LANDSAT DATA CONTINUITY MISSION

STATEMENT OF WORK

May 31, 2006

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

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LDCM PROJECT

DOCUMENT CHANGE RECORD

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REV LEVEL	DESCRIPTION OF CHANGE	APPROVED BY	DATE APPROVED

List of TBDs/TBRs

Item No.	Location	Summary	Ind./Org.	Due Date

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I. Introduction

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

II. Scope

This Statement of Work (SOW) defines the minimum effort required by the Contractor for the design, analysis, development, fabrication, integration, algorithm development, test, evaluation, delivery, and support for the Landsat Data Continuity Mission, hereafter referred to as LDCM. This Statement of Work requires delivery of one Observatory, which consists of the multi-band Sensor(s) and the spacecraft platform(s). The Observatory shall meet the requirements of the LDCM Space Segment Requirements Document. If the contract option is exercised, this Statement of Work requires addition of thermal band sensing capability to the spectral band requirements. This Statement of Work also requires delivery of the Mission Operations Element (MOE) System to the Government Mission Operations Center (MOC) and delivery of a single-string suite of the MOE system to the Government Back-up MOC. The MOE shall meet the requirements of the Mission Operations Element Requirements Document. The interface requirements of the Observatory to the ground system are detailed in the Space-to-Ground Interface Requirements Document. The Government will provide launch services. Final acceptance will take place on orbit. The Government will evaluate observatory on-orbit performance for acceptance using a predetermined set of Worldwide Reference System – 2 (WRS-2) scenes.

III. Definitions

The following definitions apply to this document:

Shall – Compliance by the Contractor is mandatory. Any deviations from these contractually imposed mandatory requirements require the approval of the contracting officer.

May – At the discretion of the Contractor or Government.

Will – Designates the intent of the Government. Unless required by other contract provisions, noncompliance with the *will* requirements does not require approval of the contracting officer and does not require documented technical substantiation.

IV. Applicable Documents

The documents listed in this section apply directly to the performance of the LDCM Prime Mission Contract. These documents establish detailed specifications, requirements, and interface information necessary for the performance of the contract. Unless otherwise specified, the document version listed herein shall apply. In case of conflicting requirements, the order of precedence of documents not specifically called out in the Contract is: this Statement of Work, the Mission Assurance Requirements document, the Contract Data Requirements List, the LDCM-modified version of the GSFC Rules, and the LDCM Environmental Verification Specification.

LDCM Space Segment Requirements Document: Document Number 427-XXX (TBD)

LDCM Mission Operations Element Requirements Document: Document Number 427-XXX (TBD)

LDCM Space-to-Ground Interface Requirements Document: Document Number 427-XXX (TBD)

Special Calibration Test Requirements: Document Number 427-XXX (TBD)

LDCM Contract Data Requirements List: Document Number 427-XXX (TBD)

LDCM Mission Assurance Requirements: Document Number 427-XXX (TBD)

LDCM Environmental Test Requirements: Document Number 427-XXX (TBD)

LDCM Acronym List and Lexicon: Document Number 427-XXX (TBD)

Top of Atmosphere Radiance Values, MODTRAN 4 Model. http://ldcm.nasa.gov/... TBS

NIST 2000 realization of scale of spectral irradiance, H. W. Yoon, C. E. Gibson and P. Y. Barnes, The realization of the NIST detector-based spectral irradiance scale, Metrologia 40 (2003) S172–S176.

Rules for the Design, Development, Verification, and Operation of Flight Systems, GSFC-STD-1000, Rev. A, 30 May 2005

Criteria for Flight Project Critical Milestone Reviews, GSFC-STD-1001, February 2005

Government-provided Work Breakdown Structure, (TBD)

NPR 2810.1, Security of Information Technology

V. Reference Documents

LDCM Operations Concept, 427-XXX (TBD)

ALIAS (TBD)

Landsat Worldwide Reference System-2 (WRS-2) Definition, February 9, 2006

VI. Work to be Performed

This section, along with the Contract Data Requirements List (CDRL) document 427-XXX (TBD), describes the specific work to be accomplished by the LDCM Prime Mission Contractor. In accordance with the requirements of this document, the contract, all associated requirements documents, and the other attachments and applicable documents to this contract, the Contractor shall provide the personnel, materials, equipment, and facilities necessary for the successful and on-time implementation of the design, analysis, development, fabrication, assembly, test, engineering data analyses, calibration, qualification, delivery, and sustaining engineering of the LDCM.

The Contractor shall deliver to the Government an LDCM that is fully tested, calibrated, and has demonstrated compliant and reliable end-to-end operation in accordance with the requirements of this contract. The Contractor shall deliver an LDCM that is ready for operation.

If the Contractor develops more than one spacecraft bus and/or more than one imaging sensor to satisfy contract requirements, the Contractor shall perform all tasks required herein for each of the spacecraft busses and imaging sensors. The Contractor shall deliver all hardware-specific documentation required herein individually for each of the spacecraft busses and imaging sensors, i.e., verification reports, test reports, and analyses that are not common across multiple units.

1 Management

1.1 Project Management

The Contractor shall maintain a project office to manage the technical activities and resources of the LDCM project. The Contractor shall appoint a dedicated Project Manager to direct and manage the LDCM project. The Contractor's Project Manager shall have responsibility for the overall technical performance and resource management of the contractual effort and all subcontracts. The Contractor's designated Project Manager shall report to a level of company management appropriate to ensure prompt resolution of all problems. The Contractor shall develop a Project Management Plan in accordance with CDRL PM-11 which addresses the overall organization, management approach, and structure of the LDCM Project plus its interrelationships with the parent company and subcontractors, and its relationship with the Government.

The Contractor shall prepare a Final Report in accordance with CDRL PM-8.

1.1.1 Government Insight

The Contractor shall open to Government attendance all Contractor and subcontractor internal data, reviews, audits, meetings and other activities pertinent to the scope of the contract. The Contractor shall provide the Government with reasonable and timely notification, to facilitate Government attendance. Government support contractors will also attend these reviews, audits, and meetings at the Government's discretion.

Government insight is defined as gaining understanding necessary to knowledgeably concur with the Contractor's action through watchful observation, inspection, or review of program events, documents, meetings, tests, audits, hardware, etc., without approval/disapproval authority. Where Government insight is required, the Contractor shall notify the Contracting Officer, the Government Resident Office or the appropriate Government operations organization of meetings, reviews or tests in sufficient time to permit meaningful Government participation.

1.2 Reviews and Meetings

1.2.1 Project Milestone Reviews

All milestone reviews at the sensor and spacecraft level and higher will be convened and review boards appointed and chaired by the Government. The Contractor shall convene a delta review if the success criteria for a review are not met to the Government's satisfaction. The Contractor shall comply with GSFC-STD-1001, Criteria for Project Flight Critical Milestone Reviews. The Contractor shall host these reviews.

1.2.1.1 Instrument Milestone Reviews

If multiple imaging sensors are developed to meet the requirements of this contract, then the Contractor shall conduct the following reviews for each sensor. The Contractor shall host, prepare and present the following instrument milestone reviews and provide review packages in accordance with the stated CDRL:

- Instrument System Requirements Review (ISRR), CDRL RE-1
- Instrument Preliminary Design Review (IPDR), CDRL RE-2
- Instrument Critical Design Review (ICDR), CDRL RE-3
- Instrument Pre-Environmental Review (IPER), CDRL RE-4
- Instrument Pre-Ship Review (IPSR), CDRL RE-5

The Contractor shall conduct dry runs of all Instrument Milestone Reviews, one week in advance of the review, with the Government. The Contractor shall assume that the dry runs will take one half the time required for the reviews. The Contractor shall host and work with the Government project and review team an additional day following all

instrument reviews to discuss and address issues raised and actions assigned at the reviews.

These reviews should not be considered a comprehensive set of reviews for the Contractor's program. Additional reviews that the Contractor deems necessary to successfully execute the program should be conducted at the Contractor's discretion. The Contractor shall notify the Government at least 10 working days in advance of lower level Contractor subsystem reviews to allow the Government time to attend the review as part of its insight activities.

For long lead items that are required to be ordered prior to IPDR to meet instrument development schedules, the Contractor shall obtain approval from the Government Contracting Officer prior to ordering these items.

1.2.1.2 Ground System Reviews

The Contractor shall develop and present the Mission Operations Element (MOE) portion of the Government-led Ground System PDR and CDR in accordance with CDRLs MO-7 and MO-8, respectively.

Prior to the Ground System SRR, PDR, and CDR the Contractor shall host, prepare and present the following MOE Peer Review packages in accordance with the stated CDRL:

- Pre-GSRR Peer Review Package, CDRL MO-1
- Pre-GPDR Peer Review Package, CDRL MO-2
- Pre-GCDR Peer Review Package, CDRL MO-3

The Contractor shall conduct dry runs of the MOE portion of the Ground System SRR, PDR, and CDR with the Government. The Contractor shall assume that the dry runs will take one half the time required for the reviews. The Contractor shall work with the Government project and review team an additional day following all Ground System reviews to discuss and address MOE issues raised and actions assigned at the reviews.

For MOE long lead items that are required to be developed/ordered prior to PDR to meet development schedules; the Contractor shall obtain approval from the Government Contracting Officer prior to ordering these items.

1.2.1.3 LDCM Mission Level Reviews

After the Government has concurred that the Contractor is ready for a specific review, the Contractor shall host, prepare and present Mission Level independent major milestone reviews and provide review packages in accordance with the stated CDRLs:

- Mission Definition review (MDR), CDRL RE-6

- Preliminary Design Review (PDR), CDRL RE-7
- Critical Design Review (CDR), CDRL RE-8
- Pre-Environmental review (PER), CDRL RE-9
- Pre-Ship Review (PSR), CDRL RE-10
- Mission Operations Review (MOR), CDRL RE-11
- Flight Operations Review (FOR), CDRL RE-12
- Operational Readiness Review (ORR), CDRL RE-13
- Flight Readiness Review (FRR), CDRL RE-14
- Launch Readiness review (LRR), CDRL RE-15
- On-Orbit Acceptance Review (OAR), CDRL RE-16
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The Contractor shall participate in Mission Level Reviews and respond to action items as requested by the Government. The Contractor shall participate in dry runs of all Mission-Level Milestone Reviews with the Government. The Contractor shall assume that the dry runs will take one half the time required for the reviews. The Contractor shall host and work with the Government project and review team an additional day following all milestone reviews to discuss and address issues raised and actions assigned at he reviews.

For long lead items that are required to be ordered prior to PDR to meet development schedules, the Contractor shall obtain approval from the Government Contracting Officer prior to ordering these items.

1.2.2 Engineering Peer Reviews (EPR)

The Contractor shall define and implement a set of Engineering Peer Reviews (EPRs) for the hardware and software subsystems of the Observatory and the Mission Operations Element commensurate with the scope, complexity and acceptable risk of the product. Subsystem peer reviews must be held prior to instrument, MOE, and mission PDR and CDR and are considered to be part of the milestone review process. The Contractor shall document the Peer Review Plan in accordance with CDRL PM-6.
The Government will use the Engineering Peer Review results to determine the Contractor's readiness to proceed to milestone reviews. The Contractor shall host EPRs at the Contractor's facilities. EPRs shall be documented in accordance with CDRL RE-17, Peer Review Data Packages. The Contractor shall systematically and comprehensively peer review the product at the individual subsystem level, and at component ("box") and lower levels of assembly, as appropriate. Subsystem and component level design reviews (e.g., Attitude Control Subsystem Critical Design Review (CDR), Reaction Wheel Assembly CDR, etc.) are considered to be EPRs and subject to this procedure. The Contractor shall conduct multiple peer reviews, as appropriate, over the lifecycle of each subsystem and component, with content consistent with the evolving design and development. All peer reviews shall be completed prior to and summarized at the sensor, mission, or ground system PDR and CDR, as deemed appropriate by the Government. The Contractor shall also use EPRs for the focused evaluation of concepts, designs, plans and processes associated with combinations of subsystems and system functions that

cross traditional subsystem or discipline boundaries. Examples include maneuver planning and execution; fault detection and correction; or solutions to address, for example, pointing, thermal or contamination constraints.

Requirements for Software Peer Reviews are covered in a subsequent section of this SOW.

As a minimum, EPRs shall be conducted to cover the following items:

1. Sensor focal plane assembly
2. Sensor data system
3. Algorithm development
4. Mechanism design and test procedures
5. Optomechanical design and alignment processes
6. Each spacecraft bus subsystem
7. Sensor calibration design and test
8. Sensor integration and test (I&T)
9. Spacecraft I&T
10. Observatory I&T
11. Review of how the Observatory Contractor will align and periodically check the alignment of the sensors, including science and attitude sensors, to the Observatory body coordinate system pre-launch and the post-launch initial relative alignment between the star trackers and/or other attitude reference sensors and the co-alignment of the on-orbit ACS coordinate system and the science sensor(s).
12. Launch and early orbit mission design
13. Each MOE subsystem
14. Fault detection and correction
15. Flight software development

Action items from EPRs shall be tracked and peer review presentation and closure documentation shall be maintained for the duration of the contract.

The Contractor shall allow co-chairmanship of EPRs by a Government representative and shall have Government representation on the review panel for subsystem PDRs and CDRs.

1.2.3 Other Reviews and Meetings

1.2.3.1 Scheduled Weekly Telecons

In addition to other informal communications, the Contractor shall participate in a scheduled weekly telecon with the LDCM Project Office to communicate status, issues, and schedule progress and plans of the overall Contract effort. The Contractor shall establish the meeting agenda and distribute meeting minutes and other documentation as

required. The minimum Contractor attendance shall consist of the Project Manger and Systems Manager or the element technical lead managers. The Contractor shall provide detailed status, description of issues, and schedule for each major element (spacecraft, instrument, MOE) of the contract.

1.2.3.2 Monthly Project Status Reviews

The Contractor shall communicate the status of the technical effort, program schedule, and resource condition to the LDCM Project on a regularly scheduled basis. The Contractor shall conduct Monthly Project Status Reviews (MPSRs), including presentation package, in accordance with CDRL PM-1. The MPSR shall include Integrated Master Schedules (IMS) prepared in accordance with CDRL PM-3. The MPSR shall be conducted face-to-face at the Contractor's site unless otherwise agreed in advance. The Contractor shall host and participate in splinter meetings with the Government for one additional day immediately following MPSRs. The Contractor shall invite the Government to attend the Contractor's status reviews with the Instrument and MOE providers.

1.2.3.3 Technical Interchange Meetings

The Contractor shall host and conduct face-to-face informal Technical Interchange Meetings (TIMs) with the Government on technical issues arising during the project at the subsystem or system level. TIMs may include discussion and resolution of any technical issue, for example: performance verification plan buy-offs, pending contract change requests (CCR's), CDRL data submission review/approval status, test data review, anomaly resolution activities, and test support planning.

Either the Contractor or the Government may request a TIM (assume for planning purposes a total of 20 TIMs per year lasting approximately one day each). The Contractor shall track action items arising from TIMs for resolution/response and report status at the MPSRs.

The Contractor shall conduct TIMS with subcontractors for issues concerning critical assemblies and subassemblies and provide the Government 10 days advanced notice so that the Government can attend.

1.2.3.4 Test Status and Planning Meetings

The Contractor shall allow the Government access to Contractor test status and planning meetings.

1.2.3.5 Focal Plane Array Status Telecon and Monthly Summary

The Contractor shall conduct a weekly telecon with the focal plane array vendor(s) with Government participation until the delivery of the focal plane array(s). The Contractor shall provide a brief agenda for the Weekly Focal Plane Array Status Telecon in

accordance with CDRL PM-2. The Contractor shall provide a summary Monthly FPA Status Report in accordance with CDRL PM-2.

1.3 Action Item Tracking

The Contractor shall develop and apply a process for capturing and responding to action items identified by the Government. The Contractor shall provide Responses to Formal Actions from Project milestone reviews in accordance with CDRL PM-7. Project milestone reviews, as defined above, are not complete until actions are dispositioned, subject to the approval of the Contracting Officer.

1.4 Electronic Access

The Contractor shall provide to the Government and Government Contractor personnel, for review purposes, access via remote desk top computer to a general purpose Windows-based electronic library. This library shall contain all completed reports, analyses, requirements documentation, internal technical memoranda, change requests and documentation, CDRLs, and all other documents prepared by the Contractor and any major subcontractors relating to the development and management of LDCM. Within the library the Contractor shall maintain an index of the material (updated monthly) and a search engine for document access. The non-CDRL material contained in these electronic databases may be in Contractor format. The Contractor shall include engineering drawings in this library or provide some other storage/retrieval arrangement, at their option.

1.5 Internal Technical Memoranda

The Contractor shall provide all LDCM-relevant technical internal memoranda as requested by the Government in accordance with CDRL SE-2, Contractor Generated Internal Technical Information. The correspondence can be informal to preserve timeliness. The Government shall have access to these memoranda on a timely basis via hard copy or the electronic library described in Section 1.4.

1.6 Access to Controlled Facilities

The Contractor shall obtain all required clearances and submit any paperwork required for the Contractor to access Government controlled facilities, such as the Mission Operations Center.

1.7 Risk Management and Problem Tracking

The Contractor shall establish and maintain a comprehensive risk management program in accordance with the LDCM Mission Assurance Requirements (MAR). The Contractor shall deliver a Risk Management Plan in accordance with CDRL PM-12. The Contractor shall generate a top risk report that is presented and reviewed at all Monthly Project Status Reviews (MPSRs). The Contractor shall invite the Government to attend Contractor Risk Management Board meetings.

The Contractor shall develop a closed-loop problem tracking process that includes problem or anomaly reporting, problem analysis, and corrective action. The process shall include: a protocol to review past performance to determine the incidence of identical or related anomalies, an escalation procedure (to inform higher levels of management and the Government) based on mission criticality, and a closeout process for root cause determination, anomaly mitigation, and recurrence control.

1.8 Resource Management

The Contractor shall establish, implement, and maintain a comprehensive resource management system for planning, authorizing, and controlling the total resources effort for each task and for providing timely and adequate visibility into manpower and schedule performance. The system shall be consistent with the Contractor's standards.

The Contractor shall provide technical data to support the Government's development and updating of the Project Cost Analysis Data Requirement (CADRe) in accordance with CDRL PM-4.

The Contractor shall establish, implement, and maintain an integrated scheduling system consistent with their corporate procedures and documented in a schedule management plan. The Contractor shall provide an Integrated Master Schedule in accordance with CDRL PM-3.

The Contractor shall provide the necessary resources for monitoring, controlling, executing, and administering the LDCM contract and subcontracts to ensure compliance with all contractual requirements

1.9 Configuration Management

The Contractor shall perform configuration management (CM) in support of the LDCM Project. The Contractor shall document the LDCM CM process in a Hardware and Software Configuration Management Plan in accordance with CDRL PM-9. The Contractor shall maintain configuration of deliverable items throughout all phases of assembly and test. The Contractor shall perform and document configuration verification

as assemblies are incorporated into higher-level assemblies and at major Project milestones (i.e. pre-environmental test, pre-ship, pre-launch, etc). The CM system shall have a change classification and impact assessment process that results in Class 1 and Class 2 Configuration Change Requests (CCRs) being forwarded to the LDCM Project for approval in accordance with CDRL SE-1. Class 1 changes are defined as changes that impact mission science and performance requirements, system safety, cost, schedule, single point failures, and external interfaces. All other changes are considered to be Class 2 changes.

Any flight item that is found to be non-compliant with the requirements of the contract Statement of Work (SOW) or the MAR and is not reworked to be compliant, or is not replaced with a compliant item, shall be dispositioned via a waiver.

The Contractor shall prepare and provide the following configuration control documentation:

1. Configuration Control Board (CCB) Summary reports in accordance with CDRL PM-5.
2. Engineering Drawings and Change Notices in accordance with CDRL SE-8.
3. The Configuration Item Identification List (CIIL) and the Computer Software Configuration Items (CSCIs) in accordance with CDRL SE-11.

1.10 Government Resident Office Support

The Contractor shall provide securable facilities to support four Government in-plant representatives at both the instrument and spacecraft development/build sites, including office space, furniture, facsimile machine,, file/storage area, telephones, network access to the Contractor's electronic database, and access to a copier and a conference room from contract award through observatory on-orbit acceptance. The Contractor shall provide within these offices high-speed (broadband) internet access and access to an ISP (Internet Service Provider) outside the Contractor's facility to allow for access to the GSFC and USGS network. The instrument in-plant representatives will relocate with the instrument and spacecraft when they are moved to the Observatory integration and test site.

The Contractor shall provide additional securable office space, furniture, phones, and high-speed internet access with access to an outside ISP for an additional two visiting Government representatives at both the instrument and spacecraft development/build sites from contract award through observatory on-orbit acceptance.

2 Systems Engineering

The Contractor shall provide a systems engineering function to support the design, development, and implementation of the LDCM spacecraft, instrument, and Mission Operations Element (MOE), and their integration to form the LDCM. The Contractor shall ensure that the LDCM Space Segment and Mission Operations Element and their implementation meet all mission requirements. The systems engineering effort shall be on-going through all stages of the LDCM program, including the allocation of the system performance specification, observatory and Mission Operations Element design, development, fabrication, qualification and acceptance testing, launch operations, launch, post launch checkout, on-orbit anomaly resolution and support to system operations.

The systems engineering effort shall comprise analyses of technical requirements and allocation of derived requirements, definition and maintenance of all interfaces, overview of LDCM design and verification of all defined and derived requirements, systems analyses and special studies as required, risk management support, and tradeoff analyses This shall include but not be limited to the following specific activities:

a. Providing technical direction and oversight throughout all phases of the program.
b. Supporting all peer reviews, project milestone, gateway and launch reviews, and program status reviews as defined in section 1.2.
c. Performing all necessary system studies and trades and risk assessments necessary to develop the LDCM design.

2.1 Requirements Analyses and Allocations

The Contractor shall provide the definition, allocation, and traceability of system and subsystem requirements and the verification approach.

The Contractor shall conduct complete analyses and simulations in support of technical requirements compliance demonstrations to fully establish, define, maintain, and control budget allocations for all required performance and design parameters. Budget allocations shall include, but not be limited to, mass properties, power, radio frequency transmission channels, alignment, line-of-sight pointing, contamination, on-board processor resources, and propellant capacities.

Tasks include the following as a minimum:

1. Flow-down of system requirements.
2. Developing and verifying the LDCM Space Segment Operations Concept in accordance with CDRL SE-21 and performing the Launch-to-Orbit Mission Analysis in accordance with CDRL SE-16.

3. Maintaining and controlling critical LDCM technical performance metrics and margins, including preparing the mass properties reports in accordance with CDRL SE-23 and the other budgets and Key Technical Parameters which are reported at the Monthly Program Status Review.
4. Defining the number and hierarchy (sub-modes) of the various observatory operating modes (e.g., the normal operating mode), if any.

2.2 Interface Definition, Verification and Control

Using the results of the analyses and allocations of technical parameters performed in support of the efforts described in section 2.1, the Contractor shall specify all external and internal interfaces. The Contractor shall define these interfaces, verify these interfaces, and control these interfaces for the duration of the contract. The Contractor shall develop Interface Control Documents for these interfaces in accordance with CDRL SE-5, except for RF interfaces, which are contained in CDRLs SE-18 and SE-19, and MOE interfaces, which are contained in CDRL MO-5. As a minimum these interfaces shall include:

1. The data and RF interfaces of the Space Segment with the Mission Operations Element, the Launch Site Network, Space Network, LDCM Ground Network, and International Cooperators. (TBR)
2. The interface between the elements of the Observatory (i.e., the Sensor, the attitude control system, the power system).
3. The interface of the Observatory to the launch vehicle.
4. All interfaces to the MOE and to the Space Segment, including interfaces to Government assets, as defined in the LDCM Interface Requirements Document.

The Contractor shall provide periodic updates of RF interfaces to support the Government's application for radio frequency spectrum access.

2.3 Design and Performance Verification

The Contractor shall address the total system design including performance margins and design approaches to assure achievement of the required Observatory life, Space Segment operations concept, design integrity, failure modes, intra-system and inter-system compatibility, reliability and maintainability, producibility, safety, survivability, training, and testability.

The Contractor shall develop and maintain all necessary plans and procedures to verify that the LDCM meets all requirements described in the LDCM Space Segment Requirements Document and the LDCM Mission Operations Element Requirements Document. The Contractor shall develop and deliver the Specification Tree in accordance with CDRL SE-17. The Contractor shall also perform and document all analyses of the data and information from the design, development, qualification testing, acceptance

testing, compatibility testing, and on-orbit testing of the Contractor's hardware and software which are required to ensure that the LDCM program will meet its specifications and objectives. These tasks include, but are not limited to the following:

1. Preparing and maintaining the System Performance Verification Plan (CDRL SE-9) for use at the component, subsystem, and Observatory level of assembly, including the MOE, and including instrument integration and interface verification. A System Performance Verification Matrix shall be prepared in accordance with CDRL SE-22 and maintained to show each LDCM requirement, the method of compliance, applicable procedure references, results, report reference numbers, etc.
2. Analyzing and providing the required lower-level design specifications in order to meet higher-level performance requirements (i.e., what detector D* should be specified in order to meet system SNR). All such analyses shall be identifiable and accessible for Government review.
3. Preparing and maintaining verification test procedures for use at the component, subsystem, MOE, spacecraft bus, instrument and observatory level of assembly, including instrument integration and interface verification.
4. Providing the effort required for data reduction and analysis of test results at the component and subsystem levels of assembly during Observatory integration and environmental testing, and during verification of sensor instrument interfaces.
5. Providing the necessary effort for data reduction and analysis during ground system testing, compatibility testing, and during on-orbit testing.
6. Preparing documentation and providing necessary support for reviews defined in section 1.2.
7. Performing systems engineering and analysis in support of the sensor Contractor's development and execution of Sensor tests at the Observatory level and launch base.
8. Supporting system level technical interface meetings, including technical issue resolution, performance verification plan buy-offs, pending contract change requests (CCR's), CDRL data submission review/approval status, test data review, anomaly resolution activities, and test support planning.
9. Developing and delivering the Calibration Validation Plan in accordance with CDRL CV-1.
10. Conducting test evaluation and test reporting.
11. Providing the Wiring Diagrams and the Engineering Drawings and Change Notices in accordance with CDRLs SE-7 and SE-8.
12. Providing a Sensor Users Manual in accordance with CDRL OO-2.
13. Conducting the analyses required to confirm the integrity of the MOE System design to ensure the performance requirements of the applicable specifications will be met over the LDCM design life.

2.4 Systems Analyses

The Contractor shall, in coordination with systems engineering activities, perform the necessary systems engineering analyses to assure that all requirements of this contract are accomplished successfully and on time. These systems engineering analyses shall include, at a minimum, the following;

1. Visible and infrared radiometry
2. Spectral performance
3. Optics, including stray light (including stray light from spacecraft and reflected off solar diffuser)
4. Line of sight jitter
5. Pointing knowledge error budget
6. Data system throughput analyses
7. Analysis of polarization sensitivity, how to minimize, achieve, and demonstrate
8. Analog amplifier analysis (stage-by-stage, each channel to include SNR, bandwidth, gain, stability, etc.)
9. Analysis of bearing-to-housing fits, tolerances, thermal effects
10. Analysis of beam alignment design, tolerances and error budget
11. Torque analyses for all motors, torsional springs, and mechanisms.
12. Analyses of CPU loading, input and output loading, disk utilization, and memory loading for all ADPE.
13. Modeling and analysis to assess the impact of phase noise on end-to-end telecommunications and tracking services.
14. Assessment of user tracking services and LDCM observatory tracking to verify the design compliance with LDCM Space Segment requirements.
15. Assessment of the interference between all observatory transmitters to ensure adequate system performance.
16. Signal Integrity Analysis of all electronics cards.
17. Modal analysis showing survival of boards and components.
18. Structural Thermal Optical Performance (STOP) analysis.

These and all other analyses performed by the Contractor under this contract shall be available to the Government for review.

2.5 Trending

The Contractor shall establish a system for trending test data during Sensor and Observatory level testing. The Contractor shall coordinate with the Government the selected list of parameters to be trended in accordance with CDRL SE-4, Trend Analysis

(List). The Contractor shall monitor selected parameters for trends starting at component acceptance testing and continuing during the system integration and test phases through the on-orbit commissioning phase. The Contractor shall log operating hours, perform trending, analyze trend data, and provide Trending Reports in accordance with CDRL SE-4, Operations Log and Trend Analysis.

A matrix of the components being trended shall be presented at the PER and the trend data shall be presented during the PSR. Additionally, during the PER, the Contractor shall define for each parameter trended how the data are analyzed and interpreted with respect to the allowable test limits of the data as the testing progresses through the test phases. Any anomalous changes and/or trend(s) in the data shall be explained during the PSR. The Contractor shall establish a system for recording and analyzing the parameters as well as any changes from the nominal even if the levels are within specified limits. The Contractor shall review trending results with the Flight Operations Team prior to launch.

2.6 Special Studies

The Contractor shall conduct, in addition to the requirements specified in this document and the contract, additional engineering studies, tests, technical analyses, table-top reviews of test results, design modifications, and tasks relating to the development, implementation, characterization, and operation of the LDCM mission requirements, as authorized by the Government and in accordance with contract clause XX (TBD). Each task will be initiated by written direction from the Government contracting officer. The Government will coordinate with the Contractor to define each task in detail, and establish manpower ceilings, performance schedules, and deliverables.

3 Mission Assurance

The Contractor shall develop, implement, and maintain a comprehensive mission assurance program which meets the requirements of the MAR (427-XXX) (TBD). The Contractor shall adhere to the requirements of the MAR, perform all tasks required by the MAR, and deliver all documents and data required by the MAR.

Upon request by the Government, the Contractor shall deliver hardware to the Government for direct or indirect examination. Direct examinations may take the form of non-destructive evaluations such x-ray fluorescence for plating thickness verification, or sample destructive examinations such as total ionizing dose tests for microcircuits or printed wiring board cross section examinations. Indirect examination will be used when direct examination is not possible. Methods of indirect examinations may include inspection of similar hardware produced on the same production line by the same personnel as the flight hardware.

4 LDCM Observatory Development

The Contractor shall develop the LDCM Observatory in accordance with all contract requirements.

4.1 Design Engineering

The Contractor shall develop and deliver design specifications for the LDCM Space Segment, Spacecraft, and Sensor(s) in accordance with CDRLs SE-12, SE-13, and SE-14, respectively.

4.1.1 Algorithms and Mathematical Models

The Contractor shall develop algorithms and mathematical models as defined below.

4.1.1.1 Calibration Algorithms and Parameters

The Contractor shall develop and deliver Calibration Algorithms and Parameters in accordance with CDRL CV-7.

4.1.1.2 Radiometric Math Model

The Contractor shall develop, deliver, and maintain a Radiometric Math Model in accordance with CDRL CV-5.

4.1.1.3 Line-of-Sight Processing Algorithms

The Contractor shall develop and deliver Data Processing Algorithms in accordance with CDRL CV-8, Data Processing Algorithms.

The Contractor shall demonstrate that the end-to-end requirements of paragraphs 5.7 and 5.8.5 of the Space Segment Requirements Document are satisfied by these algorithms. The Contractor shall document and deliver the results of the demonstration in accordance with CDRL CV-3.

4.1.1.4 Optical Analytical Model

The Contractor shall develop and maintain an Optical Analytical Model in accordance with CDRL CV-6. The Contractor shall verify the accuracy of the model with hardware testing. The Contractor shall update the model to agree with the test results.

4.1.1.5 Stray Light and Ghosting Model

The Contractor shall develop the Stray Light and Ghosting Model in accordance with the Special Calibration Test Requirements document (427-XXX) (TBD) and make the model available for review at the Contractor's facility. The Contractor shall notify the Government of revisions to the Stray Light and Ghosting Model and make these revisions available for Government review at the Contractor's facility.

4.1.1.6 Structural Math Models

The Contractor shall develop and maintain Structural and Dynamic Models and Model Verification Plan in accordance with CDRL SE-25. The Contractor shall verify the accuracy of the models with dynamic test data. The Contractor shall update the models to agree with the structural test results.

4.1.1.7 Thermal Math Model

The Contractor shall develop and maintain a Thermal Math Model in accordance with CDRL SE-6. The Contractor shall deliver a Thermal Analysis Report in accordance with CDRL SE-30.

4.1.1.8 Data Processing Algorithms

The Contractor shall develop and maintain Data Processing Algorithms (see Space Segment Requirements Document, Paragraph 5.3) in accordance with CDRL CV-8.

4.1.2 Hardware Models

4.1.2.1 Sensor Structural-Thermal Model

The Contractor shall develop a Structural Thermal Model (STM) of the sensor(s) to verify the structural and thermal design meets performance requirements. Parts used on the STM may be transferred to Engineering Development Unit (EDU) components after completion of STM testing, provided they meet EDU requirements.

4.1.2.2 Sensor Engineering Development Unit Components

The Contractor shall develop Sensor Engineering Development Unit (EDU) components to evaluate design decisions, test electrical/data interfaces, mitigate risk, and to provide a test bed for anomaly resolution for the flight model components. The EDU components are not required to be integrated together. The Contractor shall present and discuss with the Government the planned functionality level of the EDU components at the ISRR. The Contractor shall develop an EDU focal plane assembly that shall be fully populated.

The Contractor shall preserve the EDU components for the duration of the contract period and make them available as necessary for anomaly resolution.

4.1.3 Engineering Analyses and Reports

The Contractor shall provide a LDCM Space Segment to International Cooperators Interface Control Document in accordance with CDRL SE-18. The Contractor shall perform all analyses and tests required to ensure proper communications and RF compatibility between the Satellite and the International Cooperators' ground segments.

The Contractor shall provide an LDCM to Government Assets Interface Control Document in accordance with CDRL SE-19. The Contractor shall perform all analyses and tests required to ensure proper communications and RF compatibility between the Satellite and the Government-provided ground segments.

The Contractor shall develop and deliver the following items in accordance with the stated CDRL:

Structural and Mechanical Subsystem Performance and Analysis Report, CDRL SE-24.
Stress Analysis, CDRL SE-26.
Propulsion Subsystem Performance Analyses Report, CDRL SE-27
Attitude Control System Performance Analyses Report, CDRL SE-28
RF Communications Performance Analyses/Test Reports, CDRL SE-29
Power Subsystem Performance Analysis Report, CDRL SE-31
Command and Data Handling System Performance Analysis Report, CDRL SE-32
Jitter Analysis Report, CDRL CV-11.

4.2 Fabrication, Assembly, and Test

The Contractor shall provide all necessary personnel, facilities, services, and materials to fabricate, assemble, and test the Spacecraft, the Sensor, and the integrated LDCM Observatory in accordance with their respective design specifications.

The Contractor shall provide all personnel, facilities, services, and materials necessary to verify that the Sensor, Spacecraft, and Observatory meet their functional and performance specifications after exposure to the environments required by the LDCM Environmental Test Requirements (TBD).

The Contractor shall develop and deliver an LDCM System Performance Verification Plan (SPVP), which addresses Sensor-level, Spacecraft-level, and Observatory-level testing and environments, where appropriate, in accordance with CDRL SE-9.

The Contractor shall provide Verification Reports in accordance with CDRL SE-10.

The Contractor shall allow Government personnel and Government Contractor personnel access to all Sensor, Spacecraft, and Observatory:
- released and as-run test procedures, test conductor log books and electronic command logs
- testing
- test planning meetings

The Contractor shall integrate the Government Flight Operations Team into integration and test activities in accordance with CDRL OO-6, Operations Transition Plan.

The Contractor shall document and investigate anomalies and perform anomaly resolution. The Contractor shall store and maintain all output data collected during ground testing for anomaly resolution. Anomaly resolution is the identification, investigation, and resolution of anomalies including the characterization of a problem or deficiency, determination of the probable cause or missing functionality, evaluation against existing specifications and requirements, and providing analysis to the Government for prospective corrective actions or enhancements.

The Contractor shall maintain, calibrate, and certify Ground Support Equipment (GSE) to Contractor standards.

The Contractor shall make available for review by the Government test and acceptance reports for all subcontracted and purchased items.

The Contractor shall deliver the As-Run Test Procedures in accordance with CDRL IT-11.

4.2.1 Spacecraft Testing

The Contractor shall develop and deliver Spacecraft Test Plans in accordance with CDRL IT-1.

The Contractor shall develop and deliver Spacecraft Bus Test Reports in accordance with CDRL IT-2.

4.2.2 Sensor Testing

The Contractor shall develop and deliver a Sensor Integration and Test Plan in accordance with CDRL IT-3.

The Contractor shall develop and deliver Sensor Test Plans in accordance with CDRL IT-4.

The Contractor shall develop and deliver Sensor Test Reports in accordance with CDRL IT-5.

The Contractor shall develop and provide Focal Plane Array Planning Documentation in accordance with CDRL SE-15.

The Contractor shall deliver Sensor Data Sets in accordance with CDRL CV-10.

4.2.2.1 Sensor Performance and Calibration Testing

The Contractor shall develop and provide the Calibration and Validation Plan in accordance with CDRL CV-1. The Contractor shall implement the Calibration and Validation Plan. The Contractor shall calibrate the sensor(s) in accordance with the Government-approved Contractor-developed Calibration and Validation Plan. The Contractor shall provide Calibration and Validation Procedures, for every calibration/validation test described in CDRL CV-1, in accordance with CDRL CV-2. The Contractor shall provide Calibration and Validation Reports in accordance with CDRL CV-3, respectively. The Contractor shall provide Calibration and Validation Summary Reports in accordance with CDRL CV-4. In addition, the Contractor shall provide Relative Spectral Response (RSR) Component Measurements and System RSR Analysis in accordance with CDRL CV-9. The Contractor shall provide spectral filter witness samples to the Government in accordance with Contract clause XX (TBD).

4.2.2.2 Sensor Independent Testing

To maintain continuity of the Landsat data archives and calibration to the National Institute of Standards and Technology (NIST), the Contractor shall provide access to the Contractor's radiometric calibration sources sufficient for the Government and/or its subContractors to conduct source characterization at the Contractor's facility. The Contractor shall also provide coordination and support sufficient for the Government and/or its Contractors to conduct independent pre-launch measurements of the Contractor's radiometric calibration sources at the Contractor's facility.

For Government Transfer Radiometer testing, the Contractor shall provide access sufficient for the Government and/or its Contractors to conduct source characterization in the Contractor's laboratory environment for a total of five 2-day periods; three 2-day periods prior to sensor calibration; and two 2-day periods after sensor calibration. In addition, the Contractor shall provide access sufficient for the Government and/or its Contractors to conduct source monitoring during Sensor calibration activities.

The Contractor shall provide access and support for two 4-day periods, one prior to sensor calibration with the calibration source and one after sensor calibration, for NIST/Earth Observing System (EOS) radiometric scale realization activities. The radiometric scale realization activities will involve viewing of the radiometric calibration source(s), typically large aperture integrating spheres, used by the Contractor to calibrate the Sensor. These sources will be viewed by a number of transfer radiometers and the results will be compared to the Contractor's calibration of this source. The Contractor shall supply access to and an operator for the radiometric calibration source as well as the current radiometric calibration of this source.

The Contractor shall account for these Independent Testing periods of access in the contract and program schedule. The Government will provide reasonable notice of these periods of access.

4.2.2.3 Algorithm Verification

The Contractor shall participate in the comparison and reconciliation of Contractor-produced algorithms with Government-produced algorithms.

4.2.3 LDCM Observatory Integration and Test

The Contractor shall provide all personnel, facilities, services, and materials necessary to test the Sensor at the Observatory level of assembly, and to conduct Observatory integration and testing.

The Contractor shall develop and deliver an Observatory Integration and Test Plan in accordance with CDRL IT-7.

The Contractor shall develop and deliver Observatory Test Plans in accordance with CDRL IT-8.

The Contractor shall develop and deliver Observatory Test Reports in accordance with CDRL IT-9.

4.2.4 Sensor Support During Observatory Performance Testing

The Contractor shall ensure that sensor-developer personnel support Observatory-level testing on a 24/7 basis during thermal vacuum testing and at other times as deemed appropriate. The Contractor shall perform the following, at a minimum:

a. Provide on-site expert sensor-developer personnel support to all performance testing, including real-time monitoring and off-line data analysis, of the Sensor(s) after integration on the spacecraft, covering all shifts worked.
b. Provide expert sensor-developer personnel to review procedures, provide expertise, witness testing, and interpret data before, during, and after sensor-related ambient and environmental testing conducted by the Observatory Contractor.
c. Provide expert sensor-developer personnel to support and conduct anomaly investigations involving the sensor and implement corrective actions.
d. Provide expert Sensor personnel to assist in writing procedures for end-to-end compatibility tests.

4.3 Packaging, Handling, Storage, and Transportation

The Contractor shall prepare and pack the appropriate LDCM subsystems and systems and all related GSE for shipment as necessary, and shall transport and ship the material to the designated facility, providing all necessary personnel, facilities, services, and materials. The Contractor shall develop a Packaging, Handling, Storage, and Transportation (PHS&T) Plan and Procedures in accordance with CDRL IT-10 and shall deliver the appropriate LDCM systems/subsystems and all related GSE in accordance with the Plan. The Contractor shall perform a complete post shipment functional test of the LDCM systems/subsystems and all related GSE. The Contractor shall plan and support all activities necessary to safely ship the integrated LDCM Observatory to the launch base.

4.4 Flight Software

4.4.1 Software Definitions

4.4.1.1 Flight Software Element

Flight Software (FSW) for the LDCM is embedded real-time software and includes flight firmware found in the on-board microprocessor(s) and embedded in the various Observatory hardware subsystems. Some of the functions provided by the FSW are: real-time operating system, time management, guidance, navigation, and control for multiple mission phases and Observatory configurations, imaging sensor suite processing, telemetry monitoring, command storage and execution, Observatory internal communication bus control, failure detection and correction, bulk memory management, and ground operations interface. Flight Software also encompasses all non-deliverable, on-board microprocessor(s) software used in support of testing the Flight Software Element.

The Contractor shall treat the software component of firmware, which consists of computer programs and data loaded into a class of memory that cannot be dynamically modified by the computer during processing (including programmable read-only memories (PROMs), programmable logic arrays, digital signal processors, Field Programmable Gate Arrays (FPGAs), etc.) as flight software for the purposes of this SOW. For any autogenerated software from databases, models or other sources, the Contractor shall consider these sources as Flight Software for the purposes of this SOW.

For all flight software elements, the Contractor shall demonstrate compliance with the NASA Software Engineering Requirements specified in the NPR 7150.2, which provides the minimal set of requirements established by the Agency for software acquisition, development, maintenance, operations, and management. The Contractor shall implement MAR requirements with respect to Software Assurance.

The Contractor shall develop, verify, validate and maintain the complete FSW image in the LCDM observatory and associated testbeds for the duration of the contract.

4.4.1.2 Software Development and Validation (SDV) Software Element

The Contractor shall develop the Software Development and Validation software for the LDCM which supports the development and test of the Flight Software. It includes host development computer operating systems, high-level language compilers and debuggers, autocode generator software systems, machine language emulators, and test scenarios and procedures. It includes the software in the Observatory test environment simulators that model the sensors, actuators, and attitude environment and dynamics. It also includes development support software such as document and code configuration management systems.

4.4.1.3 Software Criticality Classification

The Contractor shall classify all LDCM software within the Flight and SDV Elements as belonging to one of the following criticality classifications and shall define the management approach of each class in the Software Management and Development Plan (SMDP):

(a) "Mission Critical" software is all software whose failure will cause permanent loss of the ability to successfully service. Included in this classification shall be all LDCM Flight software and firmware plus the ground software necessary to verify the correctness of the flight software (e.g., sensor, effector, and dynamics model software).

(b) "Mission Support" software is any software whose failure can impair any part of the mission. Recovery from failure of this class of software results in recovery of the ability to service.

(c) "Engineering Analysis" software is that software used in engineering analysis and simulations on an as-needed basis.

(d) "Commercial" software includes facility computer operating systems, software packages (e.g., mathematics packages, graphics packages), and high-level-language compilers employed in developing and maintaining software components. Commercial software acquired for integral use within planned operational elements shall be assigned a criticality equal to that of the element of which it is a part.

4.4.1.4 Software Types

The Contractor shall classify all LDCM software within the Flight and SDV Elements as belonging to one of the following types and shall define the management approach of each class in the SMDP:

(a) "Developed" software - This is all software developed in accordance with the full life cycle as defined in the Contractor's Software Development and Management Plan.

(b) "Reuse" software - This is any software that has been developed by previous projects which can be used in significant portions to reduce development cost or improve reliability of current projects.

(c) "Heritage" software - This is any Reuse software which has not only been previously developed, but which has been successfully flown (Flight Software Element), or successfully used for an equivalent Project (SDV Element).

(d) "Off-the-Shelf (OTS)" software - This includes any software purchased from a vendor including embedded run-time systems, data- base systems, mathematics and graphic packages, compilers, operating systems, etc.

4.4.1.4.1 Off-the-Shelf (OTS) Software

Commercial-Off-the-Shelf (COTS) software - Software that is sold, leased, or licensed to the general public, either as a stand alone software product or embedded in a software system.

Modified-Off-the-Shelf (MOTS) software - COTS software that is modified to meet unique requirements of a specific customer. This software requires ongoing unique maintenance for the life of the system not normally offered by the vendor.

Government-Off-the-Shelf (GOTS) software - Software provided to the customer as GFE with no warranty or maintenance provided.

For all OTS software that is integral to Mission Critical software, the Contractor shall include delivery of the OTS source code with the product and any upgrade purchased or received under software purchase agreements with product vendors (or the Government, as applicable).

This section does not pertain to Commercial Off-the-shelf (COTS) software that is an integral part of any unmodified commercial test equipment used on the LDCM.

The Contractor shall meet the requirements of NASA Software Engineering Requirements specified in the NPR 7150.2 when choosing to use OTS software to satisfy all or part of the software requirements implementation. The details of OTS utilization and management of such shall be provided in the Contractor’s SMDP.

4.4.2 Software Management, Requirements, Development, Verification, and Testing

The Contractor shall document their software management approaches and processes for software analysis, design, development, documentation, version control, test, validation, risk management, metric collection, and assurance of all software products in the Software Development and Management Plan (SMDP) document, in accordance with CDRL SW-1. The Contractor shall adhere to the SMDP as approved by the government.

4.4.2.1 Planning and Requirements Life Cycle Activities

The Contractor shall perform all analyses and software systems engineering required to allocate (from system and subsystem requirements) to identify software requirements and shall generate the Software Requirements Specification (SRS) in accordance with CDRL SW-2. The Contractor shall ensure that all requirements are forward and backward traceable between system and software requirements and between software requirements, design, and test.

The developer shall plan and implement a Verification and Validation (V&V) program to ensure that software being developed or maintained satisfies functional and performance requirements defined in the SRS. The Contractor's testing approach and methodology shall be documented in the Flight Software Test Plan in accordance with CDRL SW-7 program. The Contractor shall address the approach to the following levels of testing on the flight software elements as identified in the Flight Software Test Plan:

- V&V of the logic of individual software functions while exercising all critical paths of the software unit.
- V&V of an integrated FSW build delivered to the FSW Test Team operates as designed and meets each functional and performance requirement allocated to the build.
- V&V of the FSW in its target hardware environment in a manner as close as possible to post-launch operations with the intent of qualifying the FSW as a mission subsystem – meeting all on-orbit nominal, anomalous and contingency operational requirements.
- For the purposes of the SOW, Acceptance testing is defined as the formal execution of a full set of FSW System Validation Tests against the final delivery of the FSW system.

4.4.2.2 Design Life Cycle Activities

The Contractor shall maintain Algorithm Design Documents (ADD) for each LDCM subsystem that incorporates flight software in its implementation. The Contractor shall deliver the Software Design Document/Users Guide in accordance with CDRL SW-3.

4.4.2.3 Implementation and Delivery Life Cycle Activities

The Contractor shall implement the documented Configuration Management Plan described SOW Section 1.9 with respect to Flight Software Development and Test. All software elements (flight and ground test) shall be placed under Configuration Management, including default and baseline values for tables and parameters used in the Ground Test Software and Flight Software.

To assist in the verification and validation of software requirements, the Contractor shall develop and maintain a Software Requirements Verification Matrix (SRVM). The SRVM shall be available to the government upon request.

The Contractor shall capture and maintain detailed testing procedures. Electronic versions of test procedures shall be available upon request to the government. The Contractor shall document, verify and validate Formal Software Tests through the Software Test Report in accordance with CDRL SW-6.

In the Acceptance test phase, the Contractor shall prepare for formal monitoring of software testing by QA, the Contractor's System staff, and government personnel to include the NASA IV&V staff. Upon successful completion of this phase of testing, the Contractor shall close out all action items and prepare for formal delivery of the software.

The Contractor shall identify in the SRVM Flight software requirements which require observatory level hardware in the loop that shall be verified/validated during LDCM I&T testing. These tests shall include, but are not limited to, assuring correct polarity, phasing, mechanism direction and symmetry, index positions, gains, scale factors, and some failure detection and correction actions.

The Contractor shall ensure that both functional and performance test procedures execute the LDCM flight hardware and flight software in all modes and configurations. These tests will be used to verify performance during initial integration, environmental testing, pre-ship at the Observatory integration facility, post-ship at the launch facility, and on the launch vehicle. The Contractor shall design these tests to execute as much of the flight software code and data as is possible in a l-g environment.

4.4.3 Software Management Requirements

4.4.3.1 Software Measures (Metrics)

The Contractor shall acquire and include Software Measures (Metrics) as defined in the SMDP from any sub-Contractors or team members.

The Contractor shall collect and report software measures supporting the analysis of both software product quality and schedule/effort/cost performance. The collection and reporting of metrics shall be automated to the fullest extent practical. Measures shall be

provided to the Project both as raw data and in graphical form as part of the monthly status review

4.4.3.2 Software Reviews

The Contractor shall prepare and conduct flight software status reviews as part of the technical status portion of the Monthly Project Status Reviews as described in SOW Section 1.2.4.2.

Formal reviews shall be conducted with Government participation. The Government shall provide a description of the review's success criteria at least one month in advance, and shall reserve the right to require a delta review if success criteria are not met.

In addition to the Mission-level Reviews listed in SOW section 1.2, the Contractor shall conduct the following Reviews and shall deliver the accompanying documents 1 week prior to the review:

- Software Requirements Peer Review prior to the Mission PDR and deliver a Software Requirements Peer Review Package in accordance with CDRL SW-9
- Software PDR Peer Review following the Mission Preliminary Design Review and deliver a Software PDR Peer Review Package in accordance with CDRL SW-10
- Software CDR Peer Review following the Mission CDR and deliver a Software Post-CDR Peer Review Package in accordance with CDRL SW-11.
- FSW Acceptance Test Readiness Review (ATRR) and deliver a Software Test Readiness Review Data Package in accordance with CDRL SW-4
- Software Acceptance Review (SWAR) and deliver a Software Acceptance Review Data Package in accordance CDRL SW-5.

4.4.4 Government Insight and Support of Government FSW Development

This section defines Government access to Flight Software documentation, data, and analysis to allow appropriate insight of development effort, including the NASA IV&V interface.

All Contractor, sub-Contractor, and team member reviews, audits, meetings and other activities pertinent to the execution of the contract shall be open to Government review/attendance. The Contractor shall provide the Government with reasonable and timely notification, to facilitate Government attendance in person, by telecon, or by videocon. Government LDCM Contractors may also attend these reviews, audits, and meetings at the government's discretion.

4.4.4.1 NASA IV&V Support

The Contractor shall ensure that all software documentation and code required for the NASA Software Independent Verification and Validation (IV&V) effort is made available to NASA IV&V personnel. This may include access to all software reviews and reports, developer plans and procedures, software code, software design documentation, and software problem reporting data. Wherever possible, the developer shall permit electronic access to the required information or furnish soft copies of requested information to NASA IV&V personnel.

The developer shall review and assess all NASA IV&V findings and recommendations. The developer shall forward their assessment of these findings and recommendations to NASA IV&V personnel accordingly. The developer shall take necessary corrective action based upon their assessment and notify NASA IV&V personnel of this correction action. The developer shall also notify IV&V personnel of those instances where they decided not to take corrective action on specific IV&V findings and recommendations. A developer point of contact shall be assigned and available to NASA IV&V personnel, as required, for questions, clarification, and status meetings.

4.4.5 Software Maintenance

The Contractor shall develop and maintain the LDCM Flight software and documentation to ensure reliability, maintainability and operability, along with the environments, emulators, and test software necessary to develop and verify these systems through the duration of the contract.

4.4.6 Software Development, Validation, and Maintenance Environment

A software development, validation, and maintenance environment shall be used for the life cycle management of the LDCM Flight Software and associated ground operational software. This environment shall contain the software, databases, compilers, debuggers, emulators, tools, and procedures/test scripts necessary to perform software management, design, development, local configuration management, testing, debugging, integration, verification & validation, maintenance, and preparation of software images in a format(s) suitable for both loading in a ground test configuration and uplinking to LDCM. This includes a complete test environment to validate any Flight Software modifications. Also included in this environment is the test bed facility used for real-time, closed loop testing on flight-like hardware (see next section).

4.4.7 Software Development & Validation Facility (SDVF)

The Contractor shall provide all resources necessary to develop, certify, and maintain the real-time closed loop test bed facility, otherwise known as the SDVF. See the additional requirements for the SDVF in the Space Segment Requirements Document.

The Contractor shall maintain the special hardware (non-commercial such as C&DH avionics and power supplies) in the SDVF for the duration of the LDCM mission.

4.4.8 End of Contract Transition

The Contractor shall perform the final transition to the government designated software maintenance team at the end of the contract. The plan shall be documented in the Software Delivery Package and Operations Transition Plan in accordance with CDRL SW-8.

The Contractor shall provide to the government or designated representatives the following items at the end of contract transition:

- A ground reference image of the executable code in PROM and EEPROM (as applicable) on the observatory at the end of contract transition
- The complete set of source code, patch history, and associated build scripts to regenerate the image

4.5 Ground Support Equipment

4.5.1 Calibration Test Equipment

The Contractor shall define, design, build, provide, maintain, and document all equipment necessary to radiometrically and geometrically calibrate the Sensor. The Contractor shall perform tests necessary to demonstrate that all Ground Support Equipment (GSE) is functioning properly and within specification. The Contractor shall ship an appropriate set of this calibration equipment with the LDCM Observatory as required to support ambient and thermal vacuum tests at the Contractor's facility.

4.5.2 Mechanical GSE

The Contractor shall define, design, build, provide, maintain, and document and ship, as necessary, the Sensor-level, Spacecraft-level, and Observatory-level mechanical GSE. Mechanical GSE consists of equipment and fixtures required to operate, test, handle, lift, perform optical alignment, and maintain the Sensor, the Spacecraft, and the Observatory at the Contractor's facilities and at the launch processing facility. Mechanical GSE also includes equipment required to provide the appropriate thermal and vibration test environments at the Contractor's facilities as specified in the LDCM Environmental Test Requirements (TBD). The Contractor shall provide Sensor protective covers that protect fragile components from minor impact as well as contamination.

4.5.3 Electrical GSE

The Contractor shall define, design, provide, maintain, document, the Sensor-level, Spacecraft-level, and Observatory-level electrical GSE throughout the duration of the contract. The electrical GSE consists of the System Test Equipment (STE), battery reconditioning equipment and software necessary to command, monitor, and test the Sensor, Spacecraft, or Observatory at the Contractor's facilities. The LDCM electrical ground Support equipment (EGSE) shall be used for subsystem hardware and FSW development, and subsystem environmental testing prior to integration at the Observatory level. The EGSE shall be used at the spacecraft level to support bus subsystem integration, and at the observatory level to support all applicable testing (Comprehensive Performance Tests, Limited Performance Tests, environmental testing, end-to-end tests, etc.). The EGSE shall be used to verify the electrical interfaces and functionality of the various spacecraft subsystems that support the observatory. The Contractor shall ship all electrical GSE as necessary.

4.5.3.1 Electrical GSE Software

The Contractor shall design and provide all software necessary to operate the GSE. The Contractor shall prepare and conduct a GSE software design review as part of the peer reviews associated with IPDR ICDR, PDR, and CDR and provide review packages for each review in accordance with CDRL RE-17.

4.5.4 Shipping, Storage, and Purge Equipment

The Contractor shall provide environmentally controlled shipping/storage containers and necessary ancillary equipment for shipment of the Sensor and the LDCM Observatory through launch.

The Contractor shall pack and ship all flight hardware, test equipment, and support equipment as required.

4.6 Spares

The Contractor shall define and implement the spares program necessary to minimize schedule impact for the project created by failures, contamination, or by other plausible events or conditions for all flight and ground support equipment. In defining the spares program, the Contractor shall consider the reliability, handling, and environment of subsystems, components, and parts, hence the likelihood that these items would need to be replaced. The Contractor shall provide a Spare Parts Plan and List in accordance with CDRL SE-35. The Contractor shall qualify, test, and calibrate the spares to the same level as the corresponding flight parts.

4.7 Observatory Simulator

The Contractor shall design, develop, integrate, test, and deliver an Observatory Simulator to the Mission Operations Center (MOC) facility. The Contractor shall ensure that the Observatory Simulator meets all of its requirements as defined in the Space Segment Requirements Document.

4.7.1 Observatory Simulator - Review and Documentation Requirements

The Contractor shall include the Observatory Simulator in Engineering Peer Reviews, the Mission-Level MDR, PDR, and CDR reviews and review packages.

The Contractor shall provide all design and specification documentation used as the basis for development of the Observatory Simulator. The Contractor shall deliver:

Observatory Simulator Subsystem Requirements Document, SE-33
Observatory Simulator Architecture Document, SE-34
Observatory Simulator Users Guide, SE-3
Observatory Simulator Integration and Test Plan, IT-12
Observatory Simulator Software Test Reports, IT-13

4.7.2 Observatory Simulator Operator Training

4.7.2.1 Training Plan

The Contractor shall provide an Observatory Simulator Training Plan and Materials in accordance with CDRL OO-8.

4.7.2.2 Training Scope

The Contractor shall provide training for up to six Flight Operations Team personnel in the use of the Observatory Simulator and shall prepare and provide all course material. The Contractor shall execute the approved training plan provided under CDRL OO-8.

5 Mission Operations

Note: LDCM Mission Operations will be conducted from the Mission Operations Center (MOC) at a Government provided CONUS based facility (location TBD). The Government will also provide a physically separate Back-Up MOC (BMOC) Facility at a CONUS location (TBD) to conduct contingency and/or temporary Observatory mission operations in the event the primary MOC is unavailable.

The Contractor shall integrate the Government Flight Operations Team (FOT) into all operations activities related to mission integration and test and on-orbit commissioning.

The Contractor shall plan and conduct Observatory deployment, checkout, and commissioning from the MOC Facility. During this period, the Contractor shall direct the execution of all commands to the Observatory which will be performed by the Government FOT.

5.1 Mission Operations Element (MOE) System Development

The Contractor shall develop the MOE System, which includes the backup MOE, in accordance with the Mission Operations Element Requirements Document (MOERD) and the Space to Ground Interface Requirements Document.

The Contractor shall deliver and install the MOE System at the Government-provided MOC Facility and Backup MOC Facility.

5.1.1 Design

The Contractor shall design the MOE System, including requirements and interface analysis. The Contractor shall deliver a MOE Design Specification and Description in accordance with CDRL MO-18. The Contractor shall conduct trade studies of appropriate software and hardware solutions to meet the requirements and estimates of time and cost to implement and test the proposed system. The Contractor shall deliver the MOE Software Trade Study Report and the MOE Hardware Trade Study Report in accordance with CDRLs MO-21 and MO-22, respectively.

The Contractor shall design and develop the Human Computer Interface (HCI) for the MOE System in accordance with the MOERD. The Contractor shall conduct TIMs to elicit input from the Government customer and to iteratively prototype the HCI. The Contractor shall develop two prototypes as specified in the MOERD.

The Contractor shall design MOE System interfaces in accordance with the LDCM Space-to-Ground Interface Requirements Document (GSFC 427-XXX) (TBD). The Contractor shall generate corresponding MOE Interface Control Documents (ICDs) in accordance with CDRL MO-5.

The Contractor shall develop and deliver the following MOE documentation in accordance with the stated CDRLs:

MOC Concept of Operations, CDRL MO-4
MOE System – Lower-Level Systems Requirements Document (SRD), CDRL MO-6
MOE Subsystem Integration Test Plans, CDRL MO-9
MOE Subsystem Test Plans, CDRL MO-10
Mission Operations Element Internal End-to-End Test, CDRL MO-11.
MOE Software Test Reports, CDRL MO-12
MOE Software Test Procedures Documents, CDRL MO-13
MOE Operations Handbook in accordance with CDRL MO-14
LDCM Observatory Handbook, CDRL MO-15
MOE Pre-launch and Commissioning Procedures, CDRL MO-16
MOE Operations On-Orbit Procedures in accordance with CDRL MO-17

5.1.2 Contractor Documentation Review & Support

The Contractor shall review and provide input to the following Government MOC documentation:

5.1.2.1 LDCM MOC Facility Plan

The LDCM MOC Facility Plan describes the physical characteristics of the MOC and includes internal and external physical interfaces, access and security, and communications. The LDCM MOC Facility Plan describes the installation methodology and implementation schedule. The Contractor shall provide inputs to the Government in accordance with CDRL MO-20, MOE Requirements Facility Implementation Plan.

5.1.2.2 Ground Segment - Systems Integration and Test Plan

The Ground Systems Integration and Test Plan describes the means by which the ground system meets its requirements and includes the methodology to perform ground systems compatibility and end-to-end testing with the LDCM Observatory.

5.1.3 Implementation

The Contractor shall implement the MOE System in accordance with the MOERD and the Space to Ground IRD.

The Contractor shall provide all hardware, software, procedures, personnel, and services required to satisfy MOE development requirements.

5.1.3.1 MOE System Integration and Test

The Contractor shall deliver the MOE Subsystem Integration and Test Plan in accordance with CDRL MO-9.

5.1.3.2 MOE System & LDCM Observatory Compatibility Testing

The Contractor shall perform MOE Systems to LDCM Observatory compatibility testing to verify the capability of the MOE System to communicate with the Observatory and to exercise the functional performance of all MOE subsystem components. To accomplish this, the Contractor shall implement the following activities:

- Devise the test goals, requirements, and success criteria in coordination with the Government
- Schedule the test and coordinate resources
- Conduct all subsystem reviews of the commands, telemetry, procedures, scripts, contingency plans, etc. to be used in the testing
- Conduct a final test review approximately one week prior to the performance of each test that covers the test plan, procedures, scripts, and test support and coordination activities.
- Execute the planned command procedures and generate data products
- Collect, process, and document all supporting data in a post test report
- Resolve anomalies and incorporate lessons learned for future tests

5.2 Mission Operations Readiness

The Contractor shall plan and conduct Mission Operations Readiness activities to include exercises and launch rehearsals, and operator training.

5.2.1 MOC Flight Operations Team Training and Certification

The Contractor shall provide a training plan that describes course methodology, content, and criteria for performing flight operations as part of the FOT. The Contractor shall provide the training plan in accordance with CDRL MO-19. The Contractor shall train up to twenty (20) Flight Operations Team participants and shall use as a basis, the LDCM Observatory Operations Handbook and the MOE Operations Handbook. The Contractor shall prepare and provide all course materials, and conduct a five-day (40 hours) Flight Operations Team training class at the Contractor facility. The Contractor shall define the criteria for operator certification and perform all FOT certifications. The Contractor shall execute the approved Training Plan and certifications in accordance with CDRL MO-19.

5.2.2 Launch Rehearsals and Exercises

To the extent that exercises and launch rehearsals are required in Flight Operations Team Training Plan, for these exercises and launch rehearsals, the Contractor shall:

- Devise the goals and resource requirements
- Schedule the activity based on resource constraints
- Participate in reviews of planned activity with participants
- Execute the activity and collect appropriate data
- Participate in post-activity debriefs and lessons learned review with participants
- Generate a post activity report that documents the outcome of rehearsal activities.
- Resolve anomalies and incorporate lessons learned into future activities

6 Mission Systems Integration

The Contractor shall verify that the Space Segment is properly integrated with the Ground Segment. The Contractor shall plan and conduct testing which demonstrates the end-to-end functionality of the LDCM.

6.1 LDCM End-to-End Test(s)

The Contractor shall lead Space Segment to Ground System End-to-End testing to demonstrate the capability of the total LDCM system to execute and process an image collection request in accordance with the SSRD, the IRD, and MOERD. The Contractor shall implement the test(s) utilizing the MOE System to command the LDCM Observatory to produce an output that is captured to the on-board mass storage recorder for playback to pre-launch ground support equipment. The Contractor shall provide the data to the Ground System. The Contractor shall demonstrate that the Observatory data can be processed to Level 0. The Contractor shall demonstrate that Level 1 data can be produced with the raw image data using simulated attitude and ephemeris data. The Contractor shall verify test goals are met by the system during execution of the end-to-end test(s). To accomplish this, the Contractor shall:

a. Devise the test goals, requirements, and success criteria in coordination with the Government in accordance with CDRL IT-6, End-to-End Test Documentation
b. Schedule the test(s) and coordinate resources
c. Provide network services to the Government Mission Operations Center
d. Conduct all subsystem reviews of the commands, telemetry, procedures, scripts, contingency plans, etc. to be used in the testing
e. Conduct a final test review approximately one week prior to the performance of each test that covers the test plan, procedures, scripts, and test support and coordination activities.
f. Execute the planned command procedures and generate data products
g. Collect, process, and document all supporting data in a post-test report in accordance with CDRL IT-6.
h. Resolve anomalies and incorporate lessons learned for future tests

6.2 RF Compatibility Testing

The Contractor shall plan and conduct Radio Frequency (RF) Compatibility Tests between the Observatory and the NASA RF interface equipment (e.g., NASA Compatibility Test Van or other equipment). The Contractor shall devise the test goals, requirements, and success criteria in coordination with the Government in accordance with CDRL IT-14, RF Compatibility Test Documentation.

7 Pre-Launch, Launch, and Commissioning

7.1 Launch Service Support

Launch services for LDCM, including mission launch specification, safety compliance, payload processing facilities, materials, and services; launch support, mission orbit analysis, and mission support, including range services, will be provided by the Government. The Contractor shall provide support to the launch services provider as defined below. Several of the deliverables called out in this section have been developed under other deliverable requirements. The Contractor shall reformat those deliverables in accordance with the CDRL for Government delivery to the launch services provider.

7.1.1 Payload Requirements

The Contractor shall prepare the Inputs to Launch Vehicle Interface Requirements Document in accordance with CDRL LS-1.

7.1.2 Mission Specification

The Contractor shall prepare an Observatory Mathematical Model for Dynamic Analysis in accordance with CDRL LS-2 for use in a coupled loads analysis (CLA) conducted by the launch services provider. The Contractor shall also prepare the Observatory Thermal Model, CDRL LS-22, and, if liquid propellants are used, the Observatory Slosh Model CDRL LS-23.

The Contractor shall provide Inputs to the Launch Vehicle Interface Control Document, the launch vehicle/Observatory interface control document prepared by the launch services provider. These inputs shall be in accordance with CDRL LS-3.

The Contractor shall define the hardware interface from the Observatory to the blockhouse for control and monitoring of Observatory functions after Observatory installation in the launch vehicle and prepare the Electrical Wiring Requirements document in accordance with CDRL LS-5.

The Contractor shall update the Fairing Requirements initially presented in CDRLs LS-1 and LS-3 in accordance with CDRL LS-6. This document provides the final Observatory requirements used to define the mission-specific fairing modifications made during production. The Contractor shall also provide Inputs to the Venting Analysis, CDRL LS-21.

The Contractor shall prepare Observatory Drawings in accordance with CDRL LS-13. The launch services provider uses the Observatory drawings submitted under this CDRL as input in preparing the compatibility drawing, a working drawing that identifies Observatory-to-launch vehicle interfaces. The Contractor shall review the compatibility drawing and provides comments, and upon comment resolution and incorporation of the final Observatory drawings, the compatibility drawing is formally accepted as a

controlled interface between the launch vehicle Contractor and the Observatory Contractor.

7.1.3 Mission Support

The Contractor shall define any range or network requirements (operational configuration, communications, tracking, data flow) appropriate to the LDCM mission in accordance with CDRL LS-9, Mission Operational and Support Requirements.

To obtain range and network support, the Contractor shall prepare and submit Inputs to Program Requirements Document in accordance with CDRL LS-10 for use by the Government in preparing the Program Requirements Document (PRD).

7.1.4 Launch Support

To obtain use of Radio Frequency (RF) spectrum during ground processing and launch, the Contractor shall specify the RF transmitted by the Observatory during ground processing and launch in accordance with CDRL LS-7, Radiation Use Request/Authorization.

The Contractor shall prepare the Payload Processing Requirements Document (PPRD) in accordance with CDRL LS-11.

The Contractor shall specify the maximum Launch Window for any given day in accordance with CDRL LS-12.

To provide all agencies with a detailed understanding of the launch site activities and operations planned for a particular mission, the Contractor shall prepare a Launch Site Test Plan in accordance with CDRL LS-14.

The Contractor shall prepare operating procedures for all operations that are accomplished at the launch site in accordance with CDRL LS-15, Observatory Launch Site Test Procedures.

The launch services provider prepares launch site procedures for various operations that involve the Observatory after it is mated with the launch vehicle upper stage. Included are Observatory weighing, Observatory installation to the second stage and into the handling can, Observatory transportation to the launch complex, Observatory hoisting into the white room, handling can removal, Observatory mating to the launch vehicle, fairing installation, flight program verification test, and launch countdown. The Contractor shall prepare inputs to these procedures in accordance with CDRL LS-16, Inputs to Observatory Integrated Operations, in the form of handling constraints, environmental constraints, personnel requirements, and equipment requirements.

If the Contractor plans to radiate at the launch site, an FCC license shall be obtained by the Contractor. This will assure the Contractor that the Observatory frequency will not be interfered with during use. The Contractor shall deliver the Radio Frequency Application in accordance with CDRL LS-20.

7.1.5 Environmental Test Document and Reports

The Contractor shall prepare the Observatory Environmental Test Document in accordance with CDRL LS-4. The Environmental Test Plan documents the Contractor's approach for Observatory qualification and acceptance tests. The Environmental Test Reports summarize the results of system-level structural loads and dynamic environment testing performed to verify adequacy of the Observatory for flight (e.g., static loads, vibration, acoustics, shock).

7.1.6 Mission Analysis

The Performance and Guidance Accuracy Analysis (PGAA) is done by the launch services provider. The LDCM Contractor shall prepare Inputs to the PGAA in accordance with CDRL LS-8. This is the first step in the mission-planning process, intended to uncover and resolve any unusual problems inherent in accomplishing the mission objectives.

The Contractor shall compile Observatory mass data and prepare the Observatory Mass Properties Statement in accordance with CDRL LS-17.

The Contractor shall prepare Inputs to the Observatory/Launch Vehicle Separation Memorandum in accordance with CDRL LS-18. These inputs support the launch services provider's determination that there is adequate clearance and separation distance between the Observatory and expended payload attach fitting (PAF).

The Observatory Contractor shall provide Post-launch Orbit Confirmation Data in accordance with CDRL LS-19.

7.2 Launch Support

7.2.1 Launch and Early Orbit Support

The Contractor shall perform launch preparations, launch support, orbit maneuvers, Observatory appendage deployments, and spacecraft bus and instrument checkout, providing all necessary personnel, facilities, services, and materials.

Launch, Observatory deployment, and early on-orbit commissioning activities will be performed from the U.S. Government provided MOC. A Government-provided Flight Operations Team shall execute all Observatory commands subject to the control of the Contractor launch and commissioning team.

The Contractor shall develop and provide the following CDRLs:

CDRL LS-24, Launch Commit Criteria
CDRL LS-25, Launch and Early Orbit Procedure
CDRL LS-26, Launch Telemetry Data

The Contractor shall provide an LDCM Launch Data Briefing Book prior to launch in accordance with CDRL PM-10.

7.2.2 Engineering Support

The Contractor shall provide continuous engineering support during the Launch and Early Orbit mission phase, i.e., from launch through Government acceptance. This includes performing all monitoring and analysis functions, executing all orbital maneuvers, and deploying all Observatory appendages.

7.3 Commissioning (includes On-Orbit Check-out)

7.3.1 Observatory Checkout

The Contractor shall complete the orbit raising and perform Observatory checkout nominally within 90 days after launch, providing all necessary personnel, services, and materials.

The Government will provide to the Contractor a list of WRS-2 scenes that will be used by the Government for independent validation of image quality. The Contractor shall provide these scenes to the Government within 60 days of launch.

The Contractor shall provide post-launch verification and test of the LDCM Observatory, including provision of on-site personnel at the Mission Operations Center (MOC). The Contractor shall, at a minimum:

a. Provide an LDCM On-Orbit Commissioning Plan in accordance with CDRL OO-1.
b. Determine the duration of the instrument outgassing period and monitor outgassing effectiveness during commissioning phase.
c. Provide personnel at the MOC on a 24/7 basis to lead the operation of and monitoring of the health and safety of the Observatory during Commissioning.
d. Review and analyze LDCM Observatory post-launch test data and provide Observatory On-Orbit Test Reports in accordance with CDRL OO-4.

e. Provide the On-Orbit Procedures in accordance with CDRL MO-17. The Contractor shall verify these procedures on the Observatory simulator prior to approval.
f. Conduct post-launch pre-Initial Operational Capability (IOC) validations in accordance with the SPVP.
g. Conduct tests in accordance with the Special Calibration Test Requirements Document.
h. Investigate and resolve on-orbit anomalies that affect LDCM Observatory specification-related performance parameters and/or anomalies that threaten LDCM Observatory health and safety. Provide an On-orbit Anomaly Resolution Support Plan in accordance with CDRL OO-5.
i. Provide the On Orbit Performance Report in accordance with CDRL OO-3.
j. Provide the Observatory Database in accordance with CDRL SE-20.
k. Provide the Telemetry and Command Requirements Document in accordance with CDRL OO-7.
l. Participate in the comparison and reconciliation of images generated with Contractor-produced algorithms and images generated with Government-produced algorithms.

7.3.2 Handover and Acceptance

The Contractor shall supply an Operations Transition Plan in accordance with CDRL OO-6. The Contractor shall perform an On-Orbit Acceptance Review prior to Government acceptance in accordance with CDRL RE-16. The Contractor shall deliver an Acceptance Data Package in accordance with CDRL SE-36. The Contractor shall perform a handover to the Government after successful Observatory commissioning and Government acceptance, at which time the Government assumes responsibility for the health and safety of the Observatory.

In a non-nominal launch situation, the Contractor shall provide engineering and operations support until Government acceptance.

8 Post-Commissioning Maintenance and Operations Support

The Contractor shall provide the following services after Commissioning:

1. Maintain flight software development tools and the Software Development and Validation Facility.
2. Maintain the Observatory simulator as a software and procedural development tool and as a flight operations training tool.
3. Maintain the Sensor EDU components as a tool for resolving on-orbit anomalies.
4. Train the Government Flight Software (FSW) Maintenance Team on maintenance of FSW in preparation for transition of FSW maintenance to the Government at the end of the contract period.
5. Deliver the Software Development and Validation Facility (SDVF) to the Government MOC facility at the end of the contract period.
6. Participate in a joint Configuration Control Board with the Government.

The Contractor shall provide the following services after Commissioning on an as-needed basis:

1. Support post-Commissioning operations as required. This support can include: supplying technical expertise to perform analyses, to review data, or to review changes to documentation.
2. Investigate on-orbit anomalies that affect specification-related performance parameters and/or anomalies that threaten Sensor or Spacecraft health and safety and provide recommendations for resolution.
3. Investigate anomalies of the Mission Operations Element and provide recommendations for resolution.
4. Maintain flight software and provide updates to flight software to provide capabilities requested by the Government.
5. Maintain non-flight software and provide updates to non-flight software to provide capabilities requested by the Government.
6. Provide CAL/VAL Subject Matter Expert (SME) consultation support.

9 Option for Thermal Band Sensing Capability

The Contractor shall develop a Thermal Band Sensing Capability for the LDCM Observatory, providing all necessary personnel, facilities, services, and materials. This effort shall include all electrical, structural, mechanical, thermal, data, and safety and reliability development, internal and external interface development, command and data formats, sensor calibration, and ground support equipment.

The Contractor shall meet all LDCM thermal band sensing requirements as specified in the LDCM Space Segment Requirements Document.

The Contractor shall include the thermal band in all deliverable documentation, as appropriate. If the Thermal Band Sensing Capability is not incorporated in the Reflective Band Sensor, the Contractor shall deliver all hardware-specific documentation required in the basic contract individually for the thermal band sensor, i.e., design documents, test plans, verification reports, test reports, and analyses that are not common across multiple units.

9.1 Design Engineering

The Contractor shall design the Thermal Band Sensing Capability, providing all necessary personnel, facilities, services, and materials.

9.1.1 Algorithms and Mathematical Models

The Contractor shall incorporate the Thermal Band Sensing Capability as appropriate into all the algorithms and models as defined in Section 4.1.1 above, providing all necessary personnel, facilities, services, and materials.

9.1.2 Hardware Models

The Contractor shall incorporate the Thermal Band Sensing Capability into all hardware models as defined in Section 4.1.2 above, providing all necessary personnel, facilities, services, and materials.

9.2 Fabrication, Assembly, and Test

The Contractor shall provide all necessary personnel, facilities, services, and materials to incorporate a Thermal Band Sensing Capability into the fabrication, assembly, and

testing of the LDCM Observatory, including update of all relevant requirements and plans.

9.2.1 Sensor Independent Testing

The Contractor shall provide access and support for a 2 week period at a time agreed to by both the government and the Contractor, either before or after instrument thermal vacuum testing, during which US Government personnel and/or Contractors shall characterize the radiance output of the laboratory blackbody(s) used to calibrate the thermal option hardware. This characterization shall occur under thermal vacuum conditions in the thermal vacuum chamber used for the instrument testing at the Contractors site.[TBR]

9.2.2 LDCM Observatory Integration and Test

The Contractor shall provide all necessary personnel, facilities, services, and materials to incorporate a Thermal Band Sensing Capability into the LDCM Observatory Integration and Test process, as defined in Section 4.2 above, including update of all relevant requirements and plans.

9.3 Ground Support Equipment

The Contractor shall define, design, build, provide, maintain, document, and ship (as required) all Calibration Test Equipment, Mechanical GSE, and Electrical GSE as appropriate to design, implement, and test the Thermal Band Sensing Capability consistent with Section 4.5 above.