LANDSAT DATA CONTINUITY MISSION

LDCM Spacecraft Requirements Document

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Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

CM Foreword

This document is a Landsat Data Continuity Mission (LDCM) Project Configuration Management (CM)-controlled document. Changes to this document require prior approval of the applicable Configuration Control Board (CCB) Chairperson or designee. Proposed changes shall be submitted to the LDCM CM Office (CMO), along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

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1 Introduction

1.1 Scope

The Landsat Data Continuity Mission (LDCM) spacecraft requirements are defined in this document, the LDCM Spacecraft Requirements Document (S-RD).

1.2 Mission Objective and Requirements Flow

The objective of the Landsat Data Continuity Mission is to continue the 30+ years of repetitive acquisition of high resolution multispectral data of the Earth's surface on a global basis. The data from the Landsat spacecraft constitute the longest record of the Earth's continental surfaces as seen from space. It is a record unmatched in quality, detail, coverage, and value.

The major mission objectives are summarized as follows:

- Collect and archive medium resolution (circa 30 m spatial resolution) multispectral image data affording seasonal coverage of the global land mass for a period of no less than five years.
- Ensure that LDCM data are sufficiently consistent with data from the earlier Landsat missions, in terms of acquisition geometry, calibration, coverage characteristics, spectral characteristics, output product quality, and data availability to permit studies of land cover and land use change over multidecadal periods.
- Distribute LDCM data products to the general public on a nondiscriminatory basis and at a price no greater than the incremental cost of fulfilling a user request.

In support of the mission objective the LDCM spacecraft contractor is required to provide a spacecraft bus that accepts for integration up to two NASA GSFC/LDCM instruments. The instrument(s) are government furnished equipment (GFE) and their requirements and interfaces are defined as part of the LDCM requirements database. The spacecraft is to perform for 5 years within the prescribed requirements following acceptance on-orbit by the NASA / GSFC. The LDCM spacecraft contractor is required to lead the effort to integrate the GFE instrument suite with the spacecraft.

The spacecraft will be required to supply ancillary data to the instrument suite necessary to meet mission and imaging requirements. The primary instrument, the Operational Land Imager (OLI), is required to provide nine spectral bands with a maximum ground sampling distance, both in-track and cross track, of 30-m for all bands except the panchromatic band, which is required to have a 15 m ground sample distance. The OLI will have a minimum of 185-km cross track swath width as measured at the equator at an orbital altitude of 705-km. The Thermal InfraRed Sensor (TIRS) will have a similar cross track swath width but a ground sample distance of 120-m for two bands.

The spacecraft will operate in a nominal mission orbit of 716 ± 12 km altitude at 98.2 ± 0.15° inclination with a small eccentricity. This orbit is sun synchronous and with the proper orientation of the line of apsides will produce a “Frozen Orbit”. The spacecraft will implement a yaw compensation maneuver to account for earth rotation effects on the image ground track. The spacecraft must be capable of performing solar and lunar calibration maneuvers by orienting the spacecraft such that primary instrument’s field of view (and any co-aligned secondary instrument’s FOV) properly scans the calibration target. During the commissioning phase the spacecraft must be capable of scanning the Operational Land Imager across predetermined star fields.

The spacecraft will contain typical earth observing Spacecraft functionality including but not limited to:

- A primary and secondary structural subsystem providing support and stability to facilitate imaging and interface with the launch vehicle
- An instrument bench(es) to support the mounting of the GFE instrument(s)
- A thermal control subsystem
- An electrical power generation, storage, and a switched distribution subsystem
- Flight Software consisting of embedded firmware and on-orbit reprogrammable processor based software
- A command and data handling subsystem with sufficient mass storage to meet mission data volume
- An attitude and orbit control subsystem that provides pointing for imaging, calibration and orbit maintenance maneuvers
- A propulsion subsystem that provides orbit maintenance and decommissioning capability

- A radio frequency based communications subsystem with low and high data rates. The high data rate system must transmit mission data to multiple sites concurrently
- Associated Ground Support Equipment that provides for:
  - Spacecraft interface simulation
  - Flight Software development
  - Simulation of the observatory (spacecraft + GFE instrument models)
  - Mechanical handling and shipping equipment
  - Electrical interface with power and test equipment

Some terms used in this document may have unique meaning to the LDCM Project and are defined in the LDCM Acronym List and Lexicon, GSFC-427-02-06. The requirements flow-down for the LDCM Program are defined in the LDCM Observatory Interface Requirements Document 427-02-03 and shown in Figure 1-1.

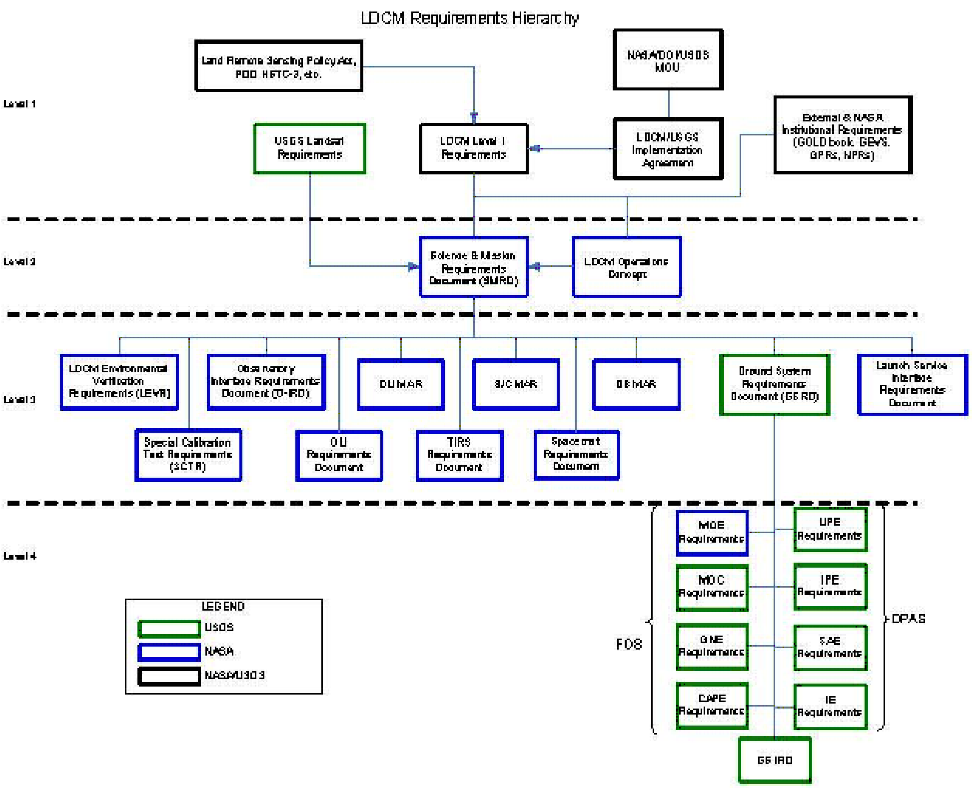

Figure 1 - 1 LDCM Requirements Flow

1.3 Use of the Terms "Spacecraft" and "Observatory"

Throughout this document all references to "spacecraft" will be considered to apply to the LDCM spacecraft bus whether or not the instruments have been integrated with the spacecraft bus. In some LDCM documentation, including but not limited to the LDCM Observatory IRD, the spacecraft when integrated with the instruments will be referred to as the LDCM "observatory".

2 Applicable and Reference Documents

2.1 Applicable Documents

The SRD is consistent with, and responsive to, the following applicable documents of the revision and release date shown. These documents establish detailed specifications, requirements, and interface information necessary for the performance of the contract. Unless otherwise stated in this document, all inconsistencies in the S-RD will be resolved as defined in the Spacecraft Statement of Work.

The spacecraft shall comply with the documents listed in this section as they apply directly to the performance of the LDCM spacecraft contract.

Applicable Documents

Document Number	**Revision/ Release Date**	**Document Title**
AFSPCMAN 91-710 (Vol. 1-7)	July 1, 2004	Air Force Space Command Manual 91-710 Range Safety User Requirements
CCSDS 232.1-B-1	September 2003	Recommendation for Space Data Systems Standards. Communications Operations Procedure-1. Blue Book. Issue 1.
CCSDS 301.0-B-3, Section 2.3	January 2002	Time Code Formats, CCSDS Day Segmented Time Code (CDS)
CCSDS 727.0-B-4	January 2007	CCSDS Recommended Standard For CCSDS File Delivery Protocol (CFDP)
GSFC 500-PG-8700.2.2	February 01, 2005	Electronics Design and Development Guidelines
NASA STD-5005	Rev. B, Sept. 15, 2003	Ground Support Equipment
NIMA TR8350.2	3rd Edition, Amendment 1, dated 3 January 2000	Department of Defense World Geodetic System 1984
NPD 8010.2	Rev. D, May 14, 2004	Use of the SI (Metric) System of Measurement in NASA Programs
NPR 2810.1A	May 16, 2006	NASA Procedural Requirement, Security of Information Technology
NPR-7150.2	Rev. A, Sept 2004	NASA Software Engineering Requirements
NPR-8715.6A	February 19, 2008	NASA Procedural Requirements for Limiting Orbital Debris
NSS 1740.14	August 1, 1995	NASA Safety Standard, Guidelines and Assessment Procedures for Limiting Orbital Debris

2.2 LDCM Documentation

The SRD is consistent with the following documents. Unless otherwise stated in this document, all inconsistencies in the SRD will be resolved as defined in the Spacecraft Statement of Work.

LDCM Documents

Document Number	**Document Title**
GSFC 427-02-02	LDCM Operations Concept Document
GSFC-427-02-03	LDCM Observatory - Interface Requirements Document (O-IRD)
GSFC 427-02-06	LDCM Acronym List and Lexicon
GSFC 427-02-07	LDCM Worldwide Reference System-2 Memorandum (WRS-2)
GSFC 427-03-04	Spacecraft Mission Assurance Requirements
GSFC 427-03-05	LDCM Environmental Verification Requirements (LEVR)
GSFC 427-05-03	OLI Requirements Document (OLI-RD)
GSFC 427-06-01	LDCM Spacecraft Statement of Work
GSFC 427-07-01	LDCM 16-Day Design Reference Case (DRC-16)
GSFC 427-08-01	LDCM Launch Services Interface Requirements Document (LS-IRD)

3 Spacecraft System Level

3.1 Mission Phases

3.1.1 Ground Storage Phase

SRD - 166 The spacecraft shall be capable of being placed in a state that requires minimal intervention by personnel, excluding anomalous events and provides for telemetry monitoring, at up to 30-day periods.

Rationale: In the event of a launch vehicle delay or instrument delay the storage of the spacecraft is necessary. After storage the spacecraft must still meet all mission requirements. Aliveness tests and functional tests may be performed once every 30-days to ensure no deterioration of the spacecraft is occurring.

SRD - 168 The spacecraft shall meet all mission requirements, including design lifetime at the completion of a Ground Storage Phase lasting 6 months.

Rationale: Storage of the spacecraft will not degrade performance.

3.1.2 Pre-Launch Phase

SRD - 171 The spacecraft shall be integrated with up to two Government Furnished Instruments.

Rationale: The spacecraft vendor leads the instrument-to-spacecraft integration effort. The primary instrument is OLI. One optional instrument is TIRS.

The Spacecraft shall interface with NASA/GSFC provided instrument(s) as defined in NASA/GSFC LDCM Observatory Interface Requirements Document (O-IRD), GSFC 427-02-03.

The Spacecraft shall interface with USGS/EROS provided ground system as defined in NASA/GSFC LDCM Observatory Interface Requirements Document (O-IRD), GSFC 427-02-03.

SRD - 173 The Spacecraft shall be designed for a launch from Vandenberg AFB.

Rationale: Launch site for polar orbiting observatories.

SRD - 175 The Spacecraft shall be compatible with a government furnished payload processing facility at Vandenberg AFB.

Rationale: Launch site processing should be as close to the launch site as is practical. The launch site support plan and other documents need to reflect processing at VAFB.

SRD - 177 The Spacecraft and its Ground Support Equipment used at the launch site shall comply with the US Air Forces Space Command Manual 91-710 Range Safety User Requirements, dated July 1, 2004.

Rationale: The controlling range will levy safety requirements on the S/C bus, instrument, E/MGSE, processing, and personnel.

The Spacecraft shall interface with NASA/KSC provided launch vehicle as defined in NASA/GSFC LDCM Launch Service Interface Requirements Document (LS-IRD), GSFC 427-08-01.

SRD - 181 The Spacecraft shall meet all contamination constraints when exposed to the cleanliness levied on the Government Furnished launch service as defined in the LS-IRD for ninety days.

Rationale: The permitted launch service cleanliness levels are defined in the LS-IRD. The Spacecraft should plan for this contamination contribution and ensure adequate margins and processes are developed to meet mission performance requirements as part of the end of life budget.

SRD - 183 The Spacecraft shall be designed to accommodate the external monitoring of all hazardous systems as defined by the US Air Forces Space Command Manual 91-710 Range Safety User Requirements, while the spacecraft is powered off, via the launch vehicle interface umbilical.

Rationale: Launch service provides electrical I/F to the spacecraft and blockhouse. Range Safety requires continuous monitoring of hazardous systems.

SRD - 185 The Spacecraft shall be designed to perform limited aliveness tests of the spacecraft and integrated instrument(s) while mated to the launch vehicle.

Rationale: To identify any possible ground handling problems and provide confidence in a successful mate to the LV, the spacecraft needs to perform some aliveness tests. This includes supporting instruments and other subsystems.

3.1.3 Launch and Early Orbit Phase

SRD - 188 The Spacecraft shall transmit real-time, narrowband, spacecraft housekeeping telemetry during launch ascent starting after launch vehicle fairing separation.

Rationale: To provide as much information as is reasonable about the spacecraft state of health during launch and to track / lock onto the spacecraft from the supporting ground stations. A transmitting S/C is easier to track.

SRD - 474 The Spacecraft mass including propellant and all necessary hardware required to interface with the launch vehicle, the upper half of the Payload Attach Fitting and any margin shall not exceed 2,360.0-kg.

Rationale: This is a mass allocation based on the total Spacecraft mass of (3085 -(OLI@375 + TIRS@200)- (Mission System Reserve@150) = 2360kg.

SRD - 193 The Spacecraft shall have a launch readiness capability once every 24 hours.

Rationale: The 10 am descending node limits LDCM to one opportunity a day. If there is a launch slip it would likely change the insertion date.

SRD - 195 The Spacecraft shall autonomously enter a power positive safe state after separation from the launch vehicle with an imparted total angular momentum of up to 90 N-m-s.

Rationale: The spacecraft must enter a power positive state without intervention from the ground. 90 N-m-s is the maximum total angular momentum that could be imparted by the launch vehicle.

SRD - 198 The Spacecraft shall autonomously acquire the sun after separation from the launch vehicle.

Rationale: To support the power positive attitude and to protect instruments from direct exposure to the sun.

3.1.4 Spacecraft Commissioning Phase

SRD - 203 The Spacecraft shall be capable of completing its commissioning within 30 days of launch.

Rationale: The 90-day requirement for observatory commissioning is to constrain the amount of time necessary before commencing operations. It is anticipated that the S/C will finish within the first 30 days, though it may not have achieved mission orbit and it may take the instruments at least 2 lunar cycles to complete commissioning.

3.1.5 Spacecraft Operational Phase

SRD - 206 The Spacecraft shall meet all design specifications at the completion of Spacecraft Commissioning.

Rationale: In support of the extensive database of global land use it is paramount that LDCM provide a meaningful mission life to support this effort. Verification of design requirements are performed on the ground and in-orbit.

3.1.6 Spacecraft Decommissioning Phase

SRD - 211 The Spacecraft shall be compliant with NASA Procedural Requirements for Limiting Orbital Debris, NPR 8715.6. Rev. A

Rationale: Minimize potential for future orbital debris, minimize non-operational lifetime on orbit, minimize earth impact debris footprint, and have a system capable of performing any required maneuvers at end of spacecraft design life.

SRD - 213 The Spacecraft shall be capable of performing a controlled re-entry at the completion of the mission design life.

Rationale: In compliance with NPR 8715.6 the spacecraft will perform a controlled re-entry. This is in lieu of a natural decay and uncontrolled entry.

SRD - 1264 The Spacecraft systems necessary for controlled re-entry shall be designed for an overall Probability of Mission Success of 0.90 or greater at the end of design mission life.

Rationale: To ensure that a controlled entry can be performed successfully at the end of the mission; the systems necessary to complete this maneuver must have a high reliability. This requirement supersedes the Pf=0.001 in the NPR/NSS.

3.2 Orbits

3.2.1 Injection Orbit

SRD - 217 The Spacecraft shall achieve the operational orbit after separation from the launch vehicle at the following injection orbit:

- Semi-Major Axis: 7063.14 km
- Mean Eccentricity: 0.000
- Mean Inclination: 98.22 deg
- Mean Local Time (MLT) of the Descending Node: 1000

SRD - 222 The Spacecraft shall achieve the operational mission orbit when the following 3-sigma dispersions are applied to the injection orbit:

- Semi-Major Axis error: -10 km, +10.0 km
- Eccentricity error: +0.00142
- Inclination error: +/- 0.09 deg
- Injection Node MLT error: +/- 10.0 minutes

3.2.2 Operational Orbit

SRD - 228 The Spacecraft shall operate in a sun-synchronous, near circular, frozen orbit that remains on the WRS-2 Path defined in the LDCM Worldwide Reference System-2 Memorandum, GSFC 427-02-07.

- Mean Local Time of the Descending Node: 10:00 a.m.
- Ground Track: WRS-2 Path
- Repeat Cycle: 16-days

SRD - 233 The Spacecraft shall maintain the operational mission orbit within the following allowed dispersions:

- MLT of the descending node: +/- 15 minutes
- Ground Track Error: +/- 5 km cross track at the descending node

SRD - 236 The Spacecraft shall be placed in the constellation of Earth Science Mission Operations morning observatories.

Rationale: LDCM will need to fly under Landsat-7 or-5 observatories during orbit raising if either is still operational. Entry into the final orbit will be done in coordination with the Earth

Science Mission Operations (ESMO) Project at NASA/Goddard Space Flight Center. This is likely to require 16 different orbit raising timelines depending on day of launch.

SRD - 238 The Spacecraft shall maintain the Operational Orbit for the design life of the mission.

Rationale: It is necessary to maintain the operational orbit to ensure proper WRS-2 Grid alignment.

3.2.3 Disposal Orbit

SRD - 240 The Spacecraft shall achieve a Perigee Altitude of 50-km or less at the end of the Decommissioning Phase

Rationale: To minimize the dispersions associated with the entry footprint it is necessary to achieve an entry angle of attack large enough to ensure capture and prevent any atmospheric skipping of the observatory.

SRD - 1312 The Spacecraft shall maintain attitude control for all propulsive maneuvers including the last disposal maneuver.

Rationale: Attitude control is required for all maneuvers. The de-orbit maneuvers maybe long and are likely to be affected by atmospheric drag. Attitude control is necessary to minimize impact dispersions

3.3 Launch Vehicle Interface

Note: The Spacecraft to launch vehicle interface is defined in the Spacecraft to Launch Services Interface Control Document, GSFC 427-08-01.

SRD - 243 The Spacecraft shall provide a launch vehicle interface connector for power to the spacecraft.

Rationale: Power to the spacecraft is supplied from the Spacecraft vendor's GSE located at the blockhouse. Power is isolated from command signals.

SRD - 245 The Spacecraft shall provide a launch vehicle interface connector for telecommunications to the spacecraft.

Rationale: Commands to the spacecraft originate from the Spacecraft vendor's GSE located at the blockhouse. Power and command signals are isolated.

3.4 Launch Services

3.4.1 Payload Processing Facility Compatibility

SRD - 1266 The Spacecraft shall be compatible with the Government Furnished spacecraft (payload) processing facility at the launch site.

Rationale: To address issues like hook height, propellant loading facilities, power supply, entry / exit and safety operations

3.4.2 Launch Site Support

Reserved

3.5 Imaging Support

SRD - 253 The Spacecraft shall support 187 minutes of mission data acquisition plus routine on-orbit calibration over any 24-hour period.

Rationale: The spacecraft needs to provide for 400 scenes at 27 sec per scene plus some transition time 1 sec/scene = 187 minutes. See LDCM memos of record for total calibration time

SRD - 255 The Spacecraft shall support the acquisition of up to 2 off-nadir image intervals per day.

Rationale: To limit the impact of off-nadir imaging the Spacecraft need only support up to 2 off-nadir acquisitions a day. For rapidly changing conditions on the earth LDCM will be able to image 1 swath width left or right of track.

SRD - 257 The Spacecraft shall support the total off-nadir image acquisition interval(s) of up to 9 minutes within a sliding 24-hour period.

Rationale: The distance across the conterminous United States is approximately 18 scenes. Most likely will not be used that extensively. Though this could be in 1 interval no other off-nadir images in 24-hrs either side would be required.

SRD - 259 The Spacecraft shall support the acquisition of a 36 minute contiguous, sunlit image interval of mission data once within a sliding 24-hour period.

Rationale: See the design reference missions in the Observatory - Interface Requirements Document which provides the longest possible daylight contiguous land pass.

SRD - 261 The Spacecraft shall support up to 8 minutes per orbit of lunar disk imaging during any three consecutive lunar calibration orbits.

Rationale: See the design reference missions in the Observatory - Interface Requirements Document which provides a possible lunar imaging scenario for calibration using the moon. The lunar phase angle may extend over 3 orbits, imaging will likely be completed in 2 orbits.

SRD - 1401 The Spacecraft shall support 140.3 minutes of mission data acquisition plus routine on-orbit calibration over a 24-hour period following the lunar calibration maneuver.

Rationale: The effective 46.7 (= 187-140.3) minute allowance is to accommodate any power, thermal stabilization and maneuver time along with data storage.

SRD - 1260 The Spacecraft shall support the acquisition of an 18 minute contiguous, night image interval of mission data within a sliding 24-hour period.

Rationale: To establish baseline response characterization of the LDCM instrument long night scenes may be required.

SRD - 263 The Spacecraft shall be capable of transferring mission data obtained to the ground within 12 hours of the observation.

Rationale: This requirement puts an upper limit on the time required for playback. That is 400 WRS-2 scene equivalent mission data and the given LGN stations. Simply, there is 12 hour latency on data returned to the LGN stations.

SRD - 265 The Spacecraft shall be capable of transferring stored housekeeping data to the ground within 12 hours of recording.

Rationale: This requirement provides for a timely return of the housekeeping data that may be necessary for generating definitive ephemeris files, support rapid response to system degradation and simply getting housekeeping data to the ground.

3.6 Spacecraft Operations

3.6.1 Spacecraft Modes

Note: This document uses the following definition of Spacecraft modes to maintain consistency between the mission system architecture and other external interfaces with the Spacecraft. Figure 4-1 represents a notional mode mapping and transitions. Though the Spacecraft contractor is not required to use the same definitions; a mapping of the contractor's Spacecraft modes to these is required.

Launch Mode *provides a launch-ready Spacecraft integrated with the launch vehicle, and includes launch, ascent, and vehicle separation. This is a non-nominal operational mode.*

Safe Hold Mode *provides a maximum power positive attitude, and a Spacecraft configuration that maintains the Spacecraft in a power positive, thermally safe, instrument safe, and optically safe configuration for at least a 16-day period of time requiring no ground contact. This is a nominal operational mode.*

Earth Point Mode *provides for a coarse nadir earth point attitude and a Spacecraft configuration that provides maximum ability for check-out, diagnostics and decontamination in a power positive, thermally safe, and optically safe configuration for an indefinite period of time. This is a nominal operational mode.*

Operational Mode *provides for a fine earth point achieving mission attitude requirements which supports continuous operations. This is a nominal operational mode.*

- ***Calibration Sub-mode*** *provides for lunar, celestial, solar and earth's limb pointing capability. This is a nominal operational mode.*

- ***Propulsion Sub-mode*** *provides for orbit and inclination adjustments. This is a nominal operational mode.*
- ***Off-nadir Point Sub-mode*** *provides for the Spacecraft to point up to 15 degrees left or right of the orbit plane. This is a nominal operational mode.*

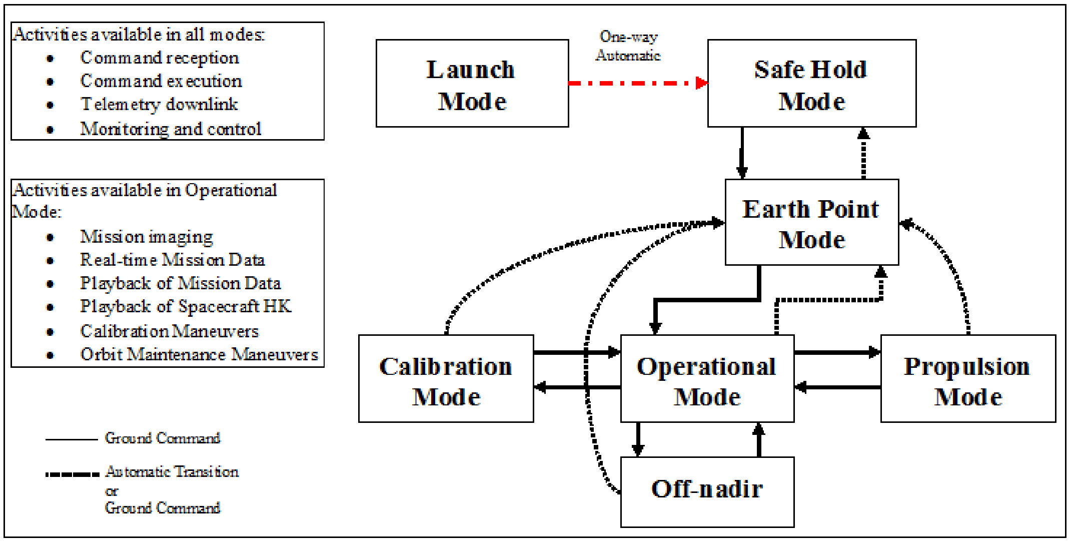

Figure 3 - 1 Mode Transition Diagram

SRD - 280 The Spacecraft shall autonomously transition from Launch Mode to Safe Hold Mode upon separation from the launch vehicle.

Rationale: The spacecraft needs to be able to achieve a safe operating condition at separation from the launch vehicle.

SRD - 1267 The Spacecraft shall be capable of being commanded by the ground into any operational mode.

Rationale: Operational flexibility but also should not be possible to command the Spacecraft into the launch or storage modes.

SRD - 282 The Spacecraft shall autonomously transition from the Operational Mode, into the Earth Point Mode upon detection of faults that threaten the health and safety of the spacecraft.

Rationale: Spacecraft should autonomously transition into a safer, less complex and less power demanding modes to recover from unexpected conditions. Calibration, propulsion and off-nadir point are sub modes of operational mode.

SRD - 284 The Spacecraft shall autonomously transition from Earth Point Mode to the Safe Hold Mode upon detection of faults that threaten the health and safety of the spacecraft.

SRD - 285 The Spacecraft shall transition out of the Safe Hold Mode only via ground command.

Rationale: Ground intervention required when faults are encountered and corrected.

SRD - 287 The Spacecraft shall transition out of Earth Point Mode into the Operational Modes only via ground command.

Rationale: Ground intervention required to return to operational modes after correction of faults.

3.6.2 Mission Lifetime

SRD - 290 The Spacecraft shall meet all design specifications for the 5.25-year design mission life.

Rationale: In support of the extensive database of global land use it is paramount that LDCM provide a meaningful mission life to support this effort.

SRD - 292 The Spacecraft shall be designed for an overall Probability of Mission Success of 0.85 or greater at the end of design mission life.

Rationale: End of mission design life Mission Success is defined as meeting 100% of the mission requirements at the end of the spacecraft design life. With a primary instrument Ps=0.85, the Spacecraft bus should have a Ps = 0.85 to produce a mission Ps of 0.72. Only the OLI instrument is included in this calculation.

3.7 Redundancy Requirements

SRD - 295 The Spacecraft shall be designed such that no single credible failure permanently precludes the Spacecraft from meeting the requirements defined in the S-RD throughout the mission design life.

Rationale: Redundancy is one of many ways to reduce exposure to single credible failures.

SRD - 296 The Spacecraft shall be capable of switching from the active unit to the backup unit for redundant systems by ground command.

Rationale: Be able to switch back and forth between prime and backup units through ground commands

SRD - 298 The Spacecraft shall isolate redundant electrical paths for command, power and telemetry.

Rationale: To protect from any credible event, which may cause the loss of a functional path, and to reduce the likelihood of the loss of the alternate or redundant path.

SRD - 300 The Spacecraft shall provide status telemetry for redundant systems when powered.

SRD - 301 The Spacecraft shall provide in housekeeping which unit in a redundant system is operating.

3.8 Autonomy

SRD - 303 The Spacecraft shall be capable of operating safely without ground intervention for 72 hours.

Rationale: In the event there is a failure in the communications or operations systems the Spacecraft can safe itself including powering off non-essential equipment as necessary.

SRD - 305 The Spacecraft shall be capable of normal operations for 72 hours autonomously.

Rationale: In support of lights-out operations, the spacecraft should be able to store 72 hours of nominal operational image collection activities. Have sufficient command storage to implement image, record and playback operations as planed during that 72-hour period. It is assumed that GS will autonomously acquire data and confirm data transmissions from the spacecraft.

SRD - 307 The Spacecraft shall autonomously switch to the backup component of redundant systems only to achieve Safe Hold Mode or Earth Point Mode based on established failure criteria.

Rationale: To ensure survivability in either the Safe Hold Mode or the Earth Point Mode the spacecraft should be able to switch to a back-up element of a redundant system. There is no requirement for autonomous switching to support nominal imaging operations.

SRD - 309 The Spacecraft shall not autonomously switch to a known failed redundant component.

Rationale: To prevent switching to failed units

SRD - 311 The Spacecraft autonomous operations shall be performed from on-board software.

Rationale: Established autonomous operations should not be in a stored command buffer that may be corrupted by an anomaly. Therefore all autonomous operations should be from code and not stored commands.

SRD - 313 The Spacecraft shall be capable of initiating a stored command sequence in response to pre-defined Spacecraft monitored conditions.

Rationale: To provide a nominal response based on changing states within the spacecraft.

SRD - 315 The Spacecraft shall be capable of over-riding autonomous functions via ground command.

Rationale: The ground may need to over-ride or suspend an autonomous response so it can be reprogrammed or just simply stopped

SRD - 317 The Spacecraft shall report autonomous reconfigurations in housekeeping telemetry.

Rationale: Whenever the state of a hardware configuration is changed this needs to be tracked and reported in T/M

SRD - 319 The Spacecraft shall monitor pre-defined components, instrument(s), and subsystems.

Rationale: Monitoring the power, temperature and operations of sub-systems provides the information necessary to take autonomous actions.

SRD - 321 The Spacecraft shall report detection of out of limit conditions for monitored systems in Spacecraft housekeeping telemetry.

Rationale: Fault detection and limit violation data should be available for ground analysis.

SRD - 323 The Spacecraft subsystems that perform self diagnostics shall report the results in Spacecraft housekeeping telemetry.

Rationale: Self-test data should be trended as part of system monitoring.

SRD - 325 The Spacecraft subsystems that support self diagnostics shall accept ground commands to run diagnostics and report the results in Spacecraft housekeeping telemetry.

Rationale: Flexibility is necessary to support debugging conditions that may not be known until after launch.

SRD - 1345 The Spacecraft shall send a warning message to all instruments upon detection of an off nominal spacecraft condition.

Rationale: Mode change from nominal to off-nominal or detected power, attitude, etc., problems so the instruments can elect to perform a self-protection as necessary.

SRD - 1468 The Spacecraft shall send a warning message to each Earth imaging instrument whenever the sun is predicted to enter each instruments glint free field of view.

Rationale: In the unlikely event the a S/C maneuver transients the sun with an imaging instruments FOV, destroying the instrument, the S/C needs to warn the instrument of the impending doom.

3.9 Availability

SRD - 328 The Spacecraft shall be available for acquiring mission data that meets the imaging requirements at least 96% as measured during each month of operations.

Rationale: Availability: Orbit Maneuvers - 700 min. / 28 days + Anomaly resolution - 12 hours / 28 days = 1-24/672 approx. 96%

SRD - 330 The Spacecraft shall be capable of operating continuously in the normal Earth pointing attitude during each 16-day observation cycle.

Rationale: There should not be any subsystem on the Spacecraft that needs maintenance that interferes with the mission observations. The ground may command the Spacecraft to different attitudes.

3.10 Ground Support Equipment

SRD - 333 The Spacecraft GSE shall consist of the following:

- Spacecraft Interface Simulator (SIS)
- Spacecraft/Observatory Simulator (SOS)
- System Test Equipment (STE)
- Handling, rotation, and lifting fixtures
- Shipping / storage containers
- Test fixtures including specialized test equipment for spacecraft subsystems

3.10.1 Spacecraft Interface Simulator (SIS)

SRD - 341 The SIS shall provide a flight-like instrument electrical interface connection for mating to the instruments.

Rationale: The SIS will mate to the flight instrument(s) to test electrical interface. This may require multiple connectors to complete the electrical connection and will include primary and survival heater power feeds.

SRD - 343 The SIS shall provide electrical power source and switching characteristics consistent with the Spacecraft.

Rationale: To provide response characteristics to the instrument during power on testing and simulations.

Note: The power feeds are laboratory quality, not necessarily with the same in-rush characteristics as flight.

SRD - 346 The SIS shall simulate the Spacecraft responses to hardware discrete commands.

Rationale: Response fidelity should be equivalent to the flight system in terms of response values and timing accuracy.

SRD - 348 The SIS shall simulate the Spacecraft responses to messages received from the instrument across the communications bus.

Rationale: The SIS should respond in a high fidelity manner to all commands consistent with the selected communication bus standards. Message acknowledged or counter changes.

SRD - 350 The SIS shall generate realistic response characteristics for analog telemetry, housekeeping telemetry and Spacecraft ancillary data.

Rationale: Realistic response implies that simulated response characteristics are equivalent to the flight system in terms of timing, and that the data/telemetry points and their range of values and default values are equivalent to the flight system.

SRD - 352 The SIS shall record up to 10 minutes of simulated mission data.

Rationale: To provide simulation to record Spacecraft science and housekeeping data.

SRD - 354 The SIS shall playback all mission data.

Rationale: To provide simulation to playback Spacecraft science and housekeeping data, for post-test analysis by the instrument provider.

SRD - 356 The SIS shall generate timing pulses with the same characteristics as the Spacecraft timing signals.

Rationale: To provide response characteristics including 1-pulse per second and time of day messages to test Spacecraft and instrument timing.

SRD - 358 The SIS shall generate a timing message with the same format and characteristics as the Spacecraft timing message.

Rationale: To provide time of day messages to test Spacecraft and instrument timing.

SRD - 360 The SIS shall provide a communication bus interface to validate message exchanges.

Rationale: To provide testing of the communication bus interface characteristics between Spacecraft and instrument consistent with the interface control document between instrument(s) and the Spacecraft.

SRD - 362 The SIS shall provide communication flow over the High Speed Science Data Bus.

Rationale: To provide testing of the of the high-speed data interface characteristics between Spacecraft and instrument(s), consistent with the interface control document between instrument(s) and the Spacecraft.

SRD - 1268 The SIS shall provide communication flow over the RS-422 Data Bus.

Rationale: To provide testing of the of the RS-422 data interface characteristics between Spacecraft and instrument(s), consistent with the interface control document between instrument(s) and the Spacecraft.

SRD - 364 The SIS shall operate using Spacecraft flight software sufficient to simulate the instrument interface functionality and testing.

Rationale: Interface tests, test rehearsals, training, and simulations should be performed using the Spacecraft flight software, associated database, limits, and conversions.

3.10.2 Spacecraft/Observatory Simulator (SOS)

SRD - 367 The SOS shall be capable of operating independently from the real-time Flight Operations Segment.

Rationale: For training the FOT, testing Spacecraft responses to new commands it is necessary to remove the SOS from the MOC interface and run off-line.

SRD - 369 The SOS shall integrate into the Flight Operations Segment.

Rationale: The terminals in the MOC (FOS) may be used for FOT training, to run new scripts against, etc. Therefore it is necessary that MOC and SS communicate

SRD - 385 The SOS shall interface with the government furnished Mission Operations Element (MOE).

Rationale: So that the SOS can talk to the MOE there needs to be a ground station interface. This requirement addresses the fact that the ground RF is not present for the simulator.

SRD - 1314 The SOS shall interface with the government furnished ground station Programmable Telemetry Processor emulator.

Rationale: So that the SOS can talk to something that looks like a ground station but does not have RF equipment. It is necessary to tie into the digital to digital I/F, i.e. no RF on S/C either. Error correction coding, etc. that maybe put on by the S/C transmitter or removed by the S/C receiver wound need to be modeled.

SRD - 1318 The SOS shall generate telemetry that conforms to the same protocol, format and data rate as the spacecraft.

Rationale: The format, rate and protocols implemented on the spacecraft need to be match in the simulated data arriving at the PTP. Needs to look just like what would be generated on the spacecraft, virtual channels.

SRD - 387 The SOS shall interface with each of the government furnished instrument simulator(s).

Rationale: The SOS can communicate, receive telemetry and data, and transmit digital, discrete and analog information, with the instrument simulators.

SRD - 379 The SOS shall communicate commands to each of the government furnished instrument simulator(s).

Rationale: For FOT training and for image instruments software updates, as applicable, the SOS should simulate the all operational flight commands to the instruments.

SRD - 383 The SOS shall receive up to 10 minutes of Mission Data from each government furnished instrument simulator(s).

Rationale: For FOT training and for image instruments software updates, as applicable, the SOS should ingest data from the government furnished instrument simulator and process the same as is done in flight software. Ten minutes is approximately a single pass of data for play back to the ground.

SRD - 381 The SOS shall simulate the spacecraft response characteristics for the data received from each of the government furnished instrument simulator(s).

Rationale: For FOT training and for image instruments software updates, as applicable, the SOS should ingest data from the government furnished instrument simulator. Instrument simulators will generate telemetry; the SSR needs to be able to receive it.

SRD - 1329 The SOS shall simulate the spacecraft command and telemetry response characteristics from each of the government furnished instrument simulator(s).

Rationale: For FOT training and for image instruments software updates, as applicable, the SOS should ingest data from the government furnished instrument simulator. Instrument simulators will generate telemetry; the SSR needs to be able to receive it.

SRD - 398 The SOS shall simulate the response characteristics of failed Spacecraft subsystems.

SRD - 371 The SOS shall simulate the Spacecraft's Command and Data Handling (C&DH) system.

SRD - 389 The SOS shall simulate the operational modes and mode transitions of the spacecraft and spacecraft systems.

Rationale: Transition between the various implemented modes

SRD - 411 The SOS shall execute spacecraft flight software and databases.

Rationale: Interface tests, test rehearsals, training, and simulations should be performed using the Spacecraft flight software, associated database, limits, and conversions.

SRD - 1317 The SOS shall simulate functional transition to the redundant side or element of the spacecraft.

Rationale: Properly handle the fail-over to redundant side, telemetry of the redundant side, stored state condition of the redundant side.

SRD - 390 The SOS shall accept valid commands, table updates and flight software modifications.

Rationale: The SS will be used to test verify commands from the MOC to the Spacecraft and/or Spacecraft before use on the flight hardware.

SRD - 391 The SOS shall reject all invalid commands, table updates and flight software modifications.

Rationale: The SS will be used to test verify commands from the MOC to the Spacecraft and/or Spacecraft before use on the flight hardware.

SRD - 393 The SOS shall receive and process commands in any valid format and data rate.

Rationale: To model TDRS data flow, various data loads, tables

SRD - 1319 The SOS shall accurately simulate the timing of absolute time commands, relative time commands and stored time commands sequences.

Rationale: Implies command ingest and execution characteristics for the SOS be equivalent in accuracy to the flight system.

SRD - 395 The SOS shall accurately simulate the timing of command responses.

Rationale: Implies command ingest and acknowledgment (via telemetry) characteristics for the SOS be equivalent in accuracy to the flight system.

SRD - 394 The SOS shall receive, process, and execute flight software updates including but not limited to complete version updates, patches, and table updates that are identical to update commands for the flight spacecraft.

Rationale: Allows testing, training, etc. of flight software loads, ephemeris updates, star catalog changes and calibration/alignment updates,

SRD - 396 The SOS shall generate real-time housekeeping telemetry streams with representative spacecraft and instrument(s) data in valid formats and data rates.

Rationale: To realistically model back-orbit data flow / storage, and T/M generation, there is no mission data in HK telemetry, there maybe

SRD - 397 The SOS shall generate stored (playback) housekeeping telemetry streams with representative Spacecraft and/or Instrument(s) data consistent with expected on-orbit conditions in all valid formats and data rates.

Rationale: This data would include the same KH data that the real SC generates and stores and collects from the real instrument. It is just simulated.

SRD - 407 The SOS shall model any redundant capabilities and functions.

Rationale: For procedure development, FOT training, command up load testing it is necessary that redundant Spacecraft systems be modeled.

SRD - 373 The SOS shall simulate the operations of the mass storage system.

Rationale: This does not need to be a full memory allocation. It is the operations that need to be simulated.

SRD - 1320 The SOS shall simulate the functionality of the mass storage system.

Rationale: file generation, handling, automated file transfer, diagnostic modes, error correction, etc.

SRD - 372 The SOS shall simulate the operations of the attitude and orbital control system.

Rationale: Model attitude and environment sensors, actuators, thrusters, valves, etc.

SRD - 375 The SOS shall simulate the outputs of the spacecraft attitude sensors and the dynamic response of the spacecraft during simulations.

Rationale: Such that telemetry responses accurately represent what would be received from the Spacecraft in flight.

SRD - 1321 The SOS shall dynamically propagate the spacecraft orbit with a position accuracy of 300 meters, 3-sigma in each axis after 24 hours.

Rationale: Provide sufficient accuracy to test mission planning tools and validate operational aspects of the mission

SRD - 1323 The SOS shall dynamically model spacecraft orbit maneuvers with a position accuracy of 50 meters, 3-sigma in each axis one orbit after completion of the maneuver.

Rationale: Provide sufficient accuracy to test mission planning tools and validate operational aspects of the mission

SRD - 1322 The SOS shall dynamically model the spacecraft attitude with an angular accuracy of 500 microradians, 3-sigma about each axis over a 1 second interval.

Rationale: Provide sufficient accuracy to test mission planning tools and validate operational aspects of the mission

SRD - 377 The SOS shall provide the ability to simulate the GPS data input to the Spacecraft.

Rationale: For functional and performance testing during operational simulations. This does not require a precise GPS simulator but something to make the SOS work.

SRD - 374 The SOS shall simulate the operations of the power system.

SRD - 1324 The SOS shall simulate the elements of the power generation and distribution system.

Rationale: Such as batteries, redundant power buses, power conditioning units, power distribution units, current limiters, shunt dissipaters and solar array.

SRD - 1325 The SOS shall simulate at a minimum the effects of spacecraft attitude, sun position and solar array attitude on the power generation and distribution system.

Rationale: Eclipse, off-nadir pointing, tumbling S/C effect the power generation capability of the S/C and need to be modeled

SRD - 1326 The SOS shall simulate electrical power buses.

Rationale: activation and loading and unloading on the various power distribution buses for training and diagnostics

SRD - 1327 The SOS shall simulate the power loading on the electrical power buses.

Rationale: activation and loading and unloading on the various power distribution buses for training and diagnostics

SRD - 1328 The SOS shall simulate the spacecraft thermal control system with its response to the spacecraft attitude and orbital position.

Rationale: activation thermal cycling on the various power consumption for training and diagnostics

SRD - 1330 The SOS shall simulate the spacecraft radio frequency (RF) communications system.

Rationale: radios on /off, command response, power consumption

SRD - 1331 The SOS shall encode data going to the Programmable Telemetry Processor (PTP) to match the flight system.

Rationale: LDPC, R/S, convolutional whatever is designed into the flight unit should be applied to the T/M streams

SRD - 1332 The SOS shall decode data received from the PTP to the SOS in a manner identical to the flight unit, exclusive of the Caribou encoding.

Rationale: any ground encoding that needs to be removed. COMSEC will not be applied to the data going to the PTP and will not need to be decode by the SOS

SRD - 1333 The SOS shall simulate the physical response characteristics of the RF communications system including but not limited to antenna tracking, power consumption and thermal effects.

Rationale: simulation of the RF system to reflect the activities the FOT will need to be proficient, antenna gimbaling,

SRD - 1334 The SOS shall simulate the telemetry and command characteristics of the RF communications system including but not limited to antenna tracking, power consumption and thermal effects.

Rationale: simulation of the RF system to reflect the activities the FOT will need to be proficient, antenna gimbaling,

SRD - 1335 The SOS shall provide a graphical user interface to display information and allow control of the simulation.

Rationale: The operator will need to control all aspects of the simulation independent of the MOE

SRD - 399 The SOS shall simulate operator defined faults in the spacecraft.

Rationale: Allow simulation operators the ability to inject faults or disable sensors, actuators or mis-configure hardware.

SRD - 400 The SOS shall respond to real-time operator changes in the configuration of the simulated spacecraft.

SRD - 401 The SOS shall accept inputs from the operator to set and change simulation variables.

Rationale: Allows users to inject faults, vary initial conditions, etc.

SRD - 403 The SOS shall accept inputs from the operator to set and synchronize simulation time.

Rationale: To synchronize the events on-orbit with the events in the simulation it might be with the Flight Spacecraft clock time or ground system time

SRD - 1337 The SOS shall provide the operator with the ability to speed up (up to 10x) or slow down (down to 0.1x) the simulation relative to real time.

Rationale: Variable rate simulation necessary for test time efficiency and/or troubleshooting.

SRD - 1340 The SOS shall be capable of recording to a file at operator defined data rate the values from a predefined parameter list with variable name and parameter values in engineering units.

Rationale: Data rate is likely to be multiples of the integration time step such that every point up to some long time step can be save.

SRD - 1341 The SOS shall record report files in delimited, ASCII text files.

Rationale: Better formats maybe agreed to between the developers and users during the development process

SRD - 405 The SOS shall be capable of saving an executed simulation and simulation data.

Rationale: To allow trainers to establish a baseline set of training simulations, to be able reproduce a simulation

SRD - 1342 The SOS shall generate an event log containing operator inputs and system responses.

Rationale: To understand the operations of the simulation and to track operator changes, inputs, etc. a log of activities is needed.

SRD - 1336 The SOS shall provide operator the ability to over-ride any telemetry value in the housekeeping telemetry stream.

Rationale: To allow trainers to test individual MOE system capabilities without forcing a simulation state that provides the desired telemetry value.

SRD - 409 The SOS shall be capable of running a previous executed simulation.

Rationale: In support of FOT training and possible flight diagnostics

SRD - 1338 The SOS shall accept predefined anomalies into the simulation.

Rationale: In support of FOT training and possible flight diagnostics

SRD - 1339 The SOS shall be capable of causing any spacecraft command in a pre-defined list to fail.

Rationale: In support of FOT training and possible flight diagnostics

3.10.3 Spacecraft Test Equipment

Note: The Spacecraft Test Equipment (STE) provides the necessary hardware and software to support all the elements of the Spacecraft ground phase integration and testing.

SRD - 415 The STE shall provide interface(s) to the Spacecraft to control the spacecraft and instrument(s).

Rationale: A suite of test racks providing all required Spacecraft ground phase services including; electrical power, command & telemetry, radio frequency (RF), external monitoring, and systems maintenance.

SRD - 417 The STE shall provide mission operational simulation of the solar array power generation capability.

Rationale: Provide capability for solar array simulated power generation, shunting, battery charging, and power system monitoring.

SRD - 419 The STE shall be capable of battery maintenance and status verification during ground processing.

Rationale: Test and flight batteries will require servicing and maintenance operations during ground processing including re-conditioning, trickle charge, environmental control, and external monitoring,

SRD - 421 The STE shall be capable of commanding the Spacecraft.

Rationale: Provide ability to perform all aspects of command generation to the Spacecraft including; Spacecraft and instrument(s) unique commands, stored command sequences, flight software table and image loads. Commanding should also be performed through an automated script language.

SRD - 423 The STE shall be capable of providing system test automation.

Rationale: Using script based automated ground support systems for setup and execution of STE power generation, RF equipment, command/telemetry front-ends, simulators, trend/analysis support, increases testing reproducibility, reduces test time and operator error.

SRD - 425 The STE shall record telemetry from the Spacecraft.

Rationale: Provide ability to record the Spacecraft telemetry ingested and archive.

SRD - 427 The STE shall display telemetry from the Spacecraft in engineering units and in raw telemetry format.

Rationale: Provide ability to perform Spacecraft telemetry ingest and processing.

SRD - 429 The STE shall process and trend telemetry from the Spacecraft.

Rationale: Provide ability to perform Spacecraft telemetry ingest and processing.

SRD - 431 The STE shall provide the necessary RF front ends and check-out capabilities to verify the Spacecraft functionality.

Rationale: Spacecraft testing requires an all cables / connector out configuration. The RF system should not injure people or other equipment. An interface is necessary to capture the RF emissions (e.g. “hats” or test ports that do not radiate through the antenna).

SRD - 433 The STE shall provide the capability to monitor the status of the Spacecraft propulsion subsystem.

Rationale: Safety and remote monitoring

SRD - 434 The STE shall provide the capability to monitor the status of the Spacecraft power bus.

Rationale: Safety and remote monitoring

3.10.4 Mechanical Ground Support Equipment (M-GSE)

SRD - 436 The Spacecraft M-GSE shall have the capability of moving the Spacecraft, Spacecraft subsystems or Spacecraft assemblies during ground processing.

Rationale: To gain access to and to work on the spacecraft or observatory during I&T at the S/C vendor facility and as necessary at the launch site.

SRD - 438 The Spacecraft M-GSE shall have the capability of lifting the Spacecraft.

Rationale: Installation/removal to/from shipping containers, test facilities, and Spacecraft integration.

SRD - 1316 The Spacecraft M-GSE shall have the capability of lifting the integrated Observatory.

Rationale: Installation/removal to/from shipping containers, test facilities, and integration to the launch vehicle supplied hardware.

SRD - 440 The Spacecraft M-GSE shall have the capability of rotating the Spacecraft and the Observatory to any orientation necessary for integration of spacecraft components or government furnished instruments.

Rationale: Need access for integration & test, inspections, instrument(s) calibration, etc.

SRD - 442 The Spacecraft M-GSE shall enable Spacecraft mechanism deployment in a 1-g environment.

Rationale: Full deployments of solar array and deployables are performed during I&T.

SRD - 444 The Spacecraft M-GSE shall provide safe access to the Instrument(s), Spacecraft or Observatory.

Rationale: Safe access

SRD - 446 The Spacecraft M-GSE shall provide purging to the Spacecraft during ground processing.

Rationale: Instrument purging of Class C nitrogen, or environmentally controlled dry air.

SRD - 448 The Spacecraft M-GSE shall provide support for the performance verification of Spacecraft functionality.

Rationale: Support MGSE for environmental qualification including; vibration, thermal, and spacecraft calibration specific fixtures.

3.10.5 Shipping/ Storage Containers

Note: Shipping containers for Spacecraft and supporting GSE are required during transportation outside the controlled environments.

SRD - 452 All Shipping and Storage Containers shall be reusable, water-resistant, and fire-resistant.

Rationale: Intent not to use wooden containers or ones with contamination sources, and to provide protection from the transportation environment.

Fire-resistant implies that the container will not be combustible when exposed to sparks or small sources of fire such as matches or lighters.

Water resistant implies that the container will not allow water inside when exposed to mist/fog, high humidity, or unpressurized external water exposure such as external drips or light rain.

SRD - 1406 The Spacecraft Shipping and Storage Container shall accommodate the spacecraft with all government furnished instrument integrated, the Observatory, for transportation and storage purposes.

Rationale: The spacecraft contractor is required to ship the spacecraft with integrated instruments to the launch site

SRD - 454 The Spacecraft Shipping and Storage Containers shall be airtight (up to 10kPa under/over pressure relative to internal pressure) with filtered pressure control system, when the Spacecraft/Observatory within shipping container is transported inside a pressurized transport (aircraft).

Rationale: The Spacecraft Shipping and Storage Containers shall include a filtered pressure control system. When the purge is not attached it is airtight to small changes in external air pressure.

SRD - 456 The Spacecraft Shipping & Storage Container shall incorporate means of purging.

Rationale: With Class C dry nitrogen or dry air clean air that meets same cleanliness as the nitrogen.

SRD - 458 The Spacecraft Shipping & Storage Container shall incorporate means of measuring and recording shocks, temperature and humidity within the container during transient.

Rationale: Transportation environment should be monitored at all times to help detect for unseen damage.

SRD - 460 The Spacecraft Shipping & Storage Container shall have external indicators for temperature, humidity, and pressure monitoring.

Rationale: To provide an early indication that the transportation environment is outside of limits.

SRD - 462 The Spacecraft Shipping & Storage Container shall maintain internal pressure conditions for over 30 days with an internal pressure greater than 1.05 atmospheres.

SRD - 466 All flight systems Shipping & Storage Containers shall be suitable for use in the clean room, after cleaning.

Rationale: The instrument(s) may be operated in the Shipping & Storage container in proximity to the spacecraft. This applies only to flight hardware or flight hardware critical support GSE.

3.11 Software Development and Verification Facility

SRD - 469 The Software Development and Verification Facility (SDVF) shall include Engineering Test Unit versions of the Spacecraft command and data handling System, Attitude and Orbit Control System and the power control system and other hardware necessary to replicate the flight hardware for software development, verification, and anomaly resolution purposes.

Rationale: The SDVF needs to consist of the proper hardware to accurately simulate Spacecraft behavior for anomaly resolution, and to maintain and update flight software over an extended operational period of the mission.

SRD - 471 The SDVF shall be self contained and not require additional software or hardware to perform flight software development and verification.

3.12 Structural and Mechanical Systems

The Spacecraft mechanical subsystem consists of all primary and secondary structures for the Spacecraft bus, any necessary deployment assemblies and mechanisms, and interface structures between the Spacecraft bus, instrument(s) and launch vehicle including the upper-half of the payload attach fitting.

SRD - 476 The Spacecraft structure shall be sufficiently stiff to meet the axial and lateral frequency requirements as defined in the Launch Service Interface Requirements Document (LS-IRD), GSFC 427-08-01.

Rationale: To prevent interaction between the Spacecraft and the launch vehicle control system there is a minimum stiffness required on the spacecraft. LDCM furnished instruments have a minimum stiffness defined in their requirements document (>=60-Hz).

SRD - 478 The Spacecraft structure shall be of sufficient strength and stiffness to maintain structural integrity and withstand all launch and launch vehicle separation environments as defined in the Launch Service - Interface Requirements Document (LS-IRD), GSFC 427-08-01.

Rationale: The KSC provided launch service and the launch vehicle induced environments for the vehicles under the NASA Launch Services contract have been enveloped in this document.

SRD - 480 The Spacecraft structure shall be of sufficient strength and stiffness to maintain structural integrity and withstand all ground testing, handling, transportation, and mission on-orbit environments as defined in the LDCM Environmental Verification Requirements, GSFC 427-03-05.

Rationale: The LEVR contains the test environments and anticipated operational environment for the Spacecraft.

SRD - 482 The Spacecraft structure shall include an instrument deck that provides a structural mounting interface with a nadir field-of-view clear of obstructions for each Earth imaging instrument as defined in the O-IRD, GSFC 427-02-03.

SRD - 484 The Spacecraft in the stowed/launch configuration shall meet the dynamic envelope for the launch vehicle fairing as specified in the LS-IRD, GSFC 427-08-01.

Rationale: The dynamic envelope takes into account the movement of the LV fairing and the movement of the Spacecraft (assuming it meets the required stiffness) to ensure no contact with the fairing wall during launch.

SRD - 486 The Spacecraft structure shall include an instrument deck that is isolated from mechanical and thermal disturbances from the Spacecraft such that the instrument interface meets the interface requirements defined in the O-IRD, GSFC 427-02-03.

Rationale: To limit the disturbances coming into the LDCM instrument and to maintain co-alignment between the LDCM instruments the mounting surface is separated from the bus.

SRD - 488 The Spacecraft structure shall provide an instrument deck and associated fixtures sufficiently stable to maintain instrument-to-instrument co-alignment as defined by the LDCM O-IRD, GSFC 427-02-03.

Rationale: Fatness and stability of the instrument deck is necessary to ensure co-alignment between instruments and between instruments and AOCS sensors.

SRD - 489 The Spacecraft shall be designed to permit full range deployment of mechanisms after integration with the Spacecraft during ground processing.

Rationale: All deployments will be tested after the Spacecraft is fully integrated. At a minimum this should be done in ambient conditions.

3.13 Contamination Control System

SRD - 1257 The Observatory shall be integrated, tested and delivered to the Launch Site in compliance with the Product Cleanliness Levels and Contamination Control Program, IEST-STD-CC1246D, Level 450 A/1.5.

Rationale: In order to meet the contamination budget referenced in the Mission Contamination Control Plan, 427-02-14, and the OLI Beginning of Life requirement of 500A referenced in the OLI Contamination Control Plan, SER 2295367.

SRD - 1258 The Observatory shall maintain a surface cleanliness Level of 400 A/2 throughout I&T in compliance with the Product Cleanliness Levels and Contamination Control Program, IEST-STD-CC1246D.

Rationale: In order to meet the contamination budget referenced in the Mission Contamination Control Plan, 427-02-14, and the OLI Beginning of Life requirement of 500A referenced in the OLI Contamination Control Plan, SER 2295367.

SRD - 1259 The Observatory shall meet a surface cleanliness Level of 500A at Beginning of Life in compliance with the Product Cleanliness Levels and Contamination Control Program, IEST-STD-CC1246D.

Rationale: Instruments require surface cleanliness at BOL, including particulate contribution from launch ascent venting, to achieve their signal to noise levels over the mission design life.

SRD - 1503 The Solar Arrays shall meet an outgassing rate of 2 x10-11 g/cm2/s, as measured with a TQCM at -20C and per the bakeout details referenced in the Spacecraft Contamination Control Plan, 99-P58022P Rev A. The bakeout may be ended if the acceleration of the outgassing rate stalls at <5 Hz/hr/hr for four consecutive hours and with the approval of the LDCM Contamination Team.

Rationale: Due to their high molecular flux to the OLI solar calibration aperture and line of sight to thermal control surfaces.

SRD - 1504 The Battery venting shall be in the -X direction.

Rationale: Due to their line of sight to thermal control surfaces, star trackers, and TIRS Earthshield.

SRD - 1505 The CCU shall meet an outgassing rate of 1 x10-7 g/s, as measured with a TQCM at -20C and per the bakeout details referenced in the Spacecraft Contamination Control Plan, 99-P58022P Rev A. The bakeout may be ended if the acceleration of the outgassing rate stalls at <5 Hz/hr/hr for four consecutive hours and with the approval of the LDCM Contamination Team. The CCU will not vent in the +X direction.

Rationale: Due to their line of sight to thermal control surfaces, star trackers, and TIRS Earthshield.

3.14 Thermal System

SRD - 492 The Spacecraft shall be thermally safe for continuous operations in the Safe Hold, Earth Point and Operational Modes.

SRD - 493 The Spacecraft shall maintain subsystems and instruments within their design survival temperature range when the Spacecraft is in Safe Hold Mode.

Rationale: During Safe Hold the Spacecraft subsystems including instruments are allowed to thermally drift to minimize power consumption. The Spacecraft supplies power to all survival heaters.

SRD - 495 The Spacecraft shall have a thermal control system that monitors and reports in housekeeping telemetry the temperatures of subsystems on the Spacecraft.

Rationale: Tracking and trending Spacecraft temperatures is important to the longevity of the mission.

SRD - 497 The Spacecraft shall maintain subsystems within their operational design temperature range when the Spacecraft is in the Earth Point Mode and Operational Modes.

Rationale: Keeping the Spacecraft thermally stable will have a direct affect on quality of image data.

SRD - 499 The Spacecraft shall keep the instrument deck thermally stable while in the Operational Mode, Calibration Mode and Off-nadir Point Mode as defined in the Observatory - IRD.

Rationale: A thermally stable instrument deck will help remove the thermal distortions and alignment uncertainty associated with pointing the instruments.

SRD - 501 The Spacecraft programmable thermal set points shall be reprogrammable on orbit.

Rationale: Mission operations and better understanding of the observatory response to the space environment sometimes makes necessary changing thermal set points on the S/C.

3.15 Electrical System

SRD - 506 The Spacecraft shall provide a single point ground within the power subsystem.

Rationale: To eliminate ground loops and current flow in the ground plane

SRD - 508 The Spacecraft shall provide power generation, power control, energy storage and distribution to the Spacecraft.

SRD - 509 The Spacecraft shall provide load shedding control and battery management.

SRD - 510 The Spacecraft shall return to a maximum state of charge condition in the battery at least once in a sliding window of six orbits, as determined from DRC-16.

Rationale: Recover to a full battery state of charge within a sliding window. To address long night time imaging followed by a long playback or real-time data transmission the load leveling is spread over 10 hours. To preserve the life of the battery its state of charge should not get too low for routine operations.

SRD - 512 The Spacecraft shall be power positive over each orbit while in the Safe Hold mode.

Rationale: Safe hold mode is a minimum power mode, in a solar array to sun attitude, the spacecraft should be able to charge battery and maintain all powered functions.

SRD - 514 The Spacecraft shall provide short circuit protection or current limitation for each switchable power circuit.

SRD - 515 The Spacecraft shall provide protection from over voltage and under voltage conditions for the Spacecraft.

SRD - 516 The Spacecraft shall provide resettable protection against over voltage, under voltage and over current for the Spacecraft.

Rationale: As systems mature and or age it may be necessary to change set points in the power system.

SRD - 518 The Spacecraft shall be capable of being powered from Spacecraft Test Equipment with flight or ground batteries installed.

Rationale: To support ground processing and operations on the LV

SRD - 520 The Spacecraft shall be capable of being powered from Spacecraft Test Equipment with flight or ground batteries uninstalled.

Rationale: Flight batteries maybe removed or held in storage, this should delay ground processing, testing, etc.

SRD - 522 The Spacecraft shall provide power distribution for selecting, connecting and disconnecting the instrument(s) and selected Spacecraft equipment to/from the electrical bus.

SRD - 523 The Spacecraft shall at a minimum monitor and report in housekeeping telemetry switch positions for each switchable power circuit at the Spacecraft distribution point.

Rationale: A good design would monitor both sides of a switched circuit to ensure that enable and disable are positively controlled.

SRD - 525 The Spacecraft shall monitor and report in housekeeping telemetry current for up to 30 power circuits at the Spacecraft power distribution point.

Rationale: Current monitoring at the individual power feeds or monitoring by the component are both acceptable.

SRD - 527 The Spacecraft shall monitor and report in housekeeping telemetry voltage status for each power circuit and bus voltage at the spacecraft distribution point.

Rationale: Monitoring state of health.

SRD - 529 The Spacecraft shall provide electrical power for all Spacecraft operational modes during eclipse conditions.

Rationale: Battery power rating will consider the operational aspects of the mission and have sufficient margins to support an end of design life needs.

SRD - 531 The Spacecraft battery shall be sized such that the state of charge remains above 40% for the Spacecraft design life.

Rationale: To maximize the operational life of the battery it should not be deep cycled. Since the DRC-16 is not a stressing profile; limited off-nominal events may incur greater depth of discharge.

SRD - 533 The Spacecraft power system shall be capable of electrically bypassing failed battery cell(s).

Rationale: Weak or shorted cells will unnecessarily consume power. Removing them from the electrical bus reduces the power consumption of the SC.

SRD - 535 The Spacecraft shall provide a separate electrical power bus for hazardous operations.

Rationale: For deployment functions such as explosive bolts, release mechanisms, or hazardous circuits

SRD - 537 The Spacecraft shall have a power/enable, arm, and fire functions for all circuits supplying power to a hazardous function.

Rationale: To provide appropriate safety and protection circuits.

SRD - 1478 The Spacecraft battery shall be sized such that the state of charge remains above 60% during normal operations for all operations defined in DRC-16.

Rationale: To maximize the operational life of the battery it should not be deep cycled.

3.16 Flight Software & Firmware

3.16.1 General

SRD - 541 The Spacecraft flight software contained in reprogrammable memory shall be reprogrammable on orbit.

Rationale: This requirement is not intended to have embedded firmware in FPGA and ASICs or permanently coded state machines be changed on-orbit. FSW contained in processors, micro-controllers, sensors, actuators and other subsystem devices are included in this requirement.

SRD - 543 The Spacecraft shall monitor Flight Software tasks or functions to detect for infinite loops or "hung" processes.

SRD - 544 The Spacecraft flight software shall verify the validity of all memory areas.

SRD - 545 The Spacecraft flight software shall detect and correct single bit memory errors.

SRD - 546 The Spacecraft flight software shall detect and report multiple bit errors in memory.

SRD - 547 The Spacecraft stored commands shall be unaffected by a flight software upload.

SRD - 548 The Spacecraft flight software tasks shall have a defined execution priority.

SRD - 549 The Spacecraft flight software shall store the version identifier of reprogrammable software onboard.

SRD - 550 The Spacecraft firmware shall store the version identifier of the embedded software onboard.

SRD - 551 The Spacecraft flight software shall maintain a mapping of table name to memory address location.

SRD - 552 The Spacecraft flight software shall be capable of updating memory table locations through ground command table names.

SRD - 553 The Spacecraft flight software shall provide the capability to load any location of on-board memory by referencing its physical memory address.

SRD - 554 The Spacecraft flight software shall be capable of dumping any location in program memory.

Rationale: to support debugging efforts and provide additional telemetry points which may have been unanticipated at development time

SRD - 556 The Spacecraft flight software shall be capable of dumping the entire memory of on-board processors.

Rationale: To support debugging efforts and provide telemetry state of the on-board flight software

SRD - 558 The Spacecraft flight software memory dump capability shall not interrupt nominal execution of the flight software.

Rationale: This requirement is not to effect the ongoing Spacecraft operations or software processes. This requirement should only effect capability to get the memory dump telemetry on the ground.

SRD - 560 The Spacecraft shall implement independent time-based monitoring circuits.

Rationale: On-board processors should use hardware “watch dog” timers, or some hardware implemented system independent of the CPU to interrupt stuck software.

SRD - 562 The Spacecraft vendor shall perform a signal integrity analysis on all Spacecraft designs involving the use of FPGA’s.

Rationale: Manufactures recommendations over/undershoot criteria are often exceeded with high speed designs in FPGA or ASICs. Noise, part degradation, and other undesirable effects may occur without proper termination and impedance matching.

3.16.2 Event Logging

SRD - 565 The Spacecraft flight software shall time tag events logged in telemetry with an accuracy of 100 milliseconds or less.

Rationale: A reported event would contain information on the source processor, flight software task or function, severity level, message identifier and informational string that identifies the cause. The event messages capture anomalous events, redundancy management switching of components and important system performance events and warm and cold restarts to the accuracy of command execution.

SRD - 567 The Spacecraft flight software shall report all event messages in the Spacecraft housekeeping telemetry.

SRD - 568 The Spacecraft shall preserve contents of the event log after rebooting or power cycling a processor.

3.16.3 Initialization

SRD - 570 The Spacecraft shall initialize flight software and begin operations without the need of a ground based command.

SRD - 571 The Spacecraft flight software shall execute a restart warm boot of a processor's software from Read Only Memory in response to a ground command.

Rationale: This is a reboot of the flight software instruction set loaded from the nonvolatile on-board memory (EEPROM, PROM, etc.) and does not require a power-on reset.

SRD - 573 The Spacecraft flight software shall execute a restart cold boot of a processor's software from Read Only Memory following a power cycle or hardware reset.

Rationale: This is a complete reboot of the flight software loaded from the nonvolatile on-board memory and initialization of RAM memory (EEPROM, PROM, etc.).

SRD - 575 The Spacecraft flight software shall default to a known telemetry configuration following a restart.

Rationale: Following a restart of the flight software a standard, default configuration of the T/M is used to ensure the ground can read what is being sent down.

3.16.4 Stored Commands

SRD - 578 The Spacecraft flight software shall provide a capability to store and execute absolute-time command sequences.

SRD - 592 The Spacecraft flight software absolute-time stored command sequences shall be capable of invoking relative-time stored command sequences.

SRD - 579 The Spacecraft flight software shall provide a capability to store and execute relative-time command sequences.

Rationale: Relative time sequenced commands are a sequence of commands that can be sent from the command storage following a pre-defined sequence. Relative time sequence are typically delta time based though they may start at an absolute time.

SRD - 580 The Spacecraft flight software shall execute real-time commands before executing stored commands.

Rationale: At times real-time commands may be a higher priority that those in the buffer.

SRD - 591 The Spacecraft flight software shall provide the capability to store multiple time-tagged command sequences.

SRD - 581 The Spacecraft flight software stored command sequences shall be modifiable by ground command.

Rationale: By command the ground will able to reload or edit the stored command buffer

SRD - 582 The Spacecraft flight software command sequences shall be enabled, disabled or canceled by ground command.

SRD - 583 The Spacecraft flight software stored command capability shall store up to 72-hours of spacecraft command sequences.

Rationale: The spacecraft needs to store its own commands, including those it needs to start and stop the science recorder, etc.

SRD - 1474 The Spacecraft shall store at least 1.024 Mbytes of instrument command sequences for the OLI instrument.

Rationale: The GFE instrument may not have stored command buffers so the S/C will have to store instrument commands.

SRD - 1475 The Spacecraft shall store at least 1.024 Mbytes of instrument command sequences for the TIRS instrument.

Rationale: The GFE instrument may not have stored command buffers so the S/C will have to store instrument commands.

SRD - 585 The Spacecraft flight software shall be capable of placing the contents of the stored command buffer(s) into the housekeeping telemetry.

Rationale: The stored command buffer needs to be read by the FOT, stored command sequence table can be dumped to the ground by a single command.

SRD - 587 The Spacecraft flight software shall uniquely identify stored command sequences.

SRD - 588 The Spacecraft flight software shall use the unique command sequence identifier to report the status of each actively executing command sequence in telemetry.

SRD - 589 The Spacecraft flight software time resolution for stored commands shall be 100 milliseconds or less.

SRD - 590 The Spacecraft flight software shall be capable of executing commands with an accuracy of 100-milliseconds or less.

3.17 Command & Data Handling System

3.17.1 General

SRD - 595 The Spacecraft shall be capable of monitoring the health and safety of designated elements of the spacecraft and instrument(s).

Rationale: The Spacecraft should continuously monitor and report on the health and safety of the Spacecraft without continuous commands.

SRD - 597 The Spacecraft shall report in spacecraft housekeeping telemetry the health and safety of the spacecraft and instrument(s).

Rationale: There should be an allocation of some instrument data in the housekeeping data stream.

SRD - 599 The Spacecraft onboard processor(s) shall be capable of being reset via a discrete command.

3.17.2 Housekeeping Telemetry

SRD - 609 The Spacecraft shall process spacecraft and instrument(s) housekeeping telemetry.

Rationale: Analog data from the instrument and S/C may need conversion to a digital format. Real-time housekeeping data is needed to monitor and control the instrument(s).

SRD - 611 The Spacecraft shall transmit real-time housekeeping data to the ground when in contact with a ground station.

Rationale: Real-time HK data is needed to monitor and control the spacecraft.

SRD - 613 The Spacecraft shall record all housekeeping telemetry.

Rationale: To account for missed passes, back orbit data, etc. This happens all the time.

SRD - 603 The Spacecraft shall time-tag housekeeping telemetry read-out to the spacecraft time reference with an accuracy of +/-100 microseconds, 3-sigma.

Rationale: Time tagging of HK data is essential to correlating events on the S/C. Many parameters may not be monitored frequently but when they are read/recorded the time at which the reading is taken should be accurate.

SRD - 615 The Spacecraft shall be capable of concurrent transmission and storage of real-time housekeeping telemetry.

Rationale: The FOT can select this capability in any permutation

SRD - 617 The Spacecraft shall report command acceptance or rejection in housekeeping telemetry upon receipt.

SRD - 618 The Spacecraft shall report command identification in housekeeping telemetry when executed.

Rationale: When a stored command or a real-time command is executed this information should be written off into the HK data.

SRD - 620 The Spacecraft shall be capable of playing back stored housekeeping data while in any mode.

SRD - 622 The Spacecraft shall be capable of changing the housekeeping telemetry data acquisition rates.

Rationale: Provide flexibility to obtain housekeeping data that does not need to support image construction. (i.e. - different sampling rates when imaging and when not imaging)

SRD - 1271 The Spacecraft shall be capable of changing the content of housekeeping telemetry data.

Rationale: During different phase of the mission different telemetry may be need in the HK information.

SRD - 674 The Spacecraft shall be capable of storing at least 72 hours of Observatory housekeeping data at the maximum onboard telemetry rate.

Rationale: The total data that can be stored at any time includes all image data plus all calibration data taken in the last 24 hours plus the corresponding ancillary data plus the spacecraft and instrument(s) housekeeping data for the last 72 hours. Size the mass storage to support all systems needing mass storage. Storing 72 hours of housekeeping telemetry on the SSR is acceptable.

3.17.3 Command

SRD - 634 The Spacecraft shall be capable of decrypting command and data uploads using civil decryption coding in compliance with NASA NPR 2810.1A, Chapter 11.3.(1)5.

Rationale: Commands sent to the spacecraft will be encrypted to meet the NPR 2810.1 as well as protecting a national asset. Unfortunately there is a typo in the NPR and second section 5. should be a 15, hence the (1).

SRD - 636 The Spacecraft shall decrypt commands using National Security Agency approved Caribou decryption and authentication equipment.

Rationale: All commands sent to the spacecraft will be encrypted to NSA standards.

SRD - 639 The Spacecraft shall be capable of source authentication of all received commands.

Rationale: Source authentication is part of ensuring the data originates from an LDCM MOC and not from some outside source.

SRD - 641 The Spacecraft shall execute only commands that are source authenticated.

Rationale: To help prevent hijacking of the spacecraft

SRD - 638 The Spacecraft shall support Command Operations Procedure-1 protocol as defined in CCSDS 232.1-B-1.

Rationale: Need requirement to not use COP-1 during mission table uploads; s/w uploads, etc.

SRD - 643 The Spacecraft shall reject invalid commands.

Rationale: The Spacecraft should be able to recognize and reject invalid or improperly constructed commands to prevent accidental actions being taken by the Spacecraft.

SRD - 645 The Spacecraft shall identify rejected commands in housekeeping telemetry.

Rationale: To provide the FOT with status information about each command sent to the Spacecraft. Commands should not be echoed back to the ground for security reasons.

SRD - 647 The Spacecraft shall identify executed commands in housekeeping telemetry.

Rationale: To provide the FOT with status information about each command sent to the Spacecraft. Commands should not be echoed back to the ground for security reasons.

SRD - 649 The Spacecraft shall execute all hardware decoded commands upon receipt.

Rationale: The intent is that the hardware won't buffer or delay execution of hardware commands that
come directly from the ground to spacecraft hardware.

SRD - 661 The Spacecraft shall validate, process, and execute flight software commands and table data loads.

SRD - 662 The Spacecraft shall be capable of receiving FSW table loads across multiple contacts.

Rationale: Large table uploads, etc. may take more than one 10 minute pass to complete

SRD - 664 The Spacecraft shall be capable of receiving flight software loads across multiple contacts.

Rationale: S/W patches, etc. may take more than one 10 minute pass to complete

SRD - 666 The Spacecraft shall use unique commands to change state and condition.

Rationale: Using toggle commands can leave the state of a switch, box, etc. unknown. Enables and disables should be unique commands or commands with on/off parameters.

SRD - 668 The Spacecraft shall be capable of supporting all nominal operations with no more than 20 minutes of command uplink every 24 hours.

SRD - 669 The Spacecraft shall enable / disable sections of mass storage by ground command.

Rationale: Needed when warranted by observed or suspected malfunction, power savings.

SRD - 671 The Spacecraft shall issue instrument commands no greater than 4 commands per second.

3.17.4 Mass Storage

SRD - 680 The Spacecraft shall record all mission data.

Rationale: Data transmitted to International Cooperator (IC) ground stations and real time data to LGN makes up the 400 scenes. It is all played back at an LGN site. LGN data that is successfully received in real-time will likely be marked for overwrite thus not needing playback.

SRD - 695 The Spacecraft shall have the capability to manage multiple instrument(s) Mission Data independently.

Rationale: The instrument(s) will at times operate independently of each other and their Mission Data still needs to be stored.

SRD - 600 The Spacecraft shall be capable of resending stored Mission Data multiple times.

Rationale: In the event the data was not received by the ground.

SRD - 697 The Spacecraft mass storage shall be power cycled independently from any other Spacecraft subsystem or instrument(s).

Rationale: The mass storage will need to be checked out, tested and diagnosed independently from the instrument(s), other equipment and be capable of being powered off.

SRD - 701 The Spacecraft shall retain all stored data when transitioning into and out of any operational mode, unless power is cycled off.

Rationale: Do not lose data stored in the mass storage during any operational mode transition.

SRD - 703 The Spacecraft shall have the capability to enable/disable sections of mass storage by command.

Rationale: Needed when warranted by observed or suspected malfunction, power savings.

SRD - 699 The Spacecraft shall have the capability to power off sections of the mass storage memory.

Rationale: There is no requirement to retain stored image and ancillary data while in a non-nominal operational mode. Survival heater power is provided by the Spacecraft.

SRD - 705 The Spacecraft shall have the capability to power cycle the science mass storage separately from any spacecraft data storage.

Rationale: Applies if there are two storage or a physically separate storage. Needed when going into Safe Hold Mode do not want to power off spacecraft housekeeping memory when entering safe hold but would accept powering off mission data mass memory.

3.17.4.1 Ancillary Data

SRD - 625 The Spacecraft shall acquire mission ancillary data from the spacecraft and instrument(s) necessary to meet instrument imaging requirements.

Rationale: A CDRL will capture the extent of ancillary data need for image processing and address spacecraft trending.

SRD - 627 The Spacecraft shall time tag Mission Ancillary ephemeris data to the spacecraft time reference with an accuracy of 50-microseconds, 3-sigma.

Rationale: Spacecraft ancillary data must be tagged (time, counter, etc.) to the instrument data to ensure proper correlation for image reconstruction.

SRD - 1272 The Spacecraft shall time tag Mission Ancillary spacecraft attitude data to the spacecraft time reference with an accuracy of 150-microseconds, 3-sigma.

Rationale: Spacecraft ancillary data must be tagged (time, counter, etc.) to the instrument data to ensure proper correlation for image reconstruction.

SRD - 1273 The Spacecraft shall time tag non-specific Mission Ancillary data to the spacecraft time reference with an accuracy of 250-microseconds, 3-sigma.

Rationale: Spacecraft ancillary data must be tagged (time, counter, etc.) to the instrument data to ensure proper correlation for image reconstruction.

SRD - 629 The Spacecraft ancillary data shall include information regarding Spacecraft attitude, attitude rate, timing and telemetry housekeeping parameters as defined in the Instrument to Spacecraft Interface Control Document (temperature, voltage, operational configuration information, mechanism states etc.…).

Rationale: The S/C contractor and the GSFC will need to identify the necessary telemetry data to ensure proper image reconstruction.

SRD - 631 The Spacecraft shall acquire Mission Ancillary data during the Operational Mode.

Rationale: Spacecraft ancillary data acquisition should be independent of image acquisition, maintaining the same resolution as that required during imaging operations.

SRD - 605 The Spacecraft shall multiplex spacecraft ancillary data with instrument(s) ancillary data.

Rationale: Ancillary data needs to be transmitted with the instrument data so that the IC's will be able to process the image data upon receipt. If the ancillary data is stale, the ICs cannot use it and when the data transfer stops, the loss of data needs to be acceptable.

SRD - 1277 The Spacecraft shall packetize mission ancillary data into unique CCSDS packets.

Rationale: Mission ancillary data (S/C + OLI and TIRS ancillary data) is place is packetized together..

SRD - 602 The Spacecraft shall produce a complete update of the mission ancillary data at least once every 4 seconds during imaging.

Rationale: The ancillary (s/c+instr) data needs to be frequently refreshed. Ancillary data will contain parameters that have a 100-Hz reporting frequency down to data that has a .25-Hz.

SRD - 691 The Spacecraft shall have the capability to ingest and store Spacecraft generated ancillary data independently of image operations.

Rationale: Ancillary data, spacecraft HK data generated by the spacecraft will be available when the instrument(s) are not imaging. Therefore, this data should be stored whether imaging or not imaging.

SRD - 693 The Spacecraft shall have the capability to receive slower data rates for ancillary data acquisition when the instrument(s) are not acquiring image data

Rationale: To support different sampling rates when imaging and when not imaging

3.17.4.2 Image Data

SRD - 676 The Spacecraft shall be capable of storing at least 72 hours of instrument(s) ancillary data at the maximum onboard telemetry rate.

Rationale: The total data that can be stored at any time includes all image data plus all calibration data taken in the last 24 hours plus the corresponding ancillary data and the spacecraft and instrument(s) housekeeping data for the last 72 hours can be in the same mass storage device. Size the mass storage to support all systems needing mass storage.

SRD - 678 The Spacecraft shall ingest and store 187 minutes of OLI and TIRS Mission Data.

Rationale: Non-continuous WRS-2 Scenes or the equivalent off-nadir scenes would not have overlap. Since scenes are produced on the ground, it is not necessary to develop and store scene overlap on the spacecraft. (400*27sec+400sec)=187 minutes approx.

SRD - 682 The Spacecraft shall ingest and store up to 87 Megabytes of instrument mission system reserve data per 24 hour period.

Rationale: Assume mission system reserve data at a buffered rate of 8kbps (internally peaks to 32kbps), so 8*24*3600/1000/8 = approx. 87MB/day

SRD - 684 The Spacecraft shall packetize instrument(s) image data into unique CCSDS packets.

Rationale: Instrument data is likely to come direct from the instrument sensor chip assemble, SCA, and needs to be packetized by SCA.

Note: This requirement does not preclude the instrument(s) from performing some or all of the band sequential organization and CCSDS formatting of image and ancillary data or compression of the image data.

SRD - 688 The Spacecraft shall ingest and store all ancillary data associated with the instrument(s) image collection.

Rationale: The mass storage shall accommodate any necessary image reconstruction data from the spacecraft and instrument(s).

SRD - 690 The Spacecraft shall ingest and store all lunar and solar calibration data from the instrument(s).

3.17.4.3 File Management

SRD - 708 The Spacecraft shall use a file based data management scheme for stored data.

Rationale: This simplifies data handling and prioritization management of data.

SRD - 710 The Spacecraft shall implement Class 1, CCSDS File Delivery Protocol (CFDP) in compliance with CCSDS 727.0-B-4.

Rationale: The candidate architecture under consideration utilizes a Class 1 CFDP, with corrupted file retransmits performed during the pass via re-plan at MOE.

SRD - 714 The Spacecraft mass storage files shall not exceed 1-Gbyte in length.

Rationale: Limiting file size is intended to reduce the amount of retransmitted data tin the event of file transmission corruption.

SRD - 720 The Spacecraft shall provide a listing or directory of its file system including file attributes on command.

SRD - 721 The Spacecraft shall maintain mass storage file attributes that include at a minimum:

Rationale: File attributes provide insight on how, what, when information for the stored data. Additional information is likely to be needed by the instrument contractor to process an image on the ground.

- A file name provided by the ground
- A unique time stamp to 1 msec accuracy relative to the Spacecraft time reference
- The file length
- Sequencing and configuration information with respect to the formatting and processing modes of the Spacecraft and instrument(s)
- Flags that provide data protection status (over-write or not)
- Priority data flag
- Flag that indicates whether the file has been transmitted
- Flag that identifies test data from Mission Data

SRD - 730 The Spacecraft shall uniquely identify each data file in mass storage using a ground generated root name associated with the data content.

Rationale: A limited set of unique root file names are needed to track the mission data interval, calibration data or diagnostic data to ensure ground operations can trace time date, source information unambiguously.

SRD - 732 The Spacecraft shall maintain a mapping of the file contents to physical block address (at a file allocation block or equivalent granularity) within mass storage.

Rationale: This allows for mass storage diagnostics, dumping data if filename or tables are corrupted. The physical address block size is determined by the SSR vendor.

SRD - 734 The Spacecraft shall report the mapping of the file contents to physical location within mass storage upon command.

Rationale: This allows for mass storage diagnostics, dumping data if filename or tables are corrupted

SRD - 736 The Spacecraft shall designate any single or set of mission data files in mass storage as priority on command.

Rationale: Mission data is marked priority by the ground and is critical data that will not be overwritten until the MOE clears the priority and protect flags.

SRD - 1291 The Spacecraft shall designate any single or set of mission data files in mass storage as non-priority on command.

Rationale: To remove any priority designation.

SRD - 738 The Spacecraft shall designate any single or set of mission data files as protected on command.

Rationale: To protect priority files or other data from being overwritten. The MOE changes the file protection state.

SRD - 740 The Spacecraft shall mark mission data files in mass storage as non-protected on command.

Rationale: Mission data is marked non-protected by the MOE after it has been successfully received on the ground.

SRD - 742 The Spacecraft shall by command designate any single or set of data as non-protected.

Rationale: This allows the MOE to remove the protection on files or other data.

SRD - 744 The Spacecraft shall by command enable or disable the file protect/overwrite flags.

Rationale: Need capability to change memory protection attributes.

SRD - 746 The Spacecraft shall only overwrite non-protected mission data.

Rationale: To protect data that has not been confirmed as received on the ground.

SRD - 748 The Spacecraft shall overwrite mission data starting from oldest to youngest.

Rationale: For data that is not protected, the Spacecraft will overwrite oldest data first.

SRD - 1261 The Spacecraft shall format Mission Data files such that undamaged packets within a damaged or missing file segment can be recovered.

Rationale: Start of file and End of file segments will not likely be seen by the ICs. It is necessary that they be able to extract mission data from the good data present through sequence numbers or some other method.

3.17.4.4 Recording and Playback

Notes:

- In this section the word "output" refers to the process of sending data to the wideband data downlink system.

- The word "stream" refers to a continuous collection of mass storage files consisting of mission data (image + ancillary).
- To calculate a required playback rate, any instrument data that is compressed for storage may be considered to have a realtime data rate of the actual instrument realtime rate divided by the pre-scene average achieved compression factor.

SRD - 754 The Spacecraft shall concurrently record real-time Mission Data and playback stored Mission Data.

Rationale: this capability can be selected in any permutation of record and playback

SRD - 762 The Spacecraft shall have the capability to playback Spacecraft generated data independently of image operations.

Rationale: Playback data acquired during periods when there were no imaging operations or if the instrument(s) are off or some other mode.

SRD - 756 The Spacecraft shall have the capability to output one or more playback streams that produce a combined playback rate of at least twice the realtime rate of all LDCM Earth imaging instrument(s) combined.

Rationale: Simultaneous playback from two locations within the mass storage. This would consist of one or two streams mission data (image data + ancillary data).

SRD - 758 The Spacecraft shall output one real-time Mission Data stream while concurrently outputting one playback stream that has a rate equal to or greater than the real-time Mission Data rate.

Rationale: Simultaneous real-time pass and files played back from the mass storage.

SRD - 760 The Spacecraft shall be capable of mass storage playback by physical block address location.

Rationale: In the event file structure is corrupted or for diagnostics, it is possible to down link user specified memory locations in mass storage.

SRD - 765 The Spacecraft shall be capable of repeat playbacks of stored data.

Rationale: To ensure data reaches the ground the ability to retransmit stored data is required.

SRD - 767 The Spacecraft shall record each Mission Data file to ground assigned filename.

Rationale: The mass storage will store data in files based on names assigned by the ground. Therefore storage playback is by known filenames.

SRD - 771 The Spacecraft shall be able to multiplex, for each instrument, image and ancillary CCSDS packets into a single file.

Rationale: The real-time data stream consist of mission data that is made up of instrument(s) image data plus instrument(s) ancillary data plus Spacecraft ancillary data

SRD - 1282 The Spacecraft shall autonomously determine which mass storage files are to be down linked at the next ground contact opportunity according to the following scheme:

Rationale: To reduce operations overhead the spacecraft is required to have sufficient autonomy to efficiently perform mission data return scheduling onboard.

- In each category oldest files are played back before newer files
- First category of playback is un-transmitted "Priority Files"
- Second category of playback is un-transmitted non-Priority Files

SRD - 1286 The Spacecraft shall handle retransmit commands received during an autonomous file playback according to the following scheme:

Rationale: When a file is not properly received by the ground the FOT may want to have the file retransmitted, an efficient scheme for handling these retransmit requests onboard will minimize ground operations.

- Complete the current file playback
- Execute the retransmit request
- Resume the autonomous playback operation

SRD - 1290 The Spacecraft shall enable or disable autonomous file order playback on command.

Rationale: It may be desired operationally to switch between autonomous file playback and ground-scheduled playback.

SRD - 773 The Spacecraft shall be capable of CFDP file playback based on ground schedules.

Rationale: The ground will be able to establish playback schedules including scheduling some files for priority playback.

SRD - 775 The Spacecraft shall playback a complete file on command.

SRD - 1278 The Spacecraft shall retransmit complete individual files on command.

Rationale: FOT may need to manually select individual files for playback.

SRD - 776 The Spacecraft shall provide incrementally increasing Virtual Channel Data Units (VCDU) counts

Rationale: Repeatedly is when portions of a file must be sent a second or third time to recover a partial playback of the first playback/read out attempt.

SRD - 778 The Spacecraft shall transfer file directory listings as a separate CCSDS packet type.

Rationale: Packet ID directs this data to the MOC. MOC will asses the number and status of files in the mass storage.

3.17.4.5 Diagnostics, Fault Detection & Correction

SRD - 787 The Spacecraft shall be capable of diagnosing mass storage problems.

Rationale: Access processor memory, data storage locations, identify bad memory, etc.

SRD - 788 The Spacecraft shall have autonomous internal fault detection, correction capabilities for the mass storage.

SRD - 791 The Spacecraft shall incur no more than one uncorrectable/uncorrected error in 10^13-bits per 24 hour period in the mass storage.

Rationale: The bit error rate is to limit the number of bad bits before transfer to the downlink interface.

SRD - 793 The Spacecraft shall provide in housekeeping telemetry that stored data has been corrected.

Rationale: Help to identify when, where problems may start to occur

SRD - 794 The Spacecraft shall provide in housekeeping telemetry data to indicate that non-correctable bit errors have been detected.

SRD - 800 The Spacecraft mass storage shall be capable to ingest a full capacity test image data pattern from the Spacecraft.

SRD - 801 The Spacecraft mass storage shall be capable of playing back stored image or test image data to the downlink output interface while simultaneously recording test image data.

SRD - 802 The Spacecraft mass storage shall generate a pseudo random noise (PN, PRN) pattern of 4,294,967,295 bits length (PN32, 2^32 - 1).

Rationale: A test pattern applied to each downlink channel supports diagnostics and bit error rate (BER) testing.

SRD - 803 The Spacecraft shall be designed for graceful degradation of data storage capacity in the event of failed memory functions.

Rationale: No more than 5% of mass storage capacity being affected by any failed memory board or memory board component per failure.

3.17.5 Data Compression and Non-Uniformity Correction

If the Spacecraft implements compression of data, the requirements of Section 3.17.5.1 Data Compression will apply.

SRD - 1293 If the Spacecraft implements non-uniformity correction of the image data then the requirements of Section 3.17.5.2 shall apply.

Rationale: NUC may improve scene compression but its effects are limited do to the reversibility constraints

3.17.5.1 Mission Data Compression

SRD - 1297 The Spacecraft data compression algorithm applied to the Mission Data shall be lossless.

Rationale: When compression is performed no loss of image quality or radiometric content is permitted.

SRD - 1298 The Spacecraft data compression algorithm shall be enabled or disabled on command.

Rationale: Be able to turn compression on or off based on the need and to support diagnostics if necessary.

3.17.5.2 Image Data Non-Uniformity Correction (NUC)

SRD - 1300 The Spacecraft Non-Uniformity Correction (NUC) algorithm shall be fully reversible.

Rationale: There can be no ambiguities in removing the corrective term. Linear and completely reversible corrections are acceptable.

SRD - 1301 The Spacecraft NUC algorithm shall have reconfigurable coefficients to allow for updates.

SRD - 1302 The Spacecraft shall record and transmit the NUC coefficients used with each image data set.

Rationale: The NUC coefficients need to be transmitted as part of the ancillary file that makes up the mission data for an interval.

SRD - 1303 The Spacecraft shall be capable of receiving and updating NUC coefficient data.

Rationale: As detectors change it may be necessary to update the NUC coefficients.

3.18 Attitude and Orbit Control

3.18.1 Maneuvers

3.18.1.1 Orbit Maneuvers

SRD - 832 The Spacecraft shall be capable of performing drag makeup maneuvers.

Rationale: To maintain the ground track tolerance the spacecraft will need to perform periodic drag make up maneuvers based on atmospheric drag affects.

SRD - 834 The Spacecraft shall be capable of performing inclination change maneuvers.

Rationale: To maintain the descending node MLT tolerance the spacecraft will need to perform periodic inclination maneuvers.

SRD - 836 The Spacecraft shall be capable of performing retrograde propulsion maneuvers.

Rationale: EOS mission maybe required to maneuver out of the way of orbital debris and if the spacecraft was near the top of its ground-track box it would need to perform an orbit lowering maneuver.

SRD - 1313 The Spacecraft shall maintain attitude control for all propulsive maneuvers including the last de-orbit maneuver.

Rationale: Attitude control is required for all maneuvers. The deorbit maneuvers maybe long and are likely to be effected by atmospheric drag. Attitude control is necessary to minimize impact dispersions

3.18.1.2 Attitude Maneuvers

SRD - 841 The Spacecraft shall maneuver to support imaging of the lunar disk when the lunar phase angle is between -9 degrees to -5 degrees or when the lunar phase is between +5 degrees and +9 degrees on a monthly basis.

Rationale: The moon will be used as a calibration source on a monthly basis. It is necessary to image the moon during specific lunar phase angles.

SRD - 843 The Spacecraft shall maneuver to support image calibration by rotating the nominal along track axis to a 90 degree, cross-track attitude for either a "routine" or "long" collection at least once a 16-day observation cycle.

Rationale: So that all the detectors in the instrument image the same conditions on the ground the focal plane array needs to be oriented parallel to the along track direction.
There are two types of yaw collections:
1) Routine (1 scene): Duration = 30 seconds.
2) Long (10 scenes): Duration = 250 seconds.

SRD - 1391 The Spacecraft shall maneuver to support solar image calibration by rotating the nominal along track axis to approximately +90 degrees attitude away from the sun at least once every 8 days.

Rationale: OLI solar calibration aperture is 90 degrees to the velocity vector and therefore approximately 60 degrees away from the sun. The spacecraft needs to rotate the aperture towards the sun. There are three types of solar cal collections:
1) Prime diffuser: Duration = 80 seconds total attitude hold with 24 seconds of data collection.
2) Pristine diffuser: Duration = 120 seconds total attitude hold with 24 seconds of data collection.
3) Linearity check (variable integration time): Duration = 304 seconds total attitude hold with 248 seconds of data collection.

SRD - 1407 The Spacecraft attitude, attitude rates, and jitter requirements for nominal mission imaging operations shall apply to the imaging period of calibration maneuvers.

Rationale: There are no jitter or pointing accuracies required during the transition to a calibration attitude. The normal imaging pointing requirements apply during calibration imaging.

SRD - 845 The Spacecraft shall perform maneuvers to any inertial attitude meeting pointing requirements at the desired attitude within 15 minutes.

Rationale: To maneuver to the calibration attitude and be ready to start imaging. All rates and attitude stability requirements will be meet once reaching the desired target.

SRD - 1306 The Spacecraft shall return from any inertial attitude to the normal Earth imaging attitude meeting pointing requirements at that attitude within 15 minutes.

Rationale: To return from any off-nominal attitude to the nominal Earth point, yaw steering, imaging fully stable ready to go.

SRD - 847 The Spacecraft shall remain thermally stable, under stable attitude control, and operationally functional within its design requirements with the +Z axis up to 15 degrees, off-nadir, either side of the current orbit plane.

Rationale: Remain thermally stable, under stable attitude control, and fully functional in off-nadir pointing attitudes. The image acquisition in this attitude is equivalent to one WRS-2 path image left or right of the grid.

SRD - 849 The Spacecraft shall maneuver the +Z axis up to 15 degrees, off-nadir, either side of the current orbit plane meeting imaging pointing requirements at the desired attitude within 5 minutes.

Rationale: To minimize the time the spacecraft is off-nadir, get to off-nadir and back as quick as possible so nominal imaging can resume.

SRD - 1307 The Spacecraft shall maneuver back from the off-nadir imaging attitude to the normal Earth pointing attitude within 5 minutes.

Rationale: To return from the off-nadir attitude to the nominal Earth point, yaw steering, fully stable imaging attitude ready to go.

SRD - 1469 The Spacecraft anti-sun side shall be limited to no more than 1 minute of direct solar exposure once every orbit.

Rationale: Need to limit the amount of sun exposure on the instrument radiators during all mission modes.

3.18.2 Ephemeris

SRD - 860 The spacecraft shall use Temps Atomique International (TAI) time as the observatory time reference.

Rationale: Conversion to mission UTC will occur in the LDCM ground system.

SRD - 1473 The Spacecraft shall use the CCSDS 301.0-B-3, Section 2.3 CCSDS Day Segmented Time Code (CDS) in the time message.

Rationale: The use of an unambiguous time stamp for data synchronization

SRD - 852 The Spacecraft shall generate an on-board ephemeris based on the Global Positioning System (GPS).

Rationale: GPS ephemeris is expected/preferred if alternative means exist to meet the accuracy requirements equivalent sensor information.

SRD - 1392 The Spacecraft shall include the GPS carrier phase and pseudo range values in the spacecraft ancillary data stream.

Rationale: GPS observables will be used to generate a definitive ephemeris file in support of image data ground processing.

SRD - 856 The Spacecraft shall be capable of receiving a ground based ephemeris update.

Rationale: As a contingency, provides the ability to continue operations in the event of a GPS outage or dual GPS receiver failure the ground will send time, position and velocity.

SRD - 854 The Spacecraft shall be capable of propagating the on-board state for at least 24 hours.

Rationale: Provides the ability to continue operations in the event of a GPS outage or dual receiver failure by propagating the state forward.

SRD - 858 The spacecraft shall support imaging operations for up to 24-hours from an on-board propagated ephemeris.

Rationale: Supports the ephemeris state vector propagation contingency

SRD - 1408 The Spacecraft shall add less than 500m absolute position error in any axis after propagating for 24 hours with no GPS or ground updates.

Rationale: A propagated state is required in the event that GPS has failed, and will be updated from the ground. The requirement is only on the propagator, and is independent of the initial conditions. (e.g. epoch, position, velocity, Cd, A, F10.7, etc).

SRD - 1269 The Spacecraft shall be capable of receiving a ground base Spacecraft reference time and time correction coefficients.

Rationale: Whenever the GPS is not available it may be necessary to updated the Spacecraft reference time and any associated timing coefficients such as the timer biases and offsets.

SRD - 862 The Spacecraft shall provide the orbital position and velocity in the Earth Centered Inertial (ECI) of Epoch J2000.0 coordinate frame.

Rationale: Consistent coordinate system used in the spacecraft and instrument

SRD - 864 The Spacecraft shall provide an estimate of position and velocity time-tagged to an accuracy of +/- 50 microseconds or more accurate to the spacecraft reference time.

Rationale: Constrains the timing-induced along-track positional error (due to orbital velocity) to be less than the allowable jitter error.

SRD - 866 The Spacecraft shall compute orbital position accurate to 30 m radial, 30 m in-track, and 30 m cross-track - all values are 3-sigma.

Rationale: Considering geocentric accuracy error allocation.

SRD - 868 The Spacecraft shall provide orbital velocity accurate to 0.30 m/sec radial, 0.30 m/sec in-track, and 0.30 m/sec cross track - all values are 3-sigma.

Rationale: Limits velocity errors to 1/2 a panchromatic pixel over a WRS scene.

SRD - 870 The Spacecraft shall report the orbital position and velocity once per second in the spacecraft housekeeping telemetry and ancillary data.

Rationale: Allows for improving the ephemeris accuracy on the ground by smoothing the individual GPS observable (measurements).

SRD - 1308 The Spacecraft shall report the Global Positioning System observables in spacecraft housekeeping telemetry and in the spacecraft ancillary data.

Rationale: Allows for improving the ephemeris accuracy on the ground by smoothing the individual GPS observables (primarily pseudo-range and carrier phase measurements).

3.19 Propulsion System

SRD - 873 The Spacecraft propulsion consumables shall provide for 10 years of operational life time at the operational orbit followed by a controlled de-orbit, assuming a 3 sigma worst case mission environment.

Rationale: Worst case atmospheric density drag, launch vehicle insertion contingency, subsystem operational uncertainty, Spacecraft attitude recovery, and controlled de-orbit decommissioning, plus propellant residuals for loading uncertainties, subsystem propellant expulsion efficiency, manifold losses, and thruster flushing need to be looked at and analyzed.

SRD - 875 The spacecraft propulsion subsystem shall operate in both pulse and continuous modes without restriction on operational duration or duty cycles as required to complete the mission.

Rationale: Provides for off pulsing, some attitude control if necessary, translational maneuvers, and inclination change maneuvers

SRD - 876 The Spacecraft propulsion subsystem shall be of all welded construction from the propellant supply tank to the first isolation valve.

Rationale: Failure of manifold joint poses critical or catastrophic threat to personnel and facility. Welds are NDE verified per safety requirements elsewhere.

SRD - 878 The Spacecraft propulsion subsystem shall be designed to prevent the entrapment of fluids.

SRD - 879 The Spacecraft propulsion subsystem design and operation shall preclude damage due to pressure surge in both the gas and liquid sides of the propulsion subsystem.

SRD - 880 The Spacecraft propulsion subsystem Maximum Expected Operating Pressure (MEOP) shall be designed to the largest expected static pressure at the Maximum Expected Operating Temperature (MEOT), with any transient (waterhammer events) being less than any component proof pressure.

SRD - 881 The Spacecraft propulsion subsystem thrusters shall be located and configured to attenuate plume impingement on the spacecraft and instrument surfaces.

Rationale: With the possibility of multiple instruments located about the S/C; thrust plume may become a contamination concern. There are no

SRD - 883 The Spacecraft propulsion subsystem shall provide, as a minimum, the following status telemetry:

- Propellant tank pressures with an accuracy of ±2 psia and resolution of less than 0.1 psia
- Propellant tank, line, thruster valve, and thruster temperatures
- Latch valve open/close status

SRD - 887 The Spacecraft propulsion subsystem thruster valves and isolation valves shall be protected by internal inlet filters.

SRD - 888 The Spacecraft propulsion subsystem nominal filter rating of the thruster valve inlet filters shall be 15µ to 20µ above the nominal micro rating of the system filters.

Rationale: System filters should provide a two stage filtering process to ensure particles do not reach the thruster valves.

3.20 Radio Frequency Telecommunications System

3.20.1 General

SRD - 892 The Spacecraft shall comply with National Telecommunications and Information Administration (NTIA) Spectrum Standards.

Rationale: The document to reference is "Manual of Regulations and Procedures for Federal Radio Frequency Management", May 2003 Edition, September 2006 Revisions. The manual contains standards for out-of-band, harmonic and spurious emissions that Spacecraft systems must comply with. It also contains limits on maximum power flux-density (PFD) at the Earth's surface and at the geostationary orbit.

SRD - 894 The Spacecraft shall comply with International Telecommunication Union (ITU) spectrum utilization and sharing requirements.

Rationale: The document to reference is the "ITU-R Radio Regulations", 2004. The document contains standards for calculating interference with other systems, including the DSN, and standards for link budget calculations.

SRD - 896 The Spacecraft shall comply with Space Frequency Coordination Group (SFCG) Handbook 2005.

Rationale: The document has requirements to which LDCM must comply. In particular, 14-1R1, 14-3R7, 21-2R2 apply to emissions in S- and X-band. The last specifies the spectral mask applicable to S- and X-band. GSFC Spectrum Manager has cleared the use of Earth Coverage Antennas.

SRD - 898 The Spacecraft shall concurrently transmit real-time Instrument(s)' image data, instrument(s)' ancillary data and Spacecraft corresponding ancillary data.

Rationale: Image data and all ancillary data needed to form an image must be received concurrently so the IC or LDCM image processing center can produce an image.

SRD - 900 The Spacecraft shall be capable of transmitting a 2^23-1 maximal pseudo noise pattern from all transmitters.

Rationale: This is a testability requirement and we do not have a testability section.

SRD - 908 The Spacecraft RF active components shall be immune from corona and multipaction effects for components with internal pressures from sea level to hard vacuum with a minimum test margin of 6 dB.

Rationale: Analytical tools are not accurate at predicting multipaction / corona effects on active elements. Therefore testing is required.

SRD - 1389 The Spacecraft RF passive components shall be immune from corona and multipaction effects for components with internal pressures from sea level to hard vacuum with a minimum test margin of 6 dB. If analysis indicates a margin of 10dB or greater at the maximum input power, then testing may be limited to the maximum RF input power.

Rationale: For passive components, if the analysis indicates a design margin of 10 dB or greater at the maximum RF input power to the component then testing can be done only at the maximum input power. The analysis must consider worst case mechanical tolerances of the component with respect to vulnerability to corona and multipaction (i.e., worst case tolerances to result in minimum possible frequency gap products within the component).

3.20.2 Narrowband

SRD - 916 The Spacecraft shall maintain power to the S-band receiver from launch countdown and through the life of the mission.

Rationale: With the receiver on is the only means of getting instructions into the spacecraft, at least one receiver should be on at all times. Only if a receiver is in a dead short should the power be removed.

SRD - 918 The Spacecraft shall be capable of narrowband reception of ground commands while in any operational mode.

Rationale: Commanding is needed to maintain control of the Spacecraft. The receiver should always be powered.

SRD - 922 The Spacecraft shall be capable of narrowband transmissions in any Spacecraft operational mode.

Rationale: Real-time HK data is needed to monitor and control the Spacecraft even if the Spacecraft is tumbling out of control.

SRD - 924 The Spacecraft shall be capable of narrowband transmissions in any Spacecraft orientation.

Rationale: Real-time HK telemetry is needed to monitor and control the Spacecraft regardless of its attitude.

SRD - 926 The Spacecraft shall be capable of narrowband transmission and reception concurrently.

Rationale: Mission operations needs to receive acknowledgment of command receipt while commanding to best maintain control of the spacecraft.

3.20.3 Wideband

SRD - 951 The Spacecraft shall transmit real-time wideband Mission Data to at least three in-view International Cooperators (ICs).

Rationale: The Spacecraft must support data transmission when multiple LGN or IC sites are in view simultaneously.

3.20.4 RF Spectrum Protection

SRD - 970 The Spacecraft wideband downlink shall not create RF interference with NASA Deep Space Network communications.

Rationale: DSN communications are protected and highly sensitive.

SRD - 1348 The maximum allowable power spectral flux-density to protect DSN in the 2290-2300 MHz band at the input of the DSN antenna shall be -257 dB (W/m*m/Hz).

SRD - 1349 The maximum allowable power spectral flux-density to protect DSN in the 8400-8450 MHz band at the input of a DSN antenna shall not exceed -255.1 dB ($W/m^2/Hz$).

Rationale: From “DSN 8 GHz RFI Prevention Guideline,” to be published in the next version of the NPR 2570.1, contains protection criteria applicable to the 8400-8450 MHz SRS (space-to-Earth) deep space band in accordance with ITU-R SA.1157.

SRD - 1368 The Spacecraft's integrated Power Spectral Density (PSD) below 8025 MHz shall be less than 1.0% of the integrated PSD below the center frequency.

Rationale: As a government earth science only mission additional limitations are placed on the spectrum allocation making it difficult to use commercial portions of the X-band spectrum

SRD - 1470 The Spacecraft's Power Spectral Density below 8025 MHz shall be attenuated by at least 12 dB relative to the maximum PSD of the emission.

Rationale: To maintain compliance with NTIA spectrum allocations below the Earth Sciences Mission spectrum allocation.

SRD - 1351 The maximum power flux-density (PFD) in any 4 kHz reference bandwidth anywhere on the Earths surface within the band 8025-8400 MHz shall not exceed the following levels:

Table 3 - 1 X-Band Protection of Terrestrial Systems

W/m^2/4kHz	**Signal Arrival Angle**
-150	0 < Theta < 5 degrees
-150 + 0.5 (Theta -5)	5 < Theta < 25 degrees
-140	25<Theta < 90 degrees

Note: Where PFD levels are specified in units of dB (watts/square meter/4 kHz) and Theta is the signal arrival angle above the horizontal plane at the Earths surface.

Note: NASA-GSFC will not be allowed to file a spectrum application with the NTIA with any significant emission outside of the EESS band.

SRD - 1370 The maximum power flux-density (PFD) in any 1MHz reference bandwidth anywhere on the Earths surface within the band 25.5 to 27.0GHz shall not exceed the following levels:

Table 3 - 2 Ka-Band Protection of Terrestrial Systems

PFD (dB)	**Signal Arrival Angle**
-115.0	0 < Theta < 5 degrees
-115 + 0.5 (theta -5)	5 < Theta < 25 degrees
-105	25<Theta < 90 degrees

Note: Where PFD levels are specified in units of dB (watts/square meter/1 MHz) and Theta is the signal arrival angle above the horizontal plane at the Earths surface.

SRD - 1386 The spacecraft emissions shall satisfy the NTIA unwanted emissions shown in Figure 3-2.

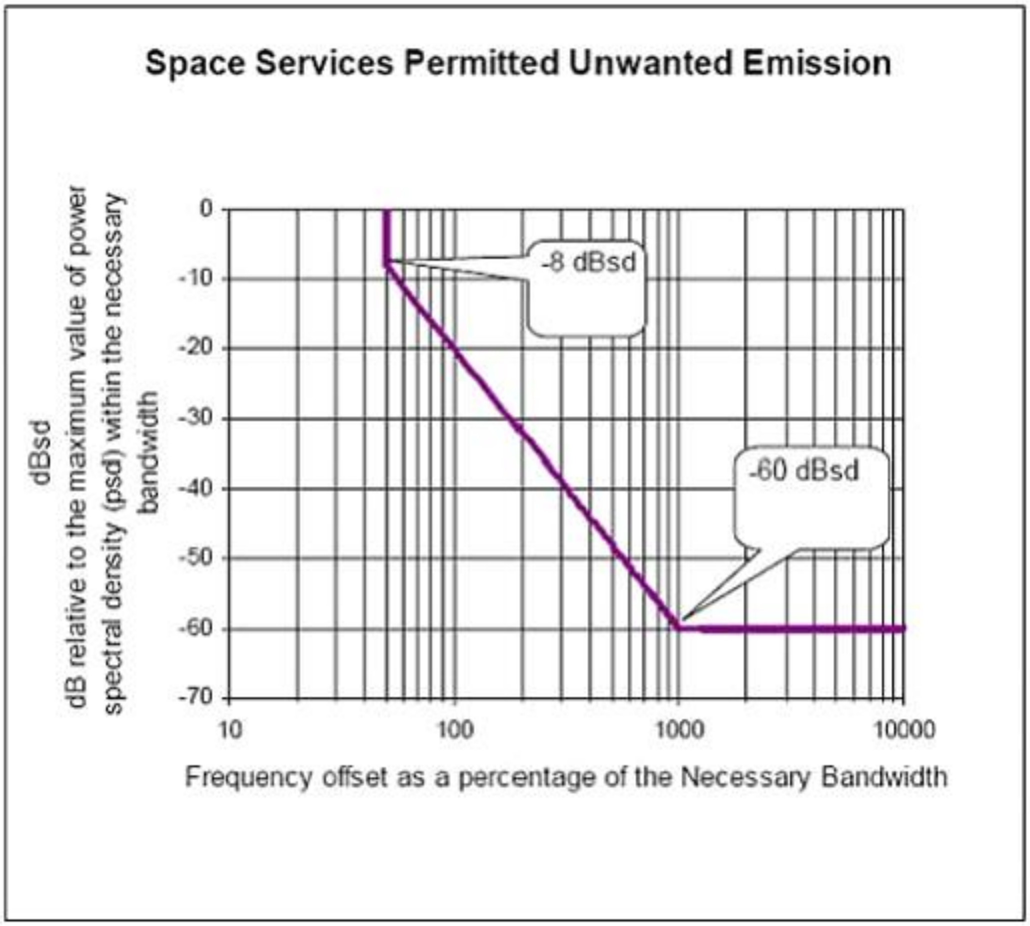

Figure 3 - 2 Space Services Permitted Unwanted Emission

3.21 Technical Resource Margins

SRD - 1121 The Spacecraft shall use the following equation for margin calculations:

Margin (in percentage) = 100% x (Available Resource-Estimated Resource) / Estimated Resource.

Rationale: Provides consistency with the GSFC GOLD book approach to tracking performance. The use of margins is intended to improve performance on mission level cost and schedule in addition to mission performance. This margin equation should be used for each technical resource.

SRD - 1124 The Spacecraft shall use a maturity level that corresponds to the development phases identified in the GSFC-STD-1000, GOLD Rules, to define required subsystem margins.

Rationale: By using the maturity level then new development items will be properly combined with heritage items to assess the total spacecraft.

SRD - 1126 The Spacecraft technical resources shall have the following minimum resource margins at the end of a component's development phase:

Technical Resource Margins

Resource	Contract ATP	Mission Design Review (Phase A)	Preliminary Design Review (Phase B)	Critical Design Review (Phase C)	Pre-Environmental Design Review (Phase D)
Mass	>30%	>25%	>20%	>15%	5%
Power (wrt End of Design Life Capacity)*	>30%	>25%	>15%	>15%	>10%*
Propellant	3σ***				3σ
Telemetry and Command Hardware Channels**	>25%	>20%	>15%	>10%	2%
RF Link	3 dB	3 dB	3 dB	3 dB	3 dB

SRD - 1169 * At launch there shall be 10% predicted power margin for mission critical and safe hold modes as well as to accommodate in-flight operational uncertainties.

** Telemetry and command hardware channels read/ write data from/to hardware such as thermistors, heaters, switches, motors, etc.

*** The 3 sigma variation is due to the following:

1. Worst-case Spacecraft mass properties;

2. 3-sigma low launch vehicle performance;

3. 3-sigma low propulsion subsystem performance (thruster performance/ alignment, propellant residuals);

4. 3-sigma flight dynamics errors and constraints;

5. Thruster failure (applies only to single-fault-tolerant systems)

SRD - 1177 The Spacecraft flight software assigned to a processor shall have the following minimum resource margins at the end of each development phase:

Processor Resource Margins

Resources	Mission Design Review (Phase A)	Preliminary Design Review (Phase B)	Critical Design Review (Phase C)	Pre-Environmental Design Review (Phase D)
Central Processing Unit Utilization	50%	50%	40%	30%
Central Processing Unit Deadlines	50%	50%	40%	30%
Programmable Read-Only Memory	50%	30%	20%	5%
Electrically Erasable Programmable Read-Only Memory	50%	50%	40%	30%
Random Access Memory	50%	50%	40%	30%

SRD - 1464 The Spacecraft communications bus(es) shall have the following minimum resource margins at the end of each development phase:

Spacecraft Communications Technical Resource Margins

Resources	Mission Design Review (Phase A)	Preliminary Design Review (Phase B)	Critical Design Review (Phase C)	Pre-Environmental Design Review (Phase D)
Peripheral Component Interconnect (PCI) bus	75%	70%	60%	50%
1553 bus	30%	25%	20%	10%
Universal Asynchronous Receiver-Transmitter (UART)	50%	50%	40%	30%

4 Appendix A

WEXP placeholder

5 Appendix B

WEXP placeholder

6 Appendix C

WEXP placeholder