch & reconfigurable after launch by command).

2.3.3 Ground Uploaded Targets of Opportunity

In addition to observations of preplanned and BAT detected GRB, Swift will be capable of reacting to GRBs detected by other spacecraft and ground based sources. Notification of new targets of opportunity (ToOs) will be uplinked in real time via the TDRSS space network. Each uplinked ToO will include a pre-calculated merit value and will be processed in the same manner by the FoM as automated observations detected by the BAT.

3 FoM Flight Software Requirements

This section defines the science requirements, operational concepts/assumptions & derived FoM FSW requirements. For requirement traceability, see Appendix A: FoM Science Requirements Traceability.

3.1 Science Requirements

The FoM requirements are driven by top-level science requirements, as defined in the MRD. The top level FoM science requirements* are:

MRD 4.9.1	The FoM will minimize time delay to slew to a new burst (design goal is <0.4 seconds for FoM processing).
MRD 4.9.2	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.
MRD 4.9.3	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.
MRD 4.9.4	The FoM shall allow for maximizing observing time to the uploaded program whenever automated target not being observed.
MRD 4.9.5	The FoM shall allow for automated termination of automated observing of a target at completion of a predetermined observing strategy.
MRD 4.9.6	The FoM shall allow for pre-specified uploaded observations to override automated observations.
MRD 4.9.7	The FoM shall allow for automated observations triggered by TDRSS commands.
MRD 4.9.8	The FoM shall allow for the current automated target to override new GRBs based on input from the instruments.
MRD 4.9.9	The FoM shall allow for extension of the automated observing time based on input from the NFIs.
MRD 4.9.10	The FoM shall allow for adjustment of fraction of observing time allocated to the automated and uploaded programs for extended automated observations.
MRD 4.9.11	The FoM shall allow for termination of automated observing by command from the ground.
MRD 4.9.12	The FoM shall allow for a workable mechanism to implement new automated observing strategies after launch.
MRD 4.9.13	The FoM shall have the capability to disable slew requests to the S/C by command.

Note: MRD 4.9.8-10 is planned for post-launch. The design of the FoM shall support the post-launch implementation of requirements MRD 4.9.8-10.

3.2 Design/Operation Notes

Listed below are design and operational assumptions:

1. The preplanned observation timeline is loaded into S/C memory and forwarded by the spacecraft to the FoM at the uploaded specified times. The baseline for operations is to be able to upload the observation schedule five times a week, at specified times.

2. The FoM will consider no more than 2 targets at any time: the current scheduled preplanned target & the current automated target (if any). The current scheduled preplanned target will always be the unique target contained in the uploaded observation plan for the current time. The current automated target will be the automated target having the highest merit and can be either a BAT detected target or a TDRSS uploaded target of opportunity. Comparison of merits occur in two contexts: a) between two automated targets, after which only the highest merit target survives, and b) between the current scheduled preplanned target and the current automated target, which determines the priority by which the FoM coordinates subsequent observations.

3. The FoM will not return to an automated target after it has been superceded by another automated target of higher merit (i.e., automated targets are not queued), although it will stay on a superceded automated target if the current automated target is out of view.

4. Preplanned targets have assigned fixed merit values, which do not change during the observation.

5. Preplanned observations will be self-contained within a single command (i.e., the FoM is only required to keep track of a single command for observing the current preplanned target.

6. The command to change the default maximum observation time of BAT detected GRB targets will take effect immediately and will be used for all GRB targets thereafter. A second command, which acts similarly, will be provided to control ToO target observations.

7. With the exception of having a pre-assigned merit value, ToOs will be treated in the same manner as BAT detected targets. Uploaded ToOs are expected to include a target ID, observation segment, instrument mode values, trigger time, and merit value.

8. Upon receiving a request to slew command from the FoM, the spacecraft will reply with either an acknowledgement message (i.e., ACK) if it can safely slew to the target or a non-acknowledgement message (i.e., NACK) if it cannot safely slew. In addition, look ahead times, of when the requested target will no longer be safely viewed for an ACK or of when it will be viewable for a NACK, will also be provide by the spacecraft.

9. The spacecraft will not respond to FoM slew request while the spacecraft is slewing.

10. Spacecraft requirements to support the FoM operations are detailed in the IRD.

11. Each instrument is responsible for managing its internal configuration for observations, based on the information provided by the FoM message (i.e., target ID/observation segment, total accumulated observation time, target type flag (e.g., BAT detected AT, ToO, PPT), instrument configuration).

12. The BAT science code will assign and forward a target ID and observation segment for each BAT detected target.

13. Every target will have a 24-bit target ID (denoting location) and a 8-bit observation Segment field (denoting some logical grouping such as instrument configuration). For simplicity's sake, the FoM will concatenate these two elements into a 32–bit Observation_Number to track observation information (e.g., past observed time). Specifically, Observation Number will consist of the Observation Segment followed by Target ID. The FoM uses this Observation_Number when coordinating between automated & preplanned targets and by the instruments for tagging their science products.

14. The FoM is responsible for sending the following TDRSS statuses:
    - Whether the FoM will or will not request a slew to the automated target (based on FoM merit comparisons)
    - Whether the S/C will or will not slew to the automated target (based on S/C's ACK or NACK to the slew request)
    - An alert message that the S/C has entered safe pointing due to anomalous condition

15. The FoM will manage up to 128 of the most recently requested targets. This includes keeping past-observed time and last observed time for each target.

16. Section 5 provides additional FoM software architectural/design notes.

17. The FoM will calculate the merit of BAT detected GRB targets based on a linear equation of 30 sets of parameters and weights (10 sets per instrument). Weight values are controlled via ground input and can be updated via a table load. Each instrument group of 10 parameters can be set via a FoM command. The FoM will recompute an AT's merit whenever an instrument's parameters are updated. For BAT detected bursts, the BAT will provide its 10 parameters for the initial merit calculation of the AT.

3.3 Definitions/Terminology

Automated_Target (AT) -- The automated target is a target selected via detection of a new gamma ray burst or a target of opportunity uploaded via ground command. A FoM target that is not an automated target is a preplanned target.

Merit -- A numeric value either assigned or calculated for a target, which defines the relative priority of a target for observation.

Scheduled_PPT -- Scheduled preplanned targets pre-determined by the ground for observation at the specified time. Scheduled_PPT commands are uploaded to the spacecraft for storage and forwarded to the FoM at the specified time. The Scheduled_PPT will be used as the FoM_PPT until the next Scheduled_PPT.

FoM_PPT -- The current preplanned target being used by FoM for scheduling observations. There is only 1 FoM_PPT at a time (i.e., the last Scheduled_PPT observed).

FoM_AT – When active, this is the automated target being used by FoM for scheduling observations. There is at most, only 1 FoM_AT at a time. When not active, there is no FoM_AT (e.g., previous FoM_AT completed observations and the FoM is waiting on the next Candidate_AT).

Candidate_AT -- The candidate automated target (either BAT detected or ToO) being evaluated against the current FoM_AT.

Target_ID –A 24-bit number associated with every target to denote target location.

Observation_Segment – A 8-bit number associated with every target to group non-continuous observations. For example, mission operations may use the Target_ID and Observation_Segment to organize non-contiguous observations of a single location with the same instrument configuration.

Observation_Number – A 32 bit number derived by the FoM by concatenating the Target_ID and the Observation_Segment. The FoM will use this Observation_Number to monitor observation parameters (e.g., past observed time). Mission operations may use a unique Observation_Segment to organize non-contiguous observations of a single location with the same instrument configuration.

3.4 FoM Flight Software Requirements

This section defines the FoM requirements to be implemented. The following is the CSCI breakdown of the FoM flight software requirements:

CSCI	Function
FM010	Initialization
FM100	Accepting Scheduled_PPTs
FM110	Accepting Candidate_ATs
FM120	Managing PPT and AT observations
FM130	Managing observation information
FM140	Inhibiting ATs and/or PPTs
FM150	Onboard reprogramming
FM160	FoM command processing

FM170	FoM command generation
FM180	FoM telemetry generation

The CSCI number associated with each will be used to track & verify that the requirements have been satisfied.

FM010 The FoM shall initialize with the following configuration:

FM011 PPT Scheduling disabled

FM012 AT scheduling disabled

FM013 Default GRB observation time of 10,000 seconds

FM014 Initialize Target_Info_Table to no past targets observed

FM015 No active FoM_AT

FM016 No active FoM_PPT

FM017 FoM Slew Request scheduling disabled

FM018 Default ToO observation time of 10,000 seconds

FM100 The FoM shall accept and execute Scheduled_PPTs (i.e., preplanned observing program commands).

FM101 The FoM shall always update the FoM_PPT with the Scheduled_PPT.

FM101.1 If no FoM_AT is being observed, the FoM shall send the spacecraft a request to slew to the new FoM_PPT.

FM101.2 If a FoM_AT of higher or equal merit than the FoM_PPT is being observed, no further action is required.

FM101.3 If a FoM_AT is of lower merit than the FoM_PPT, the FoM shall send the spacecraft a request to slew to the new FoM_PPT.

FM110 The FoM shall accept & manage Candidate_ATs (i.e., BAT detected or ToOs).

FM111 The FoM shall accept the BAT detected GRB target (with a BAT assigned Observation Number, Burst Trigger Time, and 10 BAT merit input parameter values) as a Candidate_AT & compute thetarget's merit using instrument input values and a table of weights (one weight for each parameter).

FM111.1 The table of weights for each parameter shall be uploadable via table load from the ground and shall apply for all GRB targets.

FM111.2 A command shall be provided for each instrument to provide its 10 merit input values to be used by the FoM in FoM's GRB target merit computation, and a Observation_Number to specify which target the data values shall apply.

FM111.3 The FoM shall recompute an AT's merit when it receives a merit update command from instruments.

FM111.4 The FoM, upon update to a new FoM AT, shall reset UVOT and XRT merit input parameter values to 0.

FM111.5 BAT detected target requests shall be received in the form of GRB Position messages. GRB Position messages where a position fix was not found (i.e., false alarms) shall not become Candidate_ATs and no further processing of these inputs shall be performed by FoM.

FM111.6 The 30 weight values shall be provided and stored as 32 bit floating point values.

FM111.7 The 30 instrument input values shall be provided and stored as 8 bit signed integers.

FM111.8 FoM will use the following equation to evaluate a GRB target merit

$$MeritGRB = Sum(i=1, 10)\ V_{Bi} * Wt_{Bi} + V_{Ui} * Wt_{Ui} + V_{Xi} * Wt_{Xi}$$

Where V = instrument provided merit input value, Wt = Weighting Factor, and B = BAT, U = UVOT, and X = XRT

FM112 The FoM shall accept ToO (with a ground assigned Observation Number, Trigger Time, and merit value) as a Candidate_AT.

FM113 If there is no active FoM_AT, the Candidate_AT shall become the FoM_AT &

FM113.1 if the new FoM_AT merit is of higher or equal merit than the FoM_PPT, the FoM shall send the spacecraft a request to slew to the new FoM_AT.

FM114 If there is an active FoM_AT, and the Candidate_AT has higher or equal merit, then the Candidate_AT shall become the FoM_AT &

FM114.1 if the new FoM_AT is of higher or equal merit than the FoM_PPT, then the FoM shall send the spacecraft a request to slew to the new FoM_AT.

FM114.2 If the new FoM_AT is out of view, and Swift is currently observing a superceded FoM_AT, FoM should allow observance of the superceded FoM_AT to continue while the new FoM AT is out of view.

FM115 When a Candidate_AT is received, the FoM shall send a TDRSS telemetry packet to inform the ground whether the FoM will or will not attempt to observe the Candidate_AT. Specifically this message shall indicate if the Candidate_AT has become the new FoM_AT, and if the Candidate_AT's merit is sufficient to warrant an immediate slew request.

FM116 The FoM software shall generate the spacecraft slew request command within 200 ms following receipt of a Candidate_AT, if appropriate.

FM120 The FoM shall manage the observations between the FoM_PPT & the FoM_AT (observing the FoM_AT whenever it is of a higher or equal merit & when observing of the FoM_AT is permitted by viewing constraints).

FM121 Total observing duration for each FoM_AT target shall be limited to a FoM stored threshold value. FoM_ATs shall be observed for the default time criteria

FM121.1 *The pre-defined observation time shall be reconfigurable in-flight and shall take effect immediately.*

FM121.2 *After satisfying this time criteria, the FoM shall return to a "no active FoM_AT" state and shall not return to this target unless a new request for this target is issued.*

FM121.3 *Separate observation time limits shall be available and used to control GRB and ToO type target observations.*

FM122 The FoM shall manage observations using constraint notifications from the spacecraft.

FM122.1 *Following the spacecraft's status that it has begun slewing to the FoM requested target, the FoM shall broadcast the Next_Observation_Info command message to the NFIs containing the following information:*

- *Observation_Number (i.e., Observation_Segment / Track ID)*
- *Target position in RA/DEC / ROLL*
- *Total accumulated observation time in seconds (from Target_Info Table)*
- *Flag indicating scheduled preplanned or automated target*
- *Instrument configurations*
- *"First time observing AT?" flag (used to denote S/C slew rate. Should be set to TRUE for 1st time slew to GRB target, otherwise FALSE.)*
- *Maximum available observation time (as provided in SC slew replies for AT targets; and as provided in PPT target requests for PPT targets)*
  - *Note: A new target may be selected prior to this maximum observation time.*
- *BAT trigger time – pass thru of value provided in AT target request. Value set to 0 for PPT requests.*
- *Target's merit*

FM122.1.1 *For ATs of type BAT detected GRB, the FoM shall attach the instrument configuration based on FoM stored values. (For PPTs and ToO, the instrument configuration is specified in the request command)*

FM122.1.2 *For AT targets, the Fom shall attach the maximum available observation time using the Observe_Secs value provided in Spacecraft slew replies.*

FM122.1.3 For PPT targets, the FoM shall attach the maximum available observation time using the Request Observe_Secs value provided in PPT target requests.

FM122.1.4 FoM shall not adjust maximum available observation times to be provided in Next_Observation_Info messages for PPT targets if a PPT observation is delayed.

FM122.2 Following a spacecraft NACK in reply to a FoM request to slew to the FoM_AT, the FoM shall request a slew to the FoM_AT at the future specified time the spacecraft states that the FoM_AT will no longer be constrained.

FM122.3 Following a spacecraft ACK or NACK in reply to a FoM request to slew to a new FoM_AT, the FoM shall send a TDRSS telemetry packet to inform the ground whether the spacecraft will or will not slew to the requested target. This message is not generated for subsequent slew replies or if initial slew request after target request received is delayed.

FM122.4 Following a spacecraft NACK in reply to a FoM request to slew to the FoM_PPT, the FoM shall generate a TDRSS event message, and allow the current observation to continue.

FM122.5 Following a spacecraft FVIEWCONSTRAINT (spacecraft entering viewing constraint), if the current target is the FoM_AT, then the FoM shall:

FM122.5.1 Inquire the spacecraft as to the future time of when the FoM_AT will be viewable again, and

FM122.5.2 Request the spacecraft to slew to the current FoM_PPT,

FM122.5.3 At the future specified time, request the spacecraft to slew back to the FoM_AT.

FM123 Upon receipt of the "current target entering constraint" message, if the FoM is currently observing a FoM_AT, then the FoM shall send the spacecraft a request to slew to the FoM_PPT atleast 5 seconds prior to the spacecraft entering constraints (assuming the constraint message is sent no less than 10 seconds prior to entering constraints).

FM123.1 *If the FoM is currently observing a FoM_PPT when a view constraint received, the FoM shall generate a TDRSS event message and allow the spacecraft to repoint to a safe pointing position.*

FM124 If the FoM determines that it is desirable to request a slew while the spacecraft is currently slewing (i.e., "S/C slewing" flag set), the FoM slew request shall be delayed until the spacecraft has settled on target (i.e., "settled" flag set) before sending the slew request.

FM125 FoM shall process SC provided slew responses, and shall verify requested roll positions match values in response.

FM125.1 *If a mismatch occurs for targets other than a new GRB target (for which a Roll angle is unspecified), FoM shall generate an alert message for Housekeeping data downlink.*

FM125.2 *FoM shall store updated ~~position~~ roll values provided in the slew reply. The updated roll value shall be used in subsequent slew requests to return to this target.*

FM125.3 *If a new target request for this target is received, the FoM shall use the target position provided in the target request and the older SC provided roll position shall be overwritten.*

FM126 FoM shall process an XRT position update command for BAT detected GRB targets.

FM126.1 *This command shall include position values, and a Observation_Number for which the values apply.*

FM126.2 *FoM should reject a Position update if the target type is not a GRB.*

FM126.3 *FoM should reject a Position update if the requested target is not the current FoM AT.*

FM126.4 *FoM shall store position values and use these values in subsequent slew requests to return to this target.*

FM126.5 *If a new target request for this target is received, the FoM shall use the target position provided in the target request and the older XRT provided position shall be overwritten.*

FM127 In the event FoM receives multiple position updates for a given target, FoM shall maintain and use the last provided updated positions (ie, target request values, SC slew reply updates, orXRT Position update values) .

FM130 The FoM shall maintain observation information for up to 128 of the most recently requested targets.

FM131 The FoM shall maintain the following target observation information in the Target_Info_Table:

- Observation_Number (i.e., Observation_Segment / Target_ID)
- Past_Observed_Time in seconds, and
- Last_Observed_Time in spacecraft clock time

Note: the FoM is not required to maintain target information for safe pointing or safehold positions.

FM131.1 If the FoM receives a Observation Number (either AT or PPT) which is in the Target_Info_Table, the FoM shall use and update the information from the Target_Info_Table.

FM131.2 When the FoM receives a Observation Number (either AT or PPT) which is not in the Target_Info_Table, the FoM shall replace the oldest observed target with the requested Observation Number, initialize the Past_Observed_Time to 0 seconds and set the Last_Observed_Time to current spacecraft clock time.

FM132 The FoM shall maintain the observation time parameters for the currently observed target based on SC provided values in the Attitude Info packet.

FM132.1 During an observation while SC messages indicate "settled on target" and "not in SAA" statuses, the Past_Observed_Time shall be incremented.

FM132.2 While SC messages indicate "slewing" or "in SAA" status, the Past_Observed_Time shall not be incremented.

FM132.3 The Last_Observed_Time shall be updated to current spacecraft clock time, upon the following Attitude Info packet data value transitions.

FM132.3.1 Receipt of "settled on target" status from the spacecraft.

FM132.3.2 Receipt of "IN_SAA" status from the spacecraft while settled on target.

FM132.3.3 Receipt of "NOT_IN_SAA" message from the spacecraft while settled on target.

FM132.3.4 Receipt of "slewing" status from the spacecraft.

FM140 The FoM shall have the ability to inhibit automated observations, preplanned observations, and / or slew requests. [See FM160.04-07, FM160.16-17.]

FM140.01 Fom shall provide the capability to inhibit the generation of slew requests and inquiries.

FM140.02 Fom shall provide the capability to inhibit the issuance of slew requests for Fom AT targets.

FM140.03 Fom shall provide the capability to inhibit the issuance of slew requests for Fom PPT targets.

FM150 The FoM software shall be completely uploadable in flight.

FM160 The FoM software shall process the following commands:

FM160.01 Slew_To_ToO – accept and process ToO (with uploaded merit value) as Candidate_AT [see FM112].

FM160.01.01 FoM shall reject requests and issue an event message when requested attitude values are not in range.

FM160.01.02 FoM shall perform processing of ToO requests as outlined in FM112 and FM113.

FM160.02 Slew_To_Scheduled_PPT - update the FoM_PPT with the Scheduled_PPT and request the spacecraft to slew to the new FoM_PPT

FM160.02.01 *FoM shall reject requests and issue an event message when requested attitude values are not in range.*

FM160.02.02 *FoM shall perform processing of PPT requests as outlined in FM100.*

FM160.03 (Deleted)

FM160.04 Enable_AT_Scheduling – enable the observing and scheduling of automated targets.

FM160.05 Disable_AT_Scheduling – disable the observing and scheduling of automated targets. While disabled the following shall occur:

FM160.05.01 *ToO and GRB target requests shall be accepted (i.e., requested target can become FoM AT)*

FM160.05.02 *Current FoM AT observation shall continue as scheduled.*

FM160.05.03 *Spacecraft slew inquiries for AT targets shall be allowed.*

FM160.05.04 *Spacecraft slew requests to AT targets shall be inhibited.*

FM160.06 Enable_PPT_Scheduling – enable the observing of preplanned targets.

FM160.07 Disable_PPT_Scheduling –disable the observing of preplanned targets. While disabled the following shall occur:

FM160.07.01 *Slew_To_Scheduled_PPT commands shall be accepted (i.e., FoM_PPT updated with Scheduled_PPT)*

FM160.07.02 *Current FoM PPT observation shall continue as scheduled.*

FM160.07.03 *Spacecraft slew inquiries to PPT targets shall be allowed.*

FM160.07.04 *Spacecraft slew requests to PPT targets shall be inhibited.*

FM160.08 Abort_Automated_Target – abort automated target. FoM processing will:

FM160.08.01 *Change to no active FoM_AT state.*

FM160.08.02 Perform a target update assessment to determine if a slew request is warranted.

FM160.08.03 Issue a slew request to the FomPPT if the 'aborted' target was being observed.

FM160.08.04 Allow the observance of the 'aborted' target to continue if a slew to the FomPPT does not occur. FM160.09 SC_Slew_Reply [FSLEWREQREPLY] – spacecraft reply to FoM slew request.

FM160.09.01 FoM shall reject slew replies and issue event messages for slew replies with out of range slew reply code values.

FM160.09.02 Update and maintain FoM AT or FoM PPT in view times (WAIT SECONDS and OBSERVE SECONDS fields) based on values provided in reply if reply observation number matches that of FoM AT or PPT.

FM160.09.03 FoM shall perform additional slew reply processing as outlined in requirement 122.

FM160.09.04 FoM shall handle attitude values in replies that do not match requested values as outlined in requirements FM125 and FM127.

FM160.10 SC_Inquiry_Reply [FSLEWINFOREPLY] – spacecraft reply to FoM slew inquiry.

FM160.10.01 FoM shall reject slew replies and issue event message for slew reply with out of range slew reply code values.

FM160.10.02 Update and maintain FoM AT or FoM PPT in view times (WAIT SECONDS and OBSERVE SECONDS fields) based on values provided in reply if reply observation number matches that of FoM AT or PPT.

FM160.10.03 FoM shall perform additional slew reply processing as outlined in requirement FM122.

FM160.10.04 FoM shall handle attitude values in replies that do not match requested values as outlined in requirements FM125 and FM127.

FM160.11 Request_For_Housekeeping – the FoM shall generate its housekeeping packet when this request is received.

FM160.12 Attitude_Info_Msg [SISCATTITUDE] (or equivalent) – 5 Hz spacecraft message indicating current ACS status.

FM160.12.01 Using values from Attitude_Info_Msg, FoM shall maintain observing time parameters as outlined in FM132.

FM160.12.02 Fom shall issue Next_Observation_Info command message based on Attitude_Info_Msg values as outlined in FM122.1

FM160.12.03 FoM shall monitor the slew status in the S/C attitude message, and delay slew requests and inquiries until the attitude message indicates a slew has been completed (i.e., settled on target).

FM160.12.04 FoM shall generate a TDRSS telemetry message when the Observation_Number in the Attitude Info message indicates a slew to a safe pointing target is occurring.

FM160.13 *(Deleted)*

FM160.14 Set_Instrument_Merit_Value – Calculate or recalculate AT target of type BAT detected GRB observation merit value based on input parameter values. This command shall include the source instrument, the AT's Observation Number and the 10 data values. [See FM111].

FM160.14.1 If specified AT's Observation Number matches the current FoM_AT, then the FoM shall recalculate the FoM_AT merit value & perform a comparison of the new FoM_AT merit value with the current FoM_PPT.

FM160.14.2 If specified AT's Observation Number does not match the current FoM_AT, then the FoM shall reject the command and generate an error event.

FM160.14.3 If specified target's Observation Number is not an FoM_AT, then FoM shall reject the command and generate an error event.

FM160.15 SC_Entering_View_Constaint (FVIEWCONSTRAINT) – a spacecraft message indicating that the current target is about to enter viewing constraint. Upon receipt of this command, the FoM should perform actions as outlined in FM122.5 and FM123.

FM160.16 Enable_Slew_Scheduling – enable FoM performance of target update assessment and issuance of slew requests and inquiries.

FM160.17 Disable_Slew_Scheduling – disable FoM performance of target update assessment and issuance of slew requests and inquiries.

FM160.18 Set_GRB_Inst_Mode_Val – ground command to update each instrument's mode value issued in Next Observation Info message for targets of type BAT detected GRB.

FM160.19 Set_GRB_max_obs_time_limit –ground command used to update the maximum time limit that a GRB target shall be observed.

FM160.20 Set_ToO_max_obs_time_limit –ground command used to update the maximum time limit that a ToO target shall be observed.

FM160.21 No_Op – ground no-op command to FoM. The FoM shall increment its command execution counter on the receipt of this command.

FM160.22 XRTPOSITIONUPD – XRT position update command. FoM shall perform processing as outlined in requirements FM126 and FM127.

FM160.23 SC_Slew_Abort - Spacecraft message indicating slew aborted due to UVOT not notifying spacecraft that it is safe to slew. Upon receipt of this command, FoM shall perform the following :

FM160.23.01 Generate a TDRSS message indicating slew abort has occurred.

FM160.23.02 Stay on current target while awaiting a new input that would warrant a target update assessment.

FM170 The FoM software shall be capable of sending the following commands:

FM170.01 Request_To_Slew – request spacecraft to slew to a target (the spacecraft shall slew if safety conditions are met)

FM170.01.01 FoM shall issue slew requests when conditions outlined in FM110, FM120, FM140 requirements sections occur.

FM170.01.02 Slew requests will be issued to slew to a specific target. Slew requests shall use the attitude and observation number values from the FoM AT or FoM PPT target that is the specific target.

FM170.01.03 FoM shall set the IS_NEW_AT field equal to TRUE only for 1st time slews to a GRB target. Otherwise the field should be set to FALSE.

FM170.01.04 FoM shall issue an event message if the spacecraft does not generate a slew reply within 2 second of FoM issuance of a slew request.

FM170.02 Inquiry_To_Slew – inquiry to spacecraft as to whether it can safely slew to the specified target (the spacecraft will not slew based on this inquiry)

FM170.01.01 FoM shall issue slew inquiries when conditions outlined in FM110, FM120, FM140 requirements sections occur.

FM170.01.02 Slew inquiries will be issued to slew to a specific target. Slew requests shall use the attitude and observation number values from the FoM AT or FoM PPT target that is the specific target.

FM170.01.03 FoM shall set the IS_NEW_AT field equal to TRUE only for 1st time slews to a GRB target. Otherwise the field should be set to FALSE.

FM170.01.04 FoM shall issue an event message if the spacecraft does not generate a slew reply within 2 second of FoM issuance of a slew inquiry.

FM170.03 Slew_To_Safepointing – when FoM is commanded, request spacecraft to slew to a safe pointing position

FM170.04 Next_Observation_Info – message containing observing information for next target. FoM shall issue Next_Observation_Info messages as specified in FM122.

FM180 The FoM software shall generate the following telemetry:

FM180.01 FoM_Will_WillNot_Observe_AT – following receipt of an AT target request, generate a TDRSS message to the ground indicating whether the FoM will or will not not attempt to observe a Candidate_AT.

FM180.01.01 This message should be generated under conditions specified in FM115.

FM180.01.02 This message shall include values provided in BAT GRB request (BAT Trigger Time, Trigger Satisfied, and Significance Level), along with targets calculated merit. Values not available in non-GRB requests should be set to 0.

FM180.02 SC_Will_WillNot_Observe_AT – generate a TDRSS message to the ground indicating whether the spacecraft based on SC provided slew reply will or will not attempt to observe a new FoM_AT.

FM180.02.01 This message shall be generated under conditions outlined in FM122.3.

FM180.02.02 This message shall include values provided in BAT GRB request (BAT Trigger Time, Trigger Satisfied, and Significance Level), along with target's calculated merit. Values not available in non-GRB requests should be set to 0.

FM180.03 SC_In_Safe_Pointing – generate a TDRSS message to the ground when FoM receives indication that the spacecraft is going to the safe point attitude as defined in FM160.12.04.

FM180.04 SC_Settled_On_Target – based on Attitude Info packet data, generate a housekeeping telemetry message to the ground when spacecraft settles on a target.

FM180.05 Next_Observation_Info – route for housekeeping telemetry downlink a copy of each Next_Observation_Info message provided to the NFIs to indicate observation attributes for the next target to be observed.

FM180.06 SC_Slew_Abort – generate a TDRSS message indicating that FoM has received a SC provided Slew Abort message indicating that the SC will not support a slew it had just indicated that it would.

FM180.07 PPT_Target_Error - generate a TDRSS message indicating that a slew request NACQ or view constraint was received for a PPT target.

FM185 The FoM software shall provide sufficient housekeeping telemetry to monitor the FoM processing and internal state.

FM186 The FoM software shall provide FoM housekeeping telemetry packets for inclusion in TDRSS housekeeping telemetry downlink as requested.

4 FUTURE ADD-ON FUNCTIONS

(Deleted. No Add-On Functions currently planned.)

5 FoM Architecture Notes

This section is added to assist the reader in understanding the FoM requirements by previewing the intended architecture of the FoM software. As such, this section does not constitute requirements for the FoM software. The FoM behavior can be described via the following states and associated state transitions.

- "**Viewing_PPT**" State - Observing Preplanned Target
  - monitor observing time of preplanned target
  - interrupt on AT (BAT detected GRB/ToO) of merit >= preplanned target (goto "**AT-In-View**")
  - interrupt on AT not viewable of merit >= preplanned target (goto "**Waiting For AT-In-View**")
  - interrupt by next preplanned target of merit <= AT (goto "**AT-In-View**")

- "**AT In-View**" State - Automated Target In-View
  - monitor observing time of BAT detected GRB/ToO
  - interrupt by future preplanned target of merit > AT (goto "**Viewing_PPT**")
  - interrupt by new AT of merit >= preplanned target(goto "**AT-In-View**")
  - interrupt by viewing constraints of AT (goto "**Waiting For AT-In-View**")
  - interrupt by completion of AT observation time (goto "**Viewing_PPT**")

- "**Waiting For AT-In-View**" State - Automated Target Viewing Currently Constrained
  - monitor observing time of preplanned target
  - interrupt by AT coming "back into view" (goto "**AT-In-View**")
  - interrupt by future preplanned target of merit > AT (goto "**Viewing PPT**")
  - interrupt by new AT of merit >= current AT & new AT is viewable (goto "**AT-In-View**")

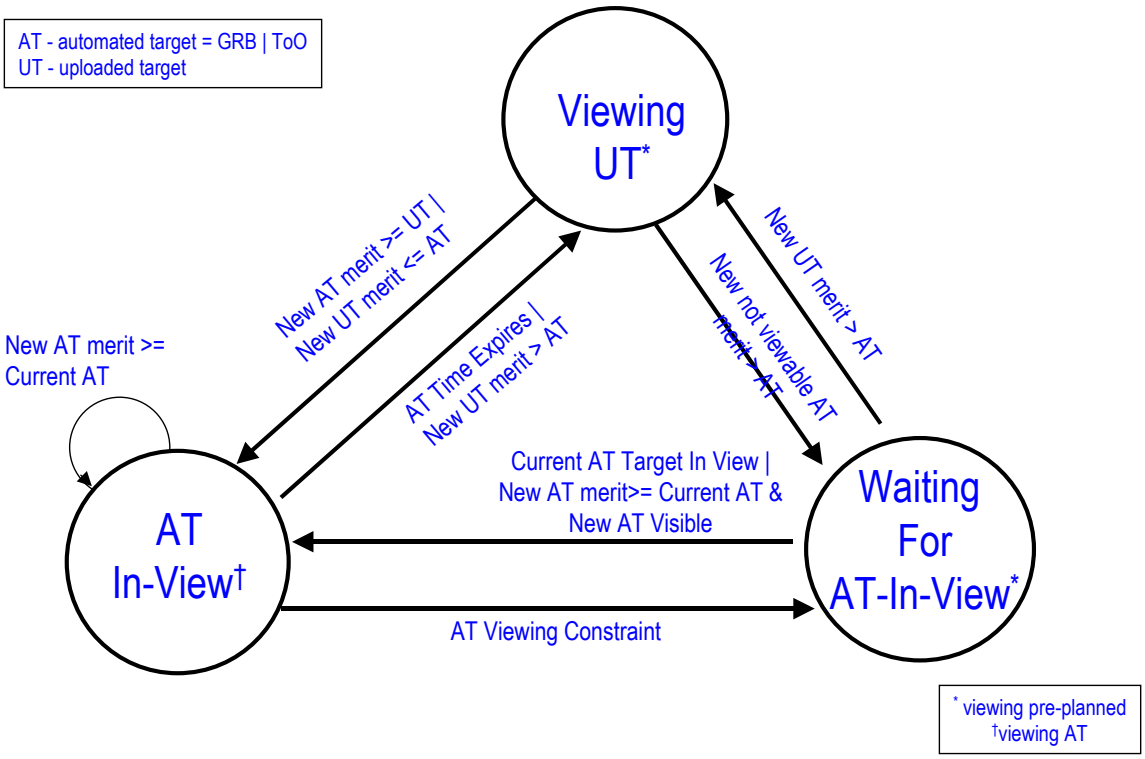

Figure 5-1 FoM State Transition Diagram

Appendix A. FoM Science Requirements Traceability

Table A-1: Requirement Traceability Matrix

SCIENCE REQUIREMENT		FoM SOFTWARE DERIVED REQUIREMENT	FoM REQ #
MRD 4.9.1	The FoM shall minimize time delay to slew to a new burst (design goal is <0.4 seconds for FoM processing)	FoM processing estimated at less than 100 ms and spacecraft interface polls BAT RT every 200 ms	• FM116
MRD 4.9.2	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.	FoM designed driven by inputs by science team for increased optimization. Design is verified by Robin Corbet's simulations to meet 80% requirement.	• FM100 • FM110 • FM120 • FM130
MRD 4.9.3	The FoM shall allow for multi-orbit automated observations of new BAT source locations	Design of Swift has all preplanned observations pass through FoM. FoM shall manage Swift observations, observing automated target when allowed by observing constraints	• FM120
MRD 4.9.4	The FoM shall allow for maximizing observing time to the uploaded program whenever automated target not being observed	FoM shall request to observe the preplanned target when automated target is not constrained	• FM120
MRD 4.9.5	The FoM shall allow for automated termination of automated observing of a target at completion	FoM shall provide a termination time for automated observations - 1 for BAT detected GRB and 1 for ToO targets (both predefined for all observations at 6000 secs). The termination time is reconfiguration in flight and takes effect immediately.	• FM121
MRD 4.9.6	The FoM shall allow for pre-specified uploaded observations to override automated observations	FoM shall provide capability to disable automated observations.	• FM140 • FM160.05
		Merit value for preplanned program is assigned by ground & can be set-up to be of higher merit value than automated observations	N/A
MRD 4.9.7	The FoM shall allow for automated observations triggered by TDRSS commands	FoM shall accept ToO, with preplanned merit value, via TDRSS link. ToO are treated by FoM in the same manner as BAT detected targets.	• FM112
MRD 4.9.8	The FoM shall allow for current automated target to override new GRBs based on input from the instruments,	FoM shall provide for each instrument to supply its 10 data values to be used by the FoM in FoM's merit computation	• FM111.1 • FM16
MRD 4.9.9 MRD 4.9.10	The FoM shall allow for extension of the automated observing time based on input from the NFIs, and The FoM shall allow for adjustment of fraction of observing time allocated to the automated and uploaded programs for extended automated observations	FoM shall provide a command which may be used by an instrument to extend the termination time for an automated observation. See description provided for MRD 4.9.7 requirement for details.	• FM121
MRD 4.9.11	The FoM shall allow for termination of automated observing of a target by TDRSS command	FoM shall provide hook to terminate/abort an automated observation	• FM160.08
MRD 4.9.12	The FoM shall allow for a workable mechanism to implement new automated observing strategies after launch	FoM shall provide capability to modify merit calculation algorithm parameters by command (the BAT also willshall have capabilities to modify triggering thresholds).	• FM111.2
		FoM shall be fully reprogramnable in flight	• FM150
MRD 4.9.13	The FoM shall have the capability to disable slew requests to the S/C by command.	Slew requests to the spacecraft can be inhibited by disabling both AT and PPT scheduling.	• FM140 • FM160.05 • FM160.07

	Both slew requests and inquiries can be inhibited by disabling Slew scheduling.	• FM140 • FM160.16