LANDSAT DATA CONTINUITY MISSION

LDCM Science and Mission Requirements Document

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National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

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

This document establishes the science and mission requirements and programmatic constraints for the Landsat Data Continuity Mission (LDCM). It is a Level 2 requirements document that includes the functional, performance, and design requirements for all LDCM systems and an allocation matrix of mission level requirements to responsible organizations.

1.2 Document Organization

Section 1 provides administrative details; Section 2 provides a mission definition with an overview of the LDCM and describes its science objectives and mission segments; Section 3 describes the applicable documents; Section 4 describes top level mission characteristics, externally-imposed requirements, and the user community and external interfaces are identified; Sections 5 through 9 describe science and other mission-unique requirements.

2 Mission Overview

2.1 Mission Statement

The LDCM, consistent with U.S. law and government policy, will continue the Landsat program's acquisition, archival, and distribution of multi-spectral imagery affording global, synoptic, and repetitive coverage of the Earth's land surfaces at a scale where natural and human-induced changes can be detected, differentiated, characterized, and monitored over time.

2.2 Mission Background

The LDCM is a component of the Landsat Program being conducted jointly by the National Aeronautics and Space Administration (NASA) and the United States Geological Survey (USGS) of the Department of the Interior (DOI). The LDCM goals are in keeping with the Landsat programmatic goals stated in the Land Remote Sensing Policy Act of 1992 (Public Law 102-555) and the Commercial Space Act of 1998 (Public Law 105-303). This policy requires that the Landsat Program provide data into the future that is sufficiently consistent with previous Landsat data to allow the detection and quantitative characterization of changes in or on the land surface of the globe. The LDCM was conceived as a follow-on mission to the highly successful Landsat series of missions, which have been providing satellite coverage of the Earth's continental surfaces since 1972. The data from these missions constitute the longest continuous record of the Earth's surface as seen from space.

The LDCM is intended to ensure that Landsat-like data will be provided to the USGS National Satellite Land Remote Sensing Data Archive (NSLRSDA) for at least 5 years. The LDCM Observatory will carry the image sensor.

2.3 Mission Objectives

The goal of the LDCM, consistent with U.S. law and government policy, is to continue the acquisition, archival, and distribution of multi-spectral imagery affording global, synoptic, and repetitive coverage of the Earth's land surfaces at a scale where natural and human-induced changes can be detected, differentiated, characterized, and monitored over time.

The following major mission objectives follow from this goal:

- Collect and archive moderate resolution (circa 30 m ground sample distance) multispectral image data affording seasonal coverage of the global landmass for a continuous period of not less than 5 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 multi-decadal 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.

2.4 Mission Implementation

The LDCM is a partnership between NASA and the USGS. Each agency has been assigned specific responsibilities and will deliver the following major elements to the overall mission. NASA will provide the Space and Launch Segments of the LDCM, while, the USGS will provide the Ground System. NASA/GSFC will provide the overall LDCM project management, mission system engineering and mission assurance for development of the LDCM. The LDCM Requirements Hierarchy in Figure 2-2 depicts the flow down of mission requirements to the major elements of the LDCM. Since LDCM is a cooperative effort between NASA and the USGS; each agency in addition to specific responsibilities, will deliver the following major segments to the overall mission. The segment requirement documents contain detailed requirements for each segment.

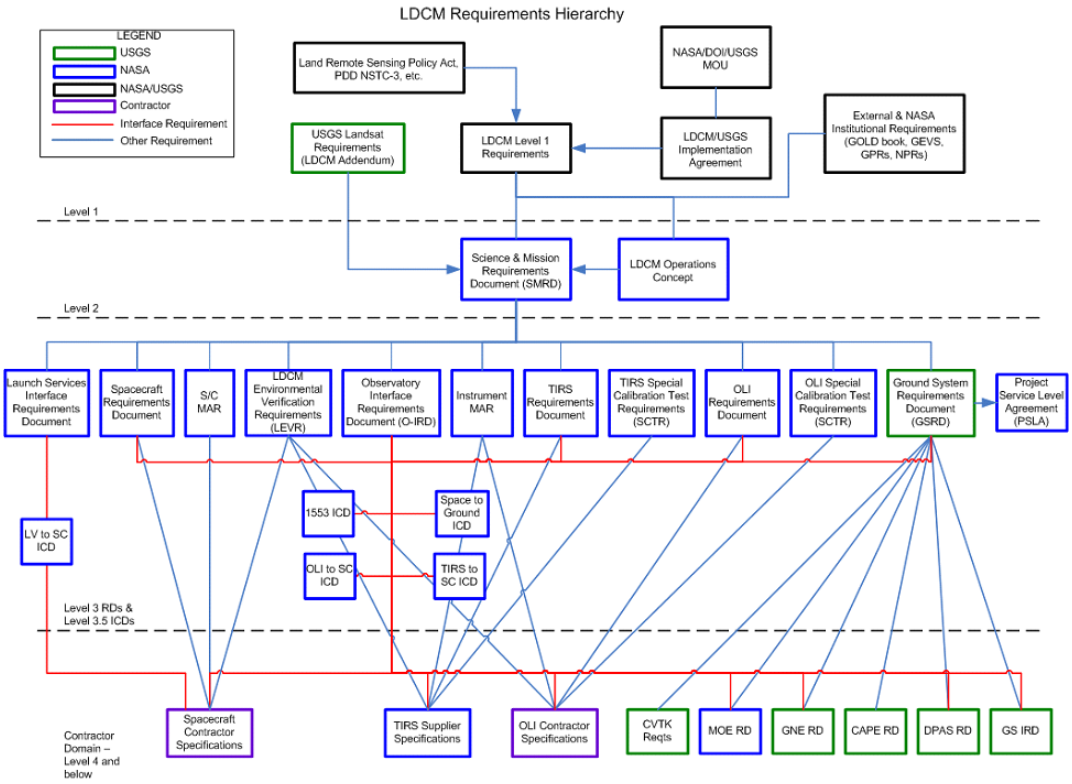

Figure 2 - 1 LDCM Requirements Hierarchy

The LDCM Mission consists of three major segments, namely: the Space Segment (SS), the Ground System (GS), the Launch Services Segment (LSS). The LDCM post-launch mission operations concept is shown graphically in Figure 2-1. Command, telemetry, and mission

data flows are shown between the Space and Ground Segments. These segments are described more fully in section 2.4.

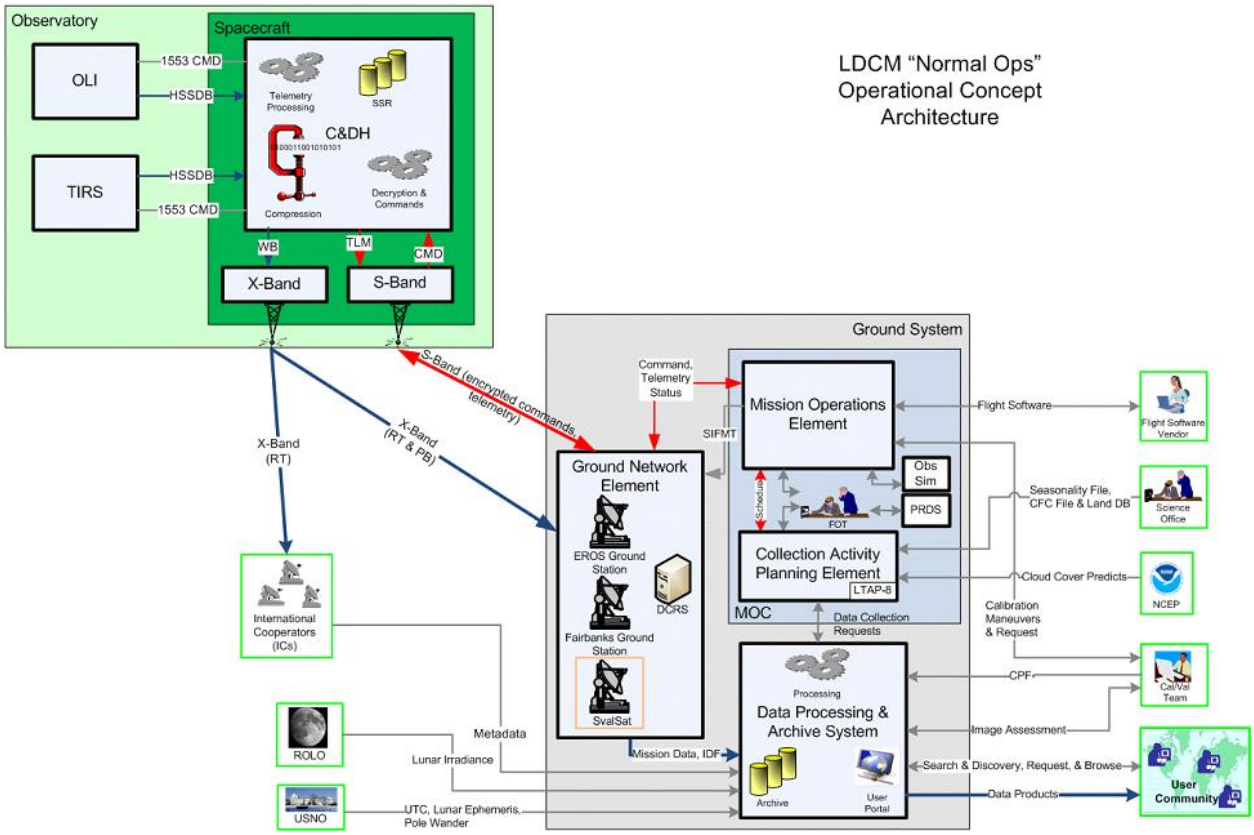

Figure 2 - 2 LDCM Operations Concept

2.4.1 Space Segment

As part of the project responsibilities NASA/GSFC will provide the Space Segment through a procurement process from contractors for the Operational Land Imager (OLI) instrument and the spacecraft bus. A thermal imaging instrument, the Thermal InfraRed Sensor (TIRS), will be built in-house at NASA-GSFC.

NASA will transition the Space Segment and associated contracts to USGS after the successful commissioning of the observatory and operational validation of the imaging sensor.

2.4.2 Ground System

NASA leads the overall ground system technical development and is responsible for ground system integration. USGS will provide the capabilities necessary for planning, scheduling

and operations of the LDCM Space Segment. Embedded within this segment is the real time command and control sub-system for real-time operations of the Space Segment, known as the Mission Operations Element (MOE). The MOE sub-system will be implemented by a vendor (The Hammers Company, Inc.) under contract to NASA (with USGS funding). The Mission Operations Center (MOC) will house the MOE, and the MOC will reside physically at NASA-GSFC in building 14. The GS will be used during the ground testing of the Space Segment and End-to-End data flow validation in preparation for mission readiness.

The USGS will provide the Ground Network Element (GNE) and the Data Processing and Archive System (DPAS). The GNE consists of the Landsat Ground Network (LGN) that includes the operational ground stations for LDCM, and the Data Capture and Routing System (DCRS) that manages the wideband data return from the ground stations back to DPAS. The DPAS ingests, processes, and archives all LDCM mission data returned from the Space Segment via GNE. The DPAS also provides a public web interface to allow users to search for and receive data products. The DPAS will be located at the USGS Earth Resources Observation and Science (EROS) Center near Sioux Falls, SD.

2.4.3 Launch Services Segment

NASA/Kennedy Space Center (KSC) will provide the launch segment under existing NASA Launch Services. The launch services include an Atlas V model 401 on a contract to the United Launch Alliance (ULA) and the processing facilities at the Vandenberg Air Force Base, Western Range launch site.

3 Reference Documents

3.1 LDCM Project Level Documents

The SMRD is consistent with the following documents of the exact issue and revision shown. Unless otherwise stated in this document, all inconsistencies in this SMRD will be resolved in the following order:

1. LDCM Level 1 Requirements
2. Final Implementation Agreement (FIA) between the National Aeronautics and Space Administration and the U. S Department of the Interior's United States Geological Survey for a Landsat Data Continuity Mission

Table 3 - 1 LDCM Project Level Documentation

Document Number	Revision/Release Date	Document Title
GSFC 427-01-06	November 16, 2009	Level 1 Requirements for the Landsat Data Continuity Mission
GSFC 427-01-12	November 30, 2009	LDCM GSFC and the USGS EROS Center Project Implementation Agreement (PIA)
GSFC 427-02-06	Rev. B / December 6, 2007	LDCM Acronym List and Lexicon
GSFC 427-02-02	Rev A / November 24,2008	LDCM Operations Concept Document
GSFC 427-03-05	Rev. A / November 30, 2007	LDCM Environmental Verification Requirements (LEVR)
GSFC 427-02-07	January 4, 2007	LDCM World Reference System-2
USGS LS-PD-53	October 2005	USGS Landsat Requirements, as amended 01/11/2007
N/A	October 29, 2009	NASA-USGS Final Implementation Agreement for LDCM

3.2 Government Documents

The LDCM is compliant with the following US Government documents:

Table 3 - 2 Government Documents

Document Number	Revision/Release Date	Document Title
NPR 8715.6	Rev. - / August 17, 2007	NASA Procedural Requirements for Limiting Orbital Debris
NASA-STD-8719.14	August 28, 2007	Process for Limiting Orbital Debris
GPD 7120.1	May 23, 2005	GSFC Space Asset Protection Policy
NPR 2810.1	Rev. A / 2006	NASA Policy Guideline, Security of Information Technology
450-SNUG	Rev. 9 / April 2007	GSFC Space Network Users' Guide (SNUG)
453-GNUG	Rev. 2 / May 2007	GSFC Ground Network Users' Guide (GNUG)
USAF	July 1, 2004	Air Force Space Command Manual 91-710 Range Safety User Requirements
KNPR 8715.3	Oct 26, 2004	KSC Safety Requirements
42 U. S. C., 4321 et seq. NEP	September 13, 1982	National Environmental Policy Act of 1969
FGDC-STD-009-1999	August 1999	Content Standard for Remote Sensing Swath Data
432-1-H	October 1990	Handbook for Managing USGS Records
22 CFR 120-130	April 1, 2007	Code of Federal Regulations, Parts 120 through 130 Subchapter M, Title 22
U.S. Code Title 15, Chapter 82	January 7, 2003	Land Remote Sensing Policy
PDD NSTC-3	October 6, 2000	Landsat Remote Sensing Strategy

3.3 Definitions

The following definitions are included for the reader's convenience, and are consistent with LDCM document 427-02-06, Landsat Acronym List and Lexicon.

Level 0 Data Products - Level 0 data products are image data with all data transmission and formatting artifacts removed, time provided, spatial, and band-sequentially ordered multi-spectral digital image data.

Level 1 Data Products - Level 1 data products consist of radiometrically calibrated data resampled for registration to a cartographic projection, referenced to the World Geodetic System 1984 (WGS84), G873 or current version. The Level 1 data have had radiometric, geometric, and terrain corrections applied.

Level 1R Data Products - Level 1R data products consist of radiometrically corrected image data derived from Level 0 data linearly scaled to at-aperture spectral radiance.

Level 1Gs Data Products - Level 1Gs data products consist of Level 1R data products resampled for registration to a cartographic projection, referenced to the World Geodetic System 1984 (WGS84), G873 or current version.

Level 1T Data Products - Level 1T data products consist of Level 1R data products resampled for registration to a cartographic projection, referenced to the WGS84, G873 or current version, orthorectified, and corrected for terrain relief.

Priority Scenes - Special image collection requests that are marked by the observatory for priority data delivery, processed immediately into Level 1 data products, and made available to the user.

WRS-2 Scene or **Scene -** A scene in LDCM parlance is an image of an approximately 185km x 180 km area on the Earth that corresponds with the definition given in the GSFC 427-02-07 LDCM WRS-2 Definition document.

The following terminology is used in this document with the specified meanings:

A ***"Requirement"*** is a specification of a function, capability, or constraint with which the system design must be compliant, verifiable and have a demonstrated achievement during the mission.

A ***"Shall"*** statement designates a mandatory requirement that must be verified through an accepted process. Any deviations from these requirements require a Configuration Control Board approval.

4 Mission Characteristics

SMRD - 6 The LDCM shall be composed of the Space Segment, Ground System, and Launch Services Segment.

Rationale: Consistency with existing Landsat systems and interfaces.

4.1 Institutional Requirements

SMRD - 9 The LDCM shall comply with National Spatial Data Infrastructure and Federal Geographic Data Committee standards for access to metadata per Content Standard for Remote Sensing Swath Data, FGDC-STD-009-1999.

Rationale: USGS institutional requirement.

SMRD - 11 The LDCM shall comply with all applicable National Archives and Records Administration requirements for archiving data and information per Handbook for Managing USGS Records, 432-1-H.

Rationale: USGS institutional requirement.

SMRD - 13 The LDCM shall comply with the International Traffic in Arms Regulations (ITAR) as defined in the Code of Federal Regulations, Parts 120 through 130 (22 CFR 120-130) Subchapter M, Title 22.

Rationale: Institutional requirement for GSFC missions.

SMRD - 15 The LDCM shall comply with the relevant NASA Policy Directives, NASA Procedural Requirements, and GSFC Procedural Requirements per the LDCM Directives Management System.

Rationale: Institutional requirements for GSFC missions.

SMRD - 17 The LDCM observatory shall be launched by a U.S. launch vehicle from a U.S. launch site that is consistent with the required operational orbit.

Rationale: Consistent with U.S. space policy.

4.2 Data Policy

SMRD - 20 The LDCM shall comply with U.S. Code Title 15, Chapter 82 Land Remote Sensing Policy and Presidential Decision Directive (PDD) NSTC-3, Landsat Remote Sensing Strategy, as amended October 6, 2000.

Rationale: Compliance with U.S. executive branch policy.

SMRD - 22 The LDCM shall document and publicly release all algorithms used to create LDCM data products while adhering to ITAR and Export Administration Regulations (EAR).

Rationale: Encourages commercial adaptation of data processing capabilities.

4.3 Engineering Standards

SMRD - 25 The LDCM shall use the Système International (SI) units for interfaces; the usage of any units other than the SI shall be clearly communicated and documented.

Rationale: The use of consistent units by all project stakeholders is necessary for mission success.

SMRD - 27 The LDCM shall use the Universal Time Coordinated (UTC) or a UTC-relatable time reference frame for all ground operation commands and data products.

Rationale: Consistent with historical mission ops practice.

SMRD - 1092 The LDCM shall employ the use of CCSDS standards for the flight and ground data systems.

Rationale: There are significant benefits utilizing standards for data structure and communication protocols between the flight and ground segments.

4.4 Mission Duration/Operating Life

Note that mission lifetime begins following observatory commissioning.

SMRD - 1095 The LDCM Observatory shall be designed to operate for 5 years after completion of Observatory commissioning for spectral band data 1-9 per table 5-1.

Rationale: The requirement establishes a design lifetime for the Observatory.

SMRD - 1102 The LDCM Observatory shall be designed to operate for 3 years after completion of Observatory commissioning for spectral band data 10-11 per table 5-4.

Rationale: The requirement establishes an operating life for the TIRS instrument consistent with its Class C designation.

SMRD - 31 The LDCM shall have a Probability of Mission Success (P_s) of at least 0.72 at the end of 5 years of mission life for spectral band data 1-9 per table 5-1.

Rationale: This Ps is based on the state of the art for spacecraft and Earth-imaging instruments, and is consistent with previous successful Earth-observing mission practice. Allocations include:

- OLI: 0.85
- Spacecraft: 0.85
- Ground System: 0.9999

Note: Thermal spectral band data not included in Ps calculation since TIRS is not included in LDCM minimum mission.

SMRD - 36 The LDCM Observatory shall have sufficient propulsion/thruster consumable resources to complete orbit raising, 10-years of nominal mission operations assuming a Schatten +2sigma solar flux distribution, and decommissioning.

Rationale: 10 years envelopes the 5-year nominal mission lifetime and additional 5 years as risk mitigation against delays in future Landsat systems, and allows the possibility of cross-calibration with future systems.

SMRD - 38 The LDCM Ground System shall support 10 years of mission life.

Rationale: 10 years envelopes the 5-year nominal mission lifetime and additional 5 years as risk mitigation against delays in future Landsat systems, and allows the possibility of cross-calibration with future systems.

4.5 External Interfaces

SMRD - 41 The LDCM shall use the NASA Space Network (SN) for anomaly support and Launch and Early Orbit support.

Rationale: SN coverage needed for observatory S-band communications in any attitude.

SMRD - 43 The LDCM shall use the NASA Near Earth Network (NEN) for anomaly support and Launch and Early Orbit support.

Rationale: NEN is needed for launch and early orbit operations S-band support, and as additional coverage in case of anomaly.

SMRD - 45 The LDCM shall transmit real-time mission data to International Cooperators (ICs).

Rationale: Consistent with historical Landsat program policy.

SMRD - 849 The LDCM shall have the capability to ingest mission data from ICs.

Rationale: Consistent with historical agreements with Landsat International Cooperators. The USGS requires a mechanism to acquire mission data from ICs that have captured data not downlinked to the LGN.

SMRD - 1099 The LDCM shall have the capability to ingest metadata from ICs.

Rationale: Consistent with historical agreements with Landsat International Cooperators. The USGS maintains an inventory of the global inventory of Landsat.

SMRD - 47 The LDCM Observatory shall be qualified for flight on an Evolved Expendable Launch Vehicle (EELV) launch vehicle supplied by the NASA/KSC Expendable Launch Vehicle Office.

Rationale: Medium-class EELV is mandated by NASA Headquarters.

SMRD - 49 The LDCM shall interface with the NASA Goddard Space Flight Center / Flight Dynamics Facility (FDF).

Rationale: FDF will supply orbit determination solutions during the launch and early orbit period or for anomalies.

SMRD - 51 The LDCM shall coordinate entry and operations within the Earth Observing System (EOS) Morning Constellation.

Rationale: Coordination for collision avoidance, debris avoidance, and ground station contact scheduling will be necessary if any existing EOS assets continue to be operational on-orbit. Note that this requirement does not imply any "precision" formation flying.

SMRD - 53 The LDCM shall coordinate and respond to orbital debris alerts from United States Strategic Command (USSTRATCOM).

Rationale: Protection of the on-orbit assets.

SMRD - 55 The LDCM shall process cloud cover predicts received from National Centers for Environmental Prediction (NCEP).

Rationale: Consistent with previous missions.

4.6 Backup Facilities

SMRD - 58 The LDCM shall maintain backup operational facilities to ensure Observatory health and safety, to protect the mission archive, and to support the mission.

Rationale: Consistent with LDCM's status as a national asset, class B mission.

5 Science Accommodation & Calibration Requirements

5.1 Science Data Delivery

SMRD - 63 The LDCM shall deliver at least 98.8% of the science data acquired by the observatory to the science data archive, measured on a quarterly average basis.

Rationale: Data loss is defined as unrecoverable data. Data that does not meet latency requirements are not considered part of data loss. Data loss starts when the command load is successfully installed on the observatory. The percentage data lost refers to entire scenes lost, not a bit error rate, i.e. a scene with excess noise is "lost." Note that data recovery relies on network connectivity between the MOC and Ground Network Element (GNE). Allocations include:

- Observatory (spacecraft plus instruments): 99.8%
- Ground System (GNE, MOC, and Flight Operations Team (FOT), and DPAS: 99%

The acceptable amount of data loss was derived from balancing capabilities of the space and ground segments with respect to availability, throughput, and data loss in order to achieve the fundamental goal of LDCM, which is to populate the Landsat archive.

5.2 Earth Observations

SMRD - 69 The LDCM observatory shall provide a nadir-pointing imaging opportunity for all the scenes identified in the Landsat Worldwide Reference System-2 (WRS-2) grid.

Rationale: The area that can be imaged by the observatory while nadir-pointing must be revisited every 16 days or less to capture seasonal changes.

SMRD - 71 The LDCM shall collect data referenced to the WRS-2 path / row coordinate system.

Rationale: Ensures that LDCM data will be acquired from an orbit providing viewing geometry consistent with Landsats 4, 5, and 7.

SMRD - 73 The LDCM shall collect and archive an average of at least 400 individual WRS-2 scenes per 24 hour period; averaged over any WRS-2 observation period.

Rationale: 400 scenes per day is consistent with previous Landsat missions when IC data is included.

SMRD - 75 The LDCM observatory shall be capable of collecting up to 5 priority scenes per day.

Rationale: This is a heritage Landsat capability, and is included in response to the potential for worldwide emergencies and homeland security concerns. The number of scenes is corresponds to two separate requests for 2-3 scenes. Three scenes cover 300+ miles on the ground which would include significant strategic political and geographic boundaries that would potentially be

of interest for national security and emergency response purposes. Priority collects are also used for particular science field campaigns.

SMRD - 77 The LDCM observatory shall be capable of collecting image data up to 15 degrees left or right of the orbit plane in lieu of the nadir WRS-2 path as requested.

Rationale: Needed for rapid acquisition of priority images at up to one path offset and allows productive imaging while nadir is ocean. 15 degrees corresponds to imaging one path "over" from the current ground track, and is a small enough angle that much of the imaging quality is preserved (compared with nadir imaging.), given that the purpose of off-nadir images is different from the archival nature of nadir imaging.

SMRD - 79 The LDCM observatory shall be capable of collecting up to 2 off-nadir intervals per day.

Rationale: This is a new Landsat requirement, and is included in response to the potential for worldwide emergencies and homeland security concerns. The off-nadir capability may also be used to capture scenes off the WRS-2 grid, such as the polar regions, as well as coastal scenes. An interval is defined as a continuous collection of imagery, and will, in many cases, consist of multiple scenes.

5.3 Science Data Calibration Requirements

SMRD - 82 The LDCM shall plan and execute spacecraft maneuvers in support of calibration.

Rationale: Lunar and solar calibration maneuvers are necessary to maintain radiometric accuracy.

SMRD - 84 The LDCM shall perform calibration for the production and validation of LDCM data products.

Rationale: Necessary to maintain radiometric/geometric accuracy.

SMRD - 86 The LDCM shall characterize the pre-launch spectral, radiometric, spatial and geometric performance of the LDCM sensors and data.

Rationale: Many sensor characterizations required for scientific use of the data can only be performed on the ground or can be performed more accurately on the ground than on orbit.

SMRD - 978 The LDCM shall calibrate its instruments to a National Institute of Standards and Technology radiometric transferred source.

Rationale: Radiometric calibration of the LDCM instruments is critical to preserving the long history of Landsat database of absolute radiometric measurements

SMRD - 88 The LDCM shall characterize the on-orbit radiometric, spatial and geometric performance of the LDCM sensors and data.

Rationale: On-orbit performance, to the extent that it can be measured, is of most value to the scientific community. Also, many characterizations can only be performed on-orbit, or can be performed on orbit better than on the ground.

SMRD - 892 The LDCM shall generate a set of spectral, radiometric, spatial and geometric correction algorithms based on the characterization of the sensor.

Rationale: The image quality from the earth sensors can be improved using established correction terms for various components of the image.

SMRD - 90 The LDCM shall provide operational trending of key LDCM radiometric, spatial, spectral, and geometric performance parameters and related telemetry data.

Rationale: Necessary to maintain radiometric/geometric accuracy

SMRD - 92 The LDCM shall assess image data quality throughout mission life to maintain LDCM data product performance specifications.

Rationale: Necessary to maintain radiometric/geometric accuracy.

SMRD - 94 The LDCM shall derive and apply calibration parameters throughout mission life.

Rationale: Necessary to maintain radiometric/geometric accuracy

SMRD - 96 The LDCM shall reprocess image data as necessary throughout mission life.

Rationale: Necessary to deal with changes to cloud cover, etc. algorithms throughout mission life. Includes reprocessing archive or user data with new parameters.

SMRD - 1213 The LDCM shall cross-calibrate the on-orbit radiometric performance of the LDCM sensors and data with other existing Landsat (or EOS) assets via near-simultaneous imaging of Earth targets.

Rationale: Direct near-simultaneous comparisons of imagery will be of value to ensure consistent calibration of Landsat data

5.4 Science Data Latency

SMRD - 113 The LDCM shall make Level 1 data products available for search and distribution within 48 hours of observations for 85% of the data received by the ground system.

Rationale: Latency is driven by the operational needs of natural resource management programs worldwide.

5.5 Reflective Band Requirements

The LDCM image performance requirements in this section only apply to nadir imaging.

5.5.1 Spectral Bands

SMRD - 122 The LDCM shall collect reflective image data for each of the spectral bands specified in Table 5.1

Rationale: Necessary to provide continuity with Landsat-7 (bands 2-8); necessary to provide detection of cirrus clouds which interfere with spectral signature extension and surface reflectance retrieval (band 9); necessary to provide water penetration and characterization of atmospheric aerosol in non-vegetated regions for atmospheric correction (band 1).

Table 5 - 1 LDCM Image Data Performance Requirements

#	Spectral Band	Center Wavelength (nm)	Center Wavelength Tolerance (+/- nm)	Minimum Lower Band Edge (nm)	Maximum Upper Band Edge (nm)
1	Coastal Aerosol	443	2	433	453
2	Blue	482	5	450	515
3	Green	562	5	525	600
4	Red	655	5	630	680
5	NIR	865	5	845	885
6	SWIR 1	1610	10	1560	1660
7	SWIR 2*	2200	10	2100	2300
8	Panchromatic**	590	10	500	680
9	Cirrus	1375	5	1360	1390

* Minimum bandwidth is 180 nm for band 7

** Minimum bandwidth is 160 nm for the panchromatic band

5.5.2 Spatial Performance

SMRD - 894 The LDCM reflective image data shall have a distinct pixel edge such that the response to a unit step function/edge as measured by the edge slope is no less than the values in Table 5.2.

Rationale: To ensure that image sharpness preserves high spatial frequency detail.

SMRD - 895 The LDCM reflective image data shall be adequately sampled such that the product of the edge slope and the Ground Sample Distance is equal to or less than 1.0.

Rationale: To protect against data undersampling or aliasing, and to ensure that image sharpness is commensurate with the ground sample distance.

SMRD - 869 The LDCM reflective image data shall meet the Ground Sample Distance requirements specified in Table 5.2

Rationale: The GSD is consistent with historical Landsat data.

Table 5 - 2 LDCM Reflective Image Data Spatial Performance

#	Spectral Band	Maximum Ground Sample Distance at Nadir (m)	Edge Slope (1/m)
1	Coastal Aerosol	30	0.027
2	Blue	30	0.027
3	Green	30	0.027
4	Red	30	0.027
5	NIR	30	0.027
6	SWIR 1	30	0.027
7	SWIR 2	30	0.027
8	Panchromatic	15	0.054
9	Cirrus	30	0.027

5.5.3 Radiometric Performance

SMRD - 221 The LDCM shall collect reflective image data providing signal-to-noise ratios at least as high as those specified in Table 5.3 for two levels of at-aperture spectral radiance, $L_{Typical}$ and L_{High}.

Rationale: Necessary to provide detection of ~0.1% differences in Earth surface reflectances for discrimination of vegetation status levels.

Table 5 - 3 Signal-to-Noise Ratio (SNR) Requirements

#	Band	SNR @ $L_{Typical}$	SNR @ L_{High}	Radiance Level for SNR, L (W/m^2 sr µm)	
				Typical, $L_{Typical}$	High, L_{High}
1	Coastal Aerosol	130	290	40	190
2	Blue	130	360	40	190
3	Green	100	390	30	194
4	Red	90	340	22	150
5	NIR	90	460	14	150
6	SWIR 1	100	540	4.0	32
7	SWIR 2	100	510	1.7	11
8	Panchromatic	80	230	23	156
9	Cirrus	50	N/A	6.0	N/A

(Note: L = Radiance, $L_{Typical}$ = Typical Radiance and L_{High} = High Radiance)

SMRD - 299 The LDCM shall relate reflective data within the Level 1 data products to at-aperture spectral radiance with an absolute radiometric uncertainty of less than 5%, 1-sigma.

Rationale: Absolute calibration is required for retrieving surface reflectances (this is the historical Landsat requirement)

SMRD - 301 The LDCM shall relate reflective data within the Level 1 data products to Top of Atmosphere (TOA) reflectance with an absolute radiometric uncertainty of less than 3%, 1-sigma.

Rationale: Absolute calibration is required for retrieving surface reflectances.

SMRD - 303 Reflective data within the Level 1 data products shall be visibly free of coherent noise.

Rationale: Coherent noise interferes with visual interpretation of the data and image quality.

SMRD - 305 Reflective data within the Level 1 data products shall be visibly free of ghosting.

Rationale: This requirement controls the level of radiometric impact of ghosting.

SMRD - 307 Reflective data within the Level 1 data products shall be visibly free of banding.

Rationale: Banding needs to be less than the noise level, i.e. not visible, to keep from degrading the image noise performance.

SMRD - 309 Reflective data within the Level 1 data products shall be visibly free of striping.

Rationale: Striping needs to be less than the noise level, i.e. not visible, to keep from degrading the image noise performance.

SMRD - 311 Reflective data within the Level 1 data products shall not be adversely affected by crosstalk.

Rationale: This requirement forces good practices and reasonably achievable performance so as to not impact data utility for Earth Surface Targets.

SMRD - 313 Reflective data within the Level 1 data products shall not be adversely affected by stray light.

Rationale: This requirement forces good practices and reasonably achievable performance so as to not impact data utility for Earth Surface Targets.

SMRD - 315 Reflective data within the Level 1 data products shall not be adversely affected by bright target saturation effects.

Rationale: This requirement forces good practices and reasonably achievable performance so as to not impact data utility for Earth Surface Targets.

SMRD - 317 Reflective data within the Level 1 data products shall not be adversely affected by radiometric calibration instability.

Rationale: This requirement forces good practices and reasonably achievable performance so as to not impact data utility for Earth Surface Targets.

SMRD - 319 Reflective data within the Level 1 data products shall not be adversely affected by polarization sensitivity.

Rationale: This requirement forces good practices and reasonably achievable performance so as to not impact data utility for Earth Surface Targets.

SMRD - 321 Reflective data within the Level 1 data products shall not be adversely affected by inoperable detectors.

Rationale: This requirement forces good practices and reasonably achievable performance so as to not impact data utility for Earth Surface Targets.

5.5.4 Geometric Performance

SMRD - 325 Reflective data within the Level 1T data products shall have a geodetic pixel uncertainty of less than 12 meters circular error at the 90% confidence level referenced to the World Geodetic System, 1984 (WGS84) geodetic reference system.

Rationale: Ensures a high accuracy product suitable for Geographic Information System (GIS) applications consistent with current Landsat 5 and 7 production systems.

SMRD - 327 Reflective data within the Level 1T data products shall have a band-to-band co-registration uncertainty of less than 4.5 meters in the along- and cross-track directions at the 90% confidence level.

Rationale: Though not quite as good as Landsat 7 band registration performance this requirement ensures band registration accuracy that is acceptable for spectral signature identification and achievable with an Advance Land Imager (ALI)-like architecture.

SMRD - 329 Reflective data within the Level 1G data products shall have a geodetic pixel uncertainty of less than 65 meters circular error at the 90% confidence level referenced to the WGS84 reference system, excluding the effects of terrain.

Rationale: Provides absolute geolocation knowledge of 30 meters Root Mean Square (RMS) which is consistent with recent (2005-2006) Landsat 7 performance. This is particularly important in a pushbroom architecture as terrain compensation is likely required to achieve band registration accuracy. Absolute geolocation knowledge is required to register the terrain data to the image data for proper processing.

SMRD - 331 Reflective data within any two Level 1T data products covering the same earth surface area with data collected on different dates shall co-register, image-to-image, with an uncertainty of less than 12 meters in the along- and cross-track directions at the 90% confidence level, when projected to the WGS84 Earth ellipsoid surface, including compensation for the effects of terrain relief.

Rationale: Ensures the image internal geometric integrity necessary for applications that require accurate image-to-image registration such as land cover change detection.

5.6 Thermal Band Requirements

The LDCM image performance requirements in this section only apply to nadir imaging.

5.6.1 Spectral Bands & Spatial Performance

SMRD - 1108 The LDCM thermal image data shall meet the image performance requirements as specified in Table 5.4.

Rationale: Two bands needed for atmospheric correction; 120 meters meets minimum user community needs for water resources analysis; edge slopes consistent with 120 GSD.

Table 5 - 4 LDCM Thermal Digital Image Data Performance Requirements

Band #	Center Wavelength (nm)	Center Wavelength Tolerance (nm)	Minimum Lower Band Edge (nm)	Maximum Upper Band Edge (nm)	Maximum Ground Sample Distance (m)	Minimum Edge Slope In-Track (1/m)	Minimum Edge Slope Cross-Track (1/m)
10	10800	200	10300	11300	120	0.007	0.007
11	12000	200	11500	12500	120	0.007	0.007

5.6.2 Radiometric Performance

SMRD - 1130 The LDCM shall relate thermal data within the Level 1 data products, after calibration, to at-aperture spectral radiance with an absolute radiometric uncertainty as specified in Table 5-5.

Rationale: Absolute calibration is required for retrieving surface temperatures.

Table 5 - 5 LDCM Thermal Band Radiometric Performance

Equivalent Blackbody Temperature Range	Absolute Radiance Uncertainty (1-sigma)
260K - 330K	<2%
240K - 260K	<4%
330K - 360K	<4%

SMRD - 1131 The LDCM thermal image data shall be acquired with the Noise Equivalent Delta Radiance (NEdL) of less than or equal to 0.059 W/m2 sr µm for the 10.8 µm channel and less than or equal to 0.049 W/m2 sr µm for the 12.0 µm channel.

Rationale: This noise performance is required to resolve surface temperature differences.

SMRD - 1132 Thermal data within the Level 1 data products shall be visibly free of coherent noise.

Rationale: Coherent noise interferes with visual interpretation of the data and image quality

SMRD - 1133 Thermal data within the Level 1 data products shall be visibly free of ghosting.

Rationale: This requirement controls the level of radiometric impact of ghosting

SMRD - 1134 Thermal data within the Level 1 data products shall be visibly free of banding.

Rationale: Banding needs to be less than the noise level, i.e. not visible, to keep from degrading the image noise performance.

SMRD - 1135 Thermal data within the Level 1 data products shall be visibly free of striping.

Rationale: Striping needs to be less than the noise level, i.e. not visible, to keep from degrading the image noise performance.

SMRD - 1136 Thermal data within the Level 1 data products shall not be adversely affected by crosstalk.

Rationale: This requirement forces good practices and reasonably achievable performance so as to not impact data utility for Earth Surface Targets.

SMRD - 1137 Thermal data within the Level 1 data products shall not be adversely affected by stray light.

Rationale: This requirement forces good practices and reasonably achievable performance so as to not impact data utility for Earth Surface Targets.

SMRD - 1138 Thermal data within the Level 1 data products shall not be adversely affected by bright target saturation effects.

Rationale: This requirement forces good practices and reasonably achievable performance so as to not impact data utility for Earth Surface Targets.

SMRD - 1139 Thermal data within the Level 1 data products shall not be adversely affected by radiometric calibration instability.

Rationale: This requirement forces good practices and reasonably achievable performance so as to not impact data utility for Earth Surface Targets.

SMRD - 1140 Thermal data within the Level 1 data products shall not be adversely affected by inoperable detectors.

Rationale: This requirement forces good practices and reasonably achievable performance so as to not impact data utility for Earth Surface Targets.

SMRD - 1141 For each thermal band, the LDCM shall be capable of observing a 360K target without saturation.

Rationale: Saturation temperature needed to image hottest Earth targets (excluding fires, lava, etc).

5.6.3 Geometric Performance

SMRD - 1143 Thermal data within the Level 1T data products shall have a thermal band-to-thermal band co-registration accuracy of 18 meters in the along- and cross-track directions at the 90% confidence level.

Rationale: Though not quite as good as Landsat 7 band registration performance this requirement ensures band registration accuracy that is acceptable for spectral signature identification and achievable with an ALI-like architecture. This accuracy corresponds to a pixel-fraction scaling of the 0.15 pixel reflective band requirement.

SMRD - 1144 Level 1T data products shall have band-to-band registration co-registration accuracy of 30 meters or less in the along and cross-track directions at the 90% level of confidence between bands 1-9 and the two thermal bands.

Rationale: Though not quite as good as Landsat 7 band registration performance this requirement (0.25 thermal pixels) ensures band registration accuracy that is acceptable for spectral signature identification, and achievable using separate reflective and thermal instruments. Note that the Landsat 7 band registration requirement was 0.28 pixels (LE90). Actual performance is significantly better.

SMRD - 1145 Thermal data within the Level 1T data products shall have a geodetic pixel accuracy of 42 meters circular error at the 90% confidence level referenced to the World Geodetic System, 1984 (WGS84) geodetic reference system.

Rationale: Ensures a high accuracy product suitable for GIS applications consistent with current Landsat 5 and 7 production systems. This accuracy is based on the RSS of the reflective band geodetic accuracy requirement and the thermal to reflective band registration requirement.

SMRD - 1146 Thermal data within the Level 1G data products shall have a geodetic pixel accuracy of 76 meters circular error at the 90% confidence level referenced to the WGS84 reference system, excluding the effects of terrain.

Rationale: Absolute geolocation knowledge is required to register the terrain data to the image data for proper processing. This accuracy is based on the Root Sun Square (RSS) of the reflective band geodetic accuracy requirement and the thermal to reflective band registration requirement.

SMRD - 1147 Thermal data within the Level 1T data products shall have internal accuracies sufficient to achieve an image-to-image co-registration accuracy of 45 meters in the along- and cross-track directions at the 90% confidence level, when projected to the WGS84 Earth ellipsoid surface, excluding the effects of terrain.

Rationale: Ensures the image internal geometric integrity necessary for applications that require accurate image-to-image registration such as land cover change detection. This accuracy is based on the RSS of the reflective band internal geometric accuracy requirement and the thermal to reflective band registration requirement.

5.7 Science Data Products

SMRD - 404 The LDCM shall generate and distribute integrated Level 1 data products for all spectral bands listed in Table 5.1 and Table 5.4.

Rationale: Continuity with Landsat 7 product suite. This is the standard product used for high accuracy applications where precise geolocation or multi-temporal image registration is required (e.g., the Multi-Resolution Land Characteristics consortium's National Land Cover Database).

SMRD - 407 The LDCM shall generate and distribute Level 0 data products for all spectral bands listed in Table 5.1 and Table 5.4.

Rationale: Continuity with Landsat 7 product suite. Used for cal/val purposes. Also, depending on the Landsat data distribution policy, used by international cooperators and members of the science community who would like to process their own data.

5.8 Engineering Data Products

SMRD - 414 The LDCM shall generate engineering data products.

Rationale: This would include Ground System products such as definitive ephemeris, long-term trend statistics, station acquisition data, calibration coefficients, and mission planning products. Space Segment (navigation, e.g. spacecraft-measured ephemeris messages telemetry statistics, etc.) will also be generated.

5.9 Reflective and Thermal Band Co-Registration

SMRD - 1197 Corresponding pixels from the two thermal bands in TIRS data and the nine reflective bands in OLI data that have been geometrically corrected including compensation for the effects of terrain relief shall be co-registered with an uncertainty of 30 meters or less in the line and sample directions at the 90% confidence level.

Rationale: This requirement (0.25 thermal pixels) ensures band registration accuracy that is acceptable for spectral signature identification, and achievable using separate reflective and thermal instruments.

6 Space System Functions

6.1 Operational Orbit

SMRD - 418 The LDCM shall operate in the sun synchronous, near circular, frozen orbit described as follows:

Equatorial Altitude: 705 ± 1 km altitude

Inclination: 98.2 ± 0.15°

Eccentricity: <= 0.00125

MLT - DN: 10:00 a.m. +/- 15 minutes

Ground Track Error: +/- 5 km cross track at DN as defined by the WRS-2 grid

Repeat Cycle: 16 days

Rationale: Consistent with Level 1 requirement.

SMRD - 425 The LDCM shall maintain the operational orbit for the life of the mission.

Rationale: Necessary for image consistency throughout mission

6.2 Communications

SMRD - 430 The LDCM observatory shall provide at least three concurrent realtime downlinks of mission data.

Rationale: Wideband transmission of Mission Data from the spacecraft to a ground station is provided by using a X-Band wideband system. The Mission Data may be either real-time data or previously recorded data (playback). The space to ground transmission combinations are:
— The transmission of 1 realtime data stream of Mission Data to LGN.
— The transmission of 1 realtime data stream and 1 playback data stream of Mission Data to LGN.
— The transmission of 1 realtime data stream of Mission Data to at least 3 International Cooperators.
— The transmission of 1 realtime data stream of Mission Data to LGN and at least 1 IC, and 1 playback data stream of Mission Data to LGN.
— The transmission of 2 playback data streams of Mission Data to LGN.
Note: Data Stream is defined as a unique source of Mission Data either in real-time or as playback

SMRD - 432 The LDCM observatory shall provide the capability to downlink playback data.

Rationale: The observatory will have an on-board mass storage device to store data on board prior to transmission to the LGN ground stations.

SMRD - 434 The LDCM observatory shall have the capability to concurrently: record mission data; transmit real-time wideband data; transmit playback wideband

data; record narrowband telemetry; transmit narrowband data; and receive narrowband commands and data.

Rationale: A realistic scenario on the observatory involves a LGN contact while imaging the earth, and that scenario involves all of these activities occurring simultaneously.

SMRD - 436 The LDCM observatory shall decrypt command uplinks compliant with NPR 2810.1 Section 11.3.15

Rationale: Institutional requirement.

6.3 Pre-Launch Requirements

SMRD - 439 The LDCM observatory shall be capable of being placed in a state that does not require intervention by personnel for 30 day periods, excluding anomalous events and telemetry monitoring.

Rationale: There is a possibility that the observatory may need to be stored temporarily, and this requirement allows costs to be minimized during that time.

SMRD - 889 The LDCM shall employ the use of ground based mission simulators.

Rationale: Mission simulators are used for FOT training, flight software testing, command and script building. Simulators are likely required for the instruments, S/C and maybe some MOE elements.

SMRD - 890 The LDCM shall employ the use of hardware interface simulators.

Rationale: With a compressed delivery schedule and to reduce risk to flight hardware external I/F simulators are necessary to provide early testing and check-out of the I/F between the S/C to instr., S/C to ground RF systems, and possibly MOE elements.

SMRD - 441 The LDCM shall perform limited observatory aliveness testing while mated to the launch vehicle.

Rationale: Necessary to assess observatory health and performance post-mate.

SMRD - 891 The LDCM Observatory shall be designed and tested to either a Qualification Development Program or to Protoflight Development Program.

Rationale: Following best practices LDCM's flight hardware is tested to stringent standards using dedicated qualification units or with test at the protoflight levels.

SMRD - 443 The LDCM systems involved in launch operations and launch site activities shall comply with the safety rules and regulations in Air Force Space Command Manual 91-710 Range Safety User Requirements, dated July 1, 2004.

Rationale: Institutional requirement for Western Range.

SMRD - 445 The LDCM shall make real-time housekeeping telemetry (sufficient for monitoring health and safety of the observatory) available at the launch site integration facility and launch pad.

Rationale: Health and safety must be monitored while on pad.

6.4 Launch and Early Orbit Requirements

SMRD - 448 The LDCM shall make real-time observatory housekeeping telemetry (sufficient for monitoring health and safety of the observatory) available during launch ascent, after fairing separation.

Rationale: Health and safety monitoring is required at all times during Launch and Early Orbit, but for safety reasons the observatory cannot transmit until after the launch vehicle fairing has separated approximately one minute into the flight.

SMRD - 450 The LDCM observatory shall be injected into a parking orbit that accommodates phasing.

Rationale: Direct injection to the EOS morning train is not feasible because launch vehicle dispersions are large enough that collision with the other observatories in the orbit would be a concern.

SMRD - 452 The LDCM observatory shall have a launch readiness capability once every 24 hours.

Rationale: Minimizes time lost due to launch delays (to range safety, etc.)

SMRD - 454 The LDCM observatory Commissioning Phase shall be a period of 90 days or less following launch.

Rationale: Reasonable period for observatory checkout and verification of all requirements.

6.5 Operational Requirements

SMRD - 887 The LDCM observatory shall include safing and operating modes.

Rationale: With complex systems it is necessary to operate systems in different states. Sometimes the instrument will be safed while the S/C is operating nominally. These modes may be as simple as on and off or more complex to account for testing, decontamination, various operational modes, etc.

SMRD - 427 The LDCM observatory shall be capable of being commanded into any valid mode.

Rationale: No untestable modes are allowed.

SMRD - 1096 The LDCM shall ensure that only valid commands are transmitted to and accepted by the Observatory.

Rationale: To control communications between the ground segment and space segment the commanding must be sufficiently secure.

SMRD - 888 The LDCM shall include the capability to update the Observatory software on orbit.

Rationale: To increase the likelihood of meeting all mission objectives the flight software may need to be updated after launch to resolve problems or to enhance performance.

SMRD - 1097 The LDCM shall be compliant with National Telecommunication & Information Administration (NTIA) and International Telecommunication Union (ITU) radio frequency emission requirements.

Rationale: The S-band and X-band transmitter's emission should not contaminate the Deep Space band (high end of X-band), have excess PFD and stay within international agreements.

6.6 Decommissioning

SMRD - 457 The LDCM shall comply with NPR-8715.6 for Decommissioning.

Rationale: Institutional requirement for NASA. (invokes NASA-STD-8719.14). NASA and the USGS, according to the U.S. National Space Policy authorized by the President on August 28, 2007, must follow the United States Government Orbital Debris Mitigation Standard Practices.

6.7 Observatory Autonomy

SMRD - 460 The LDCM observatory shall operate nominally for 72 hours autonomously.

Rationale: Sets the length of the stored command load.

SMRD - 462 The LDCM observatory shall generate on-board ephemeris.

Rationale: Ops Con requires on-board ephemeris generation rather than performing ground based tracking in normal operations.

7 Ground System Functions

7.1 Control & Monitoring

SMRD - 466 The LDCM shall plan and execute all observatory activities for the life of the mission.

Rationale: Mission planning needs to account for health and safety activities and calibration maneuvers as well as imaging activities.

SMRD - 468 The LDCM shall plan and execute all flight dynamics activities for the life of the mission.

Rationale: Planned maneuvers provide contact information, generate historical ephemeris and attitude history files.

SMRD - 470 The LDCM shall log all mission operations activities and telemetry.

Rationale: This data can potentially aid in anomaly resolution.

SMRD - 472 The LDCM ground system shall locate and track the LDCM observatory as necessary.

Rationale: During LEOP and anomalies it may be necessary to generate ephemeris and tracking data on the ground.

7.2 Image Acquisition Planning

SMRD - 475 The LDCM shall maintain an image acquisition plan based on science and operational priorities, predicted cloud cover probabilities, existing archive quality and extent, and engineering constraints.

Rationale: The Long Term Acquisition Plan-8 (LTAP-8) serves as the base for the global mapping nature of the LDCM science mission. The LTAP-8 is intended to make the most efficient use of the limited LDCM collection capacity by avoiding areas predicted to be cloudy while focusing on target areas that are not yet well represented in the archive.

SMRD - 477 The LDCM shall provide the capability for users to request LDCM data collections.

Rationale: A fraction of the daily image acquisitions and all of the priority image acquisitions are scheduled based on user requests.

SMRD - 479 The LDCM shall provide the capability for International Cooperators to request LDCM data collections.

Rationale: International Cooperators request collections over their coverage area per international agreements.

7.3 Communications

SMRD - 482 The LDCM Ground System shall generate observatory acquisition tracking data for all command and telemetry ground stations and SN.

Rationale: This capability is needed within the LDCM project to minimize dependence on external entities.

SMRD - 484 The LDCM shall support downlink of at least 400 unique WRS-2 scene equivalent data per day.

Rationale: The observatory and ground system must support the 400 scene per day Level 1 requirement.

SMRD - 486 The LDCM shall encrypt command uplinks compliant with NPR 2810.1 Section 11.3.15.

Rationale: Institutional requirement.

7.4 Science Data Processing

SMRD - 489 The LDCM shall have the capability to produce at least 400 Level 1T data products per day, averaged over a WRS-2 observation period.

Rationale: Per the Level 1 requirement.

SMRD - 1100 The LDCM shall generate a Level 1 data product for all image data collected.

Rationale: Level 1 products are needed in order to perform cloud cover assessment.

SMRD - 491 The LDCM shall have the capability to distribute at least 1250 data products per day.

Rationale: Demand for LDCM data is expected to be very high, due to high data quality and non-discriminatory web-enabled data access for users. This requirement specifies a cost-effective initial capacity, based on analysis of historical analogs and expected LDCM costs.

SMRD - 850 The LDCM shall have the capability to expand data distribution capacity to meet user demand.

Rationale: LDCM is expected to enable new applications and increase the size of the Landsat user community. User demand for data will likely eventually outstrip the initial distribution capacity. While this indicates a highly successful mission, LDCM will need the capability to expand and meet any increases in demand.

7.5 Search and Order

SMRD - 497 The LDCM shall provide the general public with the ability to search and order LDCM data products on a non-discriminatory basis.

Rationale: Consistent with previous Landsat missions and current Landsat data policy.

SMRD - 499 The LDCM shall provide a priority scheme for fulfilling user requests for data collection and data product distribution.

Rationale: Per the Level 1 priority imaging requirement.

7.6 Archive

SMRD - 502 The LDCM shall archive all LDCM wideband data, narrowband data, auxiliary data, metadata, browse images, algorithms, databases, source code, documentation, and command history.

Rationale: The mission data archive is the major end product of LDCM.

7.7 Autonomy

SMRD - 505 The LDCM Ground System shall provide 72 hours of autonomous operations in support of mission data receipt and acknowledgement.

Rationale: To offload the Solid State Recorder (SSR), it is necessary for the ground to acknowledge the receipt of mission data. This assumes a 9-5, M-F operations of the MOC.

8 Mission Assurance, Safety & Reliability

SMRD - 508 The LDCM shall perform quality control checks on all acquired telemetry, sensor, and archive data.

Rationale: Quality control of data.

SMRD - 510 The LDCM shall monitor, assess, and report on the content and quality of data products produced and distributed.

Rationale: Image product data assurance is fundamental to LDCM success.

8.1 Availability

SMRD - 513 The LDCM observatory shall be available for acquiring mission data at least 91% of the time, measured on a monthly basis.

Rationale: Observatory availability includes calibration maneuvers, orbit maneuvers, etc. Allocations include:

- OLI: 95%
- Spacecraft: 96% -- Orbit Maneuvers - 700 min / 28 days + Anomaly resolution - 12 hours / 28 days = 1-24/672 approx. 96%

8.2 Redundancy

SMRD - 520 The LDCM shall be designed such that no single credible failure permanently precludes the LDCM from completing the mission.

Rationale: 5 year lifetime and class B mission status makes redundancy a good practice for this mission.

8.3 Fault Detection and Protection

SMRD - 523 The LDCM observatory shall automatically detect and report software and hardware failures/anomalies.

Rationale: Onboard fault detection and correction (FDC) is necessary to limit fault propagation.

SMRD - 525 The LDCM observatory shall have the capability to autonomously place itself into a safe mode.

Rationale: Safe mode should limit damage due to onboard faults/failures.

8.4 Testing & Testbeds

SMRD - 528 The LDCM shall validate command loads, flight software, and algorithms on the ground prior to operational use.

Rationale: Untested uploads to the observatory may cause unexpected results.

SMRD - 530 The LDCM shall provide ground-based testing without interruption of mission activities.

Rationale: Offline testing of command loads, patches, etc. is necessary to minimize impact on continuing mission operations.

8.5 Training

SMRD - 533 The LDCM shall provide the capability to conduct FOT training activities simultaneously without interruption of mission activities.

Rationale: Training will be conducted on an ongoing basis and it must not interfere with nominal mission ops.

8.6 Security

SMRD - 536 The LDCM shall provide physical and information security for LDCM facilities, equipment, and data compliant with NPR 2810.

Rationale: NASA institutional requirement from 7120.5D to comply with 2810.

SMRD - 851 The LDCM shall provide physical and information security for USGS LDCM facilities, equipment, and data compliant with NIST SP 800-53.

Rationale: USGS institutional requirement to comply with the NIST standard.

SMRD - 852 The LDCM shall provide physical and information security for USGS LDCM facilities, equipment, and data compliant with USGS Computer Security Handbook, USGS Security Controls Policy, and the DOI Cyber Security Handbook.

Rationale: USGS institutional requirement.

8.7 Serviceability

SMRD - 539 The LDCM shall provide servicing of ground-based systems without interruption of mission activities.

Rationale: Servicing will be conducted on an ongoing as-necessary basis and it must not interfere with nominal mission ops.

8.8 Health and Safety

SMRD - 542 The LDCM shall monitor and maintain the health and safety of the observatory.

Rationale: Monitoring and reporting enables fault detection and trending.