Department of the Interior
U.S. Geological Survey

LANDSAT DATA CONTINUITY MISSION (LDCM) GROUND SYSTEM (GS) SYSTEMS ENGINEERING MANAGEMENT PLAN

Version 3.0

September 2009

Executive Summary

This Systems Engineering Management Plan (SEMP) is applicable to the Landsat Data Continuity Mission (LDCM) Ground System that identifies/defines the systems engineering activities, roles and responsibilities, overall tasks, principles, and objectives required to manage and control the United States Geological Survey (USGS) LDCM Ground System design, development, fabrication, implementation, tests and transition to operations.

Document History

Document Number	Document Version	Publication Date	Change Number
LS-PD-36	Version 1.0	November 2005	00014
LDCM-MP-007	Version 2.0	February 2007	00032
LDCM-MP-007	Version 3.0	September 2009	01071

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Section 1 Introduction

The Landsat Data Continuity Mission (LDCM) is the successor mission to Landsat 7. Landsat satellites have continuously acquired multi-spectral images of the global land surface since the launch of Landsat 1 in 1972. The Landsat data archive constitutes the longest record of the land surface as viewed from space. The LDCM mission objective is to extend the ability to detect and quantitatively characterize changes on the global land surface at a scale where natural and man-made causes of change can be detected and differentiated.

LDCM is a joint mission being formulated, implemented, and operated by the National Aeronautics and Space Administration (NASA) and the Department of the Interior's (DOI) United States Geological Survey (USGS). The LDCM systems engineering effort will lead, mange and coordinate mission systems activities between NASA and USGS and with prime mission contractors for the flight and ground segment.

1.1 Purpose and Scope

The purpose of this LDCM Systems Engineering Management Plan (SEMP) is to describe how systems engineering activities will be managed throughout the LDCM life cycle.

The scope of this SEMP encompasses the USGS Systems Engineering activities planned to ensure technical success across all aspects of the LDCM Ground System, including the generation of the work products necessary to meet the exit criteria for the product life-cycle phases. This document addresses both insight and oversight of contractor systems engineering processes.

1.2 Reference Documents

This SEMP is consistent with the requirements and guidelines provided in the following Reference Documents. The SEMP details how the USGS LDCM systems engineering team will implement the guidance provided in the Reference Documents. In the case of a conflict between this document and any of these, the SEMP will take precedence.

- LDCM Concept of Operations (427-02-02)
- LDCM Science and Mission Requirements Document (SMRD) (427-02-01)
- LDCM Ground System Requirements Document (GSRD) (LDCM-REQ-001)
- LDCM Ground System Operations Concept Document (LDCM-OCD-002)
- LDCM Ground System Interface Requirements Document (GS IRD) (LDCM-REQ-011)
- LDCM Mission Operations Element (MOE) Requirements Document (427-09-03)
- LDCM Ground System Lexicon (LDCM-REF-010)
- LDCM Continuous Risk Management Plan (LDCM-MP-006)
- LDCM Ground System Configuration Management Plan (LDCM-MP-012)
- LDCM Systems Review Plan (427-01-03)

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- LDCM Systems Engineering Management Plan (SEMP) (427-02-04)
- LDCM GSFC and USGS EROS Center Project Implementation Agreement (PIA) (427-01-12)
- Final Implementation Agreement between NASA and USGS (FIA)

1.3 LDCM Mission Overview

1.3.1 Mission Objectives

The Landsat Data Continuity Mission (LDCM) is the successor mission to Landsat 7. Landsat satellites have continuously acquired multispectral images of the global land surface since the launch of Landsat 1 in 1972. The Landsat data archive constitutes the longest moderate-resolution record of the global land surface as viewed from space. The LDCM mission objective is to extend the ability to detect and quantitatively characterize changes on the global land surface at a scale where natural and man-made causes of change can be detected and differentiated.

Land cover and land use are changing globally at rates unprecedented in human history with profound consequences for weather and climate change, ecosystem function and services, carbon cycling and sequestration, resource management, the national and global economy, human health, and society. Landsat is the only U.S. or international satellite system designed and operated to repeatedly observe the global land surface at a moderate scale. Further, Landsat is the only national or international program committed to preserving a consistent, long-term record of the Earth's land surface at this scale.

The LDCM goal is to continue the collection, archive, and distribution of multi-spectral imagery affording global, synoptic, and repetitive coverage of Earth land surfaces at a scale where natural and human-induced changes can be detected, differentiated, characterized, and monitored over time.

The major mission objectives of LDCM are as follows:

- Acquire and archive moderate-resolution (circa 30 m ground sample distance) multispectral image data affording seasonal coverage of the global land mass for a period of no less than 5 years with no credible single point failures.

- Acquire and archive medium-low resolution (circa 120 m ground sample distance) thermal image data affording seasonal coverage of the global land mass for a continuous period of not less than 3 years with no credible single point failures.

- Ensure LDCM data is 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.

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- 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.

1.3.2 Mission Roles and Responsibilities

The roles of NASA, USGS, and the LDCM contractor(s) are as follows:

NASA will:

- Develop the Space Segment, Launch Segment, and the Mission Operations Element (MOE)
- Lead mission development as the system integrator and lead the missions systems engineering for all mission segments throughout development, on-orbit check-out, and acceptance
- Lead pre-launch/orbital verification activities associated with calibration, validation, and characterization of LDCM data
- Lead Mission Operations through the completion of the on-orbit checkout period
- Accountable for mission success through on-orbit check-out and acceptance across all mission segments
- Provide support to USGS for post on-orbit check-out and acceptance performance evaluation, calibration, and anomaly investigation
- Co-Chair the USGS funded Landsat Science Team
- Provide system engineering oversight and technical authority for the entire mission through transition

USGS (and their associated support and development contractors) will:

- Develop the Ground System (comprised of the Flight Operations and Data Processing and Archive Segments), excluding procurement of the MOE
- Provide ground system functional area expertise across all mission segments
- Lead, fund, and manage the Landsat Science Team
- Acquire the Flight Operations Team (FOT) and produce the FOT products
- Lead LDCM mission operations, after the completion of the on-orbit checkout period
- Accept and execute all responsibilities associated with the transfer of the LDCM Operational Land Imager (OLI) instrument, Thermal Infrared Sensor (TIRS) instrument, spacecraft bus and Mission Operations Element contracts from NASA following on-orbit acceptance of the LDCM system including assuming contract management”
- Provide system engineering for the USGS-managed segments and elements

The LDCM contractor(s) will:

- Develop, deliver and support the Operational Land Imager (OLI) instrument and associated GSE, ETUs, and simulators
- Develop, deliver and support the Thermal Infrared Sensor (TIRS) instrument and associated GSE, ETUs, and simulators

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- Develop, deliver and support the Spacecraft Bus and associated GSE, ETUs, and simulators
- Develop the Mission Operations Element
- Provide system engineering for the contractor-developed elements and components

1.3.3 System Architecture Concept

The LDCM Project entails three major mission components: the Space Segment, Ground System, and Launch Services Segment. Because LDCM is a cooperative effort between NASA and the USGS, each agency has specific responsibilities for delivery of major overall mission capabilities. Figure 1-1 depicts the LDCM operational concept.

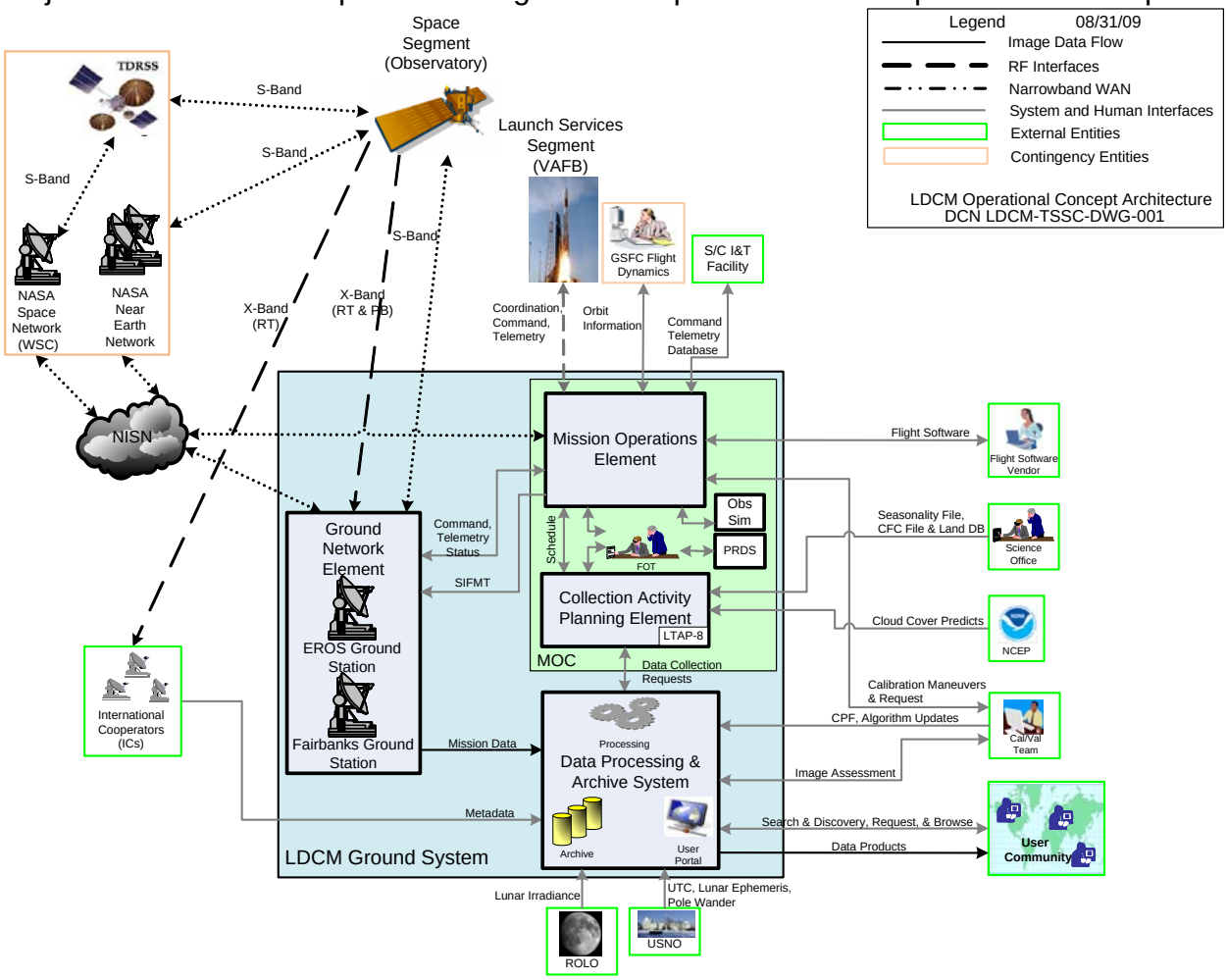

Figure 1-1LDCM Systems Architecture Concept

1.4 System Segment Overview

1.4.1 Space Segment

The Space Segment (SS) consists of the observatory and pre-launch ground support equipment (GSE). The observatory is comprised of the sensor(s) and the spacecraft

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platform. The observatory will operate in a circular, 705 km (altitude at equator), sun-synchronous (98.2º inclination) orbit with a 16-day repeat cycle and a 10:00 a.m. (+/- 15 minutes) mean local time for the descending node. Mission data that consists of sensor data and ancillary data (including relevant spacecraft housekeeping data) will be collected, stored onboard and subsequently downlinked to ground stations within the LDCM Ground Network via an X-band communications link. This link will also include stored housekeeping telemetry. Additionally, a real-time X-band downlink capability will transmit mission data to the LDCM Ground Network and International Cooperators (ICs) equipped to receive these data. The observatory will also receive and execute commands and transmit real-time and stored housekeeping telemetry via an S-band link to the LDCM Ground Network (LGN). The Ground Support Equipment (GSE) provides the functionality to perform ground-based integration and testing of the observatory prior to launch.

1.4.2 Ground System

The Ground System is comprised of four elements: the Collection Activity Planning Element (CAPE), the Mission Operations Element (MOE), the Ground Network Element (GNE), and the Data Processing and Archive System (DPAS). The CAPE develops a set of image collection and imaging sensor(s) calibration activities to be performed by the observatory. The MOE converts the CAPE input to specific imaging sensor and observatory activities; plans, deconflicts, and schedules these activities; commands and controls the observatory; and monitors the health and status of the observatory and ground operating systems. The MOE hardware and software systems reside in the LDCM Mission Operations Center (MOC). The GNE includes the ground stations that will communicate with the observatory for commanding and monitoring, and will receive mission data from the observatory. The GNE will route mission data and observatory housekeeping telemetry to the DPAS.

The DPAS ingests, processes, and archives all LDCM mission data. The DPAS processes all data to create LDCM data products, and performs image assessment. This includes the generation of WRS-2 scenes, including scene overlap regions. The LDCM Cal/Val Team interacts with the image assessment capability to assess data quality and update calibration parameters. A capability to receive and fulfill user requests for LDCM image collections and data products is provided by the DPAS. The DPAS will be located at the USGS Earth Resources Observation and Science (EROS) Center in Sioux Falls, SD.

1.4.3 Launch Services Segment

The Launch Services Segment (LSS) provides those assets and services associated with the launch vehicle (LV) and the observatory-to-launch vehicle integration. Included along with the launch vehicle are all launch vehicle ground support equipment (including hardware and software), property, and facilities to integrate the observatory to the LV, verify their integration, and conduct pre-launch testing with ground-based functions. KSC through the LSS program office will manage launch vehicle acquisition and launch services for the LDCM mission. An Atlas V-401 will launch from the Western Test Range and insert the LDCM observatory into its initial orbit.

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1.5 Project Schedule

Figure 1-2 provides the Preliminary LDCM Project Schedule; final dates for the major reviews are subject to change.

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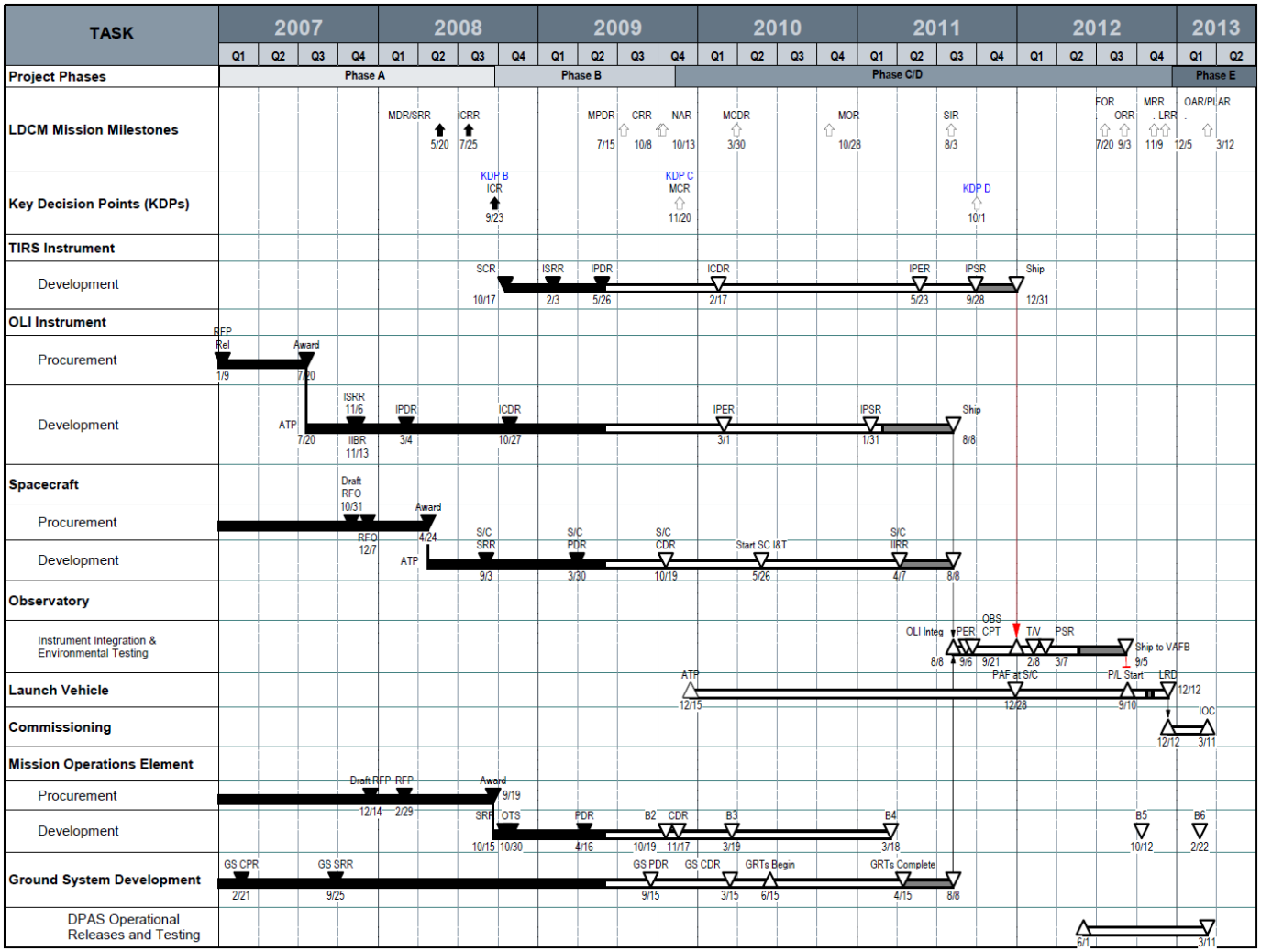

Figure 1-2 Preliminary Ground System Schedule

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Section 2 Systems Engineering Life Cycle, Gates, and Reviews

For the purposes of this section, LDCM is assumed to have three major stakeholders: NASA, USGS, and a set of LDCM contractors. NASA has overall mission programmatic, system engineering, safety and mission assurance responsibility. USGS is responsible for managing the development of the ground system. The contractors, with oversight from NASA and USGS, are responsible for the development of Ground System elements.

2.1 Formulation and Implementation Phase Reviews

Table 2-1 lists the major LDCM Formulation Phase and Implementation Phase reviews in a sequence that reflects the standard NASA 7120.5D project management lifecycle.

Review	Phase	Projected Date*
Ground System Requirements Review (GSRR)	Formulation, Phase A	September 2007
Ground Preliminary Design Review (GPDR)	Formulation, Phase B	September 2009
Ground Critical Design Review (GCDR)	Implementation, Phase C	March 2010
Mission Operations Review (MOR)	Implementation, Phase C	October 2010
Operations Readiness Review (ORR)	Implementation, Phase D	September 2012

* Based on GS schedule version dated August 2009

Table 2-1 LDCM Formulation and Implementation Review Schedule

For element development efforts, expectations for each review are defined in a set of Element Review Expectation Documents, which are based on the Statement of Work (SOW) and Contract Data Requirements List (CDRL) of the relevant contract. Uniform entry and exit criteria for systems engineering reviews, and thus for the LDCM life-cycle phases, are defined in GPR 7123.1A. Key NPR 7120.5D System Lifecycle reviews will be chaired by the HQ–sponsored Standing Review Board (SRB) and will be governed by the LDCM Terms of Reference Document that defines successful entrance and exit criteria for each review. For Ground System reviews, the Code 300 System Assurance Office will chair the reviews and lead the Integrated Independent Review Team (IIRT) and invite participation from selected SRB members. The LDCM Systems Review Plan (427-01-03) describes the chair, scope and timing of SRB and Center chaired reviews.

LDCM development will also include Engineering Peer Reviews (EPRs) at the subsystem level consistent with the intent of GPR 8700.6B. EPRs are detailed technical reviews intended to show the readiness of systems for segment-level reviews. The IIRT will be notified of all EPRs. Subsystem and component peer reviews will be attended by an LDCM ground system engineer and other appropriate NASA and USGS discipline engineers. The subsystem peer review teams will be comprised of both contractor and NASA/USGS technical experts with significant practical experience relevant to the technology and requirements of the system, component, etc. to be reviewed. Both the Review Chairperson and the review team members should be sufficiently independent from the project and product teams to ensure a thorough,

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independent review with a variety of perspectives, experiences, and processes considered. The Review Chairperson and review team members should be selected with the consideration that they will continue on throughout the subsystem product lifecycle review process for which they were initially selected, maximizing the value to the project and subsystem team.

2.2 Integrated Review Approach

To coordinate all aspects of systems engineering across the LDCM Project, an integrated review approach will be adopted for NASA, USGS, and the LDCM contractors. The process will be analogous to an integrated testing program in that lower-level (e.g. instrument, bus) reviews will be completed before the associated higher-level (e.g. observatory) reviews take place. Figure 2-2 illustrates the hierarchy and sequencing of SRR and later reviews (but not EPRs) under this approach.

Timeframes for contractor reviews have to be reasonable to pass through the competitive selection process. Additionally, the contractors are given latitude to propose additional reviews or major milestones linked to progress payments. At the time of contract award those additional reviews will be added to the list above.

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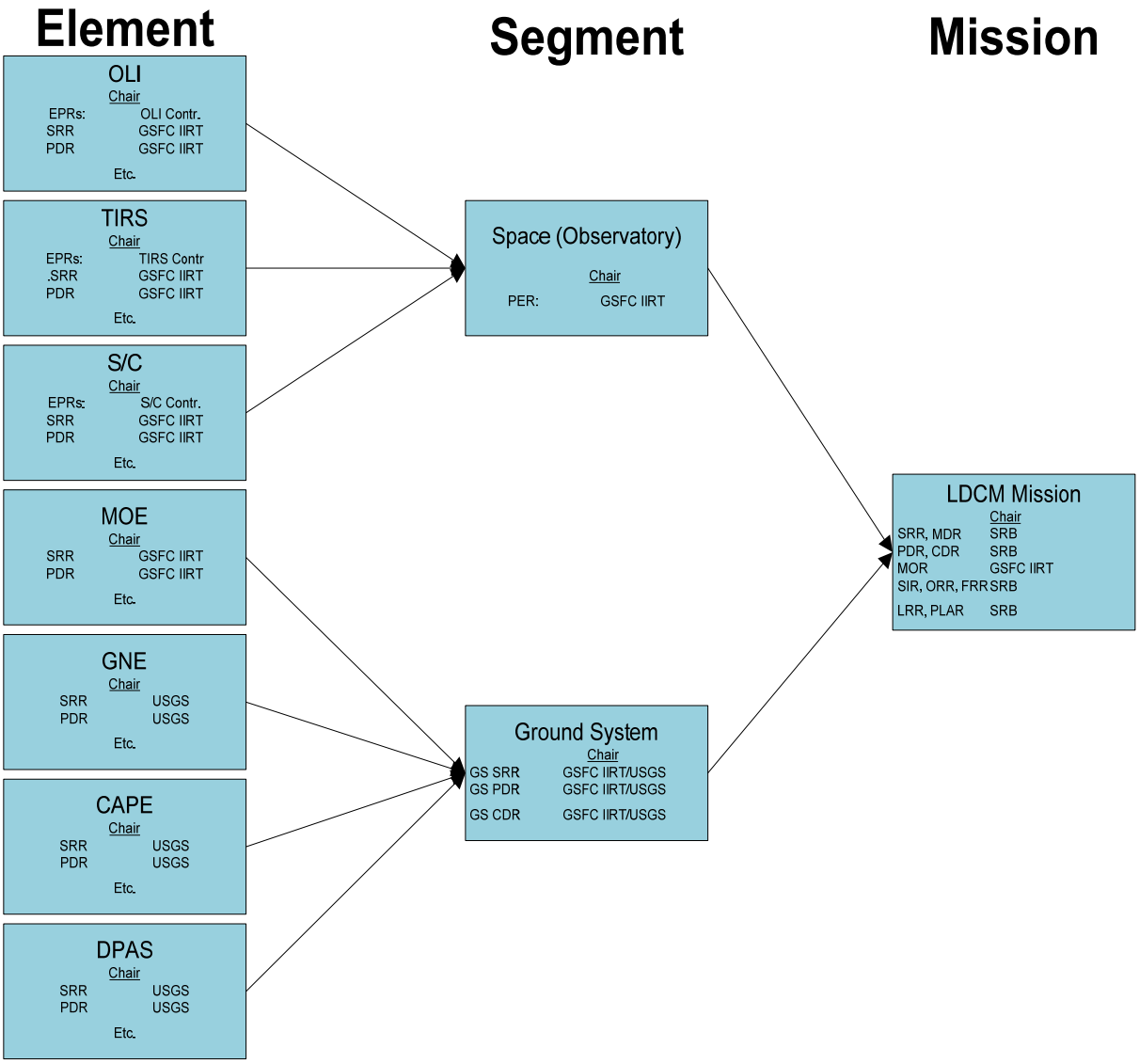

Figure 2-2 Integrated Review Approach

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Section 3 Communications of LDCM Systems Engineering Activities

Communications of LDCM System Engineering (SE) Activities occurs both internally within the project team (NASA/USGS) and externally with the LDCM contractors. Internal LDCM Team interaction is described in Section 3.1, while interaction with the LDCM contractors is described in Section 3.1.

3.1 Regular Internal LDCM Technical Interchange Meetings

To facilitate communication throughout the LDCM Project Team, the following LDCM technical interchange forums will be held:

- LDCM Core Government SE Weekly meeting – The purpose of this meeting is to identify technical and organization areas that need to be addressed that week and to disseminate information among the systems team members. Ongoing issues and upcoming events are prioritized during this meeting, allowing the systems team to address issues on a timely basis as they arise. Invitees include the NASA LDCM SE team, LDCM observatory manager, LDCM Instrument Manager, the NASA I&T Lead, the USGS SE Team Leads, and others as appropriate, such as the LDCM Risk Manager and technical discipline experts. Contractor SE Lead Engineers, such as the OLI Lead SE, may be brought in to the meeting to address specific issues. Agendas for meetings are circulated generally a day before each meeting, and meeting minutes and action items are posted on the LDCM intranet.

- Ground System SE Weekly Meeting – The purpose of this meeting is to coordinate technical interchange primarily among the USGS system engineering team in the development of the Ground System. USGS GS development element lead engineers are represented, as well as the NASA Ground System Engineer.

- Risk Management Meetings – The purpose of this meeting, which is generally held bi-weekly, is to assess mission risks and status, and to ensure proper risk mitigation actions are taking place.

- Ad Hoc Working Groups – A number of “ad hoc” working groups will be set up for different phases of the mission as appropriate. These include the Space to Ground Data Architecture Working Group, the Mission Operations Working Group, the Ground System Interface Working Group, etc.

3.2 LDCM Electronic Information Systems and Tools

The LDCM project uses several electronic information systems that include:

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- Docushare™ document management system
- Cicero Configuration Management System
- Risk Management System
- WebEx™
- Email
- Instant Messaging
- PR/PFR problem reporting system
- DOORS™ requirements management system
- Microsoft Project™

The LDCM project primarily uses the Docushare web-based document management system to share uncontrolled information informally. It provides a secure, organized file system to allow project documentation to be freely shared among all LDCM team members.

The LDCM Configuration Management System, Cicero, is web-based and allows electronic input and disposition of all configuration change requests. All LDCM controlled documents will be stored and accessed only via Cicero. The CM system provides an archive of all past Configuration Change Requests (CCRs) and their status and dispositions. Cicero is located at `https://cicero.eos.nasa.gov/ldcmgs`

The LDCM Risk Management System has the capability to create, store, update, and list all LDCM risks, both project-level and technical. It documents all risk statements, maintains a record of risk probabilities, impacts and mitigations, and allows tracking of trends.

The LDCM project office utilizes WebEx for remote presentations allowing remote users to view directly and annotate presentations or documents during working meetings.

The LDCM project office uses email extensively for communicating both project and technical status and utilizes the USGS standard calendaring system for scheduling meetings and conference room resources. Weekly status from all aspects of the project are collected and distributed to the team and upper management.

For rapid informal discussion the SE team will use ad hoc telecons and commercial Instant Messaging (IM) services.

The LDCM system engineering team is using the DOORS™ system engineering tool to manage requirements and maintain the verification database.

The LDCM project will use Microsoft Project™ as its project management tool for scheduling, milestone tracking, and work breakdown structure.

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Section 4 Key Systems Engineering Functions

The basic purpose of systems engineering is to ensure that a system meets the needs of its users within cost, schedule, and risk constraints. A systems engineering approach is incorporated throughout a system development to promote clear and correct definition of requirements (at all levels of decomposition) and to continuously keep systems development focused toward meeting these requirements. LDCM systems engineering conforms to GPR 7123.1A (Systems Engineering Processes and Requirements) by being well integrated into the larger context of the Project. It employs a system analysis approach, defines interfaces with project planning activities, and establishes project evaluation guidelines.

4.1 Mission Objectives

The Level 1 LDCM Requirements are developed by NASA and USGS working with all science and engineering stakeholders and are signed off and appended to the GSFC Earth Systematic Mission Program Office, NASA SMD Earth Science Division (ESD) and USGS Headquarters. NASA HQ will place the Level 1 Requirements under configuration management (within the LDCM CM system) where they will subsequently be flowed down to the LDCM Project.

A Memorandum of Understanding between NASA and the Department of the Interior and an LDCM / USGS Final Implementation Agreement (FIA), as well as a more detailed Project Implementation Agreement (PIA) between USGS-EROS and NASA-GSFC define all inter-organizational commitments. See Figure 4-1 for a depiction of the LDCM requirements responsibilities and flowdown.

4.2 Operations Concept Development

The LDCM Ground Systems Engineering Team established the baseline LDCM Ground Systems Operations Concept Document [LDCM-OCD-02] in June 2009. Since LDCM's charter is to continue the data record of Landsat the LDCM Ground System Ops Con draws heavily from Landsat-7 operations. Various improvements to system performance and automation have been incorporated into the LDCM Ground System Ops Con.

4.3 Architecture Development

The LDCM Project Team, led by the system engineering team, is responsible for defining the overall ground system architecture. However, within that architecture each element has significant flexibility in defining the implementation approach to meet their respective requirements.

4.4 Requirement Identification and Analysis

Producing a complete set of requirements for the Ground System involves balancing considerations from many sources that may have potentially different and incompatible best cases:

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- Financial budget and schedule are frequently paramount
- Science considerations are sometimes to “test for discovery”, and sometimes to continue an existing data record (as for LDCM)
- Pre-existing design, product, and operational constraints reduce the available trade space
    - Sub-optimal mission designs are sometimes the result of an overly constrained requirement space
- Political considerations (at the agency-, national- and international-level) can surface in the requirements set in unexpected and undesirable ways
    - Fortunately, this has never been an issue for LDCM

Adapted from NASA SE Handbook,

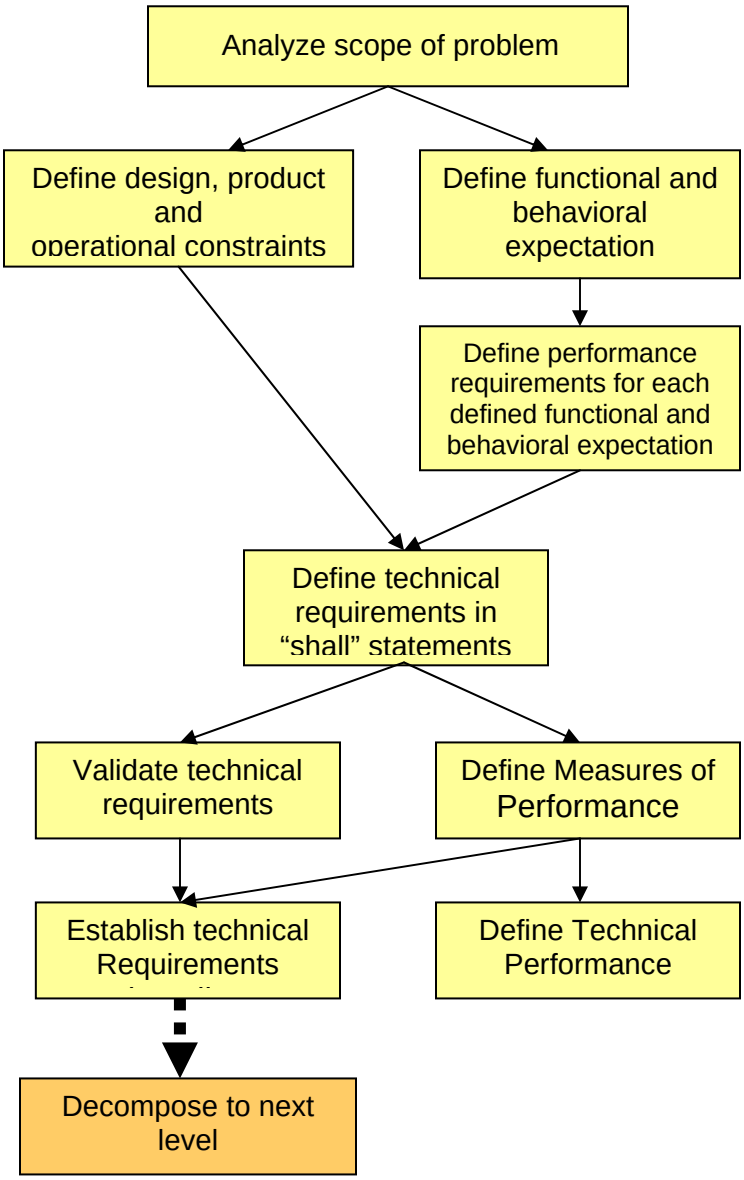

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Figure 4-1 Requirements Development Process

The “Basic” set of technical requirements include:

- Functional requirements
- Performance requirements
- Interface requirements

Other requirements to complete the set of mission requirements include considerations such as:

- Safety & Security
- Environmental Factors
  - I&T environment, launch environment, space environment
- Reliability
- Other “ilities”: Produceability, Testability, Maintainability, Backwards Compatibility, etc.
- Human Factors
- Lessons Learned (incorporated into above categories)

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The LDCM System Engineering has identified the requirements flowdown shown in Figure 4-2. Level 1 LDCM Requirements are flowed down to the Level 2 NASA/USGS Science and Mission Requirements Document (SMRD), then to the Level 3 Ground System Requirements Document. The GSRD, LDCM-REQ-001, is the parent document for all Level 4 Technical Requirements documents described in sections below.

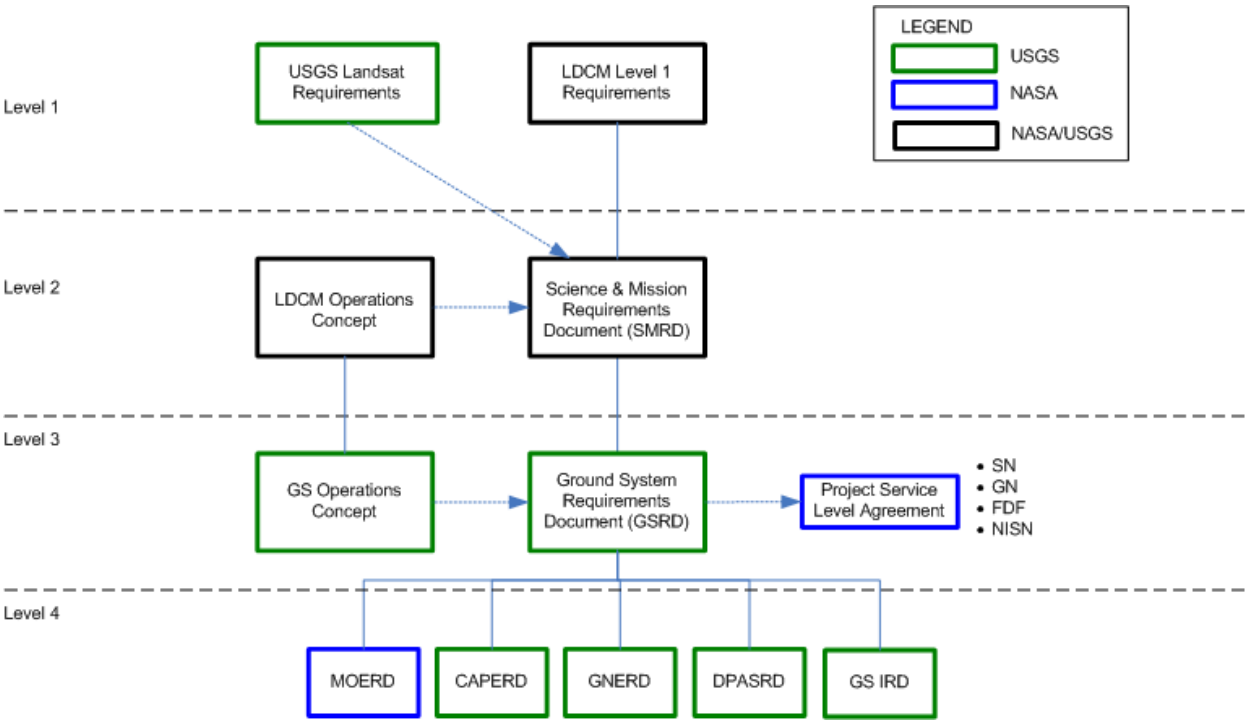

Figure 4-1 LDCM Ground System Requirements Flowdown

4.4.1 Ground System Requirements Flowdown

USGS has supplied the CAPE, GNE, and DPAS requirements flowdown and is responsible for integrating this flowdown with the overall mission requirements flowdown. For the MOE, the key technical requirements document is the MOE Requirements Document [427-09-03].

4.4.2 Requirements Management Tool

The LDCM SE team will utilize the DOORS™ requirement management tool to encompass the entire Government requirements set and maintain traceability to the contractor's requirement set. The SE team will coordinate with the contractors, using a DOORS™ - compatible method to maintain traceability. The Requirements Management Steps are outlined in the Appendix A.

4.4.2.1 Interagency Requirements Management

NASA maintains the SMRD, 427-02-01, and all Level 3 requirements (except the GSRD) in the NASA DOORS database. The USGS maintains the GSRD and all Ground System element and subsystem requirements (except the MOERD). NASA will

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maintain a read-only copy of the GSRD and the USGS will maintain a read-only copy of the SMRD and MOERD, in order to provide for appropriate traceability for both agencies. At each major revision of the SMRD, GSRD, or MOERD, changes will be provided to the other agency in order to keep the documents in sync.

4.5 Verification and Validation

This section describes the requirements verification and system validation responsibilities of the various organizations associated with the LDCM project. Ground System Engineering has overall responsibility for ensuring that the verification at all lower levels of Ground System development is performed thoroughly and correctly. Ground System Engineering also has the prime responsibility to ensure that the system validation effort meets the goal of showing that the Ground System performs as intended as captured in the Ground System Operational Concept.

Fundamentally, requirements verification proves the compliance of the as-built system to the requirements & specifications. Formal requirements verification is (usually) preferably performed:

- For every requirement, and at each level of assembly for which requirements/specs exist
- At every interface
- With the final “flight” unit (as opposed to a test or prototype unit)
- By quantitative test (method = Test)
    - Less preferable is qualitative test (method = Demonstration or Inspection)
    - Least preferable is via analysis, modeling, or simulation (method = Analysis)

Formal verification at the highest (system) level with an end-to-end performance test in a mission (flight-like) configuration is the ultimate goal. This is the “Test like you will Fly, Fly like you tested” philosophy.

4.5.1 System Verification

The USGS has the freedom to determine the method and level of verification and validation under its responsibility. As always the goal is to verify at the highest level possible. USGS is responsible for verification of all requirements contained within the Level 3 Ground Systems Requirements Document (GSRD), LDCM-REQ-001. The NASA LDCM Project is responsible for overall mission success and maintains systems engineering oversight responsibility for the successful development and delivery of the USGS-managed segments but the day-to-day management and system engineering of the USGS elements are strictly a USGS responsibility. The NASA Systems Manager will audit the verification of the GSRD requirements, will advise USGS as appropriate, and will take appropriate action should he/she identify any risks to mission success.

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The USGS SE team will review the contractor-derived traceability and flowdown from the Level 3 GSRD to the contractors' top level requirement documents at Level 4. The USGS SE team will verify that contractor verification of their Level 4 requirements/specifications is either sufficient to directly verify the parent Level 3 requirements, or else the USGS SE team will perform whatever analysis, etc. is required to fulfill the verification of the Level 3 requirement based on the flowed-down Level 4 requirements. In cases when a Government requirement (especially interface requirements) is superseded by a negotiated requirement or specification in an Interface Control Document (ICD) between two contractors, then the Government requirement will be flagged in DOORS as superseded and verification will be performed against the ICD requirement.

The highest level of verification and validation of the ground system *per se* will be achieved at the Ground System Readiness Tests (GRT), and these GRT will be led by the NASA Ground Systems Readiness Manager, with participation of all the USGS ground system elements.

In addition to the ground system segment and element development contractors, the Flight Operations Team (FOT) will be a key player in system validation. The products of the FOT will be verified by independent engineers within the FOT, and audited by the NASA MOM and USGS Deputy MOM, as well as by NASA and USGS systems engineering. Independent external review of the FOT planning and products will occur at the operations reviews including the MOR, FOR, and ORR. At launch and during commissioning the FOT will be under the direction of the NASA Mission Operations Manager (MOM), and after handover the FOT will be under the direction of a USGS MOM.

All required ground systems must be ready to support any and all SOW prescribed data flow tests between the LDCM contractors and the USGS LDCM elements.

4.5.2 System Validation

The idea of System Validation is to ensure that the as-built system operates not only ***per specification***, but also ***per expectation***. That is, the system operates *as the system designers intended* and also *as the system users wanted*.

The LDCM Ground System Operations Concept captures the expected (desired) operation of the LDCM Ground System according to the stakeholders, who include:

- Project Science
- External Science Community
- Project Management
- Systems Engineering
- Operations Personnel
- Sustaining Engineering

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Validation of the Ground System to the Level 3 mission requirements will be performed primarily via the Ground Readiness Tests (GRTs) and simulations. The GRTs and simulations will be designed to address the concepts and scenarios originally described in the Ground System Operations Concept. When the overall Ground System can demonstrate that it performs consistent with the operational expectations of the stakeholders that went into devising the Operations Concept then the Ground System requirements set will be considered to be validated.

Some of the simulations are based on the scenarios from the 16-day Design Reference Case (DRC-16) and DDRC, described below.

4.5.2.1 DRC-16

The 16-day Design Reference Case (DRC-16) was developed to provide a common reference against which LDCM system performance could be measured. The DRC-16 is an Appendix to the Observatory IRD, and compliance with the DRC-16 (plus margin) is a requirement for the OLI instrument, TIRS instrument and the Spacecraft contractors.

Scenarios in the DRC-16 are consistent with the Ops Con, and include periods of higher and lower “stress” on the systems in terms of observatory power and thermal margins, data latency and throughput. A stressing ground station outage is also included. Total LDCM system performance and margins can be gauged (modeled) against the scenarios in the DRC-16.

4.5.2.2 DDRC

The DPAS Design Reference Case (DDRC) was developed to provide a common reference against which DPAS system performance could be measured. The DDRC is an Appendix to the DPASRD, and compliance with the DDRC (plus margin) is a requirement for the DPAS.

Scenarios in the DDRC are consistent with the Ops Con, and include periods of higher and lower “stress” on the systems in terms of user orders, outages, data latency and throughput. Inputs from the space segment are provided from outputs of the DRC-16. Total DPAS performance and margins can be gauged (modeled) against the scenarios in the DDRC.

4.6 Interfaces and Interface Control Documents

The LDCM Ground System Interface Requirements Document (IRD), LDCM-REQ-011, identifies and documents a plan for interfaces between the automated segments that comprise the LDCM Ground System. The IRD presents both a functional and system interface view of the LDCM Ground System based on high level LDCM program guidance. The LDCM Ground System elements maintain Interface Control Documents (ICDs) for each interface. The ICDs contain detailed interface descriptions and performance requirements.

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The IRD includes all functions associated with the LDCM Ground System as well as those external entities that interact with the LDCM Ground System. The IRD elements support mission planning, management of the LDCM observatory, transmission of commands to the observatory, reception of observatory telemetry and image data by the LDCM Ground System, and processing, archival, and distribution of the data for the Landsat data user community.

Specific mission-level ICDs between the LDCM, USGS, and NASA are defined and documented in the IRD. Any changes to configuration-managed Government ICDs by the LDCM contractor require notification and Government approval before implementation.

4.7 Resource Budget Allocations

USGS Systems Engineering will track a set of Technical Performance Measures (TPMs) on a regular basis as part of the effort to ensure that the overall Ground System development is progressing in such a way that will continue to meet functional and performance requirements. These TPMs are selected on the basis of managing key resources that are available, and managing performance margins on the ground system driving requirements.

The TPMs for LDCM will include:

- 16 Day Cycle Contact Time
- Daily Scene Ingest Capability
- Daily L1T Scene Distribution Capacity
- Observation to Product Latency

Other parameters may be selected for formal tracking if this is found to improve SE insight into mission development.

4.8 Risk Management

The USGS risk management process manages programmatic and technical risks before they become a problem, and to reduce the overall project risk in a systematic and disciplined way within resource constraints. The Continuous Risk Management Plan (CRMP), LDCM-MP-006, describes the overall processes, procedures, organizational roles, and tools used to support this effort.

Risk management is an all-encompassing project and task necessity. Risk management is a process, not a product. It identifies, at a minimum, factors that produce cost overruns, schedule slips, reduced quality, and impacts to scope. After identifying a baseline risk set, it is necessary to quantify the probability and impact of each risk, mitigate and control each risk, and track each risk status.

The scope of the CMRP entails risk management across the USGS portion of the LDCM project. Thus, the CMRP governs the management of risks encountered by the USGS segment scope, including the Data Processing and Archive System, Ground

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Network Element and the Collection Activity Planning Element. This plan also describes the Ground System management approach for risks presented by project entities, including contractor(s), government agency partners, affiliated organizations, customers, engineering teams, and subsystems applicable to the USGS portions of LDCM.

All other risk management plans are subordinate to the NASA/LDCM Project Continuous Risk Management Plan, 427-10-01-00, to the extent required to establish consistency and maintain compatibility.

Within the USGS LDCM project, there are several Integrated Project Teams (IPTs) and Working Groups assigned to particular focus areas. The purpose of each IPT and Working Group is to provide direction and help manage project implementation. The USGS utilizes the teams and groups as a way to assign ownership and actions for risks pertaining to each work area. The USGS RMB is made up of representation from each of the teams and groups covering the USGS scope of work. The IPTs and Working Groups do not function as formal risk boards, but rather as a forum where risks and other issues are discussed, risk actions are worked, and mitigation strategies are owned.

Among IPT chartered goals are to define, evaluate, manage, and/or mitigate assigned risks in support of the UGSS Risk Management Board (RMB). IPTs are responsible for ensuring that all risks within the scope of their activities are identified and addressed using the processes and tools provided by this plan, including those risks at segment, element, and component levels of the system architecture. IPTs may delegate risk management responsibilities to individual members or working groups established to address the risk.

4.9 Configuration Management Process

The LDCM Configuration Management process and system are fully documented in the LDCM Configuration Management Plan [LDCM-MP-012], with the exception of end item configuration audits which will be described within this SEMP.

4.9.1 Inter-Agency Technical Document Review

To ensure full communication of technical developments and issues there will be a free flow of technical information between NASA and USGS. In keeping with its mandate of mission success the NASA LDCM Mission Systems Manager or designee will have concurrence on USGS ground system technical documents down to the element level. Similarly, the USGS LDCM Chief Engineer or designee will have review signature on all aspects of the space segment developments that impact USGS ground system development. Concurrence by the cross-agency representative is not strictly necessary for approval of a document since the signature is concurrence and not approval.

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4.9.2 GS CCB

The Ground System Configuration Control Board is co-chaired by the NASA Ground System Manager and the USGS Chief Engineer and includes in its membership the key technical leads from NASA and USGS Project Management and Systems Engineering, as well as discipline and operations experts. A dedicated CM manager is employed by the LDCM project to maintain CM document baselines on the NASA LDCM Cicero web system and to facilitate and document CCB board meetings.

The LDCM web-based CCR system, Cicero, is utilized to document and disposition potential changes. Generally, biweekly CCB meetings are held to disposition CCRs and incorporate changes to the LDCM documentation set. This same system is capable of expansion for tracking and incorporating future hardware or software changes for all stakeholders.

The Ground System Master Controlled Document List (MCDL) is kept in the GS CM system at https://cicero.eos.nasa.gov/ldcmgs Documents that are the direct responsibility of the USGS Chief Engineer include:

- Systems Engineering Management Plan
- Ground System Requirements (Levels 3 and 4) and Acronym/Lexicon documents
- Ground System Verification Requirements Matrix
- Ground System Operations Concept

See Section 6 below for a complete list of Systems Engineering deliverables.

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Section 5 SYSTEMS ENGINEERING MANAGEMENT

The NASA System Engineering team is described in detail in the LDCM SEMP [427-01-01], but the top-level relationship between the NASA and USGS SE teams are shown in Figure 5-1.

The primary NASA SE POC consists of:

NASA LDCM Systems Manager - is the NASA technical lead and the primary technical Point of Contact (POC). The Systems Manager is responsible for overall mission success and leads all mission systems engineering activities.

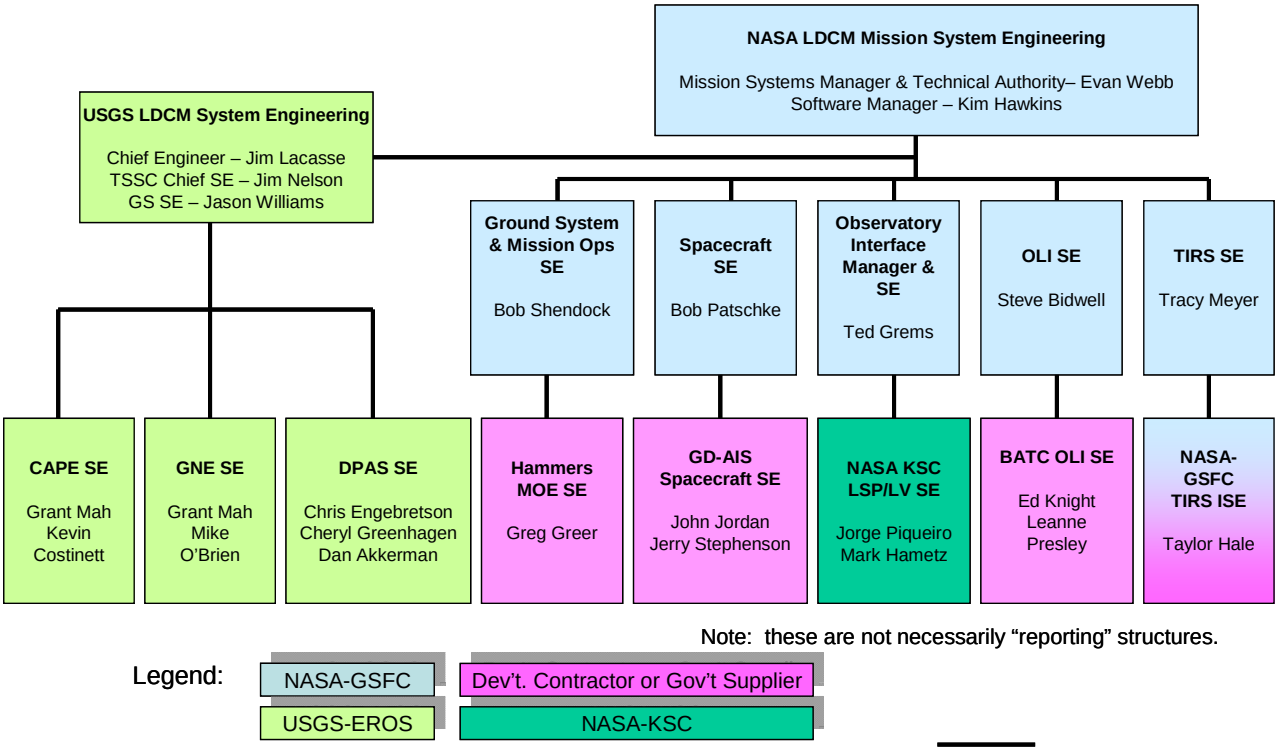

Figure 5-1 USGS/NASA/Contractors SE Combined Structure

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Section 6 Systems Engineering Deliverables

The required LDCM Systems Engineering deliverables, as determined by review of GPR 7120.5A (System Engineering), NPR-7120.5D (Project Management), and GSFC-STD-1001 (SRB Reviews) are identified in Table 6-1.

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Document Control Number	Deliverable	Responsibility
LDCM-MP-011	GS Software Acquisition Management Plan (SAMP)	Indirect
LDCM-MP-012	GS Configuration Management Plan (CM)	Indirect
LDCM-MP-007	GS Systems Engineering Management Plan (SEMP)	Direct
LDCM-MP-013	GS Software Configuration Management Plan (SCM)	Indirect
LDCM-MP-009	GS Mission Assurance Plan (MAP)	Indirect
LDCM-MP-014	GS Quality Management Plan (QMP)	Indirect
	Installation Plans	Indirect
LDCM-MP-015	GS Science Data Management Plan (DMP)	Indirect
LDCM-REF-010	GS Lexicon	Direct
LDCM-REQ-001	GS Requirements Document (GSRD) & Verification Requirements Matrix (VRM)	Direct
LDCM-REQ-011	GS Interface Requirements Document (GSIRD)	Direct
LDCM-REQ-015	Data Processing & Archive System Requirements Document (DPASRD)	Indirect
LDCM-REQ-004	Mission Operations Element Requirements Documents (MOERD)	Indirect
LDCM-REQ-003	Collection & Activity Planning Element Requirements Document (CAPERD)	Indirect
LDCM-REQ-008	Ground Network Element Requirements Document (GNERD)	Indirect
LDCM-IMP-003	Calibration and Validation Team Algorithm Development & Delivery Plan	Indirect
LDCM-DSG-005	GS Design Document (DD)	Direct
LDCM-OCD-002	GS Operations Concept (GSOCD) - (New Version)	Direct
LDCM-TEST-001	GS Integration & Test (I&T) Plan	Indirect
LDCM-ITP-001	GS Integration Plan for DPAS	Indirect
LDCM-ITP-001	GS Integration Plan for MOC	Indirect
LDCM-TEST-002	Ground Readiness Test (GRT) Plan	Indirect
LDCM-VRM-005	DPAS Verification Matrix (VRM)	Indirect
MOE-SE-6	MOE Verification Matrix (CDRL SE-6) (VRM)	Indirect
LDCM-VRM-003	CAPE Verification Matrix (VRM)	Indirect
LDCM-VRM-004	GNE Verification Matrix (VRM)	Indirect
	Interface and ICDs	Indirect
	Data Format Control Books	Indirect

Table 6-1 LDCM Systems Engineering Deliverables

6.1.1 Ground System Operations Concept

The LDCM Ground System Operations Concept Document, LDCM-OCD-002, describes the encompassed LDCM Ground System planned systems functions/operations, people, and processes. The Operations Concept document presents an LDCM Ground System functional and operational view based upon high-level LDCM program guidance contained within the Mission Operations Concept Document, 427-02-02.

6.1.2 Ground System Requirements Document

The LDCM Ground System Segment requirements documents contain requirement flow-down from the LDCM Science and Mission Requirements Document (SMRD),

USGS Landsat Requirements, EROS management requirements, and Land Remote Sensing Program (LRSP) management requirements.

6.1.3 Interface Requirements Document

The LDCM Ground System develops an Interface Requirements Document (IRD) which includes defining the functional and physical interfaces to external and between elements within the LDCM Ground System.

6.1.4 Integration and Test Plan

The LDCM Ground System Integration and Test Plan document provides a systematic test approach starting at the subsystem unit level testing and continuing to the Ground System level testing. The I&T plan will detail the roles/responsibilities, assumptions, test environments, a test prerequisite list (to begin testing), and test result management. The I&T plan will document the interface, functional, performance, exception, and day-in-the-life testing.

Appendix A Requirements Management Steps

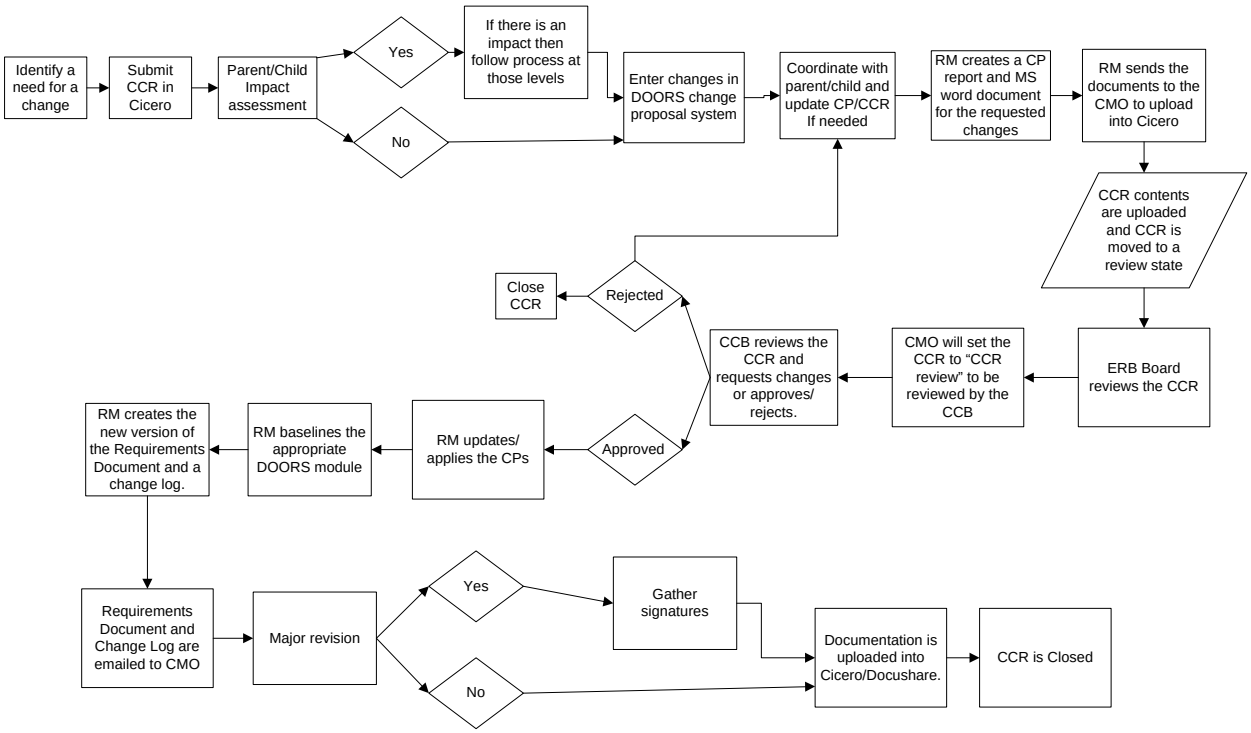

Figure A-2 Requirements Management Steps

1. The System Engineer (SE) (or project team member or customer) identifies a need.

    1. If a need exists to add, update, or delete a requirement, follow the steps defined below.
       — or —
    2. If a Configuration Change Request (CCR) that defines the requirement need already exists, skip to Step 3.

2. The SE (or project team member) submits a CCR in Cicero:

    - Ground System level requirements are level 3.
    - Element level requirements are level 4.

3. The SE assesses the CCR for impacts to other requirements. If changes to requirements are needed at higher or lower levels, follow this process at those levels also.

4. The SE enters the desired changes into the Dynamic Object-Oriented Requirements System (DOORS) application by using the DOORS change proposal (CP) system.

    - Changes are only proposed at this point and will not be visible to a general user until they are applied. In other words, DOORS will always have contained the approved requirements baseline.

5. The SE coordinates with the owners of the parent and child requirements affected by the change and then update the CP/CCR.

6. The Requirements Manager (RM) creates and exports a CP report showing the desired changes per CCR. This report contains the following set of information:
    - Requirement Id
    - CP Information (CP #, Change Type, Priority, Status, and Reason for Change.
    - Current Object Heading – Proposed Object Heading (Level 3 and 4)
    - Current Object Text – Proposed Object Text (Level 3 and 4)
    - Current Rationale – Proposed Rationale (Level 3 and 4)
    - Current Allocation – Proposed Allocation (Level 3 only)
    - Current Priority – Proposed Priority (Level 3 and 4)
    - Current Verification – Proposed Verification (Level 3 and 4)
    - Parent Out-links
    - Parent Impacts
    - Child In-links
    - Child Impacts

7. The RM creates a MS Word version of the document with track changes

8. The RM sends the CP report and the updated word document to the SE for further analysis and if any changes need to be made, repeat steps 6 and 7.

9. Once the CP report and updated word document fully reflect the desired changes, the SE or RM will send the Change Management Officer (CMO) the files to be uploaded into Cicero.

10. The Engineering Review Board (ERB) reviews the CCR for impacts to other elements in the GS or external entities.

11. The GS Configuration Control Board (CCB) approves the change request(s). Please refer to the LDCM Configuration Management Plan (CMP) (LDCM-MP-012) for more information on the Configuration Change Process (CCP).

12. The RM applies the CP(s) in the appropriate DOORS module with the requirement change(s).

13. The RM generates a baseline of the module in DOORS (X.X). It could be a minor or major baseline depending on the gravity of the change or length of time since the last major baseline.

14. The RM creates a new version of the changed requirements document using the IBM Telelogic software DocExpress and sends the new version and a change log to the CMO to upload into Cicero and Docushare.

15. The CMO will:

    1. If it was a major baseline the CMO will gather the necessary signatures for the requirements document.
       — or —
    2. If it was a minor baseline skip to step 16.

16. The CMO uploads the new documents to both Cicero and Docushare and then closes the CCR.