Department of the Interior
U.S. Geological Survey

LANDSAT DATA CONTINUITY MISSION (LDCM) GROUND SYSTEM OPERATIONS CONCEPT DOCUMENT

Version 2.0

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Executive Summary

This Ground System Operations Concept Document addresses the Landsat Data Continuity Mission. It describes the Ground System characteristics and presents the operational concepts, functions and interactions.

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Section 1 Introduction

The Landsat Data Continuity Mission (LDCM) is a joint mission between the NASA and the USGS. The LDCM is a remote sensing satellite mission providing coverage of the Earth's land surfaces. This mission continues the 30+ years of global data collection and distribution provided by the Landsat series of satellites.

1.1 Background

The goal of the LDCM is continuing the collection, archive, and distribution of multi-spectral imagery affording global, synoptic and repetitive coverage of the Earth land surfaces at a scale where natural and human-induced changes can be detected, differentiated, characterized and monitored over time. The LDCM goal compliments and adheres to the Landsat programmatic goals stated in the United States Code, Title 15, Chapter 82 "Land Remote Sensing Policy" (derived from the Land Remote Sensing Policy Act of 1992). This policy requires the Landsat program provide data into the future which is sufficiently consistent with previous Landsat data allowing external/internal global land surface change detection and quantitative characterization. The LDCM was conceived as a follow-on mission to the highly successful Landsat mission series which have provided satellite coverage of the Earth continental surfaces since 1972. The data from the missions constitutes the longest continuous record of Earth surfaces as seen from space.

The LDCM ensured Landsat-like data will be provided to the USGS National Satellite Land Remote Sensing Data Archive for at least 5 years once the observatory is in operations.

1.2 Purpose & Scope

The primary purpose of the LDCM Ground System Operations Concept Document is to provide a description of the planned functions and operations of the systems, people, and processes that comprise the LDCM Ground System. The operations concept document presents a functional view of the LDCM Ground System and operations based on high level LDCM program guidance, and requirements.

The operations concept document scope includes all functions associated with the LDCM Ground System as well as the external entities that interact with the LDCM Ground System. The operations concept encompasses mission planning, observatory management, command transmission to the observatory, Ground System reception of observatory telemetry and image data; and data processing, archive, and distributing data for the Landsat data user community.

1.3 Document Organization

This document is organized as follows:

- Section 1 Identifies, describes the purpose, introduces the objectives
- Section 2 Provides a mission overview and describes external users and interfaces of the ground system

- Section 3 describes the operations of each of the ground system elements.
- Section 4 describes the ground system roles in all the mission phases.
- Section 5 Presents the high level LDCM Ground System Scenarios.
- Section 6 is an overview of the output products of the ground system.
- Appendix A defines the Acronyms used in this document

1.4 References

1.4.1 Applicable Documents

The applicable documents listed below form a portion of this document. The listed documents carry the same weight as if stated within the body of this document.

- Science and Mission Requirements Document (GSFC 427-02-01 Rev. B)

1.4.2 Reference Documents

The reference documents listed below are part of this document and serve as document content portions.

- LDCM Operations Concept Document (GSFC 427-02-02 Rev. A)
- Ground System Requirements Document (DCN LDCM-REQ-001)
- USGS LDCM Ground System Interface Requirements Document (DCN LDCM-REQ-11)
- GDAIS LDCM Space to Ground Interface Control Document (DCN 70-P58230P)
- LDCM Government Calibration and Validation Plan (DCN GSFC 427-04-02)

Section 2 LDCM Mission Overview

2.1 LDCM Mission Objectives

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 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.

- Distribute LDCM data products to the general public on a nondiscriminatory basis and at a price no greater than the incremental cost of fulfilling a user request.

2.2 LDCM System Description

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 2-1 depicts the LDCM operational concept.

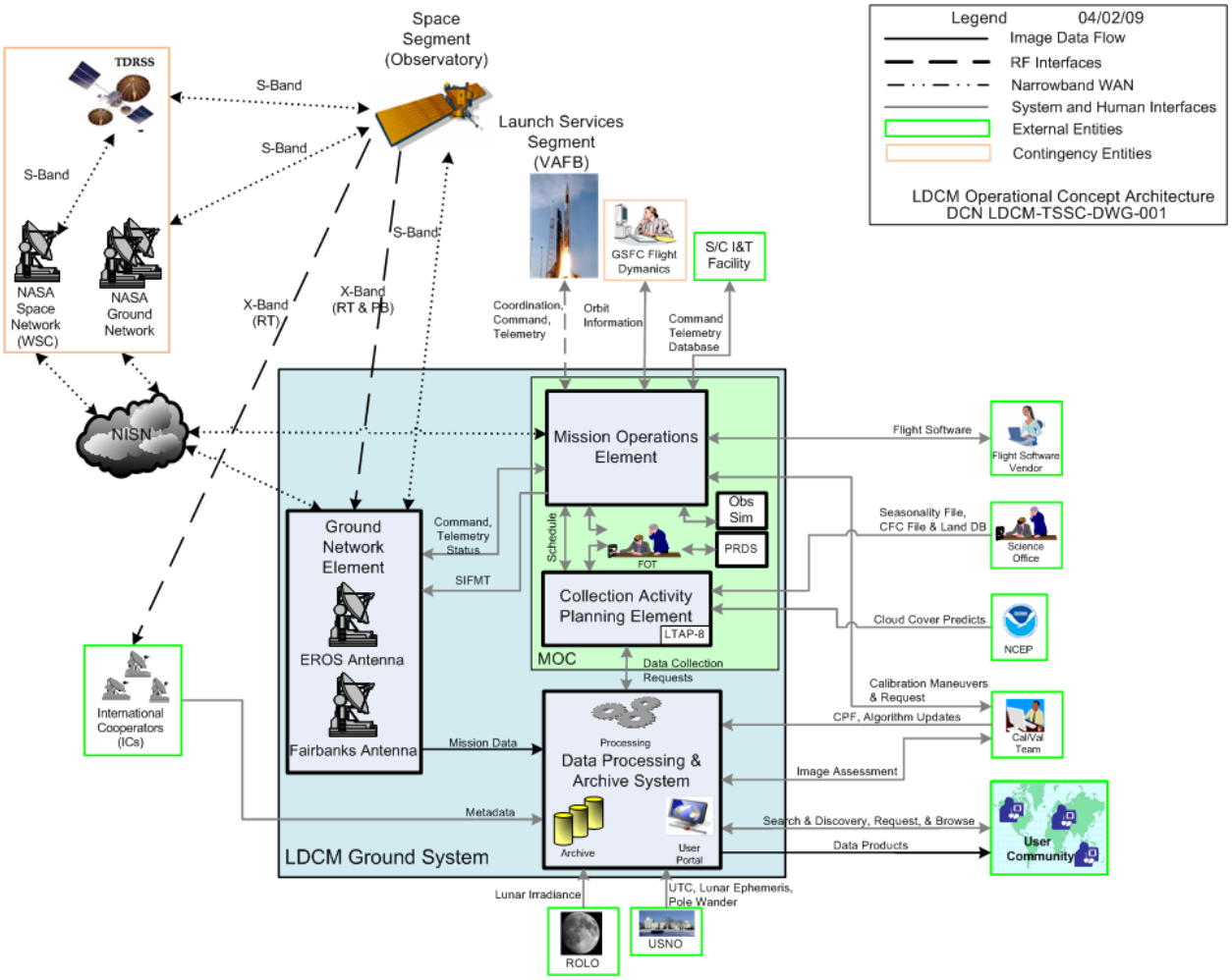

Figure 2-1 – LDCM Operations Concept

2.2.1 Science Mission Overview

The primary science objective of the LDCM mission is to conduct a global acquisition of land image data in continuity with the Landsat satellite series. In order to achieve this objective, a database housed within the Collection Activity Planning Element (CAPE), referred to as the Long-Term Acquisition Plan -8 (LTAP-8), serves as the primary input to the Master Integrated Schedule generated by the Mission Operations Element (MOE). Specifically, the LTAP-8 expresses the collective global mapping requirements that provide the primary input for establishing a continuous, scientific long-term archive.

In addition to the LTAP-8, CAPE gathers other eligible data collection requests from the user community, International Cooperators, and internal project sources along with cloud cover predictions each day to produce a de-conflicted science data acquisition schedule. Once complete, CAPE passes this schedule to MOE. The MOE then produces the Master Integrated Schedule, which includes spacecraft events or other special events. Once this schedule is set, the schedule command load is generated and sent to the Observatory during the next available Ground Network Element (GNE)

contact. The schedule command load contains up to 72 hours of events; however, is transmitted to the spacecraft once every 24 hours.

The Observatory executes the scheduled acquisitions through simultaneous image operations of the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). Operations of this instrument suite provides medium resolution (circa 30 m spatial resolution), multi-spectral image data affording seasonal coverage of the global land surface. The science mission is designed to perform for a period of no less than five years following commissioning of the LDCM System.

As scheduled, the Observatory will execute up to two off-nadir imaging sequences per day to collect image data up to 15 degrees left or right of the orbit plane in lieu of imaging the nadir World Reference System 2 (WRS-2) path. This capability affords rapid acquisition of priority image sequences at up to one path offset and allows for productive imaging while nadir pointing is the ocean surface or to fulfill high priority imaging requests.

Calibration and validation of the OLI and TIRS instruments is a key component of science mission operations. Key calibration events will include lunar and solar calibration. Both of these events offer a known source for on-orbit absolute radiance. In the case of lunar calibration, imaging operations will occur once every 28 days. In the case of solar calibration, imaging operations will occur once every 16 days. Specifics of how these calibration maneuvers will be executed depend greatly on the instrument and spacecraft bus designs. In support of TIRS, other calibration events, will be required every orbit.

Image data is collected on the spacecraft's Solid State Recorder (SSR) and transmitted to GNE in real-time or playback. Image data is transferred via a high speed wide area network to the DPAS located at USGS EROS Center for ingest, processing, archive, and distribution.

All viable (sufficiently low cloud cover) image data will be processed to L1 and made web enabled for the science and user community. Routine image data acquired will be available for distribution within 12 days of acquisition by the Observatory.

2.2.2 Scenes, Intervals, Files and Interval Types

Users interact with the ground system by ordering data in terms of WRS-2 scenes. This is a fixed, artificial grid by which data can be located in terms of a path and row location. The WRS-2 grid has a 57,784 unique scene locations covering the entire 16 day repeat cycle of the orbit. Ordering of products within DPAS is done in terms of scenes, and planning and scheduling within CAPE is done in terms of scenes.

The observatory and instruments do not image scenes, they record a duration of data called an interval. An interval is a continuous recording of data from one combination of instruments. The MOE schedules observatory operations as intervals, sufficient to provide the data necessary to later produce the appropriate scenes. The observatory

records data in a file-based manner, and imposes a maximum file size of 1 GB. One interval is composed of some number of files of OLI data and some number of files of TIRS data.

To facilitate scheduling and processing, intervals are assigned a collection type. The collection type is a classification based on a combination of the manner in which the data were recorded and the intended ground processing. The table below defines the collection types for LDCM. The primary mission dataset is “I”, for the 400 scenes per day of “Earth imaging”. The remaining collection types fall into the broad categories of calibration data or diagnostic data.

Table 1 – Collection Types

ID	Name	Instruments	#/Month	Originator
I	Earth imaging	OLI, TIRS	1,736 avg	CAPE
S	OLI Shutter	OLI	900	MOE
B	TIRS Normal Calibration	TIRS	1350 max	MOE
U	Lunar calibration	OLI, TIRS	14	MOE
L	OLI Lamp calibration	OLI	31	MOE
O	OLI Solar calibration	OLI	4	MOE
E	OLI test patterns	OLI	Not routine	MOE
Q	TIRS test patterns (TBC)	TIRS	Not routine	MOE
Y	Earth calibrations	OLI, TIRS	1	MOE
T	Stellar	OLI, TIRS	Commissioning	MOE
X	Block address data	N/A	Not routine	MOE
Z	OLI Solar integration time sweep	OLI	120	MOE
H	OLI Shutter integration time sweep	OLI	120	MOE
G	TIRS Linearity Calibration 1	TIRS	1	MOE
A	TIRS Linearity Calibration 2	TIRS	1	MOE
P	SSR PN I&T test sequence	N/A	I&T only	MOE

The instrument calibration approach for both OLI and TIRS requires that a calibration interval be acquired before and after any group of Earth Imaging intervals. For OLI and TIRS there are different maximum times between the two calibration intervals. The essence is that every descending orbit with Earth Imaging will require some calibration intervals to be collected before and after the imaging intervals. The DPAS has to ingest these calibration intervals first, before the imaging intervals can be processed.

2.2.3 Space Segment

The Space Segment consists of the observatory and pre-launch Ground Support Equipment (GSE). The observatory is comprised of the two instruments and the spacecraft platform. The observatory will operate in a 704 Km orbit with a 16-day repeat cycle and a 10:00 a.m. (+/- 15 minutes) mean local time for the descending node. Image data and ancillary data (combined as mission data) will be collected, stored onboard

and subsequently downlink to ground stations within GNE via an X-band communications link. This link utilizing separate virtual channels includes stored state of health, real time and playback mission data to GNE and real time mission data downlinked alone to International Cooperators equipped to receive this data. The observatory will also receive and execute commands and transmit real-time and stored housekeeping telemetry to GNE via the S-band link. The GSE provides the functionality to perform ground-based integration and testing of the observatory prior to launch.

2.2.4 Ground System

The Ground System includes CAPE, MOE, GNE, and the Data Processing and Archive System (DPAS). The CAPE defines the set of scenes per WRS-2 to be collected by the observatory on a daily basis. The MOE plans and schedules observatory activities, commands and controls the observatory, and monitors the observatory and ground operating systems health and status. The MOE hardware and software systems reside in the LDCM Mission Operations Center (MOC). There is a geographically separated backup MOE (bMOE) which resides in a backup MOC (bMOC). The GNE includes the ground stations located at Sioux Falls, SD and Fairbanks, AK, for S and X band RF communications, and the hardware and software systems that communicate the Command and Telemetry data with MOE and the mission data with DPAS. DPAS functions include LDCM mission data ingest, processing, archival and distribution. Ingest and processing include assessing quality based on characterization and calibration updates. DPAS provides the capability to discover, receive and fulfill user requests for LDCM image collections and data products distribution. The DPAS will be located at the USGS Earth Resources Observation and Science (EROS) Center in Sioux Falls, SD.

2.2.4.1 Collection Activity Planning Element

The CAPE generates the high level instrument image collection schedules. The bulk of the imaging is done to satisfy the requirements established in the LTAP-8. The LTAP-8 requirements are interleaved with special requests to support Cal/Val activities, user community requests, and International Cooperator data requests. The policies governing data collection scheduling are implemented in CAPE.

The CAPE encompasses four basic functions or subsystems: planning and scheduling, request management, resource management, and reporting.

2.2.4.2 Mission Operations Element

The Mission Operations Element (MOE) is a portion of the Ground System which provides the primary means to control and monitor the spacecraft. The MOE is required to accomplish mission planning and scheduling, command and control, health and status monitoring, performance analysis, and flight and ground software maintenance. The MOE is also used to detect, investigate, and resolve spacecraft anomalies. The software, procedures, and scheduling will reside at the Mission Operations Center (MOC) facility. For contingency purposes, bMOE operations will reside at a bMOC facility, located at a geographically separate MOC location. The MOC is staffed by a Flight Operations Team (FOT).

The MOE consists of four primary functions:

- Command and Control.
- Bus Planning and Scheduling.
- Trending & Analysis.
- Flight Dynamics/Orbit Determination.

The MOE will perform the planning and scheduling of all ground system resources and spacecraft contact activities. The MOE will build and send the flight software command loads to implement spacecraft flight software updates. Data exchanged with MOE may include telemetry, commands and control, plans and scheduling, trending and analysis, summaries, logs, and additional associated interactions.

2.2.4.3 Ground Network Element

GNE provides the ground stations used for S-Band housekeeping telemetry and command communications with and X-Band data reception from the observatory. The GNE also provides data caching and transfer from the ground stations to DPAS.

GNE primary functions consist of:

- Wideband and Narrowband Communications.
- Data Capture.
- Data Routing and Collection.

2.2.4.4 Data Processing and Archiving System (DPAS)

DPAS provides the archive which holds and maintains all LDCM data. DPAS contains functionality to process mission data to produce output products, and provides an interface for users to search for and access data products. DPAS also contains functionality used for calibration and validation of LDCM data and data products.

2.2.5 LDCM Ground System Geographic Description

The LDCM Ground System is made up of physical components from DPAS, GNE, CAPE and MOE. The primary components are DPAS itself, Off-site Archive, MOC and bMOC, and GNE stations depicted in Figure 2-2. The DPAS and one GNE station are located in Sioux Falls, SD. The other GNE station is located outside Fairbanks, AK. The primary MOC housing MOE and CAPE is located in Greenbelt, MD. The observatory I&T facility is located in Gilbert, AZ. The launch site is located in Lompoc, CA. The offsite archive is located in Kansas City, MO.

Figure 2-2 – LDCM Ground System Physical locations

2.2.6 Launch Segment

The Launch Segment provides those assets and services associated with the Launch Vehicle (LV) and the observatory integration. Included, along with the launch vehicle are the vehicle ground support equipments (including hardware and software), property and facilities to integrate the observatory to the LV, verify their interfaces and conduct pre-launch testing. All launch facilities are located in Lompoc, CA, as part of the Vandenberg Air Force Base infrastructure.

2.3 LDCM Ground System External Interfaces

Figure 2-1 includes all the external interfaces of the Ground System. These interfaces are further explained in the following sections.

2.3.1 LDCM Observatory

The Ground System interfaces with the LDCM Observatory directly through GNE stations, and indirectly via the external Space Network and Near Earth Network networks and various pre-launch interfaces. Refer to section 2.2.3 for a description of the Observatory.

2.3.2 NASA Ground Network

The LDCM Ground System will interface with the NASA Near Earth Network (NEN). The interface will be used for S-band communications during the LDCM observatory launch and early orbit and potentially for emergencies, critical maneuvers, and anomaly resolution following commissioning. The LDCM Ground System will be compatible with the following NEN stations:

- Norway – SGS.
- Wallops, Virginia – WGS 11.3m.
- McMurdo, Antarctica – MGS.
- Poker Flat, Alaska – AGS.

The LDCM Flight Operations Team (FOT) will schedule NEN resources through the White Sands Complex (WSC) scheduling system called the Wallops Orbital Tracking Information System (WOTIS). The NEN stations will receive S-band communications from the observatory and route them to MOE.

2.3.3 NASA Space Network

The LDCM Ground System will interface with the NASA SN Tracking Data Relay Satellite System (TDRSS). The interface will be used for S-band communications during the LDCM observatory launch and early orbit and potentially for emergencies, critical maneuvers, and anomaly resolution following commissioning. The LDCM MOC and MOE will interface with the SN through the SN White Sands Complex (WSC) in Las Cruces, New Mexico. The WSC will perform S-band communications directly with the SN satellites. Link service requests and real-time messaging will be transferred between the WSC and MOE. The SN capabilities scheduling will be performed through the SN scheduling tools resident in the MOC, through a web-based Space Network Access System (SNAS) interface.

2.3.4 Flight Software Maintainers

Observatory flight software modifications or updates will be performed by the spacecraft and instrument development contractors/organizations. For the spacecraft, flight software updates are done by General Dynamics Advanced Information Systems, in Gilbert, AZ. For the OLI, the maintainer is Ball Aerospace, located in Boulder, CO. For the TIRS, any flight software updates would come from the GSFC TIRS project office. Flight software modifications/updates will be provided to MOE for observatory upload. All flight software update command loads will be first tested on the observatory simulator prior to flight observatory upload. The MOE will maintain observatory flight software version control.

2.3.5 NASA Flight Dynamics Facility

The NASA Goddard Space Flight Center (GFSC) maintains a Flight Dynamics Facility (FDF) which provides attitude and orbit determination, prediction, and control services. This capability is completely independent from the FD capabilities of MOE. The LDCM will utilize FDF services during early orbit and for anomaly resolution activities.

2.3.6 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.

2.3.7 Observatory at Integration and Test Facility

The completed LDCM spacecraft is brought to the Integration and Test Facility at GDAIS. Here, the instruments are integrated onto the bus to complete the Observatory. During the integration period, various Integration and Test activities are performed between MOE and the Observatory. The tests are conducted both with MOE components deployed locally (known as the "mini-MOE") and through network links between the MOC and I&T facility.

2.3.8 Observatory at Launch Site

The Observatory undergoes final testing during and after integration with the Launch Vehicle. The testing may be done either with a portable telemetry and command MOE component or through network links. In addition, an Observatory telemetry feed mated to the Launch Vehicle is provided by a MOC network link.

2.3.9 International Cooperators

The USGS maintains agreements with several foreign governments referred to as the LDCM International Cooperators. The ICs are a special user community subset that has the ability to receive LDCM data from the observatory real-time downlink stream. Real-time imaging sensor and ancillary data (including spacecraft and calibration data) necessary for processing are contained in the real-time stream and received by IC ground stations depicted in Figure 2-4. 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 the respective Landsat agreement, funding conditions, observatory constraints, or the technical capabilities of the IC ground station.

Figure 2-3 – Landsat International Cooperators

The ICs will be capable of receiving real-time X-band imaging sensor data downlinks, and sending metadata to DPAS. The ICs will submit imaging sensor data collection and downlinks requests to CAPE (via DPAS user portal). ICs participate in a bilateral Data Validation & Exchange (DV&E) program with the USGS EROS Center. This program includes exchange of exchange of archive data upon request, and validation of internationally processed L1T products. Refer to the International Cooperator scenario in section 5 for more information.

2.3.10 Auxiliary Data Sources

There are several sources where auxiliary data useful for various ground system functions are obtained. These are not primary external interfaces, but mentioned for completeness.

2.3.10.1 National Centers for Environmental Prediction

The CAPE obtains global climate forecast data relevant to cloud cover forecasting from the National Centers for Environmental Prediction (NCEP). These data are retrieved by CAPE from a public Internet repository.

2.3.10.2 Robotics Lunar Observatory

The Robotics Lunar Observatory (ROLO) is a project which combines detailed models with measured data to provide lunar irradiance information. As part of the analysis of lunar calibration data, the calibration functionality within DPAS sends a specific date and time and specific observatory position to ROLO, and receives back integrated per-band spectral irradiance estimates.

2.3.10.3 Naval Observatory

The DPAS retrieves detailed Earth motion data from the US Naval Observatory as input to the algorithms required to convert spacecraft time to Coordinated Universal Time (UTC). These data are retrieved from a public Internet repository.

2.4 User Community

Users encompass all members of the general public who use LDCM data for purposes ranging from scientific research to operational resource management. Users interface to DPAS to search for, browse, order, and receive LDCM data products and request image collections. Beyond this, users have been classified into the two user types detailed below.

2.4.1 General User

The General User, is primarily concerned with fast access to existing data. The General User relies heavily upon graphical selections. In addition, the General User is less concerned with scientific data accuracy as with ease of use. The FRB metadata information has been developed to support this user type.

There is an LDCM Science Team who are members of the General User community. The Science Team also acts as representatives of the user community during the ground system development process. The Science Team recommends strategies for the effective use of Landsat sensor archived data and investigates the future sensor requirements which meet Landsat user needs, including policy maker needs at all governmental levels.

The Science Team combines USGS leadership, USGS and NASA scientists, and an external scientist and satellite data applications specialist group. The members serve in their advisory capacity through the (next Landsat-type) satellite development and launch and through the first year of data collection.

2.4.2 Authorized Users

An authorized user is one with extra permissions. Very few users fall into this category. Internal users such as Cal/Val team members and science team members typically fall into this category. The EROS Emergency Response group will include one or more Authorized Users. Specific representatives within each International Cooperator are granted Authorized User status for the purpose of submitting acquisition requests for their respective IC stations.

Section 3 Ground System Operations

3.1 MOC Operations

3.1.1 Flight Operations Team

The Flight Operations Team (FOT) uses MOE and CAPE systems to operate the LDCM Observatory from the Mission Operations Center. The FOT contractor will propose the exact FOT makeup. During launch and early orbit operations, NASA will supply the LDCM Mission Operations Manager (MOM). The USGS is providing a Flight Systems Manager (FSM) for the mission life. The FOT typically includes people in the following functional areas:

- Mission Operations Manager
- Subsystem Engineers
- Mission Planners (MOE and CAPE)
- Spacecraft Controllers
- Analysts

3.1.2 Data Acquisition Manager

The Data Acquisition Manager (DAM) oversees the image data collection activities. All authorized user collection requests are routed to the DAM for approval. The DAM approves special requests and makes priority conflict arbitration decisions. Once approved the request is added to CAPE software for scheduling. The DAM has the ability to adjust collection request priorities, adjust user priority ranges, and approve/disapprove special, IC and internal image data collection requests.

The DAM also approves any changes to Seasonality Records made prior to ingest and storage by CAPE software. Seasonality File changes are ingested into CAPE database and affect all collection activities. Only the DAM role will be given the authority to approve/disapprove changes to Seasonality Records.

3.1.3 Activities

The operational goal is for MOC operations to become automated. There will be a gradual transition from fully manual to automated mode. The MOC will eventually be staffed by the Flight Operations Team (FOT) on an 8x5 shift. During launch, early orbit, commissioning, and early operations, the MOC will have additional FOT staffing and engineering support as necessary.

Examples of FOT activities include:

- Mission activity planning and scheduling
- Payload management
- Ground Network (NEN) and Space Network (SN) scheduling
- Real-time commanding

- Telemetry monitoring
- Spacecraft and instrument Flight Software (FSW) loads
- MOC maintenance

Examples of automated MOC activities include:

- Routine pass execution
- Routine command loads
- Priority scheduling and off-nadir
- Telemetry monitoring
- Trending
- Routine Flight Dynamics product generation
- Scheduling ground station contacts
- CCSDS File Delivery Protocol (CFDP) file accounting
- Event logging
- Automated personnel notification

Non-routine MOC activities include:

- Orbit maintenance maneuvers
- Calibration slew and activities
- Spacecraft and instrument Flight Software maintenance
- Short-notice priority acquisition scheduling (sometimes as off-nadir)
- Anomaly resolution

3.2 Ground Network Operations

3.2.1 GNE Operators

The GNE operators oversee the day-to-day LDCM Ground Network (LGN) operations. The GNE operators consist of the local staff at each ground station within GNE. There are no central GNE operators other than the ground station staff. The station operations staff monitor operations, configure automation procedures, and intervene when problems occur. The nature of these tasks varies at each ground station.

3.2.2 Activities

The GNE network supports contacts with the observatory as scheduled by MOE and defined by the station locations and observatory orbit. Each contact consists of an X-band downlink for image data and stored housekeeping telemetry, and S-band telemetry downlink and command uplink.

The GNE systems route mission data files from the ground stations to a central cache located at the USGS EROS Center. The GNE systems then verify and assemble the mission data files into complete intervals based on the MOE definitions. The interval is

then provided to DPAS for archival and product processing. After successful transfer the interval is saved for a period of time in a rolling cache.

The GNE operators perform multiple activities during the course of a pass event. These activities occur in the following three phases: pre-pass, pass, and post-pass operations. The pre-pass operations are simply verifying the resources are scheduled and properly configured for the pass. The pass operations include communicating with the MOC, monitoring the housekeeping telemetry, and mission data. The post-pass operations include setting the equipment to the configuration prior to pre-pass, and verifying the post-pass reports are sent.

The GNE operators at the station located at EROS also interact with the local data collection and routing function which sends data to DPAS. If required, the GNE operators monitor logs, research anomalies, and manage the GNE cache.

3.3 Data Processing and Archive System Operations

3.3.1 DPAS Operators

The DPAS operational personnel oversee the day-to-day DPAS operations by monitoring the system and performing intervention when necessary. An operator performs several key tasks:

- Starting, stopping, and tuning of the system components.
- Monitoring status indicators for anomalous system behavior.
- Alerting key mission personnel in the event of anomaly detection.
- Supporting product media reading/writing operations
- Media receipt/dissemination for IC exchange

3.3.2 Data Quality Analyst

The Data Quality Analyst (DQA) is a point of contact internal to DPAS who interacts with ICs for data validation and exchange operations. They coordinate and facilitate the data validation process, and operational exchange of data to and from IC stations.

3.3.3 User Services

The User Services area will provide satellite data product customer services. This includes providing technical data assistance, responding to inquiries, researching issues, tracking customer feedback and complaints, supporting business partners, and assisting project and software engineers with new product options and processes.

3.3.4 Activities

The DPAS is semi-automated, and staffed 10 hours a day, 6 days a week.

Examples of automated DPAS operations include:

- Mission data ingest and processing to L0
- L0Rp and L1 product generation
- Archival of mission data
- Generation of browse data and population of the inventory
- Generation of select interval gain and bias parameters during processing
- Providing search and order interfaces online
- Providing for online data distribution
- Providing online data acquisition request functionality for Authorized Users
- User registration

Examples of manual DPAS operations include:

- Initiating reprocessing of L0
- Error and anomaly investigation and resolution
- Data management functions
- Data exchange with offsite archive
- Data Validation and Exchange with IC partners
- Assigning user roles

3.4 Calibration Operations

3.4.1 Calibration/Validation Team

The Calibration/Validation team (CVT) consists of discipline scientists and engineers who perform LDCM instrument and product characterizations and calibrations. The CVT also provides the algorithms for Level 1 data processing. The CVT is geographically dispersed and includes members from both NASA and the USGS. While the team will advise the Instrument Developers during instrument calibration, they will remain independent from the Instrument Developers concerning calibration assessments throughout the mission life. NASA leads the team during observatory development through on-orbit acceptance. Following on-orbit acceptance, the team is led by the USGS. The CVT works with the LDCM Science Team members regarding various calibration and validation issues and special LDCM data collections. For more detail refer to the LDCM Government Calibration and Validation Plan, DCN GSFC 427-04-02.

3.4.2 Description

The types of calibration activities the CVT and DPAS performs includes:

- Calibration parameter generation & validation
- Instrument performance characterization
- Product quality characterization
- Support anomaly resolution
- Algorithm development and refinement

- IC data product validation

Section 4Ground System Phases

Operations within LDCM are broken up into 5 distinct phases. Pre-Launch covers all activities from early development up to the final moments of launch readiness. Launch and Early Orbit covers the launch itself through the separation of the observatory from the Launch Vehicle. Commissioning describes the period of time from Separation through the declaration of Initial Operations Capability (IOC). Operations covers the entire period from IOC forward until the last phase. Decommissioning is the phase of operations required to assure the safe de-orbit of the observatory and decommissioning of various ground operations after that step. The Ground System arguably has a 6th phase which could be called Long Term Archive Maintenance, as the archive of LDCM data must be maintained and made available forever. (This can be viewed as an extension of the end-state of Decommissioning for all time.)

4.1 Pre-Launch

In the pre-launch phase, the LDCM spacecraft and imaging sensor will be designed, developed, and qualified. The LDCM Cal/Val Team (CVT) will participate in imaging sensor testing by performing independent characterization of the radiometric sources used to characterize the instruments. The CVT will also review imaging sensor calibration/characterization data generated by the design teams. The Ground system will be integrated and tested, and then integrated with the other segments for final mission integration and testing.

As of this writing, the instrument teams are already generating test and engineering data from early instrument development activities. These data are archived by the ground system. Various data types come from each instrument team and are archived. These data are made available to the distributed CVT located primarily at EROS and GSFC. All data are put on a small cache (as opposed to tapes on a shelf) and cataloged using a very simple set of metadata to enable a manual search capability. The data volume is on the order of 50 to 100 TB, which is only a rough estimate. There are no explicit performance requirements for data transfer performances into or out of this archive, and the archive is manually maintained. There are no automated operations associated with the archival and distribution of pre-launch test data.

The CVT employs a number of analysis packages, configuration scripts for COTS analysis packages, and custom-developed analysis tools and programs. These are collectively referred to as the CalVal ToolKit (CVTK). The CVTK is completely non-automated, and maintained at two central analysis lab locations, one at GSFC and one at EROS. The CVTK is being operationally used in a sense for evaluation of pre-launch test data and algorithms provided by instrument teams, and is configuration managed. Refer to the Government Calibration Plan for more specifics regarding the CVTK and CVTK management and operations.

This operations concept is not an integration plan, please refer to the LDCM GS Integration and Test Plan (GSFC DCN LDCM-TEST-001) for integration and test topics not mentioned in this document. The Ground System Integrated Master Schedule

drives the milestones by which various components of the Ground System are integrated tested and are ready for operations.

4.2 Launch & Early Orbit

The Launch & Early Orbit phase covers the final portion of the launch countdown, the launch, ascent, and separation of the observatory from the Launch Vehicle. The NEN stations may or may not (TBD) be in view during this brief phase, but they will be online, connected to the MOC and ready for the first in-view opportunity. The SN system will also be active and ready to establish a communications link as soon as possible. The Launch Vehicle and observatory operations throughout this phase are autonomous, so ground system operations consist only of watching the SN connection waiting for the observatory connection to be established, and the first real-time housekeeping telemetry to start flowing.

4.3 Commissioning

Commissioning phase starts with successful separation of the observatory from the Launch Vehicle. The FOT at the MOC oversees the deployment of observatory mechanisms and activation of subsystems starting with core functions and finally activation of the two instruments. These operations all use the operational MOE and GNE functionality as described in section 5. The main operational difference is that there is strong engineering support from the observatory and instrument providers onsite at the MOC. This extra support necessitates the existence of a special engineering support area with extra workstations to access MOE offline engineering analysis capabilities.

As part of the instrument commissioning activities, the ground system provides data from each instrument to the respective instrument teams, and the CVT. Data transfer will be through online access though secure password protected interface. This may be a similar interface to that used by IC stations to access special datasets.

Instrument teams will be provided with activity schedules or scene-based data acquisition schedules from MOE, through manual delivery coordinated by the FOT. Data requests will be manually coordinated with each instrument team both for scheduling acquisitions as well as ordering data from DPAS. When datasets are staged for instrument team access, notifications are coordinated offline manually by DPAS operations.

The CVT located at EROS and GSFC will be making use of the CVTK to evaluate data from both instruments as part of the checkout process. These procedures are similar to those described in section 5.

Towards the end of commissioning the observatory operations will be ramped up to the fully operational rate of 400 scenes per day. This may continue for several 16 day cycles, depending on the progress of commissioning. By this time the ground system will have fully transitioned to the same operations described in the Operations phase and section 5.

During this final commissioning period, the IC interfaces will all be exercised, including scheduling and sending mission data from the observatory to at least one IC station. This process is necessary to verify both observatory and Ground System requirements related to ICs.

4.4 Operations

The operations phase activities are fully described in Section 5 – Scenarios.

4.5 Decommissioning

Decommissioning nominally begins 5 years after Operations commences, but really does not occur until the observatory probability of failure reaches a level where de-orbiting must be performed as prescribed by law. The MOE functions are used to plan and execute a series of maneuvers to lower the orbit in a controlled manner to minimize orbital debris and ensure the early re-entry of the observatory.

After the final decommissioning activities with the observatory, all MOE and CAPE databases, documentation, and related data are brought over to DPAS for permanent archival. The CAPE, MOE, MOC and GNE are all decommissioned and removed from LDCM operations. The DPAS archive continues operations forever, as prescribed by law. All LDCM data are maintained and user access continues to be provided.

Section 5 Scenarios

5.1 Scenario Overview

Each scenario presented here describes the operations that take place to complete the scenario. The following list describes the scenarios and their scope for reference.

Collection Scheduling
Scheduling of Earth imaging intervals, including submission of requests, CAPE scheduling, MOE scheduling and command generation, and command uplink to the observatory through GNE.

Data Acquisition
Transfer of mission data from the observatory to GNE, file management feedback to MOE, MOE file management commanding and delivery of a complete interval to DPAS.

Data Ingest and Product Generation
Ingest of intervals, shutter interval dependence, archival of data, generation of L0 and L1 products, generation of metadata, browse, quality band, inline calibration data extraction and delivery of data to a product cache.

User Access and Data Management
Data search, product download, on-demand production request, documentation access, bulk metadata.

Cal/Val Operations
Processing and analysis of calibration interval types, calibration parameter generation and validation and product validation.

International Cooperators
All IC interactions with the ground system.

Observatory Management and Operations
Monitoring observatory health and safety, flight dynamics, network management.

Mission Management Reporting
Collection of metrics and reporting.

Continuity of Operations
Providing continued ground system operation in the event of major failures or catastrophe.

Priority Acquisition and Expedited Product Generation
Short notice acquisition scheduling, priority downlink to the ground, expedited processing of interval data.

5.1.1 Conventions

Note that in each scenario, the Priority 3 interfaces are shown in *blue italic font* in the diagram. The Priority 1 & 2 functionality is described in black line/text color. Statements within the scenario which are Priority 3 capability use a *blue italic font* instead of black.

Priority 3 requirements are not delivered and verified until several months after launch. The exact schedule is element specific, and may be before or after IOC. Thus, the black text in each scenario shows how that scenario will function early in commissioning, while the black text and *blue italic font* together show how the system will work after all the Priority 3 enhancements have been delivered. The graphical conventions are illustrated in the following diagram.

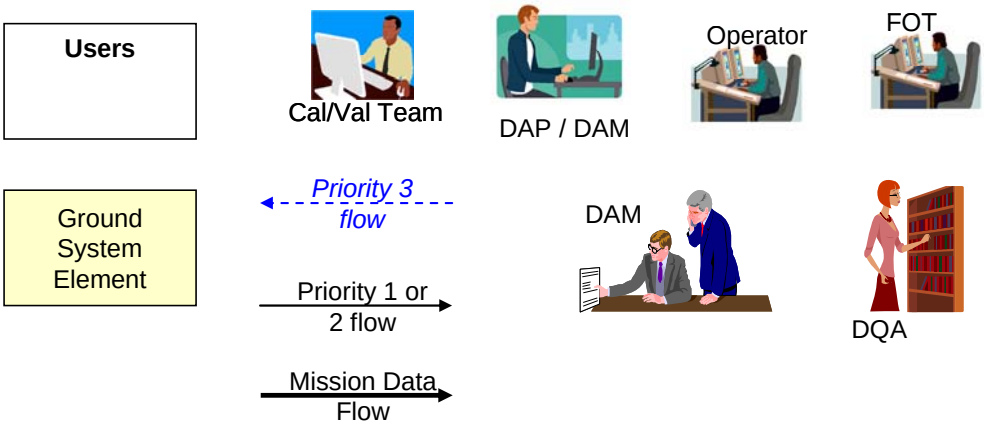

Figure 5-1 – Scenario Diagram Drawing Conventions

5.2 Collection Scheduling

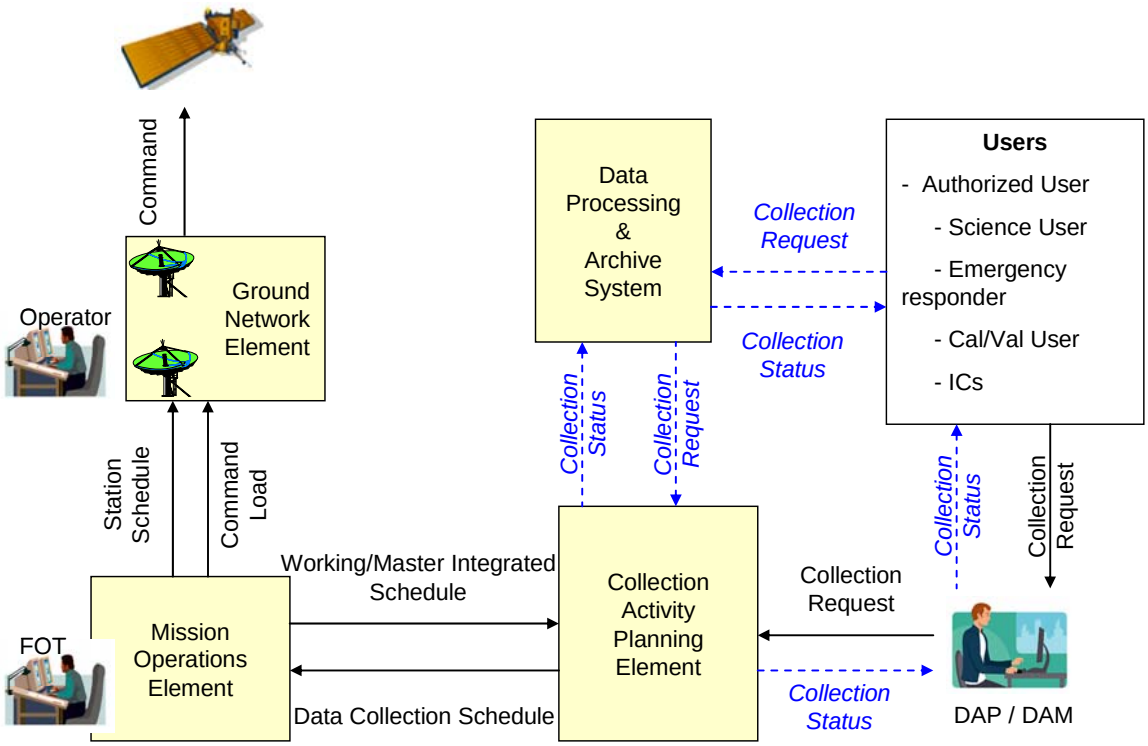

Figure 5-2 – Scenario Diagram – Collection Scheduling

Collection scheduling is primarily driven by the science requirements to build a global seasonally refreshed archive (defined by the LTAP-8) and International Cooperator data requests. *Special requests can be submitted by authorized users only through an interface provided by DPAS on the Internet. Each IC partner submits requests through the DPAS interface. All these requests are passed to CAPE for management.* It is also possible for users to directly contact the DAM (and subsequently, DAP) to submit a collection request. The DAM plays a key role in approving all the non-LTAP requests.

The LTAP-8 requirements are embodied in algorithms and databases internal to CAPE. Part of these algorithms include obtaining current LDCM archive coverage from DPAS, and obtaining global predicted cloud cover forecasts from the National Centers for Environmental Prediction. The MOE flight dynamics capabilities are used to generate input products necessary for planning and passed to CAPE. The MOE scheduler sends the three day working schedule to CAPE. The DAP uses CAPE functionality to generate a data collection schedule based on all these input factors. This image data collection schedule is then sent back to MOE from CAPE.

The MOE converts the image data collection schedule into a set of observatory operations which affect the data collection. This schedule is evaluated for various constraints and for consistency with other observatory and ground activities, and an updated working schedule is passed back to CAPE. In some cases CAPE may adjust the image data collection schedule and repeat this process, but the operational goal is to reduce or eliminate the need to iterate back and forth between CAPE and MOE. The

active master integrated schedule is converted into the appropriate stored command load.

The MOE schedules all the communications activities of the observatory. This includes scheduling of IC direct downlinks (refer to section 5.7). The MOE also schedules all GNE contacts. This planning is done on a 4 week window, and a 3 day contact schedule is sent to the ground stations on a daily basis. Each GNE station independently participates in this planning process. These GNE contacts are incorporated into the master integrated schedule. Nominally the daily command cycle targets a set of GNE contacts for the command load uplink. The CAPE and MOE functions are executed close to this window so that the most recent NCEP data can be used.

This stored command load is uploaded to the observatory during the designated GNE contact. All uplink data are encrypted within the MOC before transmission to GNE. The GNE establishes contact with the observatory and MOE communicates with the observatory through this GNE interface. Real-time housekeeping telemetry is received from the observatory and forwarded to MOE for ingest.

Off-nadir acquisitions are scheduled using the same processes, with some variations. The only source for an off-nadir acquisition is a special request from an authorized user. CAPE identifies the scenes as off-nadir and MOE plans the additional attitude changes required to orient the instruments.

5.3 Data Acquisition

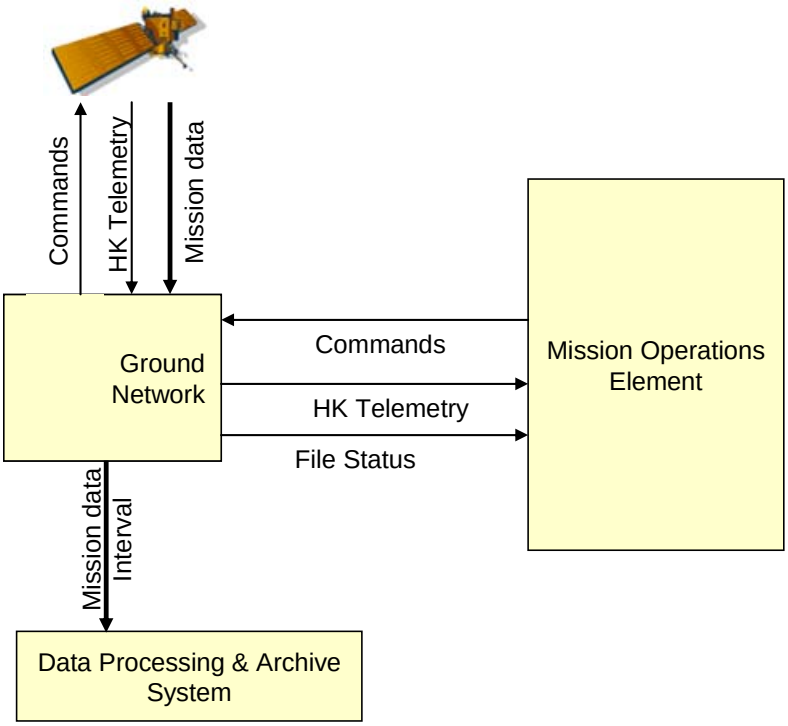

Figure 5-3 – Scenario Diagram – Data Acquisition

The observatory provides partially autonomous management of the science data downlink. For a routine contact, MOE will command the period of time where the downlink should be active, and the observatory determines what data to transfer. Files marked as priority and not yet transmitted are sent first, from oldest to youngest. Then files marked non-priority, not yet transmitted, are sent from oldest to youngest. After transmission, files remain on the observatory SSR until MOE sends a command to either transmit the file again or delete the file.

The combination of file management and retransmit means that sometimes all the files that constitute a single interval will be transmitted out of sequence and/or to more than one GNE station. Some data are collected in real-time while in view of a GNE station while most data are acquired elsewhere and stored on the SSR.

At the times scheduled by MOE, the GNE station supports a contact with the observatory. Mission data files are downlinked through the X-band interface using CFDP to the station. The station confirms the success or failure of each file and reports this information back to MOE. During each contact, the observatory downlinks housekeeping telemetry regarding the state of all mission data on the observatory.

At a time scheduled by the FOT, MOE ingests all the GNE reported file status information and the observatory reported file status information, and determines what file management operations are required. These file management operations are delete files, add or remove priority and protect indications and schedule files for retransmission. Commands to effect these file management operations are sent up to

the observatory in real-time if this is scheduled during a contact, or generated for uplink during the next scheduled contact.

Successfully received mission data files are transferred from each GNE station to the central cache located at the USGS EROS Center. Based on information received from GNE and the observatory, MOE sends information associating intervals and individual files to GNE. The GNE uses this information to assemble files into complete intervals. This assembly process does not include actual image data processing, just association. The completed intervals are transferred to DPAS when ready.

Off-nadir acquisitions are collected and downlinked in an identical manner.

5.4 Data Ingest and Product Generation

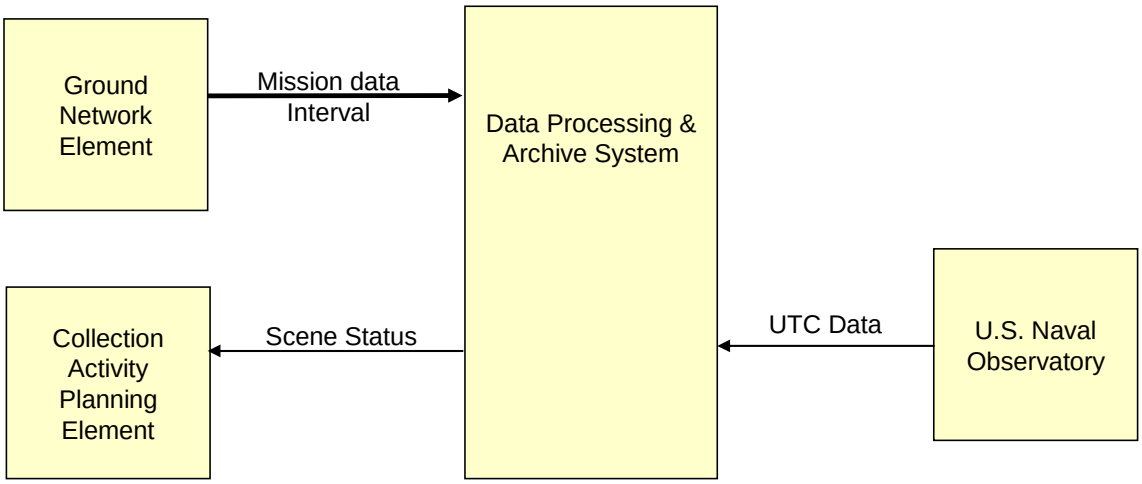

Figure 5-4 – Scenario Diagram – Data Ingest and Product Generation

Complete intervals are received from GNE. LDCM data cannot be processed until the associated shutter interval (for OLI) or blackbody/deepspace interval (for TIRS) have been ingested (refer to section 2.2.1 for more information). When ready, new intervals are automatically processed to generate L0 data. The appropriate L1 products are then automatically generated and staged to a cache for user access. The L1 products are as described in section 6; the GS produces a single OLI+TIRS integrated product (when both are present) or a product with only one instrument when only one is present. Consistent with section 6, the L1 product made is the highest level possible given the scene characteristics (such as cloud cover). The mission data is automatically ingested into the archive. Off-nadir data are also processed automatically, but will not be required to conform to the same geodetic accuracy specifications.

As part of the L1 production process, full resolution browse data, quality band data (including cloud cover) and metadata are all generated. The full resolution browse and quality band data are staged for user access automatically. The inventory is populated with the new metadata generated from both L0 and L1 processing. UTC information is

retrieved from the U.S. Naval Observatory as required to allow conversion of times for ingest and processing.

During L0 product generation, various algorithms are applied to extract interval bias parameters (for OLI shutter data) and interval gain (TBR) and bias parameters (for TIRS blackbody/deep space data). Other characterization data are generated during both L0 and L1 processing for Cal/Val use.

The DPAS periodically provides new inventory updates to CAPE. CAPE uses these updates to determine scene status for scenes CAPE scheduled.

Off-nadir data are ingested and processed in an identical manner.

The DPAS operations may at some point determine that reprocessing of mission data to L0 is required. The reprocessing is manually initiated and then completed automatically.

5.5 User Access and Data Management

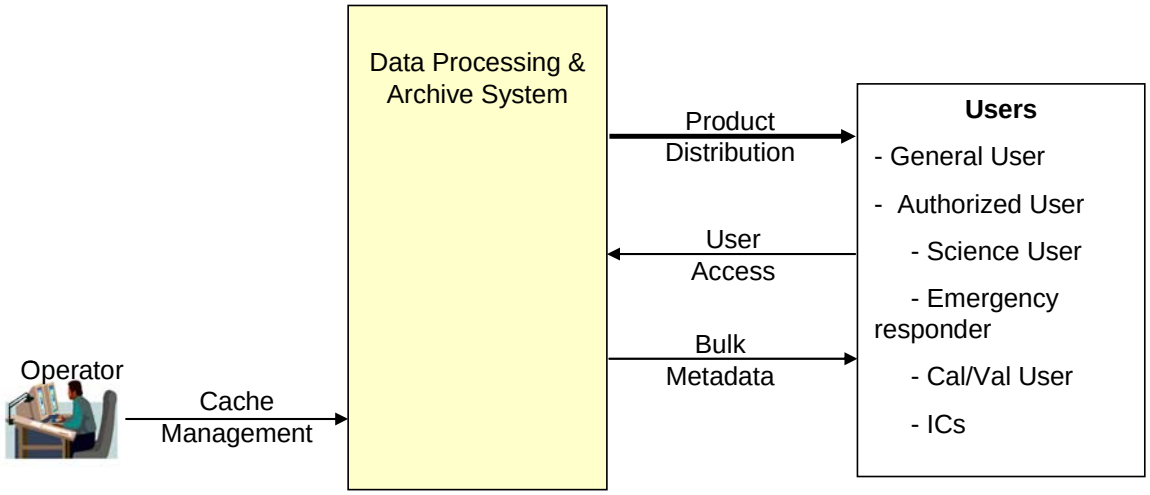

Figure 5-5 – Scenario Diagram – User Access and Data Management

The DPAS provides an online (Internet) user interface, through which users can obtain mission related documentation, *notices and other information.* This interface also allows users to search for LDCM data. *This interface provides a mechanism to view browse images and metadata.* User registration is required to access or order products. This registration capability is provided through the online user interface. User registration provides the ability to record demographics about LDCM users.

Registered users can immediately download data products which are available in the cache. *If a product is not already available, the user interface provides a means to request products, including placing a standing request. Product requests are automatically processed within DPAS and staged for user access. Users are notified*

when products are ready for access, or may manually check request status. Users also have the ability to register for metadata notifications.

LDCM products are stored in a cache for user access. This cache is sized to hold a subset of the entire mission data volume. The DPAS automatically removes data from the cache to maintain the target size. Other cache management operations are manually initiated by DPAS operators. (Note that data removed from the cache are still orderable.)

DPAS operations staff has the ability to manually perform data management tasks as needed. For example, cleaning up the data cache, updating data records, marking data as orderable or unorderable, etc.

There is a capability to search for and download bulk metadata regarding inventory holdings.

There is a User Services support capability at EROS. This group provides minimal support to users experiencing problems accessing systems online. They also provide initial triage of reported product problems. Because of the low staffing level, this group does not access the system as a proxy for the user so this interaction is not shown.

Off-nadir LDCM data are available through all the online access mechanisms. There is a user-configurable flag to control whether off-nadir products are visible through this interface.

There is an online access to obtain full resolution browse (3 bands for OLI, 1 band for TIRS) and quality band data. Open Geospatial Consortium (OGC) services are also available for users with the appropriate client functionality.

5.6 Cal/Val Operations

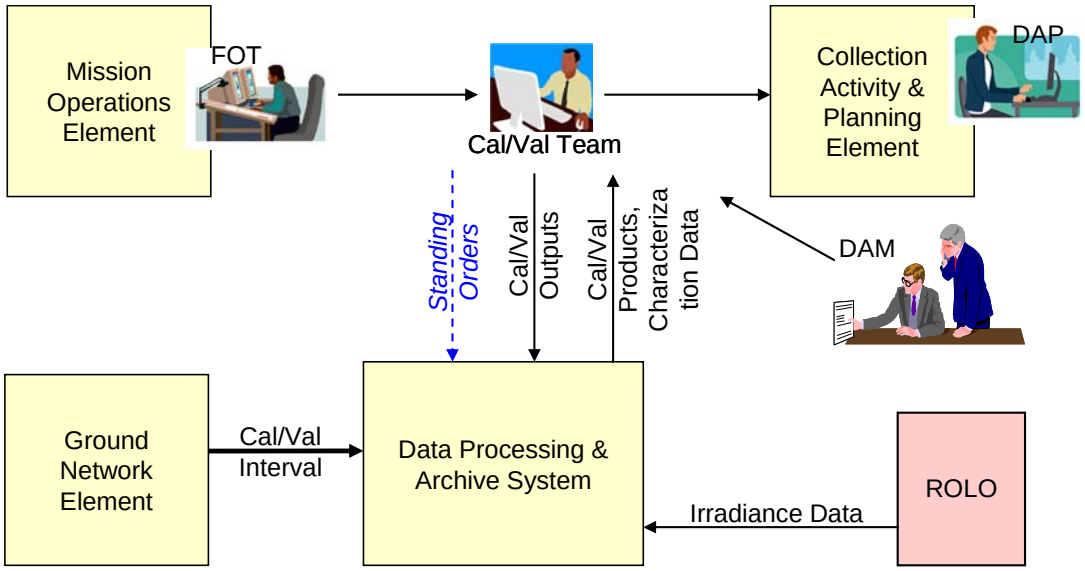

Figure 5-6 – Scenario Diagram – Cal/Val Operations

Earth imaging requests for calibration purposes are placed through the DPAS interface and scheduled by CAPE as described in the Collection Scheduling scenario.

To perform calibration, various special acquisitions by the instruments (distinct from Earth Imaging) are required. The CVT directly coordinates with the DAM and the FOT to schedule special calibration acquisitions. Examples include OLI lunar calibrations, Earth Calibration (aka 90 degree yaw), OLI solar calibration, TIRS blackbody calibration, OLI lamp calibration, etc. These types of activities are directly scheduled by the FOT using MOE functionality. Initially these may be scheduled manually, but the goal is to have all calibration data acquisitions automatically scheduled.

MOE sends a schedule of observatory calibration events to the CVT. The DPAS will automatically ingest calibration intervals. The DPAS will then *automatically process* calibration intervals to a product type *per a CVT standing order. (The capability to process is P2 but automation and the daily volume performance are P3.)* The CVT has access to the remote trending capability to allow retrieval of additional observatory engineering data which may be necessary for non-routine investigations.

Some calibration analysis functions within DPAS *are automatically initiated* while others require the CVT to manually initiate analysis using either DPAS functionality or the Cal/Val ToolKit (CVTK). These functions are used by the CVT to determine the adequacy of the current calibration parameters, and derive new calibration parameters as necessary. This processing is done on a frequency determined by the CVT.

The CVT validates new calibration parameters. This is done by manually initiating the creation of new parameters in a test CPF and generation of test products. These test products are analyzed to validate the CPF update prior to making the parameters

operational. The new CPF is published through the appropriate DPAS functionality to ICs, other users, and the DPAS processing functions.

The CVT manually initiates analysis of DPAS L0 data, L1 data and characterization data using either DPAS functionality or the CVTK. These functions are used by the CVT to determine the current instrument performance, and compare it to historical trends and performance requirements. Lunar calibration intervals are processed and compared to lunar irradiance data pulled from ROLO as part of this process.

The CVT uses similar functionality to evaluate the quality of the L1 data products created by DPAS. The characterization data generated is also evaluated. These results are compared to historical trends and performance requirements.

The CVT supports anomaly resolution for product anomalies, processing anomalies and instrument anomalies. This mainly involves various detailed data investigations using the available calibration processing tools.

The CVT adapts the algorithms to be applied for data processing within DPAS. Over time the CVT evaluates these algorithms and incorporates improvements as required in support of meeting overall product requirements.

5.7 International Cooperators

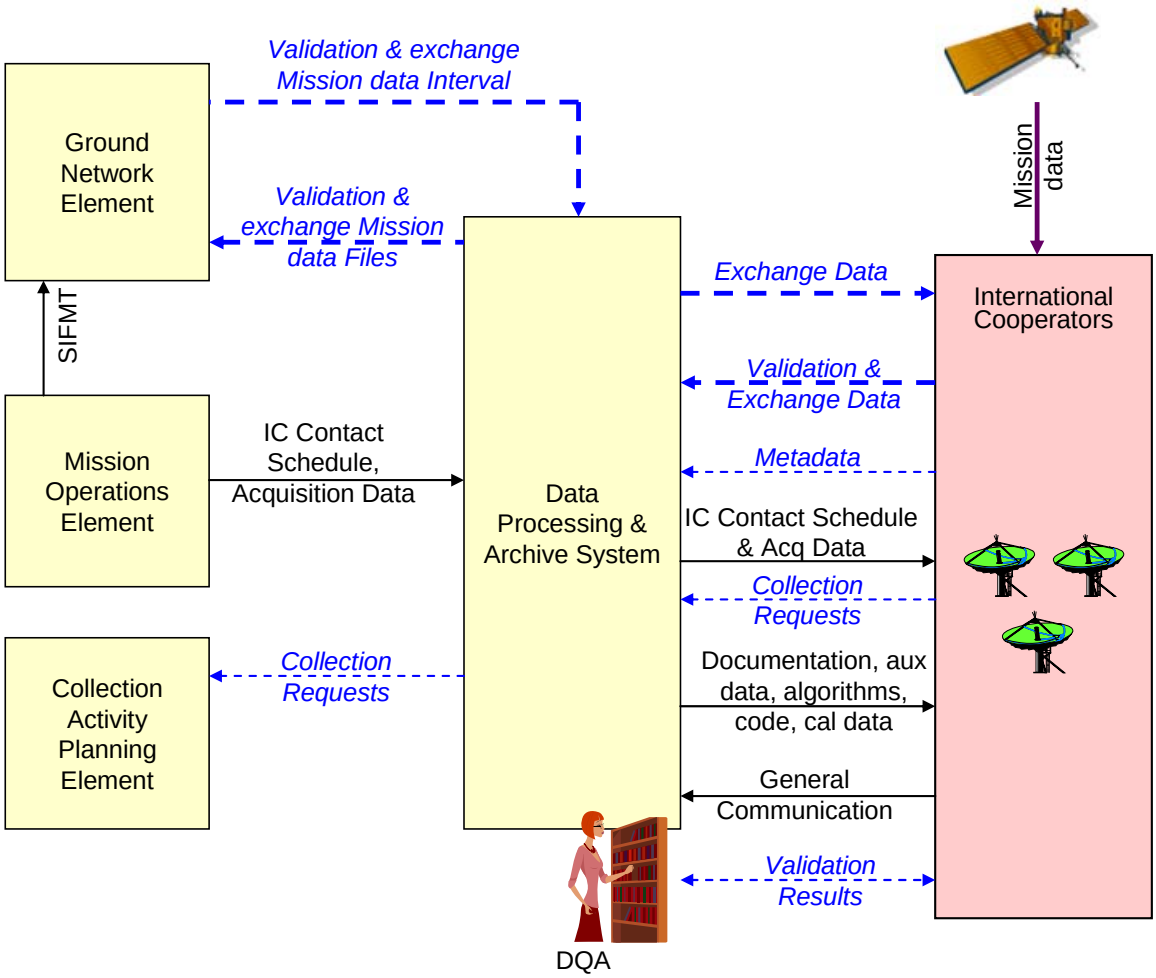

Figure 5-7 – Scenario Diagram – International Cooperators

Each IC can request new LDCM data acquisitions through two basic means. *Special requests for specific acquisitions can be submitted through the online user interface using the same mechanism that Authorized Users do.* The more basic method is submission of a large standing request which prioritizes acquisitions within the ICs coverage area. These standing requests are often submitted seasonally by the IC. Both acquisition requests are *submitted through DPAS (direct manual submission to the DAM is also possible),* and flow to CAPE for use in acquisition scheduling (refer to the acquisition scheduling scenario.)

The MOE generates IC ground station contact schedules specific to each station and makes these available to DPAS which makes them available to the IC stations for secure pull access. If necessary, the schedules are also available for DPAS operations to manually retrieve and stage for access. The acquisition data (IIRV & TLE) are generated by MOE and made available to the IC ground stations through the same mechanisms. The MOE also makes information about the WRS-2 scenes and the intervals being scheduled for the entire day (not one per IC) and this file is distributed in a similar manner.

Calibration parameters, bias parameters and related data are staged by DPAS for retrieval by ICs at their convenience, with a notification capability. These parameters are required for the IC to be able to produce calibrated L1 data products. GCP data and DEM data are also made available to ICs. As mentioned in the user access scenario (section 5.5) DPAS makes mission related information available, including documentation, software and important mission status notifications.

After the IC stations receive the mission data directly from the Observatory and optionally produce data products, metadata regarding the data acquired is sent to DPAS. IC archive metadata is placed into the user searchable inventory. This metadata is also saved in the metrics warehouse function within DPAS.

The MMO uses the metadata housed within DPAS to compare the scenes reported by the IC to the scenes CAPE/MOE scheduled for them. This standard discrepancy report is manually initiated, and used to look for problems at the IC that may not have been reported, or scheduling issues in the MOC.

The DPAS provides a mechanism for ICs to submit various problem reports to an online interface. These problem reports include reporting when ground stations will be or are offline, or other similar items. (Note that IC stations can and often do still communicate using email or other methods directly with the MMO, DAM, or FSM.)

The USGS periodically validates each IC to verify that they can successfully capture LDCM data and transfer it back to DPAS. The first step in this validation is to identify a planned acquisition or schedule an acquisition which fits entirely within the IC reception mask. The reception schedule and other interfaces work as described above. After reception the IC will send all the mission data files to DPAS, either electronically or on media. The same interval, like all LDCM mission data, is retained on the observatory SSR and downlinked to GNE using the normal data acquisition flow (section 5.3). Data validation can be performed only on complete intervals, where the files were correctly captured by the IC. The DPAS does not have the capability to ingest data with bad lines, missing data, or extra data.

The USGS also performs a validation of the Level 1 products submitted by ICs for this purpose. This is optional, at the request of the IC. The products are provided directly to the DQA, who coordinates offline analysis of these products by the CVT.

GNE operations manually ingests the IC validation data and effects the transfer to DPAS. As part of this process, GNE sets the appropriate flag to denote this interval as an IC Data Validation interval. The DPAS automatically ingests IC DV data, processes to L0, and routes it to the calibration functions for manually initiated L1 processing and evaluation by the DQA.

IC data exchange is operationally performed in a similar manner to IC validation data, except that the GNE operators use a different designation (IC Data Exchange) and

DPAS performs the same processing and archive steps after L0 as with other normal mission data. As with other mission data, only complete intervals can be transferred from GNE to DPAS.

IC partners can contact a designated point of contact (DQA) to request LDCM mission data. LDCM mission data is staged (for electronic transfer) or written to media and sent to the IC. There is no automated means for an IC to order mission data. Only complete intervals are sent to ICs.

5.8 Observatory Management and Operations

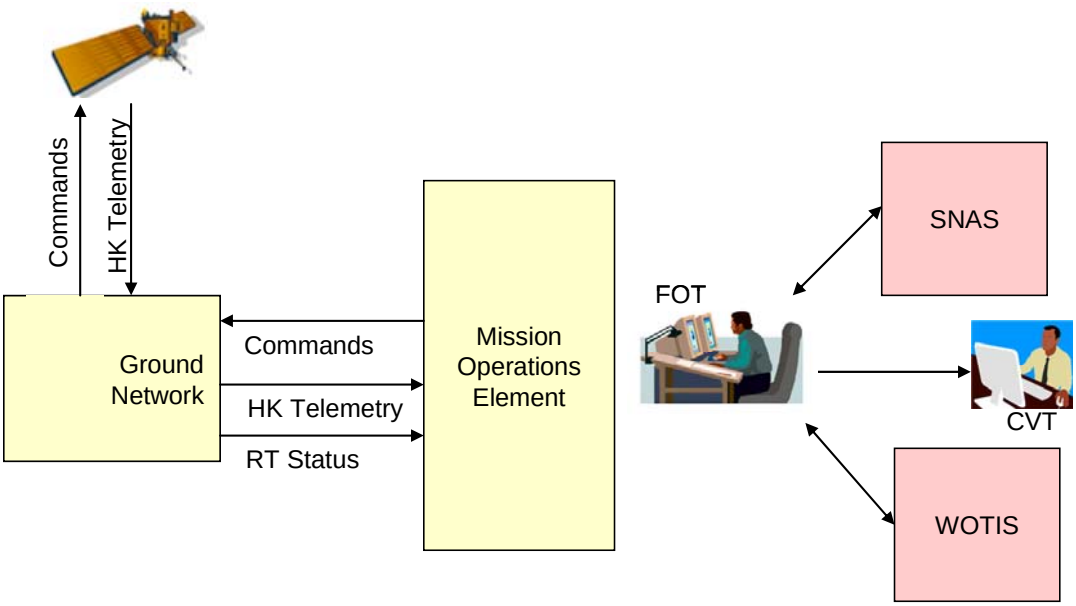

Figure 5-8 – Scenario Diagram – Observatory Management and Operations

Every time the observatory is in contact with GNE, SN, or NEN, real-time housekeeping telemetry data is sent from the observatory to MOE. The MOE ingests this data in real time, performs the necessary processing and provides real-time telemetry displays for the FOT. Individual telemetry points are evaluated against limits and constraints, and notifications and automated responses are invoked as configured by the FOT. The observatory stores housekeeping telemetry and downlinks the stored data during contacts with GNE. This downlink can occur over either X-band or S-band depending on the pass configuration. The GNE station transfers this stored data back to MOE in non-real-time. The MOE ingests stored housekeeping telemetry and stores it in a telemetry database. Offline tools are provided for the FOT to mine the telemetry database for reporting, trending and analysis purposes.

The MOE performs real-time and definitive attitude and orbit assessment. From these definitive results, mission planning products are then produced. The MOE plans and executes delta-I (inclination) and delta-V (velocity) maneuvers for the observatory. The flight dynamics capability is used to evaluate the observatory orbit against the mission

requirements. The FOT makes a determination regarding when a maneuver is required. Typically maneuvers are planned weeks to months in advance, and refined as the target epoch approaches. The target orbit is typically chosen a few weeks out, and the detailed maneuver and thruster plan is generated a few days in advance. Some maneuvers are executed while being monitored in a real-time mode through GNE, SN or NEN. Occasionally a maneuver may be conducted out of contact.

Conjunction assessment for NASA missions is coordinated and performed by the GSFC Space Asset Protection Mission Support Office. The Space Asset Protection Mission Support Office informs the FOT of possible conjunctions through email notification. Risk assessment and any required maneuvers are jointly performed by the LDCM FOT and the Space Asset Protection Mission Support Office as appropriate. The MOE portions of this process are manually initiated by the FOT as required.

Various calibration-related acquisitions require slew of the observatory to image the moon or other targets. Refer to the Cal/Val scenario for context of these operations.

Scheduling of SN and NEN contacts is handled with manual interaction by the FOT. The contacts are scheduled and appear on the master working schedule within MOE, but they are also manually requested using a web interface (SNAS) in the case of SN and email for NEN scheduling with WOTIS. An FOT member manually coordinates the SN/NEN planning system requests and the entries within MOE.

Very infrequently, flight software updates may be required for the spacecraft, OLI or TIRS. The respective vendor makes the determination that a flight software update is required in support of anomaly investigation / troubleshooting, and develops and tests the flight software update. This validated update is delivered to the FOT, who uses MOE to verify that the update can be applied to the SOS, before finally applying the update to the observatory itself.

5.9 Mission Management Reporting

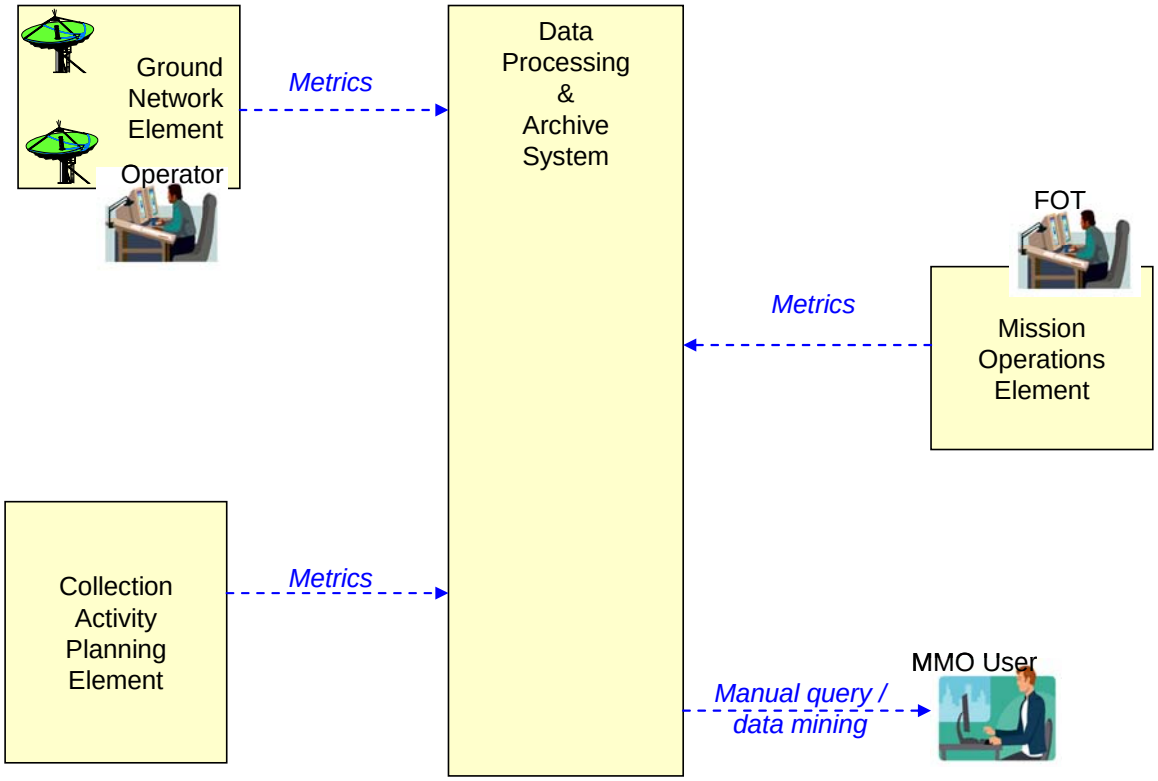

Figure 5-9 – Scenario Diagram – Mission Management Reporting

A variety of reporting functions will be required of the ground system. For example DOI and USGS headquarters impose specific reporting requirements. In support of mission operations and IC support, the MMO regularly compares the IC metadata reporting data received against MOC (MOE) reports of data that should have been transmitted. Ground system operations and management require various forms of reporting to monitor and manage the ground system. As organizations and data systems evolve over time, the exact reports required are time variant and not always foreseeable. The following list is representative, not an exhaustive list:

- Collection reconciliation (scenes scheduled vs acquired)
- Orders submitted
- Order demographics
    - Age of data
    - Cloud cover of data
    - Geographic distribution
- Customer demographics
- Scenes distributed
    - From cache
    - On demand
- IC data collection reconciliation
- Passes scheduled vs passes taken

- Files successfully captured / Files retransmitted
- S-band capture statistics / success
- Cloud cover statistics of archived data
- Processing levels which new data were able to attain (1Gt vs 1T)
- Scenes acquired to US archive
- Scenes scheduled to any given IC
- Latencies
    - From imaging to L1 staging
    - For each individual step along the way
- FRB distributed

Data report generation is not an operational function, and complex queries can sometimes cause harmful loading of operational servers. For this reason, the appropriate database tables and system messages/reports will be stored in an offline system within DPAS. This offline system provides a common database to host all the data, for easy correlation. Complex and lengthy queries on the system will not harm the operational data sources. Since reporting is not highly time sensitive, data can be fed into this DPAS system on a periodic, infrequent basis (on the order of hours) as appropriate to each source.

Whatever data reporting is required, will be done manually by the internal operator (any person in the GS authorized to access the capability). There are no automated reporting functions. The only automated functions are those required to import data from the operational systems.

5.10 Continuity of operations

Continuity of operations (COO) really is a set of unrelated major failure scenarios / catastrophe scenarios which the ground system has some capacity to mitigate. This is not an exhaustive list of failure cases, nor are the failures interrelated. This does represent a complete description of the major COO operations being planned. Each capability is described, in no particular order. Overall continuity of operations response is coordinated by the Mission Management Office.

All data in the mission archive is duplicated in an offsite backup archive within 30 days. Partial or complete data loss in the operational archive is manually recovered by DPAS operations using this offsite backup capability. This operation, including retrieval of the data and restoration of the operational archive, is completely manual, and there are no performance requirements for the time required to restore the data.

The GNE maintains a 90 day rolling archive of all mission data which was received by GNE. This rolling archive provides a 90 day operational buffer in the event major portions of DPAS become non-operational. In this scenario, new hardware required to reconstitute DPAS ingest and archive functions would be procured and setup in an available data center space. Manual backups of all operational software and system

configurations are maintained by DPAS (when configurations change, roughly twice a year) and stored offsite, which can be used to restore ingest and archive capability to the new hardware. In the event that DPAS ingest and archive functions would not be ready within 90 days, this window of time is also sufficient to allow procurement of additional storage devices/media to expand GNE capacity beyond 90 days.

In the event that an LGN station fails the project would rapidly convert an existing ground station (likely from the IC network) into another GNE station, supporting all the GNE requirements. *The converted station would continue to receive real-time data as an IC,* but also receive playback data as a GNE station. This conversion would be done on a best effort basis. The mission would continue to operate using the remaining operational GNE stations while this development/conversion takes place.

A complete set of all MOC hardware (for both CAPE and MOE functions) is stored at a backup MOC location. This hardware has all CAPE and MOE software installed but is not turned on. There is a controlled repository at the backup MOC location which is periodically updated with all the relevant CAPE and MOE databases including housekeeping telemetry and FOT products. If the backup MOC needs to be activated, this backup data is used to synchronize the backup systems to the current mission state. The observatory has a 72 hour long stored command load executing on board which provides time for the backup MOC systems to be activated, configured and made operational.

5.11 Priority Acquisition and Expedited Product Generation

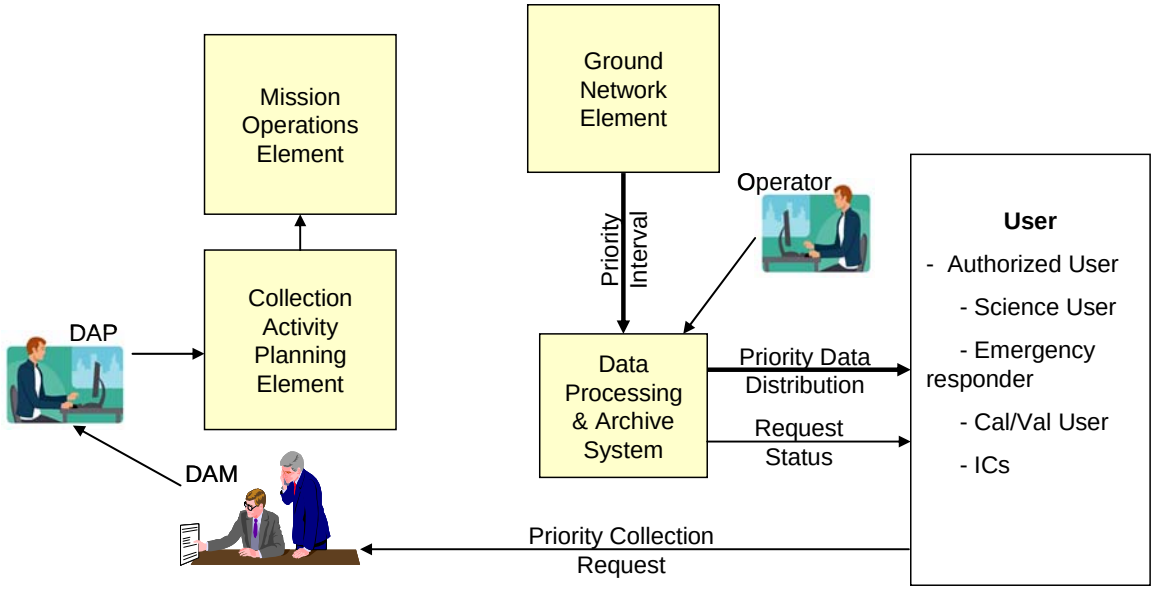

Figure 5-10 – Scenario Diagram – Priority Acquisition and Expedited Product Generation

Priority acquisitions can be requested only by Authorized Users. The request process is described in the Collection Scheduling scenario, frequently incorporating direct contact

between the requestor and the DAM. Priority acquisition requests received close to the data collect window may be manually scheduled by the DAP using CAPE functions. The observatory provides special handling of data marked as Priority, downlinking those data before non-priority data.

GNE transfers mission data from GNE ground stations to the EROS in the order received, so Priority data will always be transferred first. As soon as the priority interval is complete, it is transferred to DPAS. In order to facilitate rapid acquisition and availability for DPAS, the DAP may have to intentionally make the priority interval short enough to fit within a real time GNE station mask, or short enough for complete SSR playback within the next GNE contact window. This adjustment is manually done by the DAP using CAPE.

If required, DPAS provides the capability to produce products out of order. This capability must be manually invoked by the DPAS operators. Coordination of priority scheduling and expedited data production is manually performed by the DAM, DAP, DPAS operations and GNE operations staff as appropriate to the requirements of the request. Note that this description of expedited product generation (making products quickly) is not implying that “Expedited Product Generation” is a DPAS requirement.

Section 6 System Outputs

6.1 Standard Products

The following sections describe the standard products the ground system makes available to external users and partners. Auxiliary & supporting data, such as DEM data, algorithms, IC station contact schedules, mission documentation, etc. are not described in this document.

6.1.1 Level 0Rp

Level-0Rp Data Products - Level 0 data products are image data with all data transmission and formatting artifacts removed, time provided, spatial, and band-sequentially ordered multi-spectral digital image data. Level-0Rp are subset to WRS-2 framing conventions.

L0Rp products are only available for the mix of instruments operating within the interval. If the interval was recorded with only a single instrument, then only that instrument will be present in the L0Rp product. If the interval consisted of data from both instruments, the L0Rp product will only be available with both instruments.

6.1.2 Level 1

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

6.1.2.1 Instrument Variations

When an interval consists of only one sensor (OLI or TIRS) then the L1 product will also consist of only one sensor. When both instruments are present in the interval, the L1 product by definition shall include both instruments. The L1 product is not orderable with a sensor removed. Note that through OGC web coverage services users have the ability to subset by sensor, when the full OGC capability is implemented.

6.1.2.2 Levels of Processing

The standard L1 product is processed to the highest processing level the scene contents and quality allow. There is no option presented for the user to select a particular processing level. The following paragraphs describe the processing levels from lowest to highest. All L1 products have a 30m sample spacing for the OLI and TIRS bands, and 15m for the OLI panchromatic band.

Level 1G Data Products - Level 1Gs data products consist of radiometrically corrected image data derived from Level 0 data linearly scaled to at-aperture spectral radiance, and resampled for registration to a cartographic projection, referenced to the World Geodetic System 1984 (WGS84), G873 or current version. The geometric corrections incorporate the use of observatory ephemeris data.

Level 1Gt Data Products - Level 1Gt data products consist of Level 1R data products resampled for registration to a cartographic projection, referenced to the World Geodetic System 1984 (WGS84), G873 or current version. The geometric corrections incorporate the use of observatory ephemeris data; digital elevation model (DEM) data are used to correct for terrain relief.

Level 1T Data Products - Level 1T data products consist of Level 1R data products resampled for registration to a cartographic projection, referenced to the WGS84, G873 or current version, orthorectified, and corrected for terrain relief. The geometric corrections use observatory ephemeris data and ground control points; DEM data are used to correct for terrain relief.

6.1.2.3 Full Resolution Browse

These are full spatial resolution browse (FRB) derived from Level-1 products and which have been rescaled from 16- to 8-bits per band. The OLI FRB will be comprised of 3 spectral bands; the TIRS FRB will be a single band (which band is TBR).

6.1.2.4 Radiometric Units

The OLI bands in L1 products have 16 bit values linearly scaled to top of atmosphere reflectance values. L1 products include the metadata necessary to convert the OLI values to at-aperture radiance values if desired. For TIRS bands, the 16 bit values are linearly scaled to at-aperture radiance values.

6.1.2.5 Quality Band

A quality assessment (QA) band will be created using OLI data, or OLI and TIRS data, for all sun-lit Earth acquisitions. The QA band will be constructed by setting the bits according to specified image quality criteria (Table 2). A 16-bit QA band will accompany the 16-bit L1 science products, and an 8-bit version would accompany the full spatial resolution browse. The QA band is sampled at 30 m.

Table 2 – Quality Band bit definitions

	16-Bit Quality (QA) Band	**8-Bit Quality (QA) Band**	
Bit	**Description**	**Bit**	**Description**
0	Designated Fill	0	Designated Fill
1	Water	1	Cloud
2	Water Confidence	2	Cloud Confidence
3		3	
4	Snow/Ice	4	Cirrus
5	Snow/Ice Confidence	5	Cirrus Confidence
6		6	
7	Cirrus	7	Other (terrain occlusion)
8	Cirrus Confidence		
9			
10	Cloud		
11	Cloud Confidence		

12	
13	
14	
15	Artifact Masks

Confidence Levels

00 = none or unset
01 = 0-33% confidence
10 = 34-66% confidence
11 = 67-100% confidence

6.2 Calibration Parameter File

The Calibration Parameter File (CPF) contains all parameters needed to derive the L1R, L1Gt, and L1T products from the L0Ra product. Example parameters contained within the CPF include: radiometric conversion coefficients, radiometric artifact correction parameters, Earth constants, orbit parameters, detector positions, radiometric look up tables, bias parameter data, and alignment parameters.

6.3 Mission Data Files

Mission data files are exchanged only with International Cooperator partner stations. They are not available to the general public or other classes of LDCM GS users. A mission data file is the file that is created as a result of processing everything down to and including the CFDP protocol in the X-band downlink. The framing of the mission data files is determined by the observatory. A collection of all the mission data files comprising an interval is packaged together with an Interval Definition File. This complete interval plus IDF is the exchange format both to and from IC stations.

Appendix A Acronyms

AGS	Alaska Ground Station
AIP	Archival Information Package
AK	Alaska
AOI	Area of Interest
ART	Anomaly Resolution Team
ASN	Alice Springs Ground Station (Australia)
bMOC	Backup Missions Operations Center
bMOE	Backup Missions Operations Element
CAPE	Collection and Planning Element
CCS	Constellation Coordination System
CMD	Command
CONUS	Continental United States
COO	Continuity Of Operations
COTS	Commercial Off-the-Shelf
CPF	Calibration Parameter File
CVT	Cal/Val Team
CVTK	Cal/Val Toolkit
D/L	Downlink
DAM	Data Acquisition Manager
DCP	Data Collection Planners
DCPF	Data Capture and Processing Facility
DCS	Data Capture System
DE	Definitive Ephemeris
DEM	Digital Elevation Model
DN	Digital Number
DPAS	Data Processing and Archive System
EROS	Earth, Resources Observation and Science
ESMO	Earth Science Mission Operations
ETM+	Enhanced Thematic Mapper Plus
FAQs	Frequently Asked Questions
FAR	Federal Acquisition Regulations
FDF	Flight Dynamics Facility
FIFO	First-In First-Out
FOT	Flight Operations Team
FRB	Full Resolution Browse
FTP	File Transfer Protocol
GB	Gigabyte
GCP	Ground Control Point
GIS	Geographical Information Systems
GNE	Ground Network Element
GOS	Geospatial One-Stop

GOTS	Government-supplied Off The Shelf
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
I&T	Integration and Test
IAS	Image Assessment System
ICs	International Cooperators
LDCM	Landsat Data Continuity Mission
LGN	LDCM Ground Network
LS	Launch Segment
LV	Launch Vehicle
MDS	Mission Management Office (MMO) Database System
MGS	MODIS Ground Station
MMO	Missions Management Office
MOC	Mission Operations Center
MOE	Mission Operations Element
MOM	Mission Operations Manager
MSS	Multispectral Scanner
MTF	Modulation Transfer Function
NASA	National Aeronautics and Space Administration
NB	Narrow Band
NCC	Network Control Center
NDVI	Normalized Difference Vegetation Index
NCEP	National Centers for Environmental Prediction
NLAPS	National Land Archive Production System
NSLRSDA	National Satellite Land Remote Sensing Data Archive
OCD	Operations Concept Document
OGC	Open Geospatial Consortium
OIV	On-Orbit Initialization and Verification
OLAP	On-Line Analytical Processing
OLI	Operational Land Imager
OMB	Office of Management & Budget
PB	Playback
PCD	Payload Correction Data
QA	Quality Assurance
RF	Radio Frequency
ROLO	Robotic Lunar Observatory
RT	Real Time
S/C	Spacecraft
SAIC	Science Applications International Corporation
SAN	Storage Area Network
SD	South Dakota
SGS	Spitzbergen Ground Station
SLC	Scan Line Corrector

SMRD	Science and Mission Requirements Document
SN	Space Network
SNAS	Space Network Access System
SOA	Service Oriented Architecture
SS	Space Segment
SWIR	Short Wave Infrared
TB	Terabyte
TDRSS	Tracking and Data Relay Satellite System
TIR	Thermal Infrared
TIRS	Thermal Infrared Sensor
TLEs	Two Line Elements (Ephemeris)
TLM	Telemetry
TM	Thematic Mapper
TOA	Top Of Atmosphere
TT&C	Tracking, Telemetry and Control
U/L	Uplink
US	United States
USC	United States Code
USGS	United States Geological Survey
USSTRATCOM	U.S. Strategic Command
UTC	Coordinated Universal Time
UTM	Universal Time Measurement
VNIR	Visible and Near Infrared
WB	Wide Band
WCS	Web Coverage Services
WFS	Web Feature Services
WGS	Wallops Ground Station
WMS	Web Mapping Services
WRS	World Reference System
WSC	White Sands Complex