Preliminary Description
of
NGST Flight Software Functions

prepared by

NGST Integrated Science Instrument Module
Flight Software Development Team

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INTRODUCTION

The Next Generation Space Telescope (NGST) Integrated Science Instrument Module (ISIM) Flight Software Development Team (http://ngst.gsfc.nasa.gov/cgi-bin/pubdownload?Id=274) has collected information describing the functions that will be performed by NGST flight processors. This information has been collected for the purpose of identifying the high-level flight software functionality from a science and operations perspective. It is planed that, at the onset of phase A, this information will be used as an aide to clarifying the allocation of functions and development responsibilities between the Integrated Science Instrument Module (ISIM), ground system, and prime contractor teams.

The following tables are intended as preliminary draft source material from which requirements and interface control documents will be developed during phase A. This document is released for NGST team wide comment. Comments should be addressed to: Raymond Whitley (Raymond.Whitley.1@gsfc.nasa.gov).

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Functional Statement	ALLOCATION	COMMENTS
Observation Plan Execution	ISIM	
1. The execution of the NGST mission timeline shall be controlled by an Observation Plan Executive (OPE) that interprets and controls the flow of the observation plan [consisting of a time-ordered sequence of science and engineering (maintenance) requests periodically uplinked from the ground], issues commands to spacecraft and ISIM subsystems, and manages the timeline in response to subsystem telemetry. *Rationale: A unified Executive, responsible for the management and flow of all flight-segment activities during normal operations, simplifies the ground segment's planning and command management interface. The integration of spacecraft and ISIM command and control also enables a more dynamic paradigm for timeline execution.*		An observation plan can contain both science and engineering requests. *Science request* corresponds to the STScI term *visit*. The definition of *visit* does not adequately capture all that one may want of an *engineering request*. E.g., consider station keeping, which may involve two ΔV thruster burns at greatly different attitudes. ***kk revision***
1.1 The OPE shall employ an event-driven paradigm to coordinate all flight-segment activities that are involved in observing plan execution. *Rationale: An onboard, event-driven observation plan executive (as opposed to a traditional time-tagged command system): (1) simplifies modeling of request execution in the ground-based planning and scheduling system, (2) avoids the need to employ worst-case timing relationships amongst sequential activities, and (3) compresses, where possible, time that would be wasted due to a failure of a critical portion of an activity (e.g., a guide star acquisition).*		***kk revision***
1.1.1 The OPE shall issue commands to the request-designated flight software processes for activities to be executed in support of the observation plan.		
1.2 The OPE shall determine the validity of requests prior to execution and discard invalid requests. *Rationale: Avoids possible risk to the spacecraft. Compresses out time that would be wasted by starting observations that can't be completed.*		
1.2.1 The OPE shall discard any request with invalid syntax.		
1.2.2 The OPE shall discard any request that cannot be executed because of a constraint violation.		

Functional Statement	ALLOCATION	COMMENTS
1.2.3 The OPE shall report any discarded requests.		
1.2.4 The OPE shall initiate the next request if the current request is found to be invalid.		
1.3 The OPE shall coordinate the execution of activities relative to the availability of required resources. *Rationale: Prevents resource violation without need for detailed ground modeling.*		
1.3.1 The OPE shall delay execution of a request if required resources are temporarily unavailable (e.g., full data storage, excess momentum accumulation, or lack of some other resource). *Rationale: Prevents beginning a request for which sufficient resources are unavailable.*		
1.3.2 The OPE shall request suspension of the current activity if needed resources are lost during execution. *Rationale: Allows for unanticipated occurrences during request execution (e.g., repeated loss of guide star lock and reacquisition events that cause an exposure to extend in time beyond a momentum violation limit).*		
1.3.3 If an action has been specified for responding to a temporary resource constraint violation, the OPE shall initiate the specified action (e.g., dumping of excess momentum). *Rationale: Allows autonomous correction of violations when possible.*		
1.4 The OPE shall cause each request in the observation plan to be executed immediately after the preceding request has been completed, unless specified otherwise by constraints in the request. *Rationale: See items 1 & 2 of top-level rationale*		
1.5 The OPE shall constrain request execution based upon conditions specified in the request. *Rationale: Avoids need for detailed modeling in ground system; constraints satisfied in real-time.*		
1.5.1 The OPE shall enforce the execution of a request to fall within an absolute time window if specified in a request.		
1.5.1.1 If a time window has not opened, the OPE shall postpone initiation of a request until the window start time occurs.		

Functional Statement	ALLOCATION	COMMENTS
1.5.1.2 The OPE shall prevent a request from executing outside its associated window.		
1.5.2 The OPE shall enforce any event dependencies specified in a request.		
1.5.2.1 If occurrence of one or more events is specified, the OPE shall delay execution of the request until all required events have occurred. Note: Such events may include, but are not limited to, completion of OPE-issued requests.		
1.5.2.2 If minimum delay time(s) following one or more events is specified, the OPE shall delay execution of the request until all specified delays have elapsed.		
1.5.2.3 If maximum delay time(s) following one or more events is specified, the OPE shall skip execution of the request if too much time elapses.		
1.6 The OPE shall be able to insert unscheduled filler requests from an onboard pool into time gaps that may occur during execution of the observation plan for any reason (e.g., as a result of the use of absolute time constraints). *Rationale: Allows productive use of time that would otherwise be wasted.*		Autonomous insertion of calibration exposures.
1.7 <u>Conditional requirement</u>: The OPE shall support the use of parallel activity threads within requests. *Rationale: Allows productive use of parallel resources (e.g., parallel science) if no constraint violation would occur.*		
1.8 The OPE shall be able to insert standard house-keeping activities (e.g., dumping of angular momentum) into the execution flow as required. *Rationale: Avoids need for detailed modeling in ground system. Allows system to respond gracefully to schedule adjustments that occur due to real-time OPE function decisions.*		Consider consolidating with 1.3.3? (although house-keeping should be done whether or not an Observation Plan request has been delayed).
1.9 The OPE shall respond to a "pause" command received either from within the Observing Plan or as a real-time command. *Rationale: Gives the FOT/SOT opportunity for real-time control that may be needed.*		
1.10 The OPE shall be able to either resume, restart, or abort a "paused" activity. *Rationale: Allows graceful resumption of observation plan according to FOT/SOT decision.*		

Functional Statement	ALLOCATION	COMMENTS
1.11 The OPE shall report events related to Observation Plan execution to a logging function that can be monitored and analyzed on the ground. *Rationale: Provides FOT/SOT information needed to monitor the ongoing status of the execution of the observing plan. This is somewhat more important for an event-driven system, which is by definition somewhat unpredictable in detail.*		
Navigation	Prime	
2. The Navigation function shall provide ephemeris information for significant bodies. *Rationale: Needed to allow (1) velocity aberration corrections for AD&C, (2) antenna pointing for communications, and (3) bright object constraint checking.* *Question: What reference frame do we expect to be using? If heliocentric, we don't need solar ephemeris data; if geocentric inertial, we don't need Earth ephemeris data.* *Question: Would it be useful to have an L2 ephemeris, with the spacecraft ephemeris being relative to L2 during normal operations?*		
2.1 The Navigation function shall accept uplinked parameters for each ephemeris model.		
2.2 The Navigation function shall validate newly received ephemeris parameters.		
2.3 The Navigation function shall calculate ephemeris information for each significant body.		
2.3.1 The Navigation function shall determine position and velocity vectors for the spacecraft at TBD frequency.		
2.3.2 The Navigation function shall determine position vectors for the Sun at TBD frequency.		
2.3.3 The Navigation function shall determine position vectors for the Earth at TBD frequency.		
2.3.4 The Navigation function shall determine position vectors for the Moon at TBD frequency.		
2.4 The Navigation function shall make the calculated ephemeris information available to other subsystems that require it.		

Functional Statement	ALLOCATION	COMMENTS
Attitude Determination and Control (AD&C)	Prime	
3. The Attitude Determination and Control (AD&C) function shall be able to determine and control the attitude of the spacecraft support module. *Rationale: see sub-requirements*		
3.1 The AD&C function shall perform attitude-related constraint checking. *Rationale: see sub-requirements*		***Proposed new requirements. – gw***
3.1.1 The AD&C function shall validate slew commands, rejecting any that would result in a constraint violation *Rationale: Prevents the spacecraft from attempting to slew to an invalid attitude, possibly as a consequence of errors in the observation plan.*		***We may want a requirement for generation of "dog-leg" slews to avoid sun constraint violation during slews. gw***
3.1.2 The AD&C function shall check the current attitude against constraint limits *Rationale: Protects against real-time constraint violation. (Prevalidation of a request may not be sufficient given that it is possible to suspend execution of the observation plan and simply let the spacecraft sit at constant attitude for an extended period.)*		
3.1.3 The AD&C function shall report any real-time constraint violations *Rationale: Alerts FOT to any real-time constraint violations*		
3.2 The AD&C function shall be able to determine the attitude of the spacecraft support module to TBD arc-seconds. *Rationale: Accurate attitude knowledge is required (1) to enable pointing in the desired direction, and (2) for later analysis of science data.*		
3.3 The AD&C function shall achieve a user-specified attitude for the spacecraft support module to within TBD (~1) arc-seconds. *Rationale: SSM attitude control at this level is required to allow positioning of the SI field of view on the desired target.*		

Functional Statement	ALLOCATION	COMMENTS
3.3.1 The AD&C function shall apply SSM attitude adjustments necessary to support the Fine Guidance function in maintaining the OTA field of view pointing in the user-specified target direction. *Rationale: SSM/ISIM/OTA structural dynamics may result in some long time-scale offset relative misalignment between the SSM and OTA. Adjustments in the SSM attitude may consequently be required to compensate for such an offset and allow the Fine Guidance function to operate within its dynamic range.*		
3.4 The AD&C function shall be able to control spacecraft support module attitude to within TBD (~1) arc-seconds. *Rationale: Stable SSM control is required (1) to enable guide star acquisition for the fine guidance function, and (2) to keep OTA field of view motion within the dynamic range of the fine guidance device (i.e., the fast steering mirror in the GSFC yardstick).*		
3.4.1 The AD&C function shall correct for the effects of spacecraft velocity aberration. *Rationale: Velocity aberration for a spacecraft orbiting near L2 will introduce effective distortions around the celestial sphere of ~ 20 arcseconds, which is large relative to the required pointing accuracy.*		
3.5 The AD&C function shall be able to maintain the attitude to within TBD arc-seconds during momentum management thruster firing. *Rationale: It is desirable to minimize disturbances so as to minimize time to resume science operations. It is necessary to avoid very large attitude changes that could result in pointing violations or significant changes in thermal profile in the mirror.*		
3.6 The AD&C function shall be able to maintain the attitude to within TBD arc-seconds during orbit adjustment thruster firing. *Rationale: Depending on design, it may not be possible to maintain an attitude close to the current target attitude, so large disturbances may be inevitable. However, it is necessary that the orbit change thrust vector be kept reasonably close to the planned direction. One must also avoid pointing constraint violations.*		

Functional Statement	ALLOCATION	COMMENTS
3.7 The AD&C function shall monitor the jitter level of the spacecraft support module. *Rationale: Measuring the jitter of the spacecraft support module allows the OPE to know when jitter is low enough to allow guide star acquisition to proceed.*		Assumes a hardware design using a distinct spacecraft support module.
3.7.1 When not slewing, the AD&C function shall use data from the star trackers and gyroscopes to estimate the jitter level of the spacecraft support module at TBD frequency. *Rationale: See above*		
3.7.2 The AD&C function shall make the estimated spacecraft support module jitter level available to any subsystem requiring it. *Comment: This may include the observation plan execution system, and the engineering telemetry system.* *Rationale: See above*		
3.8 The AD&C function shall notify the originator of any command as to the final outcome (e.g., succeeded, failed, rejected, or any other agreed upon outcomes). *Rationale: part of event-driven paradigm*		Should this be imposed on each individual subsystem that can execute commands?
3.8.1 If the command cannot be completed within TBD time, the AD&C function shall notify the originator that the request has been received and the requested action is being performed. *Rationale:*		Should this be imposed on each individual subsystem that can execute commands?
Fine Guidance	Prime	
4. The Fine Guidance function shall support acquisition of and guidance with a guide star observed at TBD (~ 30) Hz with the near infrared (NIR) camera. *Rationale: Fine guidance required for acceptable stability of the OTA field of view on the SI detector focal planes.* *Note: See comments in the "Science Collection" section. If that suggestion is accepted, it may be appropriate to reorganize these requirements a bit to distinguish between high-level requirements specific to fine guidance vs. SI and FPA Detector hardware interface requirements.*		Our discussion on 11-May-99 assumed the use of the NIR camera. Should these requirements be generalized to allow for a separate guiding sensor?

Functional Statement	ALLOCATION	COMMENTS
4.1 The Fine Guidance function shall support ground-specification of which quadrant(s) may be used for guide star selection. *Rationale: The SOT is likely to want to specify which quadrant(s) are to be reserved for science, which may involve filters inappropriate for guidance.*		
4.2 The Fine Guidance function shall support acquisition of a ground-specified guide star. *Rationale: This allows the ground system to select one or more well positioned guide stars ahead of time, which (1) increases the probability that a good guide star will actually be found, and (2) allows the ground-based scheduler to not bother incorporating into the observation plan requests for which no guide star exists.*		
4.2.1 The Fine Guidance function shall support a search for up to *N* ground-specified guide star candidates. *Rationale: Allows for the possibility that there may be catalog errors that render a particular star unacceptable, e.g., a catalog object may be binary or variable.*		
4.2.2 For each candidate, the Fine Guidance function shall apply TBD procedure for accumulation of NIR camera data from a user-specified number of short exposures in a small region around the candidate star. *Rationale: Needed for next req.*		
4.2.3 For each candidate, the Fine Guidance function shall confirm that the observed object is the specified candidate. *Rationale: Allows verification of the expected position, brightness, and photon distribution of the candidate star. (PSF/jitter characterization before guidance may allow determination that the candidate is detectably extended at the ~ 1-arcsecond, and therefore rejectable a priori.)*		
4.2.3.1 The Fine Guidance function shall edit the data set used for guide star selection. *Rationale: It is likely that cosmic ray hits will have to be removed before candidate identification can be done.*		
4.2.3.2 The Fine Guidance function shall confirm the candidate location.		
4.2.3.3 The Fine Guidance function shall confirm the candidate integrated intensity.		
4.2.3.4 The Fine Guidance function shall confirm the candidate PSF/jitter characterization.		

Functional Statement	ALLOCATION	COMMENTS
4.2.4 The Fine Guidance function shall select a guide star from among the ground-specified candidates. *Rationale: Some means is required to select from among the set of N stars.*		
4.2.5 The Fine Guidance function shall be able to calculate an adjustment to be applied to the desired attitude of the spacecraft support module to shift the selected guide star from its observed position to its desired position in the NIR camera field of view. *Rationale: Allows correction for any large, systematic errors due to (1) star tracker stars vs. guide star catalog errors, or (2) star tracker vs. SI field of view relative alignment errors due to either calibration error or structural shift.*		
4.3 The Fine Guidance function shall support serendipitous acquisition of a guide star. *Rationale: If this requirement is preserved, it would be to simplify ground system processing. The claim would be that the probability of finding an acceptable guide star within the NIR camera field of view is sufficiently high that there is no need to encumber the ground system with a requirement to do guide star selection for all – perhaps any – pointings.*		***Do we want to preserve this set of requirements? gw***
4.3.1 The Fine Guidance function shall accumulate data from a user-specified number of short exposures for each NIR camera quadrant specified as acceptable for guiding. *Rationale: Required data acquisition for requirement 4.3.2.*		
4.3.2 The Fine Guidance function shall identify a set of up to *N* candidate point sources in the image. *Rationale: Creates a set of candidate guide stars and criteria for judging between them.*		
4.3.2.1 The Fine Guidance function shall edit the data set used for guide star selection. *Rationale: It is likely, particularly for serendipitous acquisition, that cosmic ray hits will have to be removed before candidate identification can be done.*		
4.3.2.2 The Fine Guidance function shall determine candidate star positions.		
4.3.2.3 The Fine Guidance function shall determine candidate star integrated intensity.		
4.3.2.4 The Fine Guidance function shall determine candidate star PSF/jitter characterization.		

Functional Statement	ALLOCATION	COMMENTS
4.3.3 The Fine Guidance function shall configure the NIR camera chip containing the selected guide star for "rapid" read-out at TBD (~ 30) Hz. *Rationale: Required for next req..*		The frequency for "rapid" read-out is TBD, but estimated for the GSFC yardstick to be ~ 30 Hz.
4.3.4 The Fine Guidance function shall read data from the configured chip at the "rapid" rate. *Rationale: Readout at ~ 30 Hz is required to suppress field-of-view motions below ~ 3 Hz, the estimated dominant mode for the sunshade in the GSFC yardstick.*		
4.3.5 The Fine Guidance function shall validate each read-out data set to validate the data. *Rationale: Prevents spurious input to the control fine guidance control law due to bad data, e.g., such as a cosmic ray hit.*		I am specifically thinking here of cosmic ray hits. I may be making a naive assumption that a CR hit will affect at most a small number of consecutive readouts.
4.3.5.1 The Fine Guidance function shall discard data found to be bad.		
4.3.6 For each validated data set, the Fine Guidance function shall determine the change in the observed guide star position relative to its reference position. *Rationale: The position error is the required to determine actuator motions (e.g., fast steering mirror adjustments) to correct the error.*		
4.3.7 The Fine Guidance function shall use the computed change in guide star position to determine actuator commands for correcting the OTA field of view direction. *Rationale: support for next req.*		Note: the control law algo-rithm should specify how to respond if good data are not available.
4.3.8 The Fine Guidance function shall issue actuator commands or correcting the OTA field of view direction at TBD (~30) Hz. *Rationale: Corrects for low to moderate frequency vibrations.* *Comment: In the GSFC yardstick, the principal mode compensated for by the Fine Guidance function is ~ 3 Hz vibrations induced by the sun shield.*		Is it known that the actuator commands should be issued at the same rate at which guide star data are accumulated?
4.4 The Fine Guidance function shall validate the star selected for guidance. *Rationale: Allows confirmation that the selected object is a point source. This can only be done at the ~ 10-milli-arcsecond level after fine guidance has started.*		The probability of accidentally selecting an extended source is non-negligible.

Functional Statement	ALLOCATION	COMMENTS
4.4.1 After fine guidance has been established, the Fine Guidance function shall apply PSF Monitoring to confirm that the guide "star" is indeed a point source. *Rationale: see above*		Question: how shall we distinguish between OTA degradation and guiding on an extended source?
4.4.2 If the guide "star" is found to be an extended source, and if there are additional guide star candidates remaining, the Fine Guidance function shall select another candidate an use it for guidance. *Rationale: see above*		
4.5 The Fine Guidance function shall support guide star reacquisition. *Rationale: Minimizes the time for reacquisition, and therefore saves valuable science time.*		
4.5.1 During fine guidance, the Fine Guidance function shall store sufficient information for rapid reacquisition of the guide star. *Rationale: see above*		
4.5.2 If guide star lock is spontaneously lost or released by command, the Fine Guidance function shall, on command, support rapid reacquisition of the guide star after the spacecraft attitude has been restored to within TBD arcseconds in pointing and TBD arcseconds in roll. *Rationale: see above*		As written, I am assuming that it will be adequate for the flight system to remember only the most recent guide star acquisition. Might there be a need for a deeper memory – e.g., to allow OTA recalibration followed by resumption of science?
4.6 During fine guidance, the Fine Guidance function shall use guide star centroid data to estimate the jitter level of the optical line of sight. *Rationale: Measuring the jitter of the optical line of sight allow the OPE function to know when science exposures can begin and provides a characterization of the quality of the science being done.*		
4.6.1 The Fine Guidance function shall make the optical line of sight jitter estimate available to any subsystem requiring it. *Rationale: see above*		

Functional Statement	ALLOCATION	COMMENTS
4.6.2 The Fine Guidance function shall compute the average optical line of sight jitter in effect during each science instrument exposure and record it in the science data header. *Rationale: see above*		
4.7 The Fine Guidance function shall inform the Observing Plan Execution function of the status, success and failure of activities performed in response to guide star acquisition requests *Rationale:*		
4.8 The Fine Guidance function shall characterize the OTA point spread function. *Rationale: (1) Provides indication to scientists of optics quality during observations. (2) Allows suspension of observations if optics configuration degrades. (3) Provides FOT input for decision to re-invoke wavefront error measurement and associated mirror adjustment.*		There was some discussion at the meeting about possibly using a star other than the guide star for this purpose
4.8.1 The Fine Guidance function shall compute the OTA point spread function characterization using guide star data whenever fine guidance is in effect. *Rationale: see above*		
4.8.2 The Fine Guidance function shall report the point spread function characterization to the Observation Plan Execution function. *Rationale: Allows the OPE function to determine whether to adjust observation plan flow (e.g., refrain from initiating next observation exposure) based on the current state of the OTA optics.*		
4.8.3 The Fine Guidance function shall report the point spread function characterization to the Engineering Data Collection and Downlink Preparation function. *Rationale: To include PSF characterization in data downlink to allow FOT to readily monitor OTA quality; allows decision for when wavefront error measurement and associated mirror adjustment requests should be reinvoked.*		
4.8.4 The Fine Guidance function shall report the point spread function characterization to the Science Collection function. *Rationale: Allows scientist to understand quality of optics at time of observation.*		
4.9 The Fine Guidance function shall notify the originator of any command as to the final outcome (e.g., succeeded, failed, rejected, or any other agreed upon outcomes). *Rationale: part of event-driven paradigm*		Should this be imposed on each individual subsystem that can execute commands?

Functional Statement	ALLOCATION	COMMENTS
4.9.1 If the command cannot be completed within TBD time, the Fine Guidance function shall notify the originator that the request has been received and the requested action is being performed. *Rationale:*		Should this be imposed on each individual subsystem that can execute commands?
Target Acquisition	ISIM (with Prime support)	
5. The Target Acquisition function shall be able, automatically, to acquire a specified science target and to position the target at a specific location in a specified science instrument's field of view. *Rationale: In case of a pre-selected guide star, local catalog errors and/or relative SI field of view alignment error could result in a significant shift in the desired position of the science target(s) relative to the intended aperture(s). In the case of serendipitous guide star acquisition, one would also have errors introduced as a consequence of global catalog errors and uncertainty in OTA pointing relative to the SSM. One must correct for these effects to put the target(s) in the desired aperture(s).* *Note: See comments in the "Science Collection" section. If that suggestion is accepted, it may be appropriate to reorganize these requirements a bit to distinguish between high-level requirements specific to target acquisition vs. SI and FPA Detector hardware interface requirements.*		Assume most targets too faint to guide on with camera. ***? – I don't think one could guide an bright extended sources either. gw*** ***? – I don't really understand the purpose except for small slit apertures.***
5.1 The Target Acquisition function shall be able to analyze science image data to determine the presence and location of the desired science target(s) within the image. *Rationale: This type of functionality could be useful if a large aperture field of view in camera mode is being used for finding targets for subsequent placement within a smaller aperture (e.g., single MIR spectrograph aperture in GSFC yardstick) or a set of smaller apertures (e.g., as could be formed by NIR Spectrograph micro-mirrors in GSFC yardstick).*		
5.2 *Conditional Requirement:* The Target Acquisition function shall be able to effect a search for the science target in an area larger than the science instrument aperture. *Rationale: Would enable raster scanning of a relatively small aperture (e.g., the yardstick MIR spectrograph ~ 2x1 arcsecond) across a region of sky to find the target.*		May be needed for narrow spectrometer slits.

Functional Statement	ALLOCATION	COMMENTS
5.2.1 <u>*Conditional Requirement:*</u> The Target Acquisition function shall be able to generate a succession of requests to move the science instrument aperture field of view relative to the sky in a specified manner. *Rationale:*		How does the search process interact with fine guidance? What if the search extends beyond the range of the FSM? Might vehicle offsets be required?
5.2.2 <u>*Conditional Requirement:*</u> The Target Acquisition function shall be able to acquire and process a succession of readouts from the science instrument to permit detection of the science target during the search process. *Rationale:*		
5.3 The Target Acquisition function shall be able to generate requests to move the science target relative to the SI field of view. *Rationale: After the target has been found, it must be placed in the desired aperture.*		
5.4 <u>*Conditional Requirement:*</u> The Target Acquisition function shall be able to generate micro-mirror commands to create an effective aperture or set of apertures around the selected targets. *Rationale: This procedure would enable multi-object spectroscopy on serendipitously selected targets for an SI like the GSFC yardstick NIR Spectrograph.* *Comment/Question: At the meeting in which Target Acquisition was first discussed, John Isaacs (I think) argued that serendipitous selection of targets for multi-object spectroscopy was extremely unlikely, but rather that all targets would be selected by the ground system ahead of time, as well as any specification of a micro-mirror aperture pattern. Is this the general consensus of the STScI members?*		***I added this requirement to invoke a bit of discussion regarding whether serendipitous multi-object spectroscopy might be useful. gw***
5.5 The Target Acquisition function shall generate a status condition to indicate when the target is properly acquired. *Rationale: Allows the OPE to proceed with the next step in the observation plan (presumably an extended exposure of the target.)*		
5.6 The Target Acquisition function shall inform the Observing Plan Execution function of the status, success and failure of activities performed in response to target acquisition requests *Rationale:*		

Functional Statement	ALLOCATION	COMMENTS
5.7 The Target Acquisition function shall notify the originator of any command as to the final outcome (e.g., succeeded, failed, rejected, or any other agreed upon outcomes). *Rationale: part of event-driven paradigm*		Should this be imposed on each individual subsystem that can execute commands?
5.7.1 If the command cannot be completed within TBD time, the Target Acquisition function shall notify the originator that the request has been received and the requested action is being performed. *Rationale:*		Should this be imposed on each individual subsystem that can execute commands?
Field of View Offset Control	ISIM & Prime	
6. The flight software shall provide capability to effect an offset of the optical field of view. *Rationale: see sub-requirements* *Comment: It may be appropriate to redistributed these requirements to the AD&C, Fine Guidance, and Target Acquisition functions. (?)*		
6.1 The flight software shall be able to effect small offset maneuvers of up to 1 arc-seconds (TBD) with induced jitter of no more than TBD arc-seconds and a settling time of no more than TBD seconds. *Rationale: Allows dithering between exposures to compensate for FPA window pane effects.*		
6.2 The flight software shall be able to effect small offset maneuvers of up to 10 arc-seconds (TBD) with induced jitter of no more than TBD arc-seconds and a settling time of no more than TBD seconds. *Rationale: Enables target acquisition.*		
6.3 The flight software shall be able to effect small offset maneuvers of up to 4 arc-minutes (TBD) with induced jitter of no more than TBD arc-seconds and a settling time of no more than TBD seconds. *Rationale: Enables mapping of areas larger than the field of view.*		
Science Collection	ISIM	
7. The Science Collection function shall coordinate the collection of science exposures. *Rationale: The basic purpose of the mission is to collect science data*		

Functional Statement	ALLOCATION	COMMENTS
7.1 The Science Collection function shall receive requests from the Observing Plan Execution function or the ground system to perform science observations. *Rationale: general event-driven operations paradigm*		Automatic exposure monitoring.
7.2 The Science Collection function shall decompose science collection requests into commands appropriate for SI element motion, FPA detector configuration, and FPA data processing. *Rationale: modularization*		Automatic exposure monitoring.
7.3 The Science Collection function shall notify the originator of any science collection command as to the final outcome (e.g., succeeded, failed, rejected, or any other agreed upon outcomes). *Rationale: part of event-driven paradigm; the usual "originator" will be the OPE.*		Should this be imposed on each individual subsystem that can execute commands?
7.3.1 If the command cannot be completed within TBD time, the Science Collection function shall notify the originator that the request has been received and the requested action is being performed.		Should this be imposed on each individual subsystem that can execute commands?
7.4 The Science Collection function shall coordinate the construction of science observation data files for transfer to the data storage device. *Rationale: The data must be stored for later downlink; it is expected that there will not be continuous contact with the control center.* *Note: See support functions under "FPA Data Processing".*		Should this be imposed on each individual subsystem that can execute commands?

Functional Statement	ALLOCATION	COMMENTS
Science Instrument Control **<u>Architecture Issues</u>** 1) Is there a separate SI Controller for each SI or are there common higher-level functions and lower-level "device drivers". 2) SI Controllers must be easily integrated. Could produce template SI Controller for SI developers. 3) Should SI Controller manage only SI mechanisms or also data readout and data processing? 4) Want to minimize "multiplication" of software modules by SI and SI mode. 5) What is the impact on SI Control of parallel operation? 6) What is the impact on SI Control of using SI data for the guiding function? 7) Should SI Health and Safety reside with the SI Control function or with the Health and safety function?	ISIM	
8. The SI Control function shall configure and control the SI hardware. *Rationale: Modularization; provides central function for any higher-level functions that need to issue commands to reconfigure the SIs.*		
8.1 The SI Control function shall be able to command SI mechanisms and actuators and configure SI modes and states. *Rationale:*		
8.2 The SI Control function shall control the collection and distribution of SI-related status data. *Rationale:*		
8.3 *Conditional Requirement:* The SI Control function shall be able to control the operation of each SI independent of the other SIs to the extent that such operations do not conflict. *Rationale:*		What does this really mean? What entity is it a requirement for?
8.3.1 *Conditional Requirement:* The SI Control function shall be able to control the operation of each SI subsystem (e.g., NIR Camera quadrants) independently of the other subsystems in the same SI to the extent that such operations do not conflict. *Rationale:*		

Functional Statement	ALLOCATION	COMMENTS
Focal Plane Array Detector Control	ISIM	
9. The FPA Detector Control function shall control command input to the FPA detectors. *Rationale: Modularization; provides central function for any higher-level functions that need to issue commands to reconfigure the SI detectors.*		
9.1 The FPA Detector Control function shall be able to issue requests that control the acquisition of data from the FPAs. *Rationale:*		***Matt J. has suggested we distinguish between SI and FPA control functions. gw***
9.1.1 The FPA Detector Control function shall be able to issue requests that invoke the readout of science image data from the FPAs. *Rationale:*		
9.1.2 The FPA Detector Control function shall be able to issue requests that invoke support functions (such as initialization and preparation of detectors) required for acquisition of data from the FPAs. *Rationale:*		
9.2 *Conditional Requirement:* The FPA Detector Control function shall be able to control the operation of each SI detector array independent of the other arrays to the extent that such operations do not conflict. *Rationale:*		What does this really mean? What entity is it a requirement for?
9.2.1 *Conditional Requirement:* The FPA Detector Control function shall be able to control the operation of each detector within a single SI independent of the other detectors in the same SI to the extent that such operations do not conflict. *Rationale:*		
Focal Plane Array Data Processing	ISIM	
10. The FPA Data Processing function shall receive, sample, and apply other general processing to FPA data sets in support of the various higher-level functions. *Rationale: Modularization; provides utility functions for any higher-level functions that need to process FPA data.*		

Functional Statement	ALLOCATION	COMMENTS
10.1 The FPA Data Processing function shall be able to apply general utility algorithms for FPA data processing *Rationale:*		Should this be with OPE or Sci. Data Acq and Proc.?
10.1.1 FPA Data Processing function shall perform signal intensity estimation over a user-specified portion of an array region. *Rationale: Signal intensity is the fundamental measurement of interest. Allowing restriction of the region processed permits specialized support, e.g., processing of a small region of data surrounding pre-selected guide star coordinates during guide star acquisition.* *Comment: There may be a number of permitted methods for intensity estimation, e.g., Fowler averaging, or "up the ramp" averaging .*		
10.1.2 The FPA Data Processing function shall be able to apply cosmic ray filtering over a user-specified portion of an array region. *Rationale: It may prove desirable to apply cosmic filtering onboard to normal science data, particularly if the selected algorithm requires a much larger quantity of data than can downlinked practically. It will almost certainly be desirable to apply cosmic ray filtering to exposures acquired for onboard analysis, e.g., in support of guide star or target acquisition.*		
10.1.3 The FPA Data Processing function shall be able to apply flat field corrections over a user-specified portion of an array region. *Question: Do we want this functionality?* *Rationale: Would generally make more accurate any onboard support calculations (e.g., guide star centroiding, PSF estimation, etc.). Should be evaluated separately for each FPA data processing function included onboard.*		
10.1.4 The FPA Data Processing function shall be able to apply dark count corrections over a user-specified portion of an array region. *Question: Do we want this functionality?* *Rationale: Would generally make more accurate any onboard support calculations (e.g., guide star centroiding, PSF estimation, etc.) Should be evaluated separately for each FPA data processing function included onboard.*		

Functional Statement	ALLOCATION	COMMENTS
10.1.5 The FPA Data Processing function shall be able to apply background corrections over a user-specified portion of an array region. *Question: Do we want this functionality?* *Rationale: Would generally make more accurate any onboard support calculations (e.g., guide star centroiding, PSF estimation, etc.) Should be evaluated separately for each FPA data processing function included onboard.*		
10.1.6 The FPA Data Processing function shall be able to compress exposure data sets. *Rationale: Data compression will probably be required for downlink of all observations over a restricted communications link*		There is some debate as to whether adequate data compression can be achieved without onboard cosmic ray / solar particle event filtering.
10.2 The FPA Data Processing function shall be able to create formatted exposure data sets for use in data file construction. *Rationale: Included as a FPA data processing utility to allow creation of data sets in support of Science Collection, as well as diagnostic data sets for FOT evaluation of the Fine Guidance, Target Acquisition, and/or any other functions that use FPA data.*		
10.2.1 The FPA Data Processing function shall be able to construct headers for significant units (files, segments, packets, etc.) of FPA detector data with time information and pertinent engineering information. This information shall include, but is not limited to, observation/exposure IDs, science instrument settings (e.g., filter setting), exposure start time, exposure duration, average OTA point function characterization during exposure, and average OTA jitter during exposure. *Rationale: It is likely to be very difficult after the fact (i.e., after the data have been downlinked) to correlate the FPA images with appropriate engineering data describing the time and conditions under which they were acquired. It is therefore desired that the engineering data be incorporated into the FPA image data files as they are produced.*		
10.3 The FPA Data Processing function shall be able to transfer exposure data sets to a science data storage device for later transmission to the ground. *Rationale: Allows non-real-time science and other processing, with results stored till ground contact is possible.*		Science data are only sent to the recorder and are not sent to the ground. I.e., there is no real-time science data.

Functional Statement	ALLOCATION	COMMENTS
OTA Actuator Control	Prime	
11. The OTA Actuator Control function shall control OTA component actuators based on commands received from the ground or other spacecraft systems. *Rationale: See below*		
11.1 The OTA Actuator Control function shall control deployment of the primary and secondary mirror. *Rationale: It is expected that it will be prohibitively expensive to launch the satellite with all OTA elements in their final configuration, so a system will be needed to support deployment of the optics.*		
11.1.1 Upon reception of deployment commands from the ground, the OTA Actuator Control function shall deploy the primary mirror petals and the secondary mirror. *Rationale: Ditto* *Question: Do we need a requirement for the flight system to monitor deployment forces, with the possibility of deactivating the deployment process either automatically or in response to ground command.* *Rationale: Protects against OTA damage.*		
11.1.2 The OTA Actuator Control function shall report to the Engineering Data Collection and Downlink Preparation function the position of the primary and secondary mirror components during the deployment process to an accuracy of TBD mm. *Rationale: Allows the FOT to monitor the deployment activity.*		
11.2 The OTA Actuator Control function shall control adjustment of the primary, secondary, and deformable mirrors. *Rationale: Allows adjustments to correct wavefront errors.*		
11.2.1 Upon reception of actuator adjustment commands from the ground, the OTA Actuator Control function shall piston adjustments to the primary mirror petals, the secondary mirror, and the deformable mirror to within TBD nano-meters and TBD arcseconds. *Rationale: The specified accuracy level is needed to achieve diffraction limited images.*		

Functional Statement	ALLOCATION	COMMENTS
11.2.2 The OTA Actuator Control function shall confirm that the commanded mirror adjustments were successfully executed. *Rationale: Allows the FOT to verify that OTA adjustments have been executed as commanded.* *Question: Would it be more appropriate to have a system to have a system to measure the actual actuator piston locations?, rather than just confirmation of command execution?* *Question: Would it be appropriate to include monitoring of actuator piston forces, with the possibility of automatic command deactivation?*		
11.2.2.1 The OTA Actuator Control function shall report the results of mirror motion confirmation to the Engineering Data Collection and Downlink Preparation function.		
11.3 The OTA Actuator Control function shall control the position of any actuator-driven OTA element included for the purpose of rapid compensation of OTA field of view pointing errors detected by the Fine Guidance function. *Rationale: Various of the envisioned NGST preliminary designs, including the GSFC yardstick, make use of a "fast steering mirror" within the OTA to compensate for low and moderate frequency vibrations in the OTA and between the OTA and SSM.*		
11.3.1 The OTA Actuator Control function shall be able to receive and apply OTA field of view pointing commands at a rate of TBD (~ 30) Hz.		
11.3.2 The OTA Actuator Control function shall be able to apply changes in field of view pointing over a dynamic range of up to TBD (~ 2) arcseconds.		
11.3.3 The OTA Actuator Control function shall be able to apply changes in field of view pointing with an accuracy of TBD (~ 5) milliarcseconds.		
11.3.4 The OTA Actuator Control function shall report the size of any applied OTA field of view pointing compensation to design-specified subsystems. *Rationale: We anticipate that this will include the AD&C function and the Engineering Data Collection and Downlink Preparation function. The AD&C function may require the information in order to adjust the SSM pointing to keep the OTA pointing control element near the center of its dynamic range.*		

Functional Statement	ALLOCATION	COMMENTS
OTA Wavefront Error Measurement and Control	TBD	
12. OTA Wavefront Error Measurement and Control (WFE M&C) shall measure the error in the telescope wavefront and determine appropriate corresponding adjustments to the OTA configuration to compensate for those errors. Note: Each sub-function shall utilize OTA Control, SI Control, FPA Detector Control, and FPA Utility Data Processing, as appropriate. *Comment: These are conditional requirements, to be included in whole or part to the extent found most cost effective in support of mission needs. An alternative is that all or part of these requirements will be implemented in the ground system.* *Comment: The breakdown of functions is as proposed by Redding et al. The actual breakdown of functionality is a responsibility of the prime contractor.* *Note: These requirements have rewritten to isolate WFE M&C specific requirements from such as SI Control, OTA Control, & FPA Data Processing* *Rationale if included: It has been found to be most cost effective to include the processing associated with these requirements within the flight system.*		
12.1 The WFE M&C function shall coordinate coarse configuration of the OTA. *Comment: The accuracy specification for each WFE M&C coarse processing procedure shall be sufficient to allow successful initiation of the next procedure.*		
12.1.1 The WFE M&C function shall coordinate capture of the primary mirror segment spots. Capture processing shall apply TBD algorithm to identify which spot image is associated with which primary mirror segment.		
12.1.2 The WFE M&C function shall coordinate coarse focus of the primary mirror segment spots. Coarse focus processing shall apply TBD algorithm to concentrate the light received from each segment into a region of approximately TBD arcseconds.		
12.1.3 The WFE M&C function shall coordinate coarse focus of the primary mirror segment spots. Coarse focus processing shall apply TBD algorithm to concentrate the light received from each segment into a region of approximately TBD arcseconds.		

Functional Statement	ALLOCATION	COMMENTS
12.1.4 The WFE M&C function shall coordinate coarse alignment of the primary mirror segments relative to each other and the secondary mirror to within TBD nano-meters and TBD arcseconds.		
12.1.5 The WFE M&C function shall coordinate coarse phasing of the primary mirror segments relative to each other to within TBD nano-meters.		
12.2 The WFE M&C function shall coordinate fine configuration of the OTA.		
12.2.1 The WFE M&C function shall apply TBD algorithm to determine the wavefront error to within TBD nano-meters. 12.2.2 *Rationale: Measurement accuracy must sufficiently good that*		
12.2.3 The WFE M&C function shall calculate TBD (primary/deformable) mirror actuator adjustments to correct the OTA wavefront to within TBD nano-meters. *Rationale: The specified correction accuracy is required to achieve a diffraction limited image.*		
Command Processing	Prime	
13. There shall be a Command Processing function that receives, verifies and distributes commands and associated information (e.g. Observation Plans, table loads, etc). *Rationale: The only means for controlling the operation of the spacecraft is through the uplink of commands and associated information.*		
13.1 The Command Processing function shall verify that received command information is intended for NGST, has correct parity and sequence information, and has properly specified source and destination designations in accordance with TBD standard (e.g. CCSDS Telecommand, Command Operation Procedure, COP-1). *Rationale: It is essential to maintain security over the command uplink and to avoid execution of corrupted or erroneous commands.*		

Functional Statement	ALLOCATION	COMMENTS
13.2 The Command Processing function shall be able to receive commands and associated information at a sustained rate of TBD Kbps. *Rationale: The required command information volume must be transmitted within the constraint of available ground contact periods. Commanding operations to respond to anomalies and to effect spacecraft recovery must be executed quickly enough to avoid risk to the spacecraft and unnecessary loss of observing time.*		
Engineering Data Collection and Downlink Preparation	Prime & ISIM	
14. Engineering Data Collection and Downlink Preparation shall acquire selected sample values from both hardware monitors and software computations from all spacecraft and instrument subsystems, and prepare these data for downlink. *Rationale: Provides a mechanism for FOT/SOT to acquire engineering stream data distinct from that incorporated into the science data files.*		
14.1 Engineering Data Collection and Downlink Preparation shall obtain engineering data values, at TBD specified rates, from both hardware monitors and software computations *Rationale: see above*		
14.2 Engineering Data Collection and Downlink Preparation shall format the data for downlink. *Rationale: see above*		
14.2.1 Engineering Data Collection and Downlink Preparation shall associate time-tags with acquired data samples accurate to TBD seconds. *Rationale: Data must have associated times to be of value*		
14.3 Engineering Data Collection and Downlink Preparation shall supply engineering data values continuously for on-board storage. *Rationale: Allows simplification in the ground system; real-time engineering data can be thrown away because all data will have been stored onboard and later downlinked. There is therefore no concern about trying to merge real-time and stored data together.*		

Functional Statement	ALLOCATION	COMMENTS
14.4 Engineering Data Collection and Downlink Preparation shall supply engineering data values for real-time downlink during contacts with the ground. *Rationale: Allows immediate monitoring of the current spacecraft state and observation plan flow without downlink of stored data files.*		
14.4.1 Engineering Data Collection and Downlink Preparation shall select a subset of the engineering data for real-time downlink to accommodate the bandwidth of the available channel. *Rationale: It may be necessary to use a restricted sample of engineering data during real-time contacts if conditions prevent use of high transmission rates.*		
Downlink Data Storage	Prime	
15. The Downlink Data Storage function shall store and manage data provided by science and engineering functions. *Rationale: The GSFC yardstick design expectation is that the spacecraft will not be in continuous contact with the ground station. Data, both science and engineering, of interest to the FOT, SOT, and/or science users must therefore be stored onboard until an opportunity for transmitting them occurs.*		
15.1 The Downlink Data Storage function shall receive science and engineering data simultaneously from the functions that produce them. *Rationale: For simplicity in science scheduling and execution, it is desired that smooth flow of the observation plan not be subject to interference by a need to schedule storage of engineering data.*		
15.1.1 The Downlink Data Storage function shall accept data at a TBD rate adequate to support all required science functions. *Rationale: Ideally, storage of science data should occur sufficiently quickly as to not represent a constraint on the rate of execution of the observation plan.*		

Functional Statement	ALLOCATION	COMMENTS
15.1.2 The Downlink Data Storage function shall accept data at a TBD rate adequate to support all required engineering functions. *Rationale: The engineering data will usually be coming into the Downlink Data Storage function at a constant rate; the function must be able to keep up with it without loss of data.*		
15.2 The Downlink Data Storage function shall store science and engineering data until it is released by command. *Rationale: The usual procedure is that the FOT, or automated ground system, will release recorder space after it has been confirmed that the data have been successfully received. If it is decided that other approaches will be allowed for deletion of data, it will be in the purview of a system at a higher level of authority than the Storage function to make that call.*		
15.3 The Downlink Data Storage function shall be able to perform simultaneous record and playback. *Rationale: It is desired that the observation plan flow not be constrained by whether or not a recorder playback is in progress at any given time.*		
15.4 The Downlink Data Storage function shall retrieve data from storage and provide the data to the communications function for transmission to the ground. *Rationale: That is the only mechanism for getting the data to the ground.*		
15.5 The Downlink Data Storage function shall be able to manage multiple files of data. *Rationale: It is believed that operations will be easier if data sets (e.g., individual exposures) are handled as files, rather than all data being simply a continuous set of bits on the recorder with no logical differentiation.*		
15.5.1 The Downlink Data Storage function shall maintain a directory of all currently stored files. *Rationale: Allows the FOT, or automated ground system, to select which files are to be downlinked.*		
15.5.2 The Downlink Data Storage function shall maintain file metadata for all currently stored files including unique name, creation date and time, and size. *Rationale: Ditto*		

Functional Statement	ALLOCATION	COMMENTS
15.5.3 The Downlink Data Storage function shall provide directory access functions that can search the file directory for files matching certain metadata. *Rationale: Ditto*		
15.5.4 The Downlink Data Storage function shall be able to retrieve and delete data files by name. *Rationale: Ditto*		
15.6 The Downlink Data Storage function shall report quantity of storage used and quantity of available storage. *Rationale: Allows OPE function to suspend observation plan flow if there is insufficient available storage to accommodate the next exposure.*		
Spacecraft/Ground Communications	Prime	
16. The Spacecraft/Ground Communications function shall provide 2-way communication with ground systems. *Rationale: Needed to both command the spacecraft and receive the results.*		
16.1 The Spacecraft/Ground Communications function shall provide real-time engineering data downlink simultaneously with downlink of stored data (e.g. stored science data, stored engineering data, stored event logs, etc.). *Rationale: It is desired that the real-time engineering data stream not be interrupted when stored data are to be downlinked.*		Assume that all science data are stored.
16.2 The Spacecraft/Ground Communications function shall support multiple downlink formats (e.g. nominal, safe mode, etc.). *Rationale: It is anticipated that there may be situations when only a low rate antenna will be available for downlink; the S/G-C function must be able to support situations when not all data can be transmitted.*		

Functional Statement	ALLOCATION	COMMENTS
16.3 The Spacecraft/Ground Communications function shall support uplink of real-time commands, science schedules, and other items (FSW patches, table loads, etc.) simultaneously with downlink. *Rationale: The real-time engineering data stream will be continuous during real-time contacts, so commanding must be allowed to occur while the downlink of real-time data is in progress. Furthermore, it is expected that the volume of science data will be so large as to require that the downlink of stored data be essentially continuous during contact periods in order to retrieve it all. Stopping the transmission of stored data to accommodate uplink would therefore be awkward.*		
16.4 The Spacecraft/Ground Communications function shall support communication via multiple onboard antennas and data rates (e.g. omni antenna, high-rate antenna). *Rationale: Support for contingency when only low-rate can be used (e.g., safe mode).. Also, even during normal operations, the needed rates for uplink, real-time engineering downlink, and stored data downlink will be significantly different from each other.*		
16.5 The Spacecraft/Ground Communications function shall support pointing control for high-rate antenna. *Rationale: The direction to Earth will change as a function of spacecraft attitude and orbit position of the spacecraft about L2.*		
16.6 The Spacecraft/Ground Communications function shall support 2-way communication via nominal and backup ground stations (e.g. NGST dedicated site, DSN, etc.). *Rationale: There are likely to be situations in which continuous coverage is required (e.g., safemode recovery, launch & deployment support). A single ground site would be inadequate to support such situations.*		
16.7 The Spacecraft/Ground Communications function shall support ground collection of 1-way and 2-way tracking data for orbit determination (e.g. coherent transponder). *Rationale: Orbit knowledge is required to support high-rate communications.*		

Functional Statement	ALLOCATION	COMMENTS
Thermal Control	Prime & ISIM	
17. The Thermal Control function shall monitor and control temperature. *Rationale: See below*		
17.1 The Thermal Control function shall monitor the thermal profile of the SSM and control it to within TBD degrees. *Rationale: ?*		
17.2 The Thermal Control function shall monitor the thermal profile of the OTA and control it to within TBD degrees. *Rationale: Required to maintain the optical configuration of the telescope.*		
17.3 The Thermal Control function shall monitor the thermal profile of the ISIM and control it to within TBD degrees. *Rationale: Required to maintain a stable environment for the SIs.*		
17.4 The Thermal Control function shall monitor the thermal profiles of the individual SIs and control them to within TBD degrees. *Rationale: Required to keep thermal emission of the SIs adequately low.*		
Electrical Power Management	Prime	
18. The Electrical Power Management function shall monitor spacecraft power usage, and ensure adequate power for spacecraft components. *Rationale: The spacecraft components require adequate power to function properly.*		Assume that the S/C is always power positive. Detailed requirements TBD by negotiation with the prime.

Functional Statement	ALLOCATION	COMMENTS
Anomaly Detection and Response **<u>Architecture Issues</u>** 1) Each system and subsystem could detect anomalies within its own boundaries and handle those it can, and report others to a higher level. 2) In addition to anomaly detection and response, which of the following does Health & Safety include: a) validation of planned activities just prior to execution? b) routine maintenance background processes such as power management? c) science-related conditions such as full storage requiring dumping of data? d) insertion of auxiliary activities that interrupt science as needed to maintain operation (such as momentum dumping)? e) verification that commands are executing as planned? f) performance of self-tests on selected components? 3) To what extent is the Anomaly Detection and Response function distributed or centralized? (see item 1)	Prime & ISIM	
19. The flight software shall provide an Anomaly Detection and Response function that detects and responds to anomalies in both hardware and software components. *Rationale: Shit happens.* *The spacecraft will not be in regular contact with the ground. It must therefore be prepared to protect itself when serious anomalies occur. It is also highly desirable, for maximum science efficiency, that the spacecraft gracefully handle minor anomalies and quickly resume science operations when possible.*		
19.1 The Anomaly Detection and Response function shall detect anomalous situations. *Rationale: see above*		
19.1.1 The Anomaly Detection and Response function shall be able to limit check status values including hardware monitors, derived parameters and accumulated (statistical) parameters. *Rationale: see above*		

Functional Statement	ALLOCATION	COMMENTS
19.1.2 The Anomaly Detection and Response function shall be able to receive status and warning messages from other subsystems. *Rationale: see above*		
19.2 The Anomaly Detection and Response function shall respond to anomalous situations. *Rationale: see above*		
19.2.1 The Anomaly Detection and Response function shall be able invoke pre-defined command sequences in response to anomalous situations. *Rationale: see above. Furthermore, it is not expected that there will be any need for the system to have "AI" level smarts to allow it to infer an appropriate response based on anomaly modeling.*		
19.2.2 The Anomaly Detection and Response function shall be able to command individual spacecraft systems and science instruments to one of several safe configurations depending on the nature and severity of the anomaly. *Rationale: see above*		
19.2.3 The Anomaly Detection and Response function shall be able to halt or interrupt the flow of Observing Plan execution. *Rationale: see above*		
19.3 The Anomaly Detection and Response shall report all events associated with the detection, assessment, and responses to anomalous situations including sufficient information to fully identify the anomaly and its subsequent processing. *Rationale: The FOT will want to be able to understand why the flight system responds as it does.*		
19.4 The Anomaly Detection and Response function shall allow the configuration of monitoring points and anomaly responses by uplink of information from the ground. *Rationale: Allows refinement of the AD&R process based on experience.*		

Functional Statement	ALLOCATION	COMMENTS
Radiation Monitoring	Prime (?)	
20. The Radiation Monitoring function shall provide a function to detect and report undesirably or dangerously high levels of ionizing radiation. *Rationale: It is expected that there will be occasional solar storms that produce ionizing radiation that can interfere with science exposures or even endanger the FPA detectors if high voltage is being applied. The storm intensity can rise too rapidly to allow time for ground monitoring of the situation. The spacecraft must protect itself.* *Note: This is a special case of AD&R, but one which may require special hardware.*		
20.1 The Radiation Monitoring function shall monitor the level of background radiation. *Rationale: see above*		Requires a radiation detector
20.2 The Radiation Monitoring function shall report the condition where background radiation is found to exceed user-specified limits. *Rationale: see above*		
Momentum Management	Prime	
21. The flight software shall manage momentum. *Rationale: The solar flux can produce significant external torque on the spacecraft; it must be managed in order to enable stable attitude control.*		
21.1 The Momentum Management function shall calculate the total angular momentum load of the spacecraft based on gyro and reaction wheel data. *Rationale: The momentum level must be known in order to be managed.*		
21.2 The Momentum Management function shall extrapolate the rate of momentum accumulation to estimate the time that momentum will exceed a user-specified limit. *Rationale: Supports next req.*		

Functional Statement	ALLOCATION	COMMENTS
21.3 The Momentum Management function shall report current momentum and the estimated time before the momentum will be violated. *Rationale: Allows the OPE function to whether or not there is sufficient remaining momentum capacity to accommodate a request under consideration for execution, and to initiate a pre-emptive momentum dump if a momentum limit violation would occur during the request. Allows the OPE function to suspend a request in progress if a momentum limit is violated while execution of the request is in progress. Allows the AD&R function to force a momentum dump (or take some other appropriate action) if the OPE function is inactive or fails to insert a required dump.*		
21.4 The Momentum Management function shall provide a momentum adjustment function, invokable by command, to change the total spacecraft angular momentum to a command-specified value. *Rationale: (1) The dump must occur somehow. (2) Allowing a dump to a specified value, as opposed to some fixed value (e.g. zero), gives the OPE function greater flexibility for minimizing fuel use and/or maximizing time to the next dump.*		Assume that science that cannot be done during momentum dumping.
21.5 The Momentum Management function shall notify the originator of momentum dump commands as to the final outcome (e.g., succeeded, failed, rejected). *Rationale: part of event-driven paradigm*		Should this be imposed on each individual subsystem that can execute commands?
Orbit Adjustment	Prime	
22. The Orbit Adjustment function shall support controlling the firing of orbit adjustment thrusters. *Rationale: The L2 location is an unstable equilibrium point. Photon pressure from solar flux will tend to push the spacecraft out of orbit. Regular orbit adjustments will be required to maintain the orbit.*		Note: It is expected that the approximate timing, required attitude, and thruster power distribution will be determined by ground calculation and uplinked to the spacecraft.

Functional Statement	ALLOCATION	COMMENTS
Deployment and Initialization Support	Prime (?)	
23. The flight software shall support deployment and initialization. *Comment: As phrased here, these requirements have little actual content; they really serve only to remind us to think explicitly about the early part of the mission.* *Rationale:*		
23.1 The flight software shall be able to provide telemetry data to and receive commands from the ground during the transfer and deployment phases of the mission. *Rationale:*		
23.2 The flight software shall be able to execute on-board command sequences, initiated via an onboard schedule/command load, and via realtime ground commands during the transfer and deployment phases of the mission. *Rationale:*		
23.3 The flight software shall be able to perform unique functions associated with transfer of the spacecraft from low Earth orbit to and insertion into its nominal L2 orbit location. (This may include special navigation, thruster control, and communications requirements.) *Rationale:*		
Safe-hold Processing	Prime & ISIM	
24. The flight software shall provide safe-hold processing functions. *Comment: This section is only just started; we must consider safe mode aspects other than just that for AD&C.* *Question: Would it be a better design to have distributed safe-hold processing?* *Rationale:*		
24.1 Safe-hold Processing shall include an attitude determination and control (AD&C) function. *Rationale:*		
24.1.1 The safe-hold AD&C function shall provide a safe mode for maintaining a constant spacecraft attitude. *Rationale:*		

Functional Statement	ALLOCATION	COMMENTS
24.1.2 The safe-hold AD&C function shall provide a safe mode for maneuvering the spacecraft so that a user-specified axis is parallel to the sun-line and thereafter maintaining that attitude. *Rationale:*		
24.1.3 The safe-hold AD&C function shall provide a safe mode to allow recovery from high tumble rates. *Question: Is this a contingency that we wish to protect against?* *Rationale:*		
Flight Software Operating Environment	Prime & ISIM	
25. The flight software shall incorporate an operating system environment that provides: task management, file management; memory management, inter-task communication, hardware/software interrupt handling, memory monitoring, error reporting, data transfer, bootstrap loading, software reprogramming, time distribution, and hardware/software diagnostics. *Rationale: Centralized services reduce overall development costs. Common environment simplifies FSW on-orbit maintenance.*		Not included: Transport protocols (e.g., 1553, TCP); Performance Monitoring
25.1 The flight software operating environment shall be able to start, suspend, resume, and end software applications independently. *Rationale:*		
25.2 The flight software operating environment shall monitor the health of all on-board software applications. *Rationale:*		
25.3 The flight software operating environment shall support the real-time monitoring and reporting of CPU and memory utilization for all flight processors.		
25.4 The flight software operating environment shall be able to respond to software application failures by reporting the failure and by restarting the task. *Rationale:*		

Functional Statement	ALLOCATION	COMMENTS
25.5 The flight software operating environment shall support scheduling the execution of software applications in accordance with a pre-determined set of execution of priorities. *Rationale: Contributes to deterministic software execution.*		
25.6 The flight software operating environment shall be able to perform transfers of data from application to application and from processor to processor. *Rationale:* Needed for general information exchange among software applications and across processors.		
25.7 The flight software operating environment shall be capable of detecting, correcting and reporting data transfer errors. *Rationale:*		
25.8 The flight software operating environment shall provide on-board clock management, time distribution, and time tagging services that can be correlate data acquisition and other on-board events with Universal Time (UT) accurate to TBD milliseconds. *Rationale:*		
25.9 The flight software operating environment shall be able to generate periodic timing signals for control of real-time processes. *Rationale:*		