Department of the Interior
U.S. Geological Survey
National Aeronautics and Space Administration

LANDSAT DATA CONTINUITY MISSION (LDCM)

Ground System (GS) Integration and Test Plan

Version 1.1

September 2009

Executive Summary

This document provides an overview of the LDCM ground system integration and test activities and documents the methodology to integrate and test the LDCM ground system to ensure ground system readiness. Detailed plans and procedures for each phase of the integration and test process are in separate documents.

Document History

Document Number	Document Version	Publication Date	Change Number
LDCM-TEST-001	1.0	May 2009	1020
LDCM-I&T-001	1.1	September 2009	1047 V1

Contents

List of Figures

List of Tables

Section 1 Introduction

The Landsat Data Continuity Mission (LDCM) is a remote sensing mission, which provides data continuity to the Landsat satellite series global multi-spectral data collection and distribution. The LDCM is a satellite and ground based capabilities collection that provides:

- Global, moderate-resolution, multi-spectral data collection.
- Long term LDCM data archiving.
- Web-enabled access.
- Continued Landsat International Cooperators (ICs) support.
- Level 0 and Level 1 data products.

The LDCM Project entails three major mission components called: the Space Segment (SS), the Ground System (GS), and the Launch Services Segment (LSS).

The LDCM Project is a collaborative effort with NASA and the Department of the Interior's United States Geological Survey (USGS). Agency roles and responsibilities are defined in detail within the joint agency Final Implementation Agreement (FIA) and Project Implementation Agreement (PIA). As a high level summary, NASA is primarily responsible for project management, the space and launch segments, including all instrument(s), the spacecraft bus and associated launch services, and the Mission Operations Element (MOE) of the GS. The USGS is primarily responsible for the ground system, except for the MOE. After launch and early orbit checkout, NASA will turn the LDCM over to the USGS for operations.

1.1 Purpose

The objective of the LANDSAT Data Continuity Mission (LDCM) Ground System (GS) Integration and Test (I&T) Plan is to provide an overview of the LDCM ground system integration and test activities and to document the methodology to integrate and test the LDCM ground system to ensure ground system readiness. The final ground system readiness determination will be achieved through a series of Ground Readiness Tests (GRTs), Radio Frequency (RF) compatibility tests, and Mission Readiness Tests (MRTs). Opportunities to verify requirements not verified in the planned test suite will be sought, including conducting special tests as necessary.

The following sections describe the plan for integration and test activities and the associated management approach, data analysis, level of participation, and discrepancy management strategy that will be used to demonstrate the ground system's operational readiness.

1.2 Scope

The scope of this I&T Plan includes an Overview of the Ground System Elements and Interfaces, I&T Plan, and the Ground I&T Management Approach.

Five phases have been identified for the complete integration and test of the LDCM ground system:

- Ground System Integration
- Ground Readiness Testing
- RF Compatibility Testing
- Mission Readiness Testing
- Mission Operations Simulations

The LDCM GS I&T Plan, an umbrella document for the Mission Operations Center (MOC) Integration Plan, the Data Processing and Archive System (DPAS) Integration Plan and the NASA Ground Readiness Test (GRT) Plan, describes the role of the ground system in the RF Compatibility, Mission Readiness Test (MRT), and Mission Operations Simulation (MOS) Plans. An overview of the plans for each phase is discussed in Section 3.

Prior to the start of ground system integration, each ground system facility will be certified as ready to support both ground system integration and testing. Level 3 physical requirements will be verified as part of the certification process. Details of the certification are documented in the EROS Facility Certification Plan and the MOC Certification Plan. Ground System elements will be integrated during the Ground System Integration period. This will include element hardware and software installation and checkout and interface connectivity testing. Details of these activities will be documented in the MOC and DPAS Integration Plans. The GRT Plan and procedures will be used to verify ground system Level 3 functional requirements. The RF Compatibility Test Plan documents the methods used to verify RF communications data flow compatibility between the space segment and LDCM ground networks (LGN, SN, and NEN). The MRT Plan and procedures will be used to perform mission level end-to-end testing with the actual space segment flight hardware and ground system, including verification of ground system Level 3 performance requirements. The MOS Plan and procedures will be used for evaluation of mission operations difficult to run on flight hardware. All FOT products and the integrated ground system must successfully pass acceptance testing with the flight system as part of MRTs or MOSs before launch.

The LDCM GS I&T Plan is controlled and managed by the LDCM Ground System Configuration Control Board (CCB) and in accordance with LDCM configuration management documentation.

Section 2 GROUND SYSTEM OVERVIEW

This section provides a brief overview of the LDCM Ground System, its major components, and the responsibilities of each component. The LDCM Ground System will provide the following functions for the mission.

- Radio Frequency (RF) Communications with the Spacecraft
- Spacecraft Monitoring and Control
- Instrument Monitoring and Control
- Mission Planning
- Science Data Processing
- Science Data Archive and Distribution
- Orbit Management

These functions are performed by existing and new facilities. Figure 2-1 depicts the LDCM Operational Concept Architecture. A description of the segments and their constituent elements is shown in Table 2-1. Specifically, the MOE, CAPE, and GNE are responsible for communication and control of the observatory, and collecting and transferring mission data to the DPAS for processing, storage, and distribution. The space segment consists of the spacecraft (S/C) bus and the Operational Land Imager (OLI) and the Thermal Infra-Red Sensor (TIRS) instruments (jointly referred to as the observatory). NASA's Space Network (SN) and White Sands Complex (WSC) and Near Earth Network (NEN) provide S-band Narrowband communications between the observatory and MOC during launch and early orbit and during observatory critical events and contingency activities.

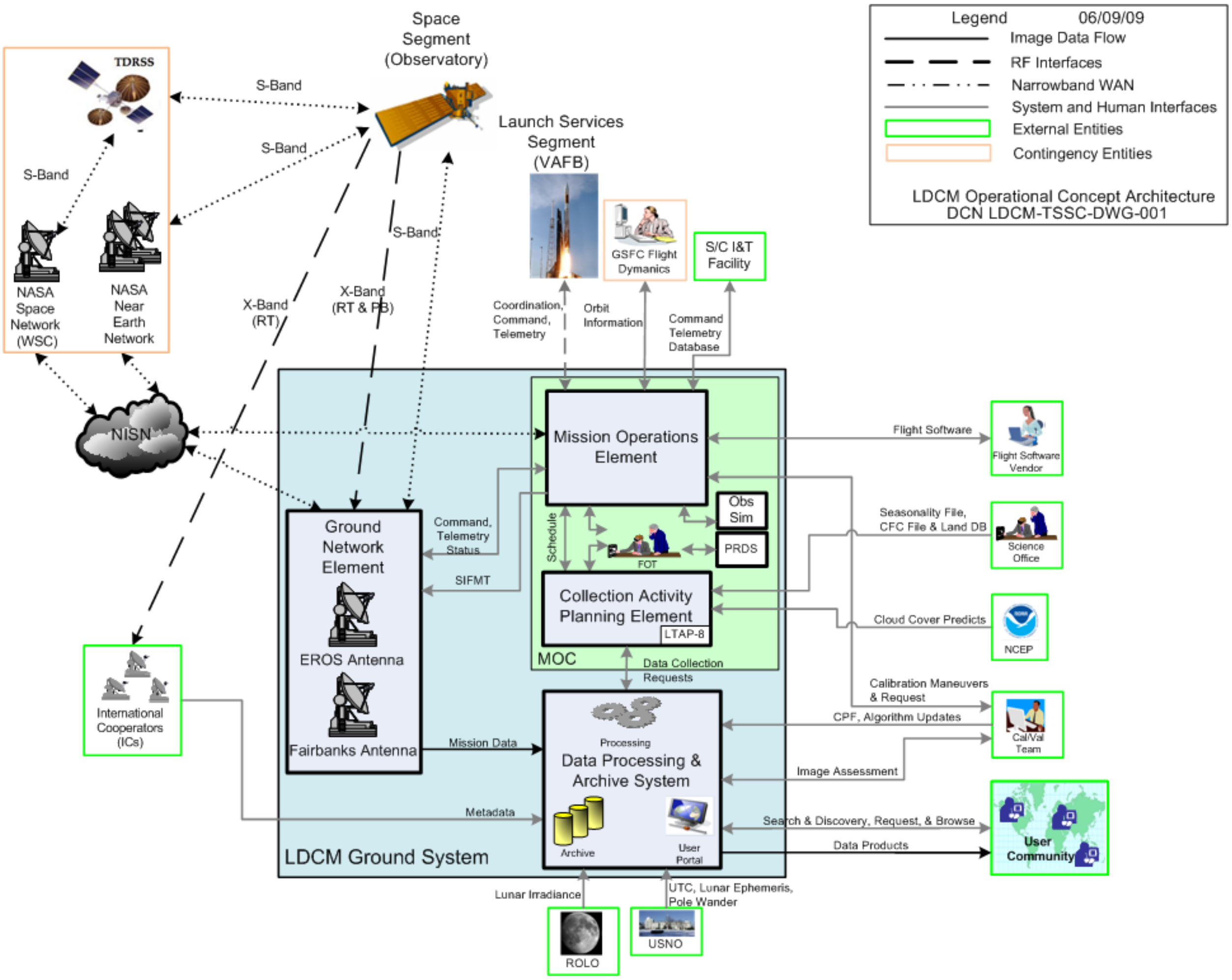

Figure 2-1 LDCM Operational Concept Architecture

Segment/System	Element	Description/Function
Space	Bus	Provides power, command and control, and data handling for the OLI
	OLI	Acquires science image data
	TIRS	Acquires thermal infra-red data
Launch Services	Launch Vehicle	Places Observatory in proper orbit
Ground System	Collection Activity Planning Element (CAPE)	Generates schedules for instrument image acquisition

Ground Network Element (GNE) Gilmore Creek LGN station (GLC) USGS/EROS LGN station (LGS)	Provides S-Band and X-Band radio frequency (RF) communication with the Observatory to send commands (CMD), receive housekeeping telemetry (TLM), and receive mission data via LDCM Ground Network (LGN) stations and wide area networks. The GNE also provides a mission data cache at the stations for disaster recovery.
Mission Operations Element (MOE)	Provides the primary means to control and monitor the observatory; including mission planning and scheduling, command and control, monitoring and analysis, flight dynamics and onboard memory management. Resides within the Mission Operations Center (MOC), backup MOC (bMOC) and is operated by the Flight Operations Team (FOT)
Data Processing and Archive System (DPAS)	Performs mission data ingest, data product generation, and image assessment; provides online, near-line, and offline storage for LDCM archive and product data; provides user interface for data search/discovery and distribution, and allows for users to submit imaging requests

Table 2-1 LDCM Segment/System Overview and Functions

2.1 LDCM System Interfaces

There are certain external entities that exchange information with the LDCM System. They are described in the sections that follow.

2.1.1 NASA Space Network (SN)

NASA's Space Network (SN) will provide S-band communications capabilities for the LDCM observatory. The SN Tracking and Data Relay Satellite System (TDRSS) will provide bi-directional data transmission services between LDCM and ground receiving stations, using satellite-to-satellite communications links to allow communications even when the observatory is not in view of a ground station. LDCM will utilize the SN during launch and early orbit for low-rate S-band uplink and downlink operations. Following commissioning, the SN will only be used to support observatory emergency operations and maneuvers.

2.1.2 Near Earth Network (NEN)

The Near Earth Network (NEN) includes several satellite ground receiving stations throughout the world that are available to support NASA missions. LDCM will interface with a subset of NEN stations for support during launch and early orbit operations. Following commissioning, the NEN will only be used in support of observatory emergencies and maneuvers. The NEN stations will provide S-band services for uplink and downlink only, with no X-band reception.

2.1.3 NASA Integrated Services Network (NISN)

NISN provides Wide Area Network (WAN), data, voice, facsimile, video, and other communications services. LDCM will utilize the Restricted IO Net between the MOC and other LDCM System Interfaces, NASCOM voice services, FAX, video and other services.

2.1.4 NASA Flight Dynamics Analysis

The LDCM will utilize Flight Dynamics Analysis services during pre-launch, early orbit and for anomaly resolution activities. The NASA Goddard Space Flight Center maintains a Flight Dynamics Facility (FDF) that provides orbit determination, prediction, and control services which may be utilized in this support. The FD Analysis group offers interface and coordination support between operational missions and the entities discussed in the following sub-paragraphs. These interface needs may be satisfied directly by the LDCM Mission or through the FD Analysis group.

2.1.5 GSFC Space Asset Protection Mission Support Office

The GSFC Space Asset Protection Mission Support Office performs routine Conjunction Assessment (CA) analysis for LDCM utilizing data provided by the United States Strategic Command (USSTRATCOM) Joint Space Operations Center (JSpOC). The JSpOC generates close approach predictions between LDCM and other objects in USSTRATCOM's Space Object Catalog using an LDCM–provided ephemeris. The GSFC CA Team determines the threat posed to LDCM by each predicted event by computing the collision risk probability and analyzing other relevant factors. If needed, the GSFC CA Team provides consultation support to LDCM in planning any appropriate risk-mitigating action.

2.1.6 Earth Science Mission Operations (ESMO)

The ESMO office at NASA GSFC is responsible for the operation of several NASA Earth science missions. The LDCM orbit will allow LDCM to fly as part of a morning constellation that includes several ESMO missions, if they are still operational. (This constellation presently consists of Landsat 7, Terra, SAC-C, and EO-1). Any required orbit or maneuver coordination to maintain this constellation is performed through human interaction with the ESMO staff and the potential exchange of state vectors corresponding to observatory orbits.

2.1.7 External Data Sources

LDCM will utilize certain external data as input to the ground system. These data will include auxiliary data such as government-provided ground control data and digital elevation models for terrain correction or lunar irradiance data to support imaging sensor calibration. External data will also include cloud prediction information used in data collection scheduling, or other data that are used to operate the mission or produce LDCM data products.

2.1.8 National Centers for Environmental Prediction (NCEP)

LDCM will obtain cloud cover predictions from NCEP periodically throughout the day to support CAPE scene selection and image acquisition scheduling.

2.1.9 US Naval Observatory (USNO)

LDCM will obtain UTC / UTC1 timing and polar wander information from the USNO for use in geometric correction.

2.1.10 Robotics Lunar Observatory (ROLO)

The USGS lunar calibration program provides radiometric calibration and sensor stability monitoring for remote sensing satellite imaging instruments using the moon.

2.1.11 Spacecraft Integration and Test Facility (S/C I&T Facility)

LDCM interfaces with the Spacecraft Integration and Test Facility during the pre-launch phase to develop and test interfaces between the LDCM Observatory and Ground System. Database information, housekeeping telemetry and mission data are provided to the Ground System. A command interface is made available during controlled test periods. Testing is supported by a secure network between the MOC and LDCM resources at the I&T facility. An RF link is provided for test while the Compatibility Test Van is resident at the facility.

2.2 Primary Internal & External Users

This section describes the groups and teams that use or interact with the capabilities of the LDCM.

2.2.1 User Community

The User Community encompasses all those members of the general public that use Landsat data for purposes as diverse as scientific research and operational resource management. The User Community interfaces to the Data Processing and Archive System to search for, browse, order, receive LDCM data products, and request image collections. For ground system I&T this role will be performed by a member of the GS test team or their designee.

The USGS convenes a Landsat Science Team (LST) composed of competitively selected investigators. The LST conducts research on issues critical to the success of the LDCM, including data collection, product access and format, practical applications, and science opportunities for new- and past-generation Landsat data. The LST offers research and science support to the USGS on topics that will affect the overall success of the LDCM mission. The USGS and NASA LDCM Project Scientists will co-chair the Science Team.

2.2.2 International Cooperators (ICs)

The USGS maintains agreements with several foreign entities (typically, governmental) referred to as the LDCM International Cooperators (ICs). The ICs are a special subset of the User

Community that has the ability to receive LDCM data from the observatory real-time downlink stream. Real-time imaging sensor and ancillary data (including spacecraft, calibration data, etc.) necessary for processing are contained in the real-time stream and are received by IC ground stations. The number of active IC ground stations is not constant. IC ground stations may move to/from an active condition based upon the state/terms of their respective Landsat agreement, funding conditions, or the technical capabilities of the IC ground station. For ground system I&T this role will be performed by a member of the GS test team or their designee.

2.2.3 Flight Operations Team (FOT)

The LDCM Flight Operations Team (FOT) is the team of mission operations personnel managed by the USGS. The LDCM FOT will use the MOE to operate the observatory from launch vehicle separation through the life of the mission. The FOT operates the MOE and CAPE at the MOC and interfaces with the GNE. The FOT will exercise its normal responsibilities during ground system I&T.

2.2.4 Data Acquisition Manager (DAM)

The USGS Data Acquisition Manager (DAM) manages the data collection schedules for LDCM. The DAM adjudicates data collections for input into the CAPE within the MOC. The DAM will exercise its normal responsibilities during ground system I&T.

2.2.5 Cal/Val Team (CVT)

The Calibration/Validation Team (CVT) consists of discipline scientists and engineers who perform calibration of the LDCM imaging sensor and data. The CVT is geographically dispersed and includes representatives from both NASA and USGS. While the team will advise on and review imaging sensor calibration activities, they will remain independent from the development contractor/organization in their calibration assessments through the life of the mission. NASA leads this team during observatory development through on-orbit acceptance. Following on-orbit acceptance, this team is led by USGS. The CVT works with members of the LST and from academia on various calibration and validation issues and special collections of LDCM data. The FOT and DAM interact with the CVT on a routine basis to schedule Lunar Calibration events, etc. The CVT will participate as itself in support of ground system I&T.

2.2.6 DPAS Operators

The DPAS Operators are responsible for all operations related to long term LDCM data archiving, processing, assessment, and data product distribution to the general public. The DPAS will be housed and operated out of the USGS EROS Center. In addition, the USGS provided DPAS will be used during the SS ground testing and end-to-end data flow validation in preparation for mission readiness as well as On-orbit Initialization and Verification (OIV) for support of instrument checkout through Level 0 generation.

2.2.7 GNE Operators

The USGS GNE Operators will operate the LGN stations and the GNE for data collection and routing.

Section 3 I&T PLAN

The Ground System I&T Plan describes a series of integration activities and tests to be completed to fully establish and verify the LDCM ground system. The MOC integration is performed by NASA and the DPAS integration is performed by USGS with oversight provided by NASA. Test planning and oversight for Ground Readiness Tests (GRTs), Mission Readiness Tests (MRTs), and Mission Operations Simulations (MOSs) are done by NASA and the detailed planning and execution is performed by Ground System operators (FOT, GNE, DPAS, and other operations staff).

The plan for integrating the various element hardware and software releases into a single working LDCM Ground System is detailed in the MOC and DPAS Integration Plans written by NASA and USGS respectively. The MOC and DPAS Integration Plans document the processes used to manage the delivery, acceptance, testing and certification of the GS elements. The completion of the certification process will result in a system ready to support Ground Readiness Testing.

The plan for testing the functional capabilities of the ground system elements and the interfaces between those elements is detailed in the Ground Readiness Test (GRT) Plan written by NASA. The GRT Plan documents the test strategy and methodology and the distribution of functionality to be tested in each of 6 planned GRTs. The successful completion of GRTs is pre-requisite for Mission Readiness Testing.

Several series of mission level tests are planned including MRTs, Radio Frequency Compatibility Tests (RF Compats) and MOSs. Test plans for each test series will be written by NASA.

3.1 Integration

3.1.1 Pre-Integration Activities

Several activities are pre-requisite to delivery and integration of the MOC, GNE, and the DPAS. The MOC, GNE and DPAS each undergo a Facility and Network Infrastructure Preparation prior to integration. A listing of additional pre-integration activities involved is provided below.

3.1.2 Facility and Network Infrastructure Preparation

Prior to integration of any ground system element, the LDCM Ground System facilities and network infrastructure will be in place. Facility and network infrastructure includes physical space, furniture, power, cooling, physical and IT security, and operational network connectivity.

For the MOC (and bMOC), infrastructure preparations include securing sufficient floor space to support launch, early orbit, and nominal operations; coordination with facility personnel for installation of power supply/sources, heating and cooling, and physical security. A MOC network is installed to support the integration of mission operations hardware and software. Network connectivity between the MOC and several other ground assets is established through extensive coordination with NISN, including connectivity to the LGN sites, NEN and SN, mini-MOE at the S/C I&T facility and the DPAS.

Infrastructure preparations include completion of operations/computer room floor space needed to house the DPAS and GNE hardware at EROS, installation of any equipment being ordered prior to integration, installation of the operational DPAS and GNE (non-NISN) network, connection to the MOC network and the EROS campus network within EROS, setup of the EROS Long Term Archive (LTA) and establishing a connection to the instrument providers.

Network connectivity also includes completing and implementing interface applications as required.

Infrastructure preparations also include any equipment installation at the LGN station sites and the establishment of network connectivity between the LGN stations and DPAS for the transfer of mission data. This preparation is being done by the GNE developers and station partners.

Infrastructure preparations are performed by the LDCM GS Infrastructure Team in coordination with facility and network personnel, element leads, ground system operators (FOT, GNE and DPAS), and GS management.

Ground system facilities (MOC, DPAS and GNE) will undergo a facility certification prior to integration of the first element. Level 3 facility requirements will be verified as part of the certification process and are identified in the GS Verification Requirements Matrix (VRM). Details on the MOC facility preparations are provided in the LDCM MOC Infrastructure Implementation Plan and the LDCM MOC Infrastructure Network Design Document. The implementation plan will cover the stand-up of the MOC infrastructure (network, power, data communications cabling, external network connectivity, and voice keysets) and the infrastructure portion of the work to support the physical implementation of the MOC elements (MOE, CAPE, LSIMSS, and other simulators). Details on the GNE and DPAS facility preparations are provided in the LDCM DPAS GNE Facilities Definition Document, and in the LDCM DPAS GNE Network Interface Planning Document.

3.1.3 Element Level 4 Requirements Verification

Each LDCM element must verify its Level 4 requirements through Factory Acceptance Tests (FATs) and Lab Acceptance Tests (LATs) for MOE or Formal Qualification Tests (FQTs) for USGS elements. Verification of CAPE and MOE Level 4 requirements will be completed at the vendor site and then repeated in part following delivery and installation at the MOC. For the GNE, Level 4 verification will be done at each station site. Verification of DPAS Level 4 requirements will be completed at the USGS Integrated Test Environment site. NASA and/or the USGS or their designated representatives will witness the verification of the Level 4 requirements and/or review the test evidence of the verification efforts. Any verification failures or unresolved discrepancies will be documented and will be presented as part of the element Pre-ship Review (PSR).

Element development includes development of element functionality and interfaces. Each element is expected to comply with all appropriate requirements and ICDs during development. Preliminary tests of ICD compliance can be accomplished by the informal exchange of data products or test data between elements. The exchange can be via a mock-up of the interface or a method other than the expected operational interface.

3.1.3.1 Element Pre Ship Review (PSR)

A final element-level review is required before integration into the ground system and the execution of ICTs and eventually GRTs. The PSR confirms both the fulfillment of all element expectations (see below) and the readiness of the MOC or the DPAS operational environment to accept the element.

Fulfillment of the following expectations must be presented at the element PSR:

- Technical maturity of element is sufficient to proceed to next test phase
- Level 4 requirements verification results
- Documentation of unresolved discrepancies
- Element release package(s) or Version Description Document(s) (VDD(s))
- Element HW Configuration items
- Element SW executable
- Element final source code
- Complete CDRL listing
- Build/installation instructions
- Logistics of element system delivery
- As-built documentation
- As-tested documentation
- Training plans/status
- Receiving facility/environment readiness to accept delivery
- NASA/USGS concurrence that element is ready to proceed to next test phase

3.1.4 Integration Activities

Ground System Integration demonstrates the successful integration of ground system elements and the end-to-end data flow between elements of the LDCM ground system and external interfaces such as NASA SN and NEN. Ground system integration is divided between MOC integration (including bMOC) and DPAS integration. MOC integration includes installation of the MOE, CAPE, Spacecraft/Observatory Simulator (SOS), Project Reference Database System (PRDS), and any SN/NEN scheduling tools in the MOC. MOC integration also includes installation and integration of the LGN stations hardware, networks, and the GNE Data Capture and Reporting Sub-System (DCRS) with the MOC. DPAS integration includes installation of hardware and software for the DPAS and connectivity with the MOE. Appropriate simulators will be integrated as an element where needed (LSIMSS, SOS, etc.). Details of the MOC and DPAS integration are provided in the MOC and DPAS Integration Plans.

The primary activities performed during the integration sequence are installation, configuration, and checkout and the Interface Connectivity Tests (ICTs). An explanation of each activity is provided in the following sections.

3.1.4.1 Installation and Checkout

LDCM Ground System integration consists of the installation of each ground system element's hardware and software into its operational facility and onto the operational network. This includes installation; system's power up sequence; configuration of environments, networks, and firewall rules; and pinging of systems.

Element developers are responsible for performing the hardware and software installation for the initial element release. In the case of the DPAS and GNE DCRS, the USGS is responsible for hardware purchase and installation. USGS technical support contractors will perform hardware installation for these systems, the details of which are included in the DPAS and GNE Installation Plan. Element developers delivering to the MOC will train the FOT in the installation of hardware and software so that the FOT can install future updates or perform re-installation, as needed. Similarly, DPAS developers will train the DPAS Operations team in the installation of hardware and software so that they can install future updates or perform re-installation, as needed. Developers are also responsible for the element/system checkout process to ensure the element/system was installed and configured correctly.

3.1.4.2 Interface Connectivity Tests (ICTs)

Interface connectivity between element and entity interfaces will be tested as the system is built-up from a single element to a completed system; starting with the successful installation and checkout of the second element of the system. Interface Connectivity Tests (ICTs) will be conducted for each interface between the newly installed element and each of the already integrated elements. ICTs will focus on the verification of operational connectivity between ground system elements and entities. ICTs will only verify that the file was received and that connectivity exists (and will not formally verify the file received contains the correct data type, size and format).

Interface Connectivity Test Procedures will be jointly developed by the ground system integration team and element developers. ICTs will be conducted by the element developers under the supervision of the ground system integration team. The FOT in the MOC and the DPAS operators in the DPAS facility will closely participate in the ICTs, observing and receiving on-the-job training.

3.2 Testing

3.2.1 Ground Readiness Tests (GRTs)

The purpose of ground readiness testing is to verify that the ground system meets its functional, Level 3 (GSRD) requirements. GRTs also verify that the interfaces between elements perform as defined in the ICDs and that data products exchanged between elements can be used by the receiving element and conform to ICD specifications. GRTs do NOT verify performance requirements, FOT product (page displays, STOL procedures, Ops procedures, etc) performance and FOT readiness. The ground system operators, including the FOT, GNE and DPAS operators, will perform all element activities during the GRTs. GRTs, with the exception of GRT 4b, are planned to be completed prior to testing with the space segment and execution of MRTs.

A series of 6 tests are planned. The overall plan for these 6 tests is detailed in the GRT Plan. Details of each test will be coordinated in the regular GRTT meetings/telecons and will be documented in a test procedure. Test configurations will be identified and documented in the test procedure. An outline of the planned GRTs is included in Table 3-1.

GRT #	GRT Focus
GRT 1	TLM/CMD (S-band/X-band)
GRT 2	Planning and Scheduling
GRT 3	Maneuvers and Special Event
GRT 4a	DPAS connectivity to MOC
GRT 4b	DPAS
GRT 5	Contingency Operations
GRT 6	Capstone/Clean-up

Table 3-1 Ground Readiness Tests

3.2.2 Mission Tests

Ground System elements and element operators will support several series of mission tests including:

- Network Compatibility Tests
- Mission Readiness Tests (MRTs)
- Mission Operations Simulations (MOSs)

The purpose of these tests is very focused and is summarized below. The tests are defined and managed by either the NASA NOM or the NASA MOM. The Observatory I&T Manager is responsible for the observatory configuration and the Mission I&T Manager will help plan, coordinate and schedule the necessary resources. A minimum of 200 hours of mission testing from the MOC is required by the NASA GSFC Gold Rules.

Anomalies may be introduced via “green cards” at the discretion of the test director. Ground system elements and element operators will respond appropriately.

Some Level 3 GSRD requirements have been identified in the GS VRM to be verified in these tests.

3.2.2.1 Network Compatibility Tests

LDCM ground system requires confirmation of compatibility with NEN and SN services. LDCM ground system will participate as needed in testing to prepare the integrated networks (SN, NEN, NISN, and FDF) for LDCM program tests (MRTs and MOSs). This testing is defined in the LDCM Project Service Level Agreement (PSLA) with NASA/GSFC Code 450.

The main objectives of the testing are to demonstrate compatibility among the Networks' S-band RF equipment and demonstrate data flow starting in the LDCM MOC with sequences and real-time commands and then telemetry.

3.2.2.1.1 SN/NEN Connectivity Testing

Connectivity testing ensures connectivity between NISN and the LDCM ground system.

3.2.2.1.2 RF Compatibility Test

RF Compatibility Testing verifies the RF and data flow compatibility between the spacecraft and the ground networks. A set of compatibility test equipment (CTE), provided by GSFC (X-band) and the USGS (X-band), will be used at the spacecraft vendor facility to interface with the spacecraft to support RF compatibility testing. The CTE will emulate the LGN, SN, and NEN. The RF Compatibility (Compat) test may include a full SN S-band RF (command and telemetry) interfaced with the spacecraft utilizing TDRSS. An RF suitcase may also be provided by the spacecraft vendor and will provide additional X-band RF testing at the NEN and LGN sites. The RF suitcase will emulate the spacecraft's RF X-band system. These tests assess the spacecraft RF and data flow compatibility with the LGN, NEN, and SN, verify spacecraft telemetry transmit functions, measure telemetry values at the receivers, and verify the spacecraft command receiver operations.

RF Compatibility Testing at the spacecraft vendor facility is led by GSFC Code 450 and performed in coordination with the spacecraft vendor and LDCM ground system team. Code 450 will develop an RF Compatibility Test Plan which will describe this testing in detail. Testing at the LGN sites is led by the LDCM Ground System with support from the spacecraft vendor, as needed.

3.2.2.1.3 RF Long Loop Testing

The RF Long Loop Test tests the configuration (including scheduling) and configuration codes of SN and NEN by flowing recorded spacecraft data, provided during the RF Compatibility Test through the SN and NEN RF equipment. RF Long Loop Testing is typically internal to the SN and NEN but participants will include the LDCM MOC.

3.2.2.1.4 End to End (ETE) Testing

The ETE test verifies end-to-end connectivity between the LDCM MOC, NISN, NEN, and SN. The End to End testing will utilize WDISC (Command and Telemetry) and Scheduling Interface Space Network Access System (SNAS). SN End to End Testing participants will include SN, LDCM MOC, NISN, and NOM. This test is completed prior to the start of MRTs.

3.2.2.1.5 Launch Day Dress Rehearsal

The launch day dress rehearsal exercises the sequence of launch preparation activities as they will occur on launch day. Each organization will exercise its determination and declaration of readiness to proceed in the launch count activities. An end-to-end data flow from the observatory mated with the launch vehicle to the LDCM MOC via the NEN/SN is included in the launch rehearsal activities. FDF's vector transmission for launch day is also verified during the Launch Day Dress Rehearsal.

3.2.2.2 Mission Readiness Tests (MRTs)

The purpose of the mission readiness testing is to ensure that the ground system can support all mission requirements in an end-to-end configuration with the observatory. MRTs will also verify ground system performance requirements, FOT product performance and FOT readiness. The MRT plan will be written by the NASA MOM, and the details of each MRT test procedure will be written by the FOT under the direction of the NASA MOM.

A series of 6 tests are planned and will be conducted in a flight-like environment as defined by the Flight Operations Plan. All procedures used in MRTs are verified against the Spacecraft/Observatory Simulator (SOS) prior to use with the observatory and are part of the Flight Procedures Manual. An outline of the MRTs is included in Table 3-2.

MRT #	MRT Focus	MRT Duration
MRT 1	DITL-Routine & Periodic Operations	1 day
MRT 2	Contingency Operations	2 days
MRT 3	Special Operations	2 days
MRT 4	Maneuver Operations	2 days
MRT 5	Instrument Operations	3 days
MRT 6	SPITL-Scheduling Period in the Life	4 days

Table 3-2 Mission Readiness Tests

3.2.2.3 Mission Operations Simulations

Mission operations simulations are run to execute and evaluate mission operations that are difficult to run on flight hardware. A series of 5 simulations are planned to be run against the SOS. A Mission Operations Simulations Plan details the 5 simulations planned and is written by the NASA MOM. The detailed procedures for each of these simulations will be written by the FOT under the direction of the NASA MOM. The five simulations planned are listed below.

- MOS1 Contingency Operations
- MOS2 Special Operations
- MOS3 Launch and Activation Operations
- MOS4 Total WRS-2 (DRC16) In The Life (TWITL)

- MOS5 Total WRS-2 (DRC16) In The Life with Contingencies

3.3 Simulators and Data Sets

A variety of simulators will be available for use during ground system I&T. The use of simulators is designed into the GS I&T phases to allow for early verification of interfaces and functional capabilities of the ground system reducing risk and schedule delay. These interfaces include instrument to spacecraft, MOE to spacecraft, and ground stations to spacecraft. These are critical interfaces to verify as early as possible. The hardware providers and recipients are from all the various LDCM vendors and agencies.

The simulator providers will integrate and checkout the hardware and software, train the simulator operators (FOT members and ground system operators), and provide support as necessary. The simulator providers will also deliver the necessary simulator documents: test plans, reports, and Users guides and training materials.

Table 3-3 provides an overview of the simulators that may be used during the integration and testing of the LDCM ground system.

Simulator/Provider	Deliver to	Purpose	Need By
LDCM Scalable Integrated Multi-mission Support System (L-SIMSS)/GSFC Code 450	MOC	Provides a capability to test low-rate forward- and return-link interfaces between the LDCM Ground Network (LGN), Near Earth Network (NEN), Space Network (SN) and the LDCM Mission Operations Center (MOC)	First customized release of the MOE
Spacecraft/Observatory Simulator (SOS)/Bus Vendor	MOC	Provides high-fidelity representation of Observatory (both spacecraft and instruments) to support GS certification during GRTs, FOT training, proc development, and Mission sims	Must be integrated into MOC in time to support GRTs
RF Suitcase/ Bus Vendor TBR	LGN Stations	Emulates X-band and S-band (TBR) downlink for compatibility tests with LGN stations	MRT #1

Table 3-3 LDCM Simulators

Generation of specific data sets which cannot be simulated by any of the available simulators may be necessary to complete the I&T plan. The need for data sets will be identified in individual plans and the specifics of the necessary data sets will be detailed in the appropriate test procedures.

Section 4 GROUND I&T MANAGEMENT APPROACH

4.1 Ground I&T Documentation

I&T documentation will include a series of test plans and test procedures (See Figure 4-1). Test plans will be high level guidance documents that include, but are not limited to, objectives, resources, schedules and reference documentation. Test procedures will be written for each GRT, MRT, MOS, and RF Compatibility test and will include the detailed steps to be performed during the test and the requirements being verified in that test. NASA is responsible for producing the GS I&T Plan, the MOC Integration Plan, the GRT Plan, the RF Compatibility Test Plan, the MRT Plan, and the Mission Operations Simulation Test Plan. USGS is responsible for producing the DPAS Integration Plan. Test procedures will be drafted by the agency owning that test, but will be refined and detailed by the FOT and other ground system operators. Table 4.1 identifies the I&T documents to be generated, due dates, and the controlling CCB.

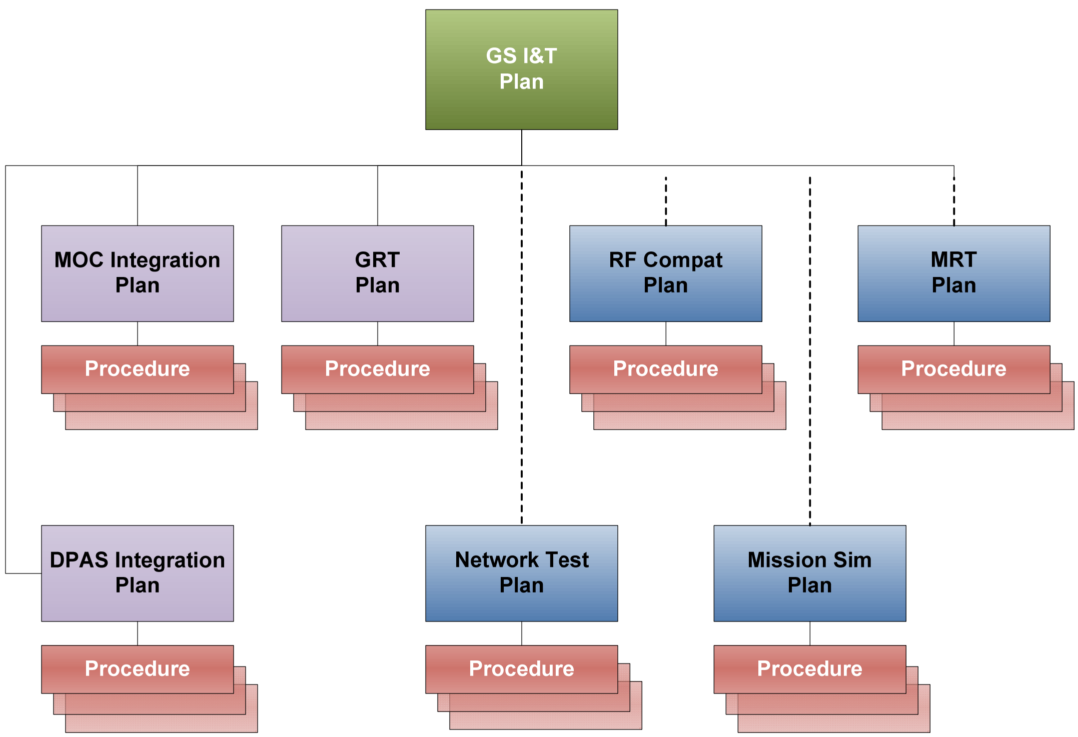

Figure 4-1 Ground System I&T Documentation Tree

Document	Purpose	Draft	Final	CCB
Ground System I&T Plan	Overarching document describing the overall approach to planning and coordinating the ground system integration and testing	G-SRR	G-PDR	GS
MOC Integration Plan	Objectives, approach, resources, , and schedule for integrating the MOCs with the GNE, NEN, SN, and FDF	G-PDR	G-CDR	GS
DPAS Integration Plan	Objectives, approach, resources, and schedule for integrating the DPAS	G-PDR	G-CDR	GS
Ground Readiness Test Plan	Objectives, approach, resources, and schedule for Ground Readiness Tests	G-PDR	G-CDR	GS
RF Compatibility Test Plan	Objectives, approach, resources, and schedule for RF compatibility testing between the spacecraft and ground networks (GNE, SN, and NEN)	M-CDR (TBR)	MOR (TBR)	NASA GSFC Code 450
Mission Readiness Test Plan	Objectives, approach, resources, and schedule for mission readiness testing	M-PDR	M-CDR	LDCM mission
Mission Operations Simulation Plan	Objectives, approach, resources, and schedules	M-PDR	M-CDR	Ops

Table 4-1 Ground I&T Documentation

4.2 Roles and Responsibilities

4.2.1 NASA/USGS

The development, integration and test of the LDCM ground system is a collaborative effort between NASA and USGS. NASA will serve as the mission system integrator and USGS will serve as the ground system developer and integrator.

NASA shall serve as the LDCM Mission Integrator. In this role, NASA shall perform the following:

- Authorize launch
- Provide for a MOC at GSFC used in support of LDCM pre-launch, launch, on-orbit verification and checkout, and commissioning
- Produce a Mission I&T Plan
- Lead mission I&T
- Provide mission level systems engineering
- Oversee observatory and instrument I&T
- Oversee Ground System development, integration, and testing
    - Provide ground system I&T oversight, guidance and expertise
        - Develop the Ground System I&T Plan
        - Review and provide input to all element test plans and procedures, GS integration plan and procedures, and GRT procedures
        - Lead the integration of the MOC and develop the MOC Integration Plan and procedures
        - Develop Ground Readiness Test Plan
        - Lead Ground Readiness Testing
        - Co-chair, with USGS, the Ground Readiness Test Team
        - Perform necessary analysis of test results
        - Store MOC related test records
        - Write and manage test discrepancies as necessary
    - Provide contractual oversight for MOE integration to spacecraft and to ground system elements
    - Facilitate integration to NASA SN, FD services, NISN, and NEN
- Lead Mission Readiness Testing and Mission Operations Simulation
    - Develop MRT Plan and MOS Plan
    - Prepare and maintain simulation configuration
    - Oversee training and certification of FOT
    - Verify FOT product performance
    - Review and provide input to all MRT and MOS procedures
- Declare mission readiness
- Lead a Mission I&T Working Group

As Ground System Developer, the USGS shall perform the following:

- Lead DPAS Integration and develop the DPAS Integration Plan and procedures
- Coordinate with NASA on all MOE, SN, FD, NISN, and NEN integration activities
- Co-chair the Ground Readiness Test Team
- Perform the majority of ground I&T activities through the FOT, element operators, and element developers
    - Develop plans and procedures for GNE, CAPE, and DPAS acceptance tests
    - Conduct GNE, CAPE, and DPAS acceptance testing prior to GS integration
    - Through the FOT and other ground system operators, develop GRT, MRT, and mission simulation procedures
    - Provide test conductors (element operators)
    - Perform tests

    - Perform necessary analysis of test results
    - Store DPAS and GNE test records
    - Write and manage test discrepancies as necessary
- Support Mission Readiness Testing and Mission Operations Simulation through the FOT
- Participate in the Mission I&T Working Group.

4.2.2 Mission I&T Team

NASA Mission Operations Mgr (MOM) – The MOM is responsible for the verification of performance requirements of the integrated ground system and space segment. The MOM determines the operational readiness of the ground system and the FOT. Additional MOM responsibilities include:

- Manage the Mission Operations Center and the activities conducted therein
- Development of the MRT Plan
- Approval of the MRT Procedures
- Conduct MRT TRRs
- Witness/verify MRTs
- Produce test reports
- Training and certification of the FOT
- Verification of the FOT product performance

NASA Mission Sim Mgr (MSM) – The NASA MSM is responsible for the development of the Mission Operations Simulation Plan and prepares and maintains all simulation configurations.

GD-AIS Observatory I&T Mgr – The Observatory I&T Mgr is responsible for the instrument to bus integration and the observatory integration and test. The Observatory I&T Mgr receives support from the Instrument vendor and oversight and coordination between the bus and instrument vendors is provided by the NASA Mission I&T Mgr. Additionally the Observatory I&T Mgr supports launch vehicle I&T and MRTs.

NASA Mission I&T Mgr – The Mission I&T Mgr is the overall I&T focal point for the mission and as such oversees instrument, spacecraft, observatory and ground system I&T activities and schedules. Additional Mission I&T Mgr. responsibilities include:

- Development of the LDCM Mission I&T Plan
- Participation in mission test TRRs
- Coordination of observatory resource availability to support tests with the ground system
- Chairperson of the I&T Working Group

NASA Mission Systems Mgr – The Mission Systems Mgr is responsible for the verification of mission requirements and determines LDCM Mission Readiness.

4.2.3 Ground System I&T Team

Ground System I&T roles and responsibilities are described in this section.

NASA Ground System Mgr. (GSM) – The Ground System Mgr (GSM) is responsible for the overall ground system development, integration, and testing. The GSM leads the development of the Ground System Integration and Test Plan, oversees MOC integration and is responsible for the MOC Integration Plan and procedures.

USGS Integration and Test Lead – The USGS Integration and Test (I&T) Lead is responsible for the overall ground system integration and test coordination of USGS elements. The USGS I&T Lead leads development of the DPAS Integration Plan and procedures.

NASA Ground Readiness Manager (GRM) – The Ground Readiness Manager (GRM) is responsible for the verification of the ground system functional requirements. This does NOT include ground system performance requirements, FOT product performance, or FOT readiness. The GRM develops the Ground System Integration and Test Plan, the Ground Readiness Test Plan and the Ground System Verification Requirements Matrix.

Together the NASA GRM and the USGS I&T Lead lead the Ground Readiness Test Team (GRTT) to develop and execute the Ground Readiness Tests (GRTs). Their joint responsibilities include:

- Co-chair the regular GRTT meetings
- Produce the GRT Procedure Outline
- Approve the GRT Procedures
- Oversee the preliminary interface and engineering tests
- Ensure element readiness for GRTs
- Conduct GRT TRRs
- Witness/verify GRTs
- Ensure PR/PFRs are captured and worked
- Support GS Discrepancy Review Board
- Produce test reports
- Develop management-level reporting material

Element Operators (FOT, GNE, DPAS Operators) – The element operators together with the element system engineers are responsible for developing the details of the GRT and Mission Readiness Tests (MRT) procedures and scripts, act as test conductors for the GRTs and MRTs and work off assigned PR/PFRs. These responsibilities are assumed beginning with GRTs.

4.3 Ground System Requirements Verification

4.3.1 Verification Requirements Matrix (VRM)

The GRM and the USGS Integration and Test Lead, with assistance from the Ground System Engineers and the GRTT, are responsible for developing and maintaining the Level 3 GSRD Verification Requirements Matrix (VRM) for tracking verification of all ground system requirements. The GS VRM includes both the verification plan and results (partial or full verification or verification failure). The GS VRM identifies the test(s) in which each requirement will be verified and the test method to be used to verify each requirement. The GS VRM will also include the verification status, verification comments, and links to supporting documentation.

Full and partial verification will be distinguished in the matrix. Requirements, which are retested due to fixes and/updates, will be re-verified and appropriately denoted in the matrix. Requirements, which undergo regression testing, will also be identified in the matrix.

The GS VRM will be updated before and after each test as necessary and a new version of the GS VRM will be generated following completion of each test. The GS VRM will be maintained in DOORS but will be exported from DOORS into an EXCEL spreadsheet and stored in DocuShare for publication and use during testing. Systems Engineering owns the GS VRM but the GRM and USGS Integration and Test Lead have primary responsibility for the development and maintenance of the GS VRM.

4.3.2 Interface Verification Matrix (IVM)

The USGS Integration Team is responsible for developing and maintaining the Level 4 GSIRD Interface Verification Matrix (IVM) for tracking verification of all interface requirements. The IVM can also be used as a tool during ground system and mission readiness testing to track the interfaces exercised and the data products exchanged during each test. A summary of this information can be used to support a declaration of mission readiness.

4.4 Discrepancy Management

This section briefly describes the discrepancy management approach for use by the LDCM Ground System. Discrepancy management refers to the processes used to document, prioritize, track, and close out anomalies that are detected in the Ground System. These anomalies may be detected during element development, element-level acceptance testing, ground system integration, ground system testing, mission readiness testing or operations activities.

At Level 4 and below, each element developer will manage its own discrepancies internally. However, NASA and USGS ground system management will need summary information including number of discrepancies found, number of priority 1 and severity 1 discrepancies and delivery impacts because of discrepancies. While no specific discrepancy management approach will be dictated for the elements, the approach must provide the ability to document, prioritize, status/update, track, and archive each detected anomaly.

During ground system integration, ground readiness testing and mission readiness testing, all discrepancies, regardless of requirement level, will be recorded and managed through the NASA GSFC Problem Report/Problem Failure Report (PR/PFR) System. The PR/PFR System requires problem information regarding the observation, investigation, resolution and assessment of the problem. Discrepancies will be assigned to elements for resolution by the Ground System Discrepancy Review Board (DRB).

4.4.1 Integration and GRT Phase

The Ground System DRB manages PR/PFRs written during the ground system integration and ground system testing as well as those PR/PFRs assigned to the ground system that are found during other tests supported by the ground system. The GS DRB will disposition all PR/PFRs, allocating the proper criticality based on the criticality of the associated functionality. The GS DRB is responsible for the evaluation and tracking of the individual system anomalies and associated repairs. Problems that are considered essential to supporting launch and early orbit activation will be categorized as "launch critical," and will thus receive the appropriate level of priority by the development team. The GS DRB will be chaired by the GSM, and will be made up of representatives from each of the Ground System elements and appropriate operations personnel. The GS DRB will assign each discrepancy to the appropriate element for analysis, resolution proposal, resolution and testing. The element developer will update the PR/PFRs at each phase of resolution as required by the GS DRB. The GS DRB will review PR/PFRs regularly. Only the GS DRB chairperson, or their designee, can close a PR/PFR following successful testing and concurrence from the originator of the PR/PFR. If the PR/PFR is assigned to the GS DRB by the LDCM DRB, the GS DRB chairperson will recommend closure to the LDCM DRB.

4.4.2 Mission Readiness Phase

The LDCM Discrepancy Review Board (DRB) manages all PR/PFRs discovered during mission readiness testing. The LDCM DRB will allocate appropriate criticality and will assign PR/PFRs to either the flight or ground system for resolution. Following resolution, the flight or ground system will recommend closure to the LDCM DRB. The LDCM DRB will be chaired by the NASA MOM and will be made up of representatives from all of the support segments. Discrepancies found during mission level testing can only be closed by the LDCM DRB chairperson, or their designee.

4.5 Configuration Management (CM)

All participating elements are expected to follow configuration management and mission assurance (MA) guidelines during the development and test phase as defined in their configuration management documentation. Participating elements will identify configuration items to be used in ground system testing. These configuration items will be included in individual test procedures and verified as part of the pre-test activities.

Detailed test plans will be controlled by the GS CCB in accordance with ground system configuration management documentation. Individual test procedures will be managed in DocuShare. Baselined versions of procedures will be placed in DocuShare following the TRR. The most current version of the test procedure will be accessed from DocuShare by participating elements on test day. Test data, results, and reports will also be stored in and accessible from DocuShare.

4.6 Mission Assurance

GSFC Code 300 (MA) will monitor test preparation, execution and reporting according to MA procedures. As a member of the GRTT, MA will review and comment on test procedures and reports. MA will witness tests and/or request access to review test artifacts. MA will also be a member of both the GS DRB and the LDCM DRB and will concur with the closure of PR/PFRs.

Appendix A Glossary

<u>Glossary Item</u>: Definition

Appendix B Acronyms

For information regarding the acronyms contained within this document please refer to LDCM-REF-006 Acronym List

Acronym	Description
bMOC	Back-up MOC
CAPE	Collection Activity Planning Element
CCB	Configuration Control Board
CCS	Constellation Coordination System
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CM	Configuration Management
CMD	Commands
CTE	Compatibility Test Equipment
CTV	Compatibility Test Van
CVT	Cal/Val Team
DAM	Data Acquisition Manager
DCRS	Data Collection and Routing System
DiTL	Day in The Life
DOORS	Dynamic Object Oriented Requirement System
DPAS	Data Processing and Archive System
DR	Discrepancy Report
DRB	Discrepancy Review Board
DTS	Development and Training Simulations
EROS	Earth Resources Observation and Science
ESMO	Earth Science Mission Operations
ETE	End to End
FDD	Facility Definition Document
FDF	Flight Dynamics Facility
FIA	Final Implementation Agreement
FOR	Flight Operations Review
FOT	Flight Operations Team
FQT	Formal Qualification Testing
GNE	Ground Network Element
GRM	Ground Readiness Manager
GRT	Ground Readiness Test
GRTT	Ground Readiness Test Team
GS	Ground System
GSFC	Goddard Space Flight Center
GSM	Ground System Manager
GSIRD	Ground System Interface Requirements Document
GSRD	Ground System Requirements Document
HW	Hardware
I&T	Integration and Test
IC	International Cooperator

ICD	Interface Control Document
ICT	Interface Connectivity Test
IO	Input Output
IP	Installation Plan
IVM	Interface Verification Matrix
JSpOC	Joint Space Operations Center
LDCM	Landsat Data Continuity Mission
LGN	LDCM Ground Network
LGS	Landsat Ground Station
LSIMSS	LDCM Scalable Integrated Multi-mission Support System
LSS	Launch Services Segment
LST	Landsat Science Team
LTA	Long Term Archive
MA	Mission Assurance
MOC	Mission Operations Control Center
MOE	Mission Operations Element
MOM	Mission Operations Manager
MOS	Mission Operations Simulation
MOR	Mission Operations Review
MRT	Mission Readiness Test
MSM	Mission Simulations Manager
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications Network
NCEP	National Centers for Environmental Prediction
NEN	Near Earth Network
NISN	NASA Integrated Services Network
NOAA	National Oceanic and Atmospheric Administration
NOM	Network Operations Manager
OIV	On-orbit Initialization and Verification
OLI	Operational Land Imager
OSS	Operations Support Simulations
PDR	Preliminary Design Review
PIA	Project Implementation Agreement
PFR	Problem Failure Report
PR	Problem Report
PSLA	Project Service Level Agreement
PSR	Pre Ship Review
QA	Quality Assurance
RF	Radio Frequency
SC	Spacecraft
SMRD	Science and Mission Requirements Document
SN	Space Network
SNAS	Space Network Access System
SOA	Service Oriented Architecture
SOS	Spacecraft/Observatory Simulator
SPITL	Scheduling Period In The Life

SRR	System Requirements Review
SS	Space Segment
STOL	
SW	Software
TDRSS	Tracking and Data Relay Satellite System
TLM	Telemetry
TRR	Test Readiness Review
TWITL	Total WRS-2 in the Life
UP	User Portal
USGS	United States Geological Survey
USNO	US Naval Observatory
USSTRATCOM	U.S. Strategic Command
UTC	Universal Time Code
VDD	Version Description Document
VRM	Verification Requirements Matrix
WAN	Wide Area Network
WSC	White Sands Complex
WSGT	White Sands Ground Terminal

References

LDCM Science and Mission Requirements Document (SMRD), GSFC 427-02-01, Revision B April 25, 2008

LDCM Operations Concept, GSFC 427-02-02, December 5, 2006

LDCM Ground System Requirements Document (GSRD), LDCM-REQ-001, Version 1.18, April 5, 2009

LDCM Ground System (GS) Verification Requirements Matrix (VRM)

LDCM GS Interface Requirements Document (GSIRD), LDCM-REQ-011, Version 1.1,March 4, 2009

LDCM GS Interface Verification Matrix (IVM)

LDCM Mission Integration and Test Plan, GSFC 427-10-01, December 18, 2008

LDCM Ground System Operations Concept, LDCM-OCD-002, Version 1.0, December 15, 2007

MOC Integration Plan, LDCM-ITP-002, Draft

DPAS Integration Plan, LDCM-ITP-001, Draft

Ground Readiness Test (GRT) Plan, LDCM-Test-002, Draft April 2009

RF Compatibility Test Plan

Mission Readiness Test (MRT) Plan

Mission Operations Simulation Test Plan

LDCM Project Service Level Agreement (PSLA), 451-PSLA-LDCM, Draft March 2009

NASA Gold Rules, NASA-GSFC-1000