MODERATE RESOLUTION IMAGING
SPECTRORADIOMETER
(MODIS)

SRCA OPERATIONS CONCEPT DOCUMENT

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1.0 INTRODUCTION

This SRCA Flight Operations Concept Document is a statement of the MODIS Characterization Support Team (MCST) flight operations plans for the SpectroRadiometric Calibration Assembly (SRCA). The intent of this paper is to document planned on-orbit tests and to describe the operations data base. This document will not go into the fine detail of the operational activity components but instead will concentrate on basic operations and data products. This paper is intended for inclusion in the MODIS Operations Concept Document (OCD).

1.1 Description of Problem

Substantially before launch, it is necessary to establish the operational activities of the SRCA. This is intended to provide opportunities for Science Team and Flight Operations Team (FOT) concurrence. Additionally, it is necessary to provide the scheduled use of the SRCA in order to maximize the data products without overstepping any of its operational limitations.

1.2 Outline of Paper

The contents of this document have been organized into five sections. The following are summaries of the sections:

Section One identifies the document and its contents.

Section Two provides references and information sources that are related to the contents of this document.

Section Three provides a brief description and layout of the SRCA including its three sub-assemblies.

Section Four provides a brief description of general and emergency operations. Science mode definitions are detailed.

Section Five provides a detailed description of operational activities along with corresponding schedules and data products.

Appendix I provides a summary of the operations schedule.

Appendix II provides limited life constraints.

Appendix III is a glossary.

2.0 RELEVANT DOCUMENTS

The concept and content of this document are consistent with the documents listed below:

GSFC Documents

421-13-10-01 EOS AM-1 Mission Operations Concept

April 7, 1995 MODIS Level 1B Algorithm Theoretical Basis Document

422-20-02 MODIS Instrument Specification

MCST Calibration Plan

Lockheed-Martin Documents

20043115* MODIS Instrument Flight Operations Understanding

20008847* Interface Control Drawing, Command and Telemetry, EOS AM Spacecraft to MODIS

E151840 Engineering Telemetry Description (CDRL 305)

SBRC Documents

MODIS Calibration Management Plan

422-20-02 MODIS Instrument Specification

CDRL 405

PL3095-Q01474 SRCA Motor Requirements and Operational Activities (E. Johnson)

PL3096-N04744 SRCA Spectral Calibration Methodology (J. Young)

Updated MODIS SRCA Radiometric Calibration Sequence (Mehrten, 11/23/93)

* These 2 documents will be incorporated into the upcoming Operations Interface Control Document (OICD) release.

3.0 BRIEF SRCA DESCRIPTION & LAYOUT

The SRCA performs radiometric calibration for the reflective bands, determines the center wavelength of the reflective bands (spectral characterization), and determines the along-scan spatial registration (for all detectors) and the along-track spatial registration for each of the 36 spectral bands (spatial characterization).

The SRCA consists of three sub-assemblies: a light source, a monochromator, and a collimator (Figure 1).

3.1 Light Source

The light source contains a two-inch Spherical Integrating Source (SIS), a thermal source and a filter wheel. Six lamps (four 10-W and two 1-W) are embedded in the SIS. Four lamps, three 10W and one 1W, are used to provide different output radiance levels while the remaining two lamps, one 10-W and one 1-W, are backups. A temperature-controlled silicon photodiode (SiPD), (D1 in Figure 1), provides radiance feedback control to the SIS.

The thermal source nominally operates at 390K +/- 5K in the spatial mode only. The filter wheel can be placed at six positions: one of three diffraction order sorting filters, dichroic beam-combiner, open slit, or a neutral density filter.

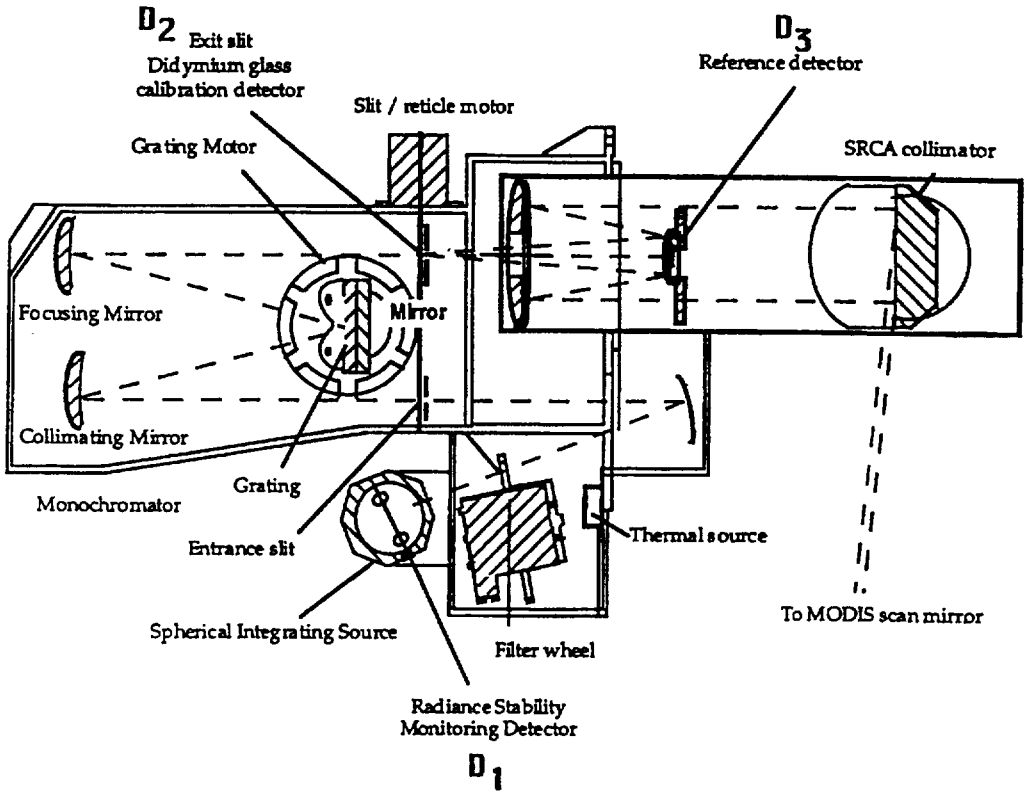

Figure 1: SRCA Layout

3.2 Monochromator

The Czerny-Turner monochromator subassembly includes a slit/reticle section, a grating/plane mirror section, focusing mirror and a collimating mirror. The slit/reticle section is operated by a motor. There are three configurations controlled by the slit/reticle motor: 1) entrance and exit slits open (no pattern in place); 2) open at the entrance slit and the along-scan reticle in place at the location of the exit slit; and 3) open at the entrance slit and the along-track reticle in place at the location of the exit slit. When the exit slit is in position, a second exit slit, filtered with didymium glass (backed by detector D2) is operational (built parallel in the same plate). Rotating the calibration detector, D2, (the SiPD between the didymium absorption glass) provides the spectral calibration signal. This rotation is controlled by a grating motor. The grating motor rotates the diffraction grating into the optical path of the monochromator, which then rotates through various angles in small increments to provide the spectral selection of the monochromator's output during spectral calibration. During spatial and radiometric calibration the grating motor rotates a plane relay mirror into a fixed position in the monochromator's optical path. The grating has 236 lines per millimeter (4.24×10^{-3}mm between rulings) with a blaze angle of 9.2°.

3.3 Collimator

The SRCA collimator is a two-mirror Cassegrain telescope. The collimated beam is further reflected by a plane fold mirror and directed to the MODIS. A reference SiPD, D3, with the same characteristics as the calibration detector, D2, is embedded in the secondary mirror of the telescope. This provides a reference signal for normalizing the calibration signal in the spectral mode.

4.0 BRIEF OPERATIONS DESCRIPTION

4.1 Brief Description of Operations Procedures

4.1.1 General Operations

EOS-AM1 operations are managed using an operations database developed by SBRC and GSFC. This database is organized by operational activities. Each activity has a set of commands, command macros, telemetry, state checks and constraints associated with it. Command macros are command sequences designed to accomplish an assigned task. Command units are the individual commands which, when joined in sequence, compose the command macros. Command generation includes real-time commands, the Spacecraft Control Computer (SCC) stored commands, and command/loads for the MODIS microprocessor. MODIS operational commands reside in the Flight Operations Database.

4.1.2 Operational Modes

The MODIS operational modes define subsystem configurations to perform particular mission functions. The primary operational mode is the Science Mode. The remaining modes are: Safe Mode, Survival Mode, Launch Mode, Standby Mode and Science & Outgas Mode.

The Science Mode is commonly divided in two parts: Day Mode and Night Mode. Day Mode is fully functional with a data rate of 10.2 Mbps and is coincident with the ability to command the instrument. During Night Mode only bands 20-36 are collected on earth scenes.

The Safe Mode places the instrument in a state where it is capable of independent operation. Safe Mode is expected to be entered when the spacecraft has lost lock on the Earth and will be transitioning to Sun orientation or the spacecraft is about to enable thrusters for attitude control or momentum unloading. Power supplies are on. Doors are closed. All subsystems are off with the exceptions of Command and Telemetry. Safe Mode is entered by direct command from the ground or Spacecraft or by a missing "I'm OK" message from the SCC. If Safe Mode is entered autonomously, the FOT performs analysis procedures to identify the cause and execute any necessary recovery strategies following procedures agreed upon with the MODIS Sensor Operations Team (MODSOT).

The Survival Mode is a minimal power mode in which only essential functions (e.g. survival heaters) are supported. Transition into Survival Mode causes non-essential instrument functions to power down. Power supplies are off. Doors are closed. Survival Mode is entered and exited only by direct command from the ground or Spacecraft. Upon realization that the instrument is in Survival Mode, the FOT performs failure analysis procedures to identify and isolate the failure. After isolation of the failed component, the FOT executes a predefined recovery strategy, agreed upon with MODSOT, to transition the instrument into the desired mode of operation. Survival Mode and Safe Mode differ primarily in power consumption.

Launch Mode is a configuration for launch consisting of doors closed and manually latched, all subsystems and power supplies are off, and survival heaters are disabled. Once exited, a return to Launch Mode is not possible because manual door latches cannot be relatched on-orbit.

The Standby Mode is entered to establish and maintain instrument thermal stability prior to transition to Science Mode. The doors may be open or closed. Command and telemetry are supported, however high rate science data is not.

The Science & Outgas Mode configures the MODIS to a ready state for outgas of the instrument. In Science & Outgas Mode, power supplies are on, command and telemetry is supported and cold and intermediate stage outgas heaters are on.

4.1.3 Alarms
4.1.3.1 Yellow Alarm

Spontaneous interruption of a command execution which does not compromise the health of the instrument causes a yellow alarm. The MODSOT is alerted to the situation. Analysis and recovery strategies are implemented. Yellow alarms are also initiated when telemetry values cross a pre-defined minimum or maximum threshold.

4.1.3.2 Red Alarm

Spontaneous interruption of a command execution which compromises the health of the instrument causes a red alarm. Red alarms are also initiated when telemetry values cross pre-defined minimum or maximum thresholds. In both situations, the FOT deals immediately with the solution according to procedures agreed upon with MODSOT. MODSOT is informed and briefed on the situation.

4.2 Brief Description of SRCA Operations

There are currently 54 defined commands for SRCA operations (CRDL 305) which can be broken down into the categories listed in Tables 1 and 2. SBRC has defined SRCA subsystem operations according to function (Table 1). MODSOT has defined the SRCA subsystem operations according to subsystem (Table 2). Although there is not a one to one mapping between the two, all commands are contained in both sets. It is the intention of MODSOT to clarify commandable components, therefore MODSOT will focus on the second classification. The commands in the categories are the foundation from which the command macros will be built.

Table 1: SBRC Defined SRCA Subsystem Operations

SBRC SRCA Functions
On/Off
Set Mode
Set Lamps
Use Lamps
Set Mtr Grps
Step/Halt Mtrs

Table 2: MCST Defined SRCA Subsystem Operations

MCST SRCA Subsystems
Power & Configuration
Filter Wheel
Grating/Mirror
Reticle Slit
Lamps
Thermal Source

4.3 Brief Mode Definitions
4.3.1 Current SRCA Modes

Command operations combined with telemetry monitoring compose the primary operational mode - Science Mode. Currently planned macros define eight basic SRCA modes (Table 3). Note that this is not a comprehensive list of all possible modes.

Table 3: Operational Science Modes

MODE DEFINITIONS Current SRCA Modes (07/31/95)
Full Radiometric
10W Radiometric
1W Radiometric
Full Spectral
Partial Spectral
Full Spatial
Along-Scan Spatial
1W Spatial

4.3.2 Descriptions
4.3.2.1 Radiometric Modes

There are three planned radiometric modes: full, 10W and 1W. Radiometric mode is used to 1) track changes in MODIS reflective band radiometric calibration from prelaunch to on-orbit; 2) maintain the radiometric calibration accuracy on-orbit; and 3) track changes over an orbit. Different radiance levels are necessary for calibrating the MODIS bands at appropriate signal levels. The SRCA configuration for the radiometric mode uses either the open hole or the neutral density filter setting of the filter wheel. The slit/reticle section has an open hole at the location of the entrance slit and the along-scan reticle in place at the location of the exit slit. The grating/plane mirror section utilizes the plane mirror. Table 4 lists the positions of the filter wheel, grating motor, and entrance & exit slit reticle as well as the lamp configuration and affected MODIS bands for all planned radiometric modes. Note that this table reflects the recent design change of the use of a 0.25 neutral density filter.

Table 4: Radiometric Modes

Science Mode	Filter Wheel Position	Grating Motor Position	Entrance & Exit Reticle Slit Position	Lamp Config	MODIS Band
Full Radiometric	open	relay mirror	along-scan reticle	3-10W	3,8
	open	relay mirror	along-scan reticle	2-10W	1,4,9
	open	relay mirror	along-scan reticle	1-10W	10
	ND filter	relay mirror	along-scan reticle	1-10W	2,5,6,7,11,12, 17,18,19,26
	open	relay mirror	along-scan reticle	1-1W	13,14,15
	ND filter	relay mirror	along-scan reticle	1-1W	16
10 W Radiometric	ND filter	relay mirror	along-scan reticle	1-10W	2,5,6,7,11,12, 17,18,19,26
	open	relay mirror	along-scan reticle	1-10W	10
1W Radiometric	open	relay mirror	along-scan reticle	1-1W	13,14,15
	ND filter	relay mirror	along-scan reticle	1-1W	16

4.3.2.1.1 Full Radiometric Mode

Full Radiometric Mode consists of six different settings, corresponding to the six light levels available, run in a series. The combination of three 10W lamps and one 1W lamp provides four light levels (three 10W, two 10W, one 10W, and one 1W) combined with the open hole filter wheel setting, the plane mirror of the grating/plane mirror section and the open hole at the entrance slit and along-scan reticle at the exit slit of the slit/reticle section. Insertion of the neutral density filter for the one 10W and one 1W cases provides the two additional light levels.

4.3.2.1.2 10W Radiometric Mode

10W Radiometric Mode consists of one 10W lamp combined with the open hole filter wheel setting, the plane mirror of the grating/plane mirror section and the open hole at the entrance slit and along-scan reticle at the exit slit of the slit/reticle section. Insertion of the neutral density filter effectively measures MODIS bands 2, 5 - 7, 11, 12, 17 - 19 and 26. Removal of the neutral density filter complements the data set with data for MODIS band 10. However, use without the neutral density filter is considered a variation of the 10W radiometric mode and will not be performed unless specifically requested.

4.3.2.1.3 1W Radiometric Mode

1W Radiometric Mode consists of two different settings corresponding to two different light levels. One 1W lamp combined with the open hole filter wheel setting, the plane

mirror of the grating/plane mirror section and the open hole at the entrance slit and along-scan reticle at the exit slit of the slit/reticle section constitutes the first setting. Insertion of the neutral density filter constitutes the second setting.

4.3.2.2 Spectral Modes

Spectral characterization is needed because of the observed spectral shifts in solar reflective band filters during ground testing of MODIS precursor instruments, and because some on-orbit measurements on precursor instruments have been interpreted as showing evidence of on-orbit spectral shifts. The spectral calibration is operable for VIS, NIR, and SWIR bands (1-19, 26), and the uncertainty is limited in spectral range by the spectral response of

Table 5: Spectral Modes

Science Mode	Filter Wheel Position	Grating Motor Position	Entrance & Exit Reticle Slit Position	Lamp Config	MODIS Band
Full Spectral	filter 2	grating	open	3-10W	4,D23
	filter 1	grating	open	3-10W	8
	filter 2	grating	open	3-10W	1
	filter 1	grating	open	3-10W	9,3,D32
	filter 2	grating	open	3-10W	D33
	filter 2	grating	open	2-10W	D23
	filter 1	grating	open	2-10W	10,D32
	filter 2	grating	open	2-10W	11,12,D33
	filter 3	grating	open	2-10W	2,17
	filter 2	grating	open	1-10W	D23
	open	grating	open	1-10W	5
	filter 2	grating	open	1-10W	13,14
	open	grating	open	1-10W	26
	filter 3	grating	open	1-10W	15,D25
	open	grating	open	1-10W	6
	filter 3	grating	open	1-10W	16,18,19
	open	grating	open	1-10W	7

the reference detector. The spectral calibration relies upon the signals output from two SiPD detectors: one SiPD at the didymium slit, which provides the calibration signal; the second SiPD embedded onto the secondary folded mirror of MODIS detector signals for band 1-19, and 26. Table 5 lists the positions of the filter wheel, grating motor, and entrance & exit slit reticle as well the lamp configuration and affected MODIS bands for all planned spectral modes. Note that the grating is rotated in small increments at each configuration. Also note in the MODIS Band column that "D" represents a didymium peak that is measured at that position as part of the spectral self-calibration.

4.3.2.2.1 Full Spectral Mode

Full Spectral Mode consists three different light levels and four different filter wheel positions. The grating of the grating/plane mirror section is continually in place along with an open hole at both the entrance and exit slits of the slit/reticle section. The filter positions used are an open hole, and filters numbered 1, 2 and 3.

4.3.2.2.2 Partial Spectral Mode

Partial Spectral Mode monitors select bands. These bands have yet to be defined and are dependent upon the results of system level tests designed to highlight those bands shown to be susceptible to center wavelength shifts.

4.3.2.3 Spatial Modes

There are three planned spatial characterizations: full, along-scan spatial and 1W spatial

Table 6: Spatial Modes

Science Mode	Filter Wheel Position	Grating Motor Position	Entrance & Exit Reticle Slit Position	Lamp Config	MODIS Band
Full Spatial	beam-splitter	relay mirror	along-scan reticle	3-10W	3,8,9
	beam-splitter	relay mirror	along-track reticle	3-10W	3,8,9
	beam-splitter	relay mirror	along-track reticle	2-10W	1,4,10
	beam-splitter	relay mirror	along-scan reticle	2-10W	1,4,10
	beam-splitter	relay mirror	along-scan reticle	1-10W	2,11
	beam-splitter	relay mirror	along-track reticle	1-10W	2,11
	beam-splitter	relay mirror	along-track reticle	1-1W	5-7,12-19,26
	beam-splitter	relay mirror	along-scan reticle	1-1W	5-7,12-19,26
	beam-splitter	relay mirror	along-scan reticle	IR source	20-25,27-36
	beam-splitter	relay mirror	along-track reticle	IR source	20-25,27-36
Along-Scan Spatial	beam-splitter	relay mirror	along-scan reticle	3-10W	3,8,9
	beam-splitter	relay mirror	along-scan reticle	2-10W	1,4,10
	beam-splitter	relay mirror	along-scan reticle	1-10W	2,11
	beam-splitter	relay mirror	along-scan reticle	1-1W	5-7,12-19,26
	beam-splitter	relay mirror	along-scan reticle	IR source	20-25,27-36
1 W Spatial	beam-splitter	relay mirror	along-scan reticle	1-1W, IR source	5-7,12-19,26
	beam-splitter	relay mirror	along-track reticle	1-1W	5-7,12-19,26

(Table 6). In the spatial characterization mode, the SRCA projects the images of an illuminated reticle onto each detector focal plane array. Scan mirror rotation causes the image to scan each array in the MODIS scan line direction. There are two differently shaped reticles, designed to optimally detect either along-scan spatial shifts for each detector, or along-track band centroid spatial shifts. The spatial location accuracy has two aspects: 1) the accuracy of the geolocation for a single reference band; and 2) the accuracy of the shift of the other bands relative to the reference band. Table 6 lists the positions of the filter wheel, grating motor, and entrance & exit slit reticle as well the lamp configuration and affected MODIS bands for all planned spatial modes.

4.3.2.3.1 Full Spatial Mode

Full Spatial Mode consists of three different settings, corresponding to three lamp configurations: three 10W, two 10W, and one 10W. Unlike the previous two modes, in spatial mode the SRCA Infrared (IR) source is heated to 390K +/- 5K. Additionally, a dichroic beam combiner in the filter wheel is selected, which combines the VIS/NIR beam from the SRCA integrating sphere and IR from the thermal source. The plane mirror of the grating/plane mirror section is in position. The slit/reticle section has an open hole over the entrance slit and the exit slit has either the along-scan reticle or the along-track reticle in place depending on the lamp configuration.

4.3.2.3.2 Along-Scan Spatial Mode

Along-Scan Spatial Mode consists of the same configuration as the full spatial mode, except that it uses only the along-scan reticle exit slit motor position. This encompasses all bulb configurations as well as the heated IR source.

4.3.2.3.3 1W Spatial Mode

1W Spatial Mode consists of the same configuration as the Full Spatial Mode, except that it uses only the 1W bulb configuration. This includes both the along-scan and along-track reticle exit slit motor positions. Additionally, the IR source has no lifetime constraints and so will be used during the along-scan run.

5.0 OPERATIONAL ACTIVITIES

Table 7 summarizes the SRCA operational activities, data products and product categories. Each activity is described in detail following the table.

TABLE 7: SRCA OPERATIONAL ACTIVITIES

OPERATIONAL ACTIVITY	OPERATIONAL MODE(S)	DATA PRODUCT	PRODUCT CATEGORY
Transfer Radiometric Calibration to Orbit	Full Radiometric Full Spectral	(L,DN) $\delta L_{transfer}$	A A
Intra-Orbit Radiometric Calibration	Full Radiometric @ 3 Locations 10W Radiometric Continuous 1W Radiometric Continuous	(L[t],DN[t])	B
Radiometric Comparison w/SD	TBD	(L[t],DN[t])	C
Radiometric Check on Linearity	Full Radiometric	%TBD	C
Spectral Calibration	Full Spectral	$\Delta\lambda_{cw}$ $\Delta\lambda_{bw}$ $\Delta\lambda_{shape}$ Out of Band	A B C C
Spectral Monitoring	Full Spectral Partial Spectral	$\Delta\lambda_{cw}(t)$ $\Delta\lambda(t)$	B C
FPA Coregistration Measurement in Scan Direction	Full Spatial Along-Scan Spatial	Δx ΔM $\Delta\theta$ MTF	A C C C
FPA Coregistration Measurement in Track Direction	Full Spatial Along-Track Spatial	Δy MTF	A C
Coregistration Monitoring Activity	Full Spatial Along-Scan Spatial 1W Spatial	$\Delta x(t)$ $\Delta y(t)$	B B

Data Product Key

(L,DN)	Radiance, Count Pair for calibration
$\delta L_{transfer}$	Uncertainty in transfer of Radiometric Calibration to Orbit
(L[t],DN[t])	Radiance, Count Pair as a function of time
%TBD	not yet defined
$\Delta\lambda_{cw}$	shift in center wavelength
$\Delta\lambda_{bw}$	shift in bandwidth
$\Delta\lambda_{shape}$	change in spectral profile
$\Delta\lambda_{cw}(t)$	change in center wavelength as function of time
$\Delta\lambda(t)$	change in other spectral information as function of time.
Δx	spatial shift in scan direction
Δy	spatial shift in track direction
ΔM	change in magnification for each FPA
$\Delta\theta$	focal plane rotation
MTF	Modulation Transfer Function
$\Delta x(t),\Delta y(t)$	spatial shift as a function of time

The Product Category column refers to one of the following classifications:

A. Level 1B Standard Data Products

The instrument operational activity produces data that are processed in the Science Data Processing System (SDPS) and reported as part of the Level 1B product.

B. Level 1B Special Data Products

The instrument operational activity produces data that require additional processing in the Team Leader's Computing Facility (TLCF) before the product can be archived in the DAAC. Two examples are QA/monitoring data not checked in the Level 1B routines and trending data. The TLCF processing code is presumed to be on-line at launch.

C. Research Products

The instrument operational activity produces data that require additional processing in the TLCF and require additional peer review before archiving. The TLCF processing code is not required to be completed at launch.

The MODIS operations team develops the command blocks and telemetry checks for activities in category A first, then B, and finally C. Activities are only included in category A if the data product is published in the Algorithm Theoretical Basis Document (ATBD) and included in the Level 1B code. Activities are only included in category B if the product and algorithm are specifically described in the ATBD. Activities are included in category C with the approval of the verification/validation scientist and MCST head.

Note that this is currently restricted to Level 1B because operational activities unique to Level 1A or Level 2 products in any category have not been identified.

5.1 Transfer Radiometric Calibration to Orbit

5.1.1 Activity Description

A mission requirement is to establish traceability to NIST. For the reflective bands this is accomplished through ground testing and transfer to the SRCA. During A&E, the SRCA transfers the calibration to the SD/SDSM. This test ensures the validity of that transfer.

Full radiometric mode will be used to obtain the radiance, count pair for calibration. Full spectral mode will be used to reduce the uncertainty of this transfer.

5.1.1.1 Transfer Schedule

The transfer of the radiometric calibration is accomplished during A&E. Full radiometric and full spectral mode cycles are required to be run 100 times for adequate validation and check mechanisms.

All transfers should be completed during A&E, therefore no schedule is required for on-going operations.

5.1.2 Transfer Data Product

Full Radiometric Mode produces known radiance, count pairs for all reflective bands (1-19 and 26) at optimum SNR, secondary radiance values for bands 1-10, 17-19 and 26 at less optimal SNR's and tertiary radiance values for bands 1, 3, 4, 8 and 9. Full spectral mode produces uncertainties in the transfer of the radiometric calibration to orbit. This is a required product of the Science Data Processing System (SDPS) and therefore is classified as a Level 1B standard data product.

5.2 Intra-orbit Radiometric Calibration
5.2.1 Activity Description

The SD/SDSM will be unable to measure intra-orbit variations. Therefore, the SRCA will be used to measure these variations.

Intra-orbit radiometric calibration requires the use of Full Radiometric Mode, 10W Radiometric Mode and 1W Radiometric Mode. Full Radiometric Mode data will be collected at a minimum of three separate intra-orbit locations. 10W and 1W radiometric modes will be run continuously for the day mode of consecutive orbits.

5.2.1.1 Intra-orbit Schedule

The Full Radiometric, 10W Radiometric and 1W Radiometric Modes are run 100 times during A&E. Data to calculate intra-orbit radiometric calibration will be taken from these collects.

Full Radiometric Mode is run at one of three distinct locations in one orbit and is run once every four week period. Both 10W and 1W Radiometric Modes are run continuously for one orbit of day mode. Each mode is run in consecutive orbits. This procedure will be conducted once per week. This schedule is subject to change depending on bulb lifetimes.

5.2.2 Intra-orbit Data Product

Full Radiometric Mode produces known radiance values for all reflective bands (1-19 and 26) at optimum SNR, secondary radiance values for bands 1-10, 17-19 and 26 at less optimal SNR's and tertiary radiance values for bands 1, 3, 4, 8 and 9. 10W ND Radiometric Mode produces known radiance values for bands 2, 5, 6, 7, 11, 12, 17, 18, 19 and 26. 1W Radiometric Mode produces known radiance values for bands 2, 5, 6, 7, 11, 12, 17 - 19 and 26. This is classified as a Level 1B special data product.

5.3 Radiometric Comparison w/SD
5.3.1 Activity Description

After transfer, the SRCA provides a potential second calibration source for determining calibration coefficients.

Bands for radiometric comparison with the SD have not yet been selected.

5.3.1.1 Comparison w/SD Schedule

The schedule for radiometric comparison with the SD during A&E has not yet been determined.

The radiometric comparison with the SD will be conducted simultaneously once every four week period. This schedule is subject to change depending on bulb lifetimes.

5.3.2 Comparison w/SD Data Product

A radiance, count pair as a function of time will be required for the radiometric comparison with the solar diffuser. Specific information will be provided when bands are selected for this comparison. Intra-orbit stability calculations will be completed in the TLCF and will have the units of $W/m^2/sr/\mu m$. This is classified as a research product.

5.4 Radiometric Check on Linearity
5.4.1 Activity Description

Linearity checks are performed for the purpose of verification and validation. A radiometric check on linearity will be performed by compiling radiance values for all reflective bands that can be measured with multiple lamp levels. The calculations will be completed in the TLCF and are a function of percent.

Radiometric checks on linearity will require the use of Full Radiometric Mode for all reflective bands.

5.4.1.1 Linearity Check Schedule

A complete full radiometric cycle of the MODIS spectral bands 1-19 and band 26 will last 16.2 minutes (disregarding any setup preparation time).

Full Radiometric Mode will be run 100 times during A&E. Data to perform a radiometric check on linearity will be taken from these collects.

During on-going operations this procedure will be conducted once every four week period. This schedule is subject to change depending on bulb lifetimes.

5.4.2 Linearity Check Data Product

A percentage deviation from linearity will be calculated by the verification/validation scientist using the radiance, count pairs collected during full radiometric mode. This is classified as a research product and will require additional processing and peer review.

5.5 Spectral Calibration
5.5.1 Activity Description

Precursor instruments similar to MODIS may have observed evidence of on-orbit spectral shifts. Full spectral mode will be used to find shifts in the center wavelength of the reflective bands and to detect shifts in bandwidth and changes in spectral profiles. Data aquired in this mode will be used to determine out of band statistics.

Spectral calibration will require the use of Full Spectral Mode.

5.5.1.1 Spectral Calibration Schedule

A complete full spectral cycle of the MODIS spectral bands will last approximately 100 minutes.

Full Spectral Mode will be run 100 times during A&E. Data to calculate the spectral calibration will be taken from these collects.

During on-going operations data for spectral calibration will be collected once every four week period. This schedule is subject to change depending on bulb lifetimes.

5.5.2 Spectral Calibration Data Product

Full Spectral Mode will identify shifts in center wavelengths and bandwidths, changes in spectral profile and out of band statistics. Shifts in center wavelengths are a Level 1B data product, whereas shifts in bandwidths are Level 1B special data products. Changes in center wavelength as a function of time and out of band statistics are research products requiring additional processing and peer review.

5.6 Spectral Monitoring
5.6.1 Activity Description

It is desirable to monitor center wavelength shifts as a function of time as well as changes in other spectral information as a function of time.

Spectral monitoring will require the use of Full Spectral and Partial Spectral Modes.

5.6.1.1 Spectral Monitoring Schedule

Full Spectral Mode will be run 100 time during A&E. Data to calculate the spectral calibration will be taken from these collects.

During on-going operations, data for spectral monitoring will be collected once every four week period. This schedule is subject to change depending on bulb lifetimes.

5.6.2 Spectral Monitoring Data Product

Spectral monitoring identifies and tracks changes in the center wavelength as a function of time. This is a Level 1B special data product. Changes in other spectral information as a function of time will also be collected for a research product.

5.7 FPA Coregistration Measurement in Scan Direction
5.7.1 Activity Description

A mission requirement is to track the shift of each MODIS detector in the along-scan direction. These data are also required for the Level 1A geolocation product. Along-scan shifts will be used to adjust the sampling phase for improved registration of the four focal planes.

FPA coregistration measurements in the scan direction will require the use of Full Spatial and Along-Scan Spatial Modes.

5.7.1.1 Scan Direction Schedule

Full Spatial Mode will be run 100 times during A&E. Data to calculate the FPA coregistration measurement in the scan direction will be taken from these collects.

An along-scan spatial cycle will be run once every 13 week period (4/year). This mode will be sufficient to provide the necessary data for the FPA coregistration measurement in the scan direction. This schedule is subject to change depending on bulb lifetimes.

5.7.2 Scan Direction Data Product

Full Spatial Mode coupled with the Along-Scan Spatial Mode identifies spatial shifts in the scan direction which is a Level 1B data product. Also produced as research products requiring further processing and peer review are changes in magnification, changes in focal plane rotation and MTF.

5.8 FPA Coregistration Measurement in Track Direction
5.8.1 Activity Description

A mission requirement is to track the centroid position of each MODIS band in the along-track direction. MODIS is not expected to experience shifts only in this direction but as a combination of the scan and track directions.

FPA coregistration measurements in the track direction will require the use of Full Spatial and Along-Track Spatial Modes.

5.8.1.1 Track Direction Schedule

Full Spatial Mode will be run 100 time during A&E. Data to calculate the FPA coregistration measurement in the track direction will be taken from these collects.

An along-track spatial cycle will be run once every 13 week period (4/year). This mode will be sufficient to provide the necessary data for the FPA coregistration measurement in the track direction. This schedule is subject to change depending on bulb lifetimes.

5.8.2 Track Direction Data Product

Full Spatial Mode and the Along-Track Spatial Mode will identify spatial shifts in the scan direction which is a Level 1B data product. Also to be produced, although requiring additional processing in the TLCF and/or peer review, will be MTF.

5.9 Coregistration Monitoring Activity
5.9.1 Activity Description

It is desirable to measure shifts in the scan and track directions as a function of time.

Coregistration monitoring requires the use of Full Spatial, Along-Scan Spatial and 1W Spatial Modes.

5.9.1.1 Coregistration Monitoring Schedule

Full Spatial Mode will be run 100 time during A&E. Data to calculate the FPA coregistration measurement in the scan direction will be taken from these collects.

An along-scan spatial cycle will be run once every 13 week period (4/year). This correlates with the once every 13 week period for a 1W spatial cycle. Each will be conducted on consecutive orbits. This schedule is subject to change depending on bulb lifetimes.

5.9.2 Coregistration Data Product

Along-Scan Spatial Mode coupled with the 1W Spatial Mode will detect spatial shifts in two dimensions as a function of time. These are Level 1B special data products and will require additional processing in the TLCF.

APPENDIX I: SUMMARY OF SCHEDULE

Table I-1 presents the current schedule of planned activities. The basic A&E plan will be: 1) Checkout; 2) Transfer calibration to orbit; 3) Establish calibration baseline; and 4) Experiments for calibration with priority given to Product Category A.

Table I-1: SRCA Schedule Summary

	A&E	On-Orbit
Transfer Radiometric Calibration to Orbit	100	-
Full Radiometric	100	1/month
Full Spectral	100	1/month
Intra-Orbit Radiometric Calibration	**100**	**1/week & 1/month**
Full Radiometric	100	1/month
Low Radiometric	100	1/week
1W Radiometric	100	1/week
Radiometric Comparison with Solar Diffuser	TBD	1/month
TBD	TBD	TBD
Radiometric Check on Linearity	**100**	**1/month**
Full Radiometric	100	1/month
Spectral Calibration	**100**	**1/month**
Full Spectral	100	1/month
Spectral Monitoring	**100**	**1/month**
Full Spectral	100	1/month
Partial Spectral	TBD	TBD
FPA Coregistration in Scan Direction	**100**	**4/year**
Full Spatial	100	-
Along-Scan Spatial	-	4/year
FPA Coregistration in Track Direction	**100**	**4/year**
Full Spatial	100	-
Along-Scan Spatial	-	4/year
Coregistration Monitoring	**100**	**4/year**
Full Spatial	100	-
Along-Scan Spatial	-	4/year
1W Spatial	-	4/year

APPENDIX II: LIMITED LIFE CONSTRAINTS

At the time of this memo, SBRC's current lifetime bulb extimates are 570 hours and 10,000 hours (3σ) for the 10W and 1W bulbs, respectively. These are documented in SBRC memo PL3095-Q64694.

Table II-1: SRCA Lampe Estimated Duration

Test/Cal Mode	Estimated Duration (min)				
	Total	10W Lamp #1	10W Lamp #2	10W Lamp #3	1W Lamp #1
Full Radiometric	17	12.75	8.5	4.25	4.25
10W Radiometric	50	50	-	-	-
10W Radiometric	10	10	-	-	-
1W Radiometric	100	-	-	-	100
1W Radiometric	10	-	-	-	10
Full Spectral	75	75	50	25	-
Partial Spectral	25	25	-	-	-
Full Spatial	37	27	18	9	9
Scan Dir Spatial	32	24	16	8	8
1W Spatial	-	-	-	-	8
10W Burn-in	3600	3600	3600	3600	-
1W Burn-in	6000	-	-	-	6000
Aliveness Tests	TBD	20	15	10	10
Subassy Tests	TBD	3000	3000	3000	3000

Table II-2: SRCA Lamp Frequency of Use

Test/Cal Mode	Estimated Frequency of Use					
	Sub-assy	SysTest (SBRC)	SysTest (MM)	A&E	On-orbit (5 years)	Total
Full Radiometric	-	75	30	100	60	265
10W Radiometric	-	10	30	100	260	400
10W Radiometric	-	50	30	-	-	80
1W Radiometric	-	10	30	100	260	400
1W Radiometric	-	50	30	-	-	80
Full Spectral	-	50	25	100	60	235
Partial Spectral	-	50	25	25	20	120
Full Spatial	-	50	20	100	20	190
Scan Dir Spatial	-	-	20	20	20	60
1W Spatial	-	25	20	25	20	90
10W Burn-in	1	-	-	-	-	1
1W Burn-in	1	-	-	-	-	1
Aliveness Tests	-	10	5	1	-	16
Subassy Tests	1	-	-	1	-	1

Total Use:	10W Bulbs (w/rotation)	552 hours
	1W Bulbs	900 hours

GLOSSARY

Activity	Represent command blocks that change the mode/configuration of an instrument.
Command Macros	Sequences of commands designed to accomplish an activity.
Commands	Individual instruction for a specific task.
Constraints	Restrictions for command macros to execute effectively.
Day Mode	Division of Science mode; Normal full operating mode of the instrument
Launch Mode	Configuration for launch; Power supplies are off; Doors are closed and manually latched; survival heaters are disabled.
Level 1B	The sensor output given as the instantaneous fully calibrated radiances in scientific units valid at instrument aperture.
Night Mode	Division of Science mode; Reduced operating mode due to the absence of earth sector data for bands 1-19.
Operational Database	Contains the EOS-AM 1 operations data definitions used real-time by the FOs and includes: command definitions; telemetry definition, limits; alarms; calibration curves; constraints; procedures; and activities.
Out-Of-Band	Spectral regions beyond the extended band pass.
Reflective Bands	MODIS Bands 1-19 and 26 encompassing the VIS, NIR and SWIR regions of the electromagnetic spectrum.
Safe Mode	Instrument operational mode where instrument is capable of independent operation. Power supplies are on; Doors are closed; all subsystems are off with the exception of command and telemetry.
Science Mode	Primary operational mode of supporting high rate science data composed of Day Mode and Night Mode.
Science Outgas Mode	Establishes ready state for the outgassing of MODIS; Power supplies are on; Doors may be open or closed; cold and intermediate stage outgas heaters are on.
Standby Mode	Transitional mode to establish and maintain thermal stability. Power supplies are on; Doors may be open or closed.
State Checks	Checks that a spacecraft telemetry parameter is in a database defined state.
Survival Mode	Minimal power mode supporting only essential functions (e.g. survival heaters). Power supplies are off; Doors are closed.
Telemetry	Stream of data that is transferred from the MODIS instrument to the spacecraft for transmission to the ground.

APPENDIX IV: ACRONYMS AND ABBREVIATIONS

ATBD	Algorithm Theorectical Basis Document
A&E	Activation & Evaluation
D1	Detector 1, Radiance Stability Monitoring Detector
D2	Detector 2, Didymium Glass Calibration Detector
D3	Detector 3, Reference Detector
DAAC	Distributed Active Archive Center
EOS-AM1	Earth Observing System-AM Platform
FOT	Flight Operations Team
FPA	Focal Plane Assembly
GSFC	Goddard Space Flight Center
IR	Infrared
LWIR	Long Wave Infrared - Region from 5 to 15μm, Bands 27 - 36
MCST	MODIS Characterization Support Team
MODIS	Moderate Resolution Imaging Spectroradiometer
MODSOT	MODIS Sensor Operations Team
MTF	Modulation Transfer Function
MWIR	Mid Wave Infrared - Region from 2.3 to 5μm, Bands 20 - 25
ND	Neutral Density Filter
NIR	Near Infrared - Region from 0.6 - 1.0μm, Bands 1, 2, 13 - 19
NIST	National Institute of Standards & Technology
OCD	Operations Concept Document
OICD	Operations Interface Control Document
OOB	Out of Band
QA	Quality Assurance
SBRC	Santa Barbara Research Center

SCC	Spacecraft Control Computer
SD	Solar Diffuser
SDPS	Science Data Processing System
SDSM	Solar Diffuser Stability Monitor
SiPD	Silicon Photodiode
SIS	Spherical Integrating Source
SNR	Signal to Noise Ratio
SRCA	SpectroRadiometric Calibration Assembly
SWIR	Short-Wave Infrared - Region from 1.0 - 2.3μm, Bands 5 - 7, 26
TBD	To Be Determined
TLCF	Team Leader's Computing Facility
VIS	Visible - Region from 0.4 - 0.6μm, Bands 3, 4, 8 - 12