Large Synoptic Survey Telescope Camera Management Plan	Document # **LCA-00038-C**		Status LSST Camera APPROVED Effective Date: 26 June 2015
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Document Title **LSST Camera System Engineering Management Plan**			

1. Change History Log

Revision	Effective Date	Description of Changes
A	19 Oct 2011 25 April 2012	Finalized for CD-1 Review Added disclaimer in footer; converted to .docx format; prep'ed for release; reviewed under change notice LCN-1014.
B	21 October 2014	Updated for CD-2 Review
C	26 June 2015	Updated for CD-3 review. Released per LCN-1361.

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3. Acronyms

CCB	Change Control Board
CD-	Critical Decision
CE	Chief Engineer
CoDR	Conceptual Design Review
CPM	Camera Project Manager
CRM	Continuous Risk Management
CVP	Camera Verification Plan
DOE	Department of Energy
FDR	Final Design Review
ICD	Interface Control Document
IDD	Interface Definition Drawing
IRR	Integration Readiness Review
I&T	Integration and Test
LSR	LSST Science Requirements documents
LSST	Large Synoptic Survey Telescope
LSSTC	Large Synoptic Survey Telescope Corporation
MRR	Manufacturing Readiness Review
OSS	Observatory System Specification
PDR	Preliminary Design Review
PMP	Project Management Plan
PSR	Pre-Ship Review
RRB	Risk Review Board
SEMP	System Engineering Management Plan
SIM	Systems Integration Manager
SLAC	SLAC National Accelerator Laboratory
SRD	Science Requirements Document
SRR	System Requirements Review
TBD	To Be Determined
TBR	To Be Resolved
TRR	Test Readiness Review
VTP	Verification Test Plan

4. Applicable Documents

The following documents are applicable to the use of this Plan

[1] LCA-226, “LSST Camera Project Management Plan”

[2] LSE-38, “LSST System Engineering Management Plan”

[3] LCA-39, “LSST Camera Configuration Management Plan”

[4] LCA-29, “LSST Camera Risk Management Plan”

[5] LCA-141, “LSST Camera Value Management Plan”

[6] LCA-282, “Camera Operations Concept”

[7] LCA-40, "LSST Camera Integration and Test Plan"

[8] LCA-283, "Camera Verification Test Plan"

[9] LCA- 138, "LSST Camera Performance and Safety Assurance Plan"

[10] LCA-98, "LSST Camera Design Review Plan"

[11] LCA-145. "LSST Camera Internal Interfaces"

[12] LCA-343. "LSST Camera Block Diagrams"

5. Purpose and Scope

This System Engineering Management Plan (SEMP) describes the organization, processes, products, and methodology implemented by the Camera management team to ensure a coordinated development of the Large Synoptic Survey Telescope (LSST) Camera system. This Plan includes:

Organizational responsibilities—including relationships with the rest of the Camera management team, the LSST project, and Camera collaborating institutions.

Processes—including requirements and interface management, and operations concept development, as well as integration and verification test planning; also involves design value management and risk management, as well as configuration control plans.

Methodology—plans for communication within the system engineering group and with the rest of the camera and LSST team; description of system engineering involvement and planning for programmatic and other external reviews, as well as the internal technical review process for the camera.

The Camera SEMP supports and is subordinate to the Camera Project Management Plan (PMP) Ref. [1]. The SEMP defines the technical management of the camera project, while the PMP specifies programmatic management. Furthermore, the SEMP is responsive to the LSST Observatory SEMP Ref [2]. The Camera SEMP provides the specific processes required to manage the system engineering effort at the Camera level of integration and lower. The Observatory SEMP provides processes required to specify and control the functionality and requirements allocated to the Camera, interfaces between the Camera and other Observatory subsystems and integration of the entire system.

6. System Engineering Management

6.1. Organization

The LSST camera team consists of members from geographically diverse organizations and is managed by the Camera project office at the SLAC National Accelerator Lab (SLAC). The Camera System organizational structure is shown in Figure 1. The Camera Project Manager (CPM) provides overall project direction and interface to the LSST project, has along with responsibility for day to day execution of the project. The Camera project scientist provides the primary technical oversight of camera science performance and is the focal point for coordination of science requirements with the LSST Observatory science team.

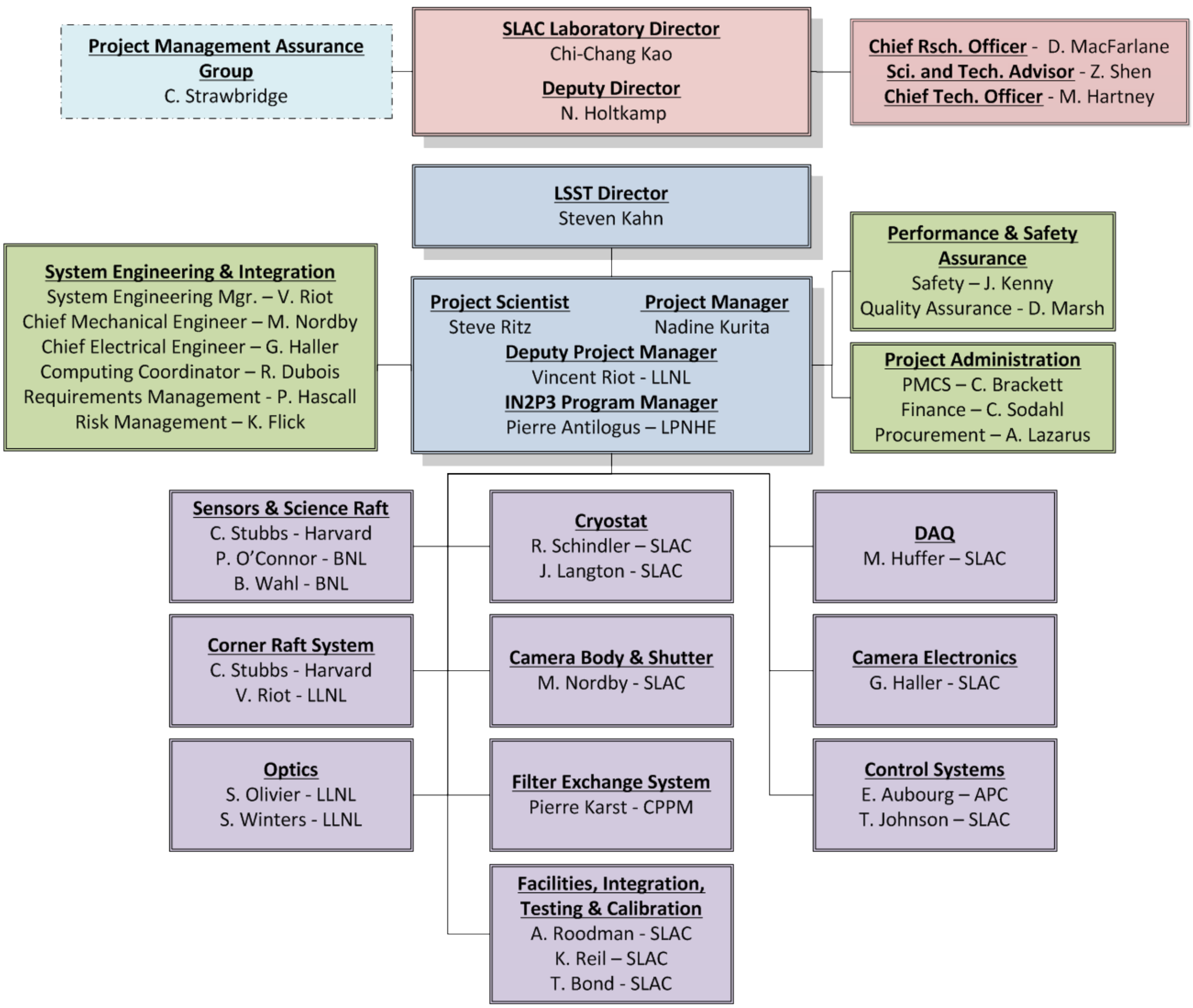

Figure 1: Camera Project Organization Chart

The Camera Project Manager is supported by the Camera Systems Integration Manager (SIM), the Chief Engineers (CE), the Requirement Manager, the Risk Manager and Quality Assurance Manager and Safety Officer in the execution, technical oversight and coordination of the Camera development, construction and commissioning activities. Camera Subsystem Managers report to the project manager, with the SIM, QA Manager, and Safety Officer providing technical support and oversight.

The camera is managed through application of processes described by a hierarchy of management and implementation plans as shown in Figure 2. The system engineering related plans are discussed throughout the following sections.

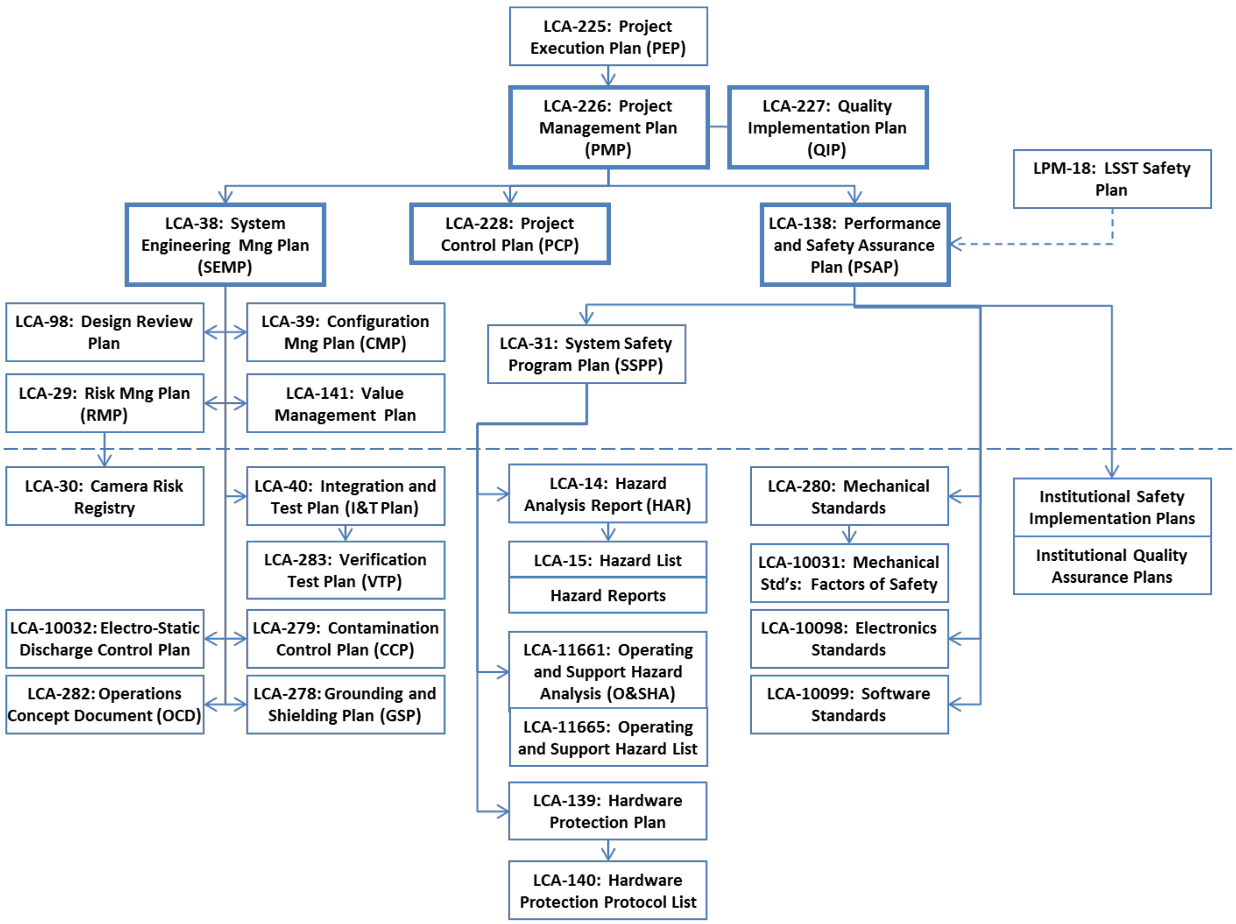

Figure 2: Camera Project Management Planning Documentation

6.2. Roles and Responsibilities

The SIM, chief engineers and requirement manager provide technical leadership and directs the work of the subsystem development teams through the development and tracking of requirements, allocations, interface control documents, and performance and verification specifications. The SIM and CEs are responsible for assuring that the subsystems are compatible and meet their overall objectives. The SIM and CEs also oversee, from the camera side, all aspects of camera-telescope and camera-data management interfaces, as well as flow-down of LSST system-level requirements.

The camera system engineering organization is also responsible for the overall design development process of the camera in three ways. First, it supports and manages system-level and subsystem trade-studies and value engineering analyses. Second, it performs and oversees integrated technical analyses of the camera system and subsystems. These on-going design analyses include risk analysis and management, and integrated structural, thermal, and optical analysis to assess system-level performance. Third, system engineering maintains camera design baselines by handling configuration management for all system- and subsystem-level configuration items, and the baseline review process whereby technical baselines are modified and designs implemented.

The means by which these responsibilities are executed are described in the following sections.

6.3. Timeline

The Camera project review and execution sequence of events is shown in Figure 4. This shows the stages of the project, along with technical reviews and Department of Energy (DOE) programmatic reviews.

The sequence also shows the needed completion of key camera and subsystem documents and reviews. A more detailed look at the engineering process flow is shown in Figure 4. The reviews shown in racetrack boxes serve as gates through which subsystems must pass for the design to proceed forward. Key documents and system engineering products are also shown.

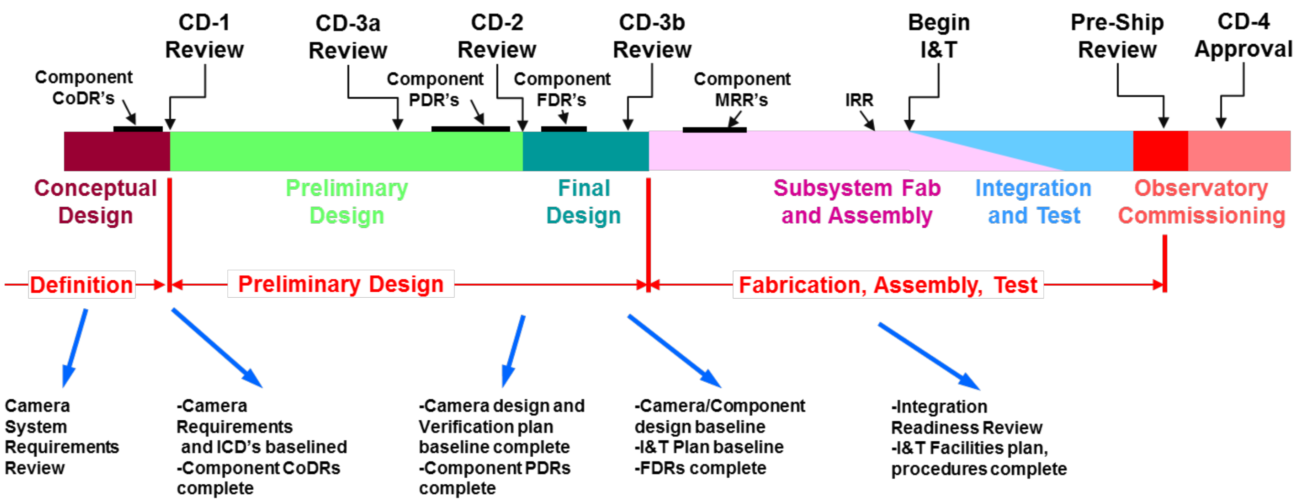

Figure 3: Camera Project Review and Execution Sequence

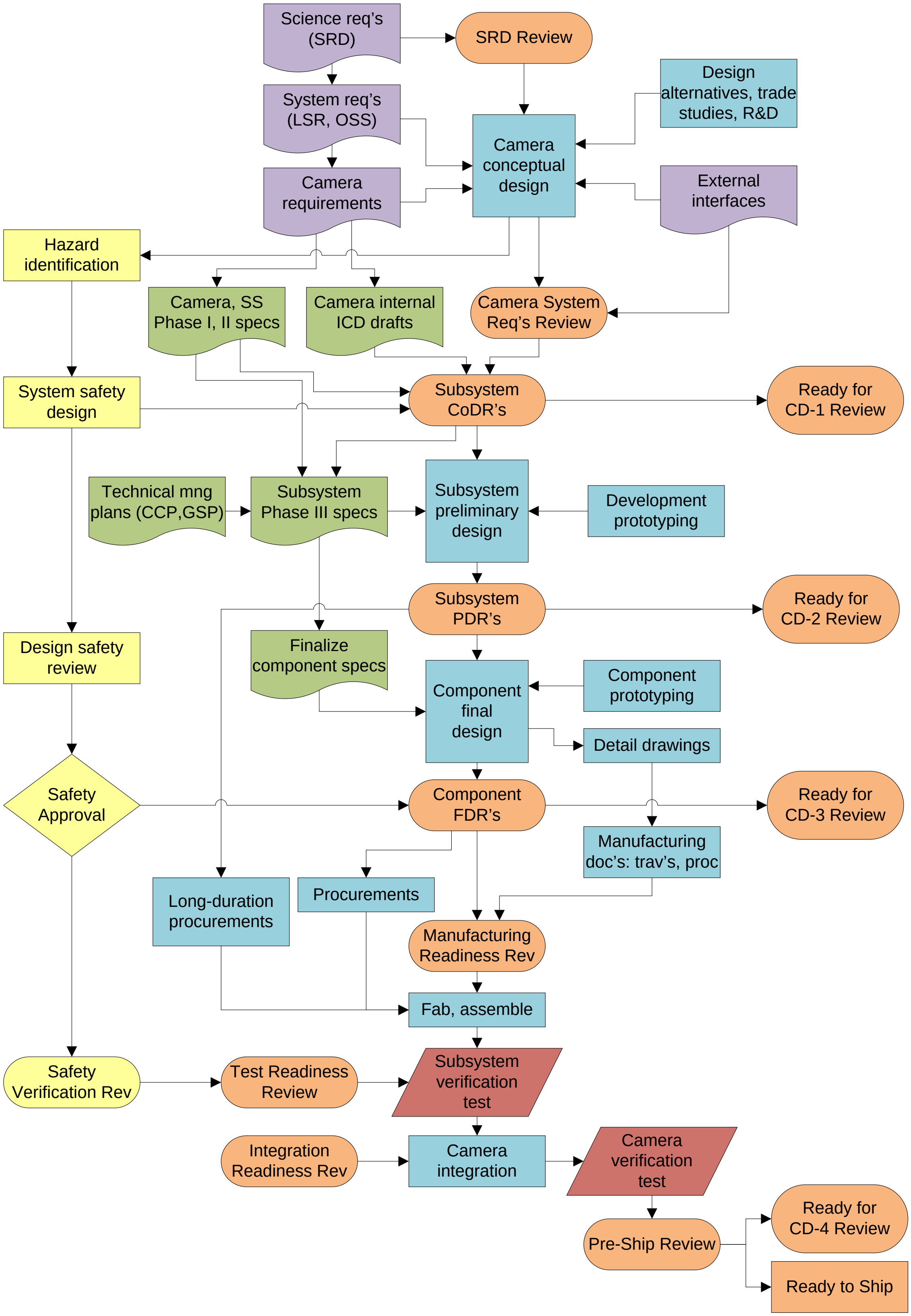

Figure 4: System Engineering Process Flow

7. System Engineering Processes

7.1. Requirements Management

7.1.1. Requirements Flow-Down and Control Authority

The requirements analysis and flow-down process involves transforming the LSST Science Requirements Document (SRD) into high level system functional and performance requirements. These are further refined into functional and performance requirements for the four LSST subsystems—one being the Camera—and on down to lower-level camera subsystem and component design specifications. This requirements flow-down is shown in Figure 5, along with a definition of the control authority in place for each level of requirement.

High level LSST science requirements are transformed to system level requirements and captured in the LSST Science Requirements (LSR) and Observatory System Specification (OSS) documents, and put under configuration control by the LSST project office.

Elements of the Observatory then have their requirements derived from the OSS. This flow-down of requirements and their traceability are documented and tracked by the LSST system engineer. The Camera requirements document (LSE-59) defines the performance and functional requirements for the camera deliverable to the project, and is reviewed by Camera and subsystem managers, as well as by LSST personnel.

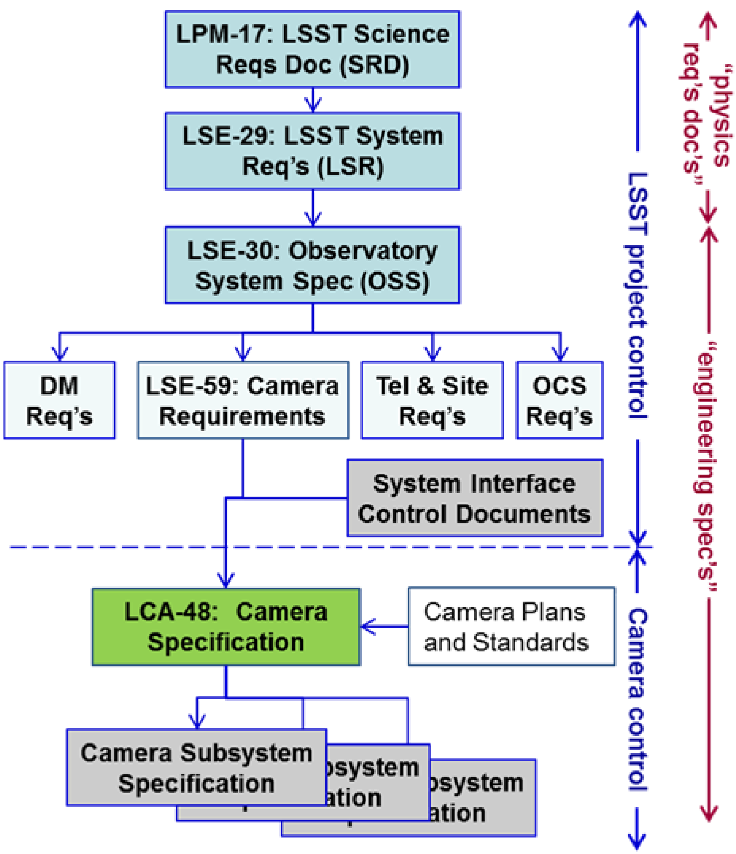

Figure 5: Requirements Hierarchy and Allocation Traceability Diagram

Interface agreements between Observatory elements are also defined at this level. These are intended to fully define external interfaces between the Camera and the rest of the Observatory, and undergo the same review and configuration control process as any other Observatory-level requirements document.

Below this, requirements are configuration controlled by the Camera project. LCA-48, the Camera Specification, is intended to capture all high-level requirements under camera control, while subsystem specifications include requirements flowed down to individual camera subsystems. Note that requirements may have as their source either higher-level specifications, or Camera plan-level documents that define Camera procedural or other requirements. Table 1 lists specifications for all subsystem entities.

Table 1: Camera Subsystem Entity High-Level Specifications

Subsystem Specifications	
Doc #	Specification
LCA-57	Science Raft and Sensor Specification
LCA-53	Corner Raft Specification
LCA-52	Optics Specification
LCA-49	Exchange System Specification
LCA-56	Shutter Specification
LCA-55	Camera Body Specification
LCA-50	Camera Control System Specification
LCA-10872	Auxiliary Electronics Specification
LCA-51	Cryostat Specification
LCA-54	Data Acquisition System Specification

Lower level specifications involve any requirements or specifications that are fully within the control of a camera subsystem. “Fully within” is defined such that any change to such a specification does not impact the subsystem’s ability to meet its higher-level requirements or interface agreements. The subsystem manager is responsible for reviewing and approving all such camera subsystem component requirements and specifications in consultation with the SIM.

All requirements documents and specifications are Camera documents and their review, approval, release, and revision are subject to the configuration management plans (LCA-39) and processes defined in Section 7.3, below.

7.1.2. Requirements Definition Process

7.1.2.1. Goals of the Process

The goals of the requirements definition process are to understand how a lower-level requirement relates to higher-level ones, and to establish clear linkages between the derivation of requirements and the analyses that go into the derivation process. This helps to link individual requirements both to parent and child requirements, allowing us to check that requirements are suitably parsed into lower level ones, make sure that lower level requirements have viable parents, and understand the impact of changes flowing from above or pushing back from below.

Requirements at each control level define the minimum performance and functional capabilities of the corresponding system. Thus, requirements must be defined such that they are clear and unambiguous, and that they can actually be used in the design process. Requirements should have the following characteristics to ensure clarity:

Achievable—the requirement or specification must be technically achievable within the allowed schedule and budget constraints

Verifiable—the requirement or specification must be defined in a way that can be verified by an objective measurement, test or analysis.

Clear—the requirement or specification must be unambiguous with only one meaning, and must be capable of being met solely by the system being defined.

Complete—the set of requirements and specifications must define all information necessary to successfully meet the objectives of the system being defined, including operational and maintenance concepts.

Consistent—individual requirements must not conflict with each other.

7.1.2.2. Aspects of a Requirement

There are five aspects in the process of defining a requirement. Each is a separate action that needs to be completed to fully define a requirement. These are not exactly steps of the definition process, since they do not need to be strictly performed in sequence, but all must be accomplished to produce a well-understood requirement. These aspects are:

Identify: describe the requirement and check that it is separable, achievable, clear, complete, and consistent.

Flow down: determine where in the hierarchy a requirement belongs (observatory, camera, subsystem, component).

Establish verification: establish the method by which the requirement will be checked as met. This verification process may include measurement, testing, or analysis, or some combination of these.

Trace: identify the “parent” of the requirement at the next higher level. This process may unearth missing requirements at one or more levels, if the trace process cannot identify a viable “parent” requirement.

Validate: check that the requirement has been correctly derived from its parent and that nothing is missing.

The results of this definition process is a well-formed requirement that is clearly defined, and whose flow-down path is understood. This is important to justify the rationale for the cost and risk associated with the design that is developed to satisfy the requirement.

7.1.2.3. Requirements Phasing

Requirements development at the Camera and subsystem level follows a phased approach to match the design development process and roll-out of system-level implementation plans. Ideally, all requirements affecting the design would be known in advance of the start of the design. However, this is typically an unrealistic expectation. Recognizing that not all requirements will be fully defined at the start of the project, this phasing process is intended to reduce the risk to the design associated with an incomplete requirements set while ensuring that ultimately all requirements and all aspects of each requirement are captured.

Requirements are grouped into three phases, depending on their relative importance in driving the design and cost. This phasing pertains to all aspects of the requirement definition process, as discussed above. Phases are defined as follows:

Phase I: key requirements that drive the conceptual design, often derived directly from science performance or high-level operational requirements. Most of these may be at the Camera system level, while subsystem support hardware that responds to implementation details may have very few.

Phase II: engineering requirements impacting the preliminary design, many of which are at the subsystem level, or that are needed to define subsystem-level performance margins.

Phase III: detailed engineering or fabrication requirements, often at the component level, that are needed to finalize either design details or fabrication or assembly processes.

Aspects of requirements are completed according to the phase of the requirement. Table 2 shows the phasing for Camera and subsystem requirements and when in the development cycle of the Camera each phase should be complete.

Table 2: Implementation of Requirement Phasing Over the Development Cycle of the Camera

		Identify	**Flow down**	**Verify**	**Trace**	**Validate**
Camera	Phase I	CoDR	CoDR	CoDR	CoDR	CoDR
	Phase II	CoDR	CoDR	PDR	PDR	PDR
	Phase III	PDR	PDR	PDR	PDR	FDR
Subsystem	Phase I	CoDR	CoDR	CoDR	PDR	PDR
	Phase II	CoDR	PDR	PDR	PDR	PDR
	Phase III	PDR	PDR	PDR	FDR	FDR

7.1.3. Technical Performance Budget Management

The SIM is responsible for establishing, managing and tracking camera technical performance budgets, margins and allocations throughout the duration of the development and construction process. Performance budgets are maintained by the SIM, with individual allocations allotted to subsystems as determined by the system-level analysis and subsystem design needs. Performance budgets that are tracked by the SIM include the following:

Mass
Center of gravity
Image quality error
Throughput
Photometric stability
Power

Such performance budgets are treated like other requirements, but unlike most requirements, their allocations can be traded and balanced among the subsystems. Thus, system-level re-optimization is performed as the project proceeds, to ensure that subsystem margins are maintained and reduction of margin or increasing risk within a subsystem is addressed by system-level re-allocation if warranted.

The SIM tracks these parameters and their margins to camera subsystem allocations as part of the systems engineering process to ensure that the camera performance requirements are met.

7.1.4. Requirements Management Process

Camera and subsystem requirements are captured in spreadsheet specifications documents, with each row of the spreadsheet containing one requirement. This is done to allow for tracing requirements to their parents, generating statistics on specifications, and allowing for filtering and sorting of requirements.

Information collected for each requirement includes the following:

Serial number: unique identifier for each requirement, including a prefix delineating the specification and a base serial number

Parent requirement: serial number(s) of the parent requirement(s)

Title: requirement title

Requirement definition: text, numerical values, and units to fully define the requirement

Analysis reference: document number of the analysis or budget that validates the flow-down or derivation process

Verification method: process by which the requirement is verified (analysis, test, test/analysis, inspection, measurement)

Macros have been developed to track flow-down between specification sheets and diagnose tracing, identify orphan requirements, and collect issues. The individual specification sheets are simple worksheets with no intelligence—the macros are included in a separate workbook that operates on any identified specification. This allows each subsystem specification to be a complete stand-alone document, for ease of use, sharing, and updating between Camera system engineers and subsystem leads.

Individual specifications are developed, assessed, reviewed, and approved separately. Since these are all Camera-level documents, they are subject to the appropriate level of control authority as described in Section 7.3.

7.2. Interface Control

7.2.1. External Interfaces

The external camera interfaces are identified in Figure 6. These interfaces are developed under the leadership of the LSST Observatory system engineer in coordination with and concurrence by the SIM and Observatory counterparts. Upon joint approval, the appropriate interface control documents (ICD's) are brought under LSST Project configuration control. Future changes to these interfaces require LSST project change control board (CCB) action, to ensure that full technical, cost and schedule impacts to the Camera are understood and agreed on.

7.2.2. Internal Interface Definition Process

7.2.2.1. Goals of the Process

The goal of the interface definition and control process is to clarify subsystem boundaries, ensure clean definitions of work scope on both sides of the interface, and document dependencies of one subsystem on another. For systems with many complex interfaces and interactions, managing internal interfaces is essential to reduce the risk of design incompatibilities arising at interfaces. Furthermore, documenting and managing interfaces ensures that subsystems on both sides of the interface clearly understand their scope of work and deliverables. This ensures that subsystem costs and work scope are correctly estimated.

Figure 6: Camera External Interfaces

7.2.2.2. Interface Definition and Control

Internal camera interfaces are identified in the N^2 diagram shown in Figure 7 and the list is maintained in the camera interface list in Ref [11]. The diagram defines all interfaces between subsystem entities, and the nature of the interface. These interfaces are developed under the leadership of the SIM and CEs, in coordination with and concurrence by the subsystem managers involved. Internal ICD's are defined as Camera-level items, since they signify agreements between camera subsystems. Upon approval, these ICD's are brought under Camera change control, pursuant to the processes referenced in Section 7.3. Future changes to these interfaces require Camera CCB actions to ensure that full technical, cost, schedule, and risk impacts to subsystems on both sides of the interface are understood and agreed on.

CCS	Auxiliary Electronics			DAQ		Cryostat			CB&M			Sci Raft	Crnr Raft	Opt	I&T	WBS
Camera Control System	Electronics Infrastructure	Power Control & Monitoring	Master Protect. Module	CDS (Gnd Unit)	OTM (Optical Transition Module)	Cryostat	Utility Trunk	Refrig System (Gnd Unit)	Shutter	Camera Body	Filter Exch System	Science Raft Tower	Corner Raft Tower	Optics	Integration & Test	Entity
	LCA-10839 <LCA-10771>			LCA-336 <LCA-10771>		LCA-10838 <LCA-10771>			LCA-230 <LCA-10771>	LCA-315 <LCA-10771>	LCA-231 <LCA-10771>	LCA-339 <LCA-10771>	LCA-340 <LCA-10771>		LCA-317 <LCA-10771>	**Camera Control System**
					LCA-10840	LCA-10841			LCA-10842	LCA-10843	LCA-10844	LCA-10845	LCA-10846			**Electronics Infrastructure** / **Power Distribution** / **Protection**
												LCA-335 LCA-341	LCA-334 LCA-341			**CDS (Gnd Unit)**
						LCA-332										**OTM**
										LCA-10847 (LCA-78)		LCA-151 (LCA-121)	LCA-311 (LCA-123)	LCA-310 (LCA-120)	LCA-10848	**Cryostat** / **Utility Trunk** / **Refrig System (Base Unit)**
										LCA-224 (LCA-73)					LCA-289 (LCA-10205) (LCA-10206)	**Shutter**
											LCA-294 (LCA-72) (LCA-74)			LCA-232 (LCA-77)	LCA-284	**Camera Body**
														LCA-338 (LCA-71)	LCA-286 (LCA-75) (LCA-10204)	**Filter Exch System**
															LCA-291	**Science Raft Tower**
															LCA-292	**Corner Raft Tower**
															LCA-287 (LCA-10615)	**Optics**
																Integration & Test

Legend:
( ): Interface Definition Drawing
< >: Interface Support Document

Integrated Interface Drawings
LCA-126, Camera Opto-Mechanical Definition Drawing
LCA-10333, Optical Element Assembly Drawing
LCA-10203, Camera Mechanical Interface Assembly Drawing

Figure 7: Camera Internal Interfaces

Interface Control Documents form the core of the interface definition and agreements. These are typically text documents that describe the interface features in writing. Supporting documents may be needed to fully define the interface, but these must be referenced from the ICD and not developed as a stand-alone document. Supporting documents may include Interface Definition Drawings (IDD's), schematics, drawings showing connector pin-outs or other interface details, or separate documents describing generic protocols. The intent is that the ICD forms the single definition of the interface, and calls on supporting documents as needed.

A camera block diagram summarizing the type of interfaces is maintained in Ref. [12].

7.2.2.3. Content of Interface Agreements

Interface control documents should include all information necessary to fully characterize the interface and eliminate uncertainty or risk on either side of the interface which may affect the subsystem's ability to meet functional or performance requirements. The following is a list of possible topics to be covered in an ICD. The exact content of an ICD depends on the nature of the interface, but all topics should be addressed to ensure that the interface is fully defined.

Possible contents of interface agreements:

Description: description of the interface and its characteristics.

Mechanical interface details: dimensional and mounting details; description of interface hardware and who supplies it; definition of loads transmitted across the interface; details of cable strain-relief or support.

Thermal interface details: allowed temperature range of the interface; effective heat capacitance or conductivity of elements on either side of the interface; maximum or minimum heat transferred across the interface; thermal joint details.

Electrical interface details: connector type and pin definitions; voltage or current requirements for pins; grounding or shielding requirements.

Software interface details: command, control, and telemetry types, format, and communication protocols.

Special topics: vent paths, particulate flow, fluid flow, or other special interface details.

Interface control documents are agreements between the two interfacing subsystems, and are not to be construed as one imposing requirements on the other. Interface agreements arise out of the design implementation plans both for the Camera as a system and for the involved subsystems. Thus, they are largely dependent on design choices made and are not flowed down from higher level performance or functional requirements.

However, interface development involves designing interfaces to minimize the overall system-level cost and risk to the system and subsystems involved. Thus, interface issues may well be driven more by needs of one side than the other. In any case, once an ICD is approved by both sides, the agreed-to interface details become design requirements for the involved subsystems. These must be verified prior to delivery, and should be treated as seriously as any other subsystem requirement. Toward that end, the ICD's should be clear about the nature of all interface details. This includes:

Defining requirements and constraints: describing agreed-to constraints for the interface, or requirements imposed on one side by the other.

Identifying the supplier: listing who provides what to complete the interface, so there is no ambiguity.

Agreeing on subsystem deliverables: listing and describing items required of one subsystem from another before the completion of the interface. These could be simulators, test gauges, test electronic crates, or other hardware or software to qualify or verify functionality across the interface. This includes the requirements of the delivered units and any differences between them and the final implementation.

7.2.2.4. Phasing of Interface Development

Interface development follows a phased approach to match the design development process and completion of subsystem design and operations details. This phasing process is intended to reduce the risk to the design associated with incomplete interfaces, while ensuring that ultimately all interfaces are fully specified and agreed to.

Interface topics are grouped into three phases, depending on their relative importance in driving the design at that particular phase. Phases are defined as follows:

Phase I: basic interface connectivity and design envelopes; list of deliverable items and interface hardware definitions; these interfaces define the basic interconnectivity and scope of the Camera subsystems and often drive the conceptual design.

Phase II: engineering details of all aspects of the interface; full definition of loads, flows, and communication protocols across the interface; these details drive subsystem preliminary design decisions.

Phase III: component-level interface details, such as cable pin-out details; this information is needed to finalize part design details and communication.

7.3. Configuration Management

Camera configuration management is the responsibility of the Camera Project Manager, but is coordinated with the SIM. The Camera configuration management process is described in detail in the Camera Configuration Management Plan Ref [3]. The systems engineering effort uses configuration management to control the camera design during all phases of the project. The Camera configuration control effort has the following objectives:

System baselines are defined and documented

System documentation is identified, released, and controlled

A Change Control Board (CCB) is established and functions according to guidelines expressed in the Configuration Management Plan

Changes to the baseline are formally evaluated and controlled

Approved changes are implemented and tracked

Configuration status is tracked and accounted during the life of the project

7.4. Risk Management

Risk management is the on-going process of comprehensively assessing project risks, developing and implementing plans to manage those risks, and tracking and communicating those risks as they evolve over the life of the project. The SIM implements a continuous risk management (CRM) system to accomplish three goals. First, the CRM process is intended to manage the risks associated with the development and construction of the Camera. Project risks are centrally managed, but are the result of project-wide risk assessment. Thus, relative risk is assessed across the project in a coherent fashion. Second, project-wide risk assessment supports management decision-making by providing integrated and quantitative assessments of risk. Current and comprehensive risk updates provide management with additional information in preparing for and reacting to contingent events and adverse outcomes to planned events. Third, the CRM process provides a uniform language for tracking risk elements and communicating that information both within the project and its subsystems, as well as to project sponsors and reviewers.

The risk management process for the LSST Camera project is described in detail in the LSST Camera Risk Management Plan Ref [4].

7.5. Value Management

The SIM implements reviews and trade studies directed at analyzing the functions of the camera systems, equipment, facilities, services, and supplies for achieving the essential functions at the lowest life cycle cost consistent with required performance, quality, reliability, and safety. The processes for carrying out these trade studies are described in Ref [5], the LSST Camera Value Management Plan.

7.6. Operations Concept Development

The entire range of camera operations is documented in the Camera Operations Concept Document Ref [6]. This includes sequence diagrams for maintenance, calibration, all observing modes and transitions, camera health and safety monitoring, constraints and anomaly responses. This document is developed by the SIM working with subsystem managers. The development of these concepts likely results in derived camera and camera subsystem requirements and/or interface needs, particularly in the areas of reliability, maintainability, and supportability.

The Camera Operations Concept Document is also developed in conjunction with Observatory operations plans. Camera-level requirements derived from operations plans in the observatory are captured first in the camera-level document, then flowed down as appropriate to Camera subsystem requirements.

7.7. Integration and Verification Test Planning

7.7.1. Camera Integration and Test Planning

The Integration and Test Manager develops the Camera Integration and Test (I&T) Plan Ref. [7] in coordination with the SIM. This plan includes, at a minimum, the following topics:

Roles and responsibilities—responsibilities of the camera I&T organization and of subsystems relating to subsystem component delivery and requirements verification.

I&T plans—facilities and infrastructure, work authorization, and quality assurance implementation; these may impart delivery or verification requirements on subsystems or reflect requirements for hardware protection (e.g.: contamination control).

Integration flow—sequence of integration and test processes, including test events and objectives, subsystem component delivery inputs, and review points.

Support equipment and software needs—requirements for mechanical fixturing, support electronics for system-level testing, software for test execution, or data transport and storage needs for handling test data results.

The plan defines specific test events required to complete the Camera verification effort as well as appropriate progressive functionality tests throughout the integration period. The plan is reviewed and approved by the I&T Manager, SIM, Camera Project Manager, and subsystem managers.

7.7.2. Requirements Verification Methodology

Verification of requirements should be completed at the lowest level of integration practical. Each camera subsystem manager is responsible for developing and executing a plan to verify all subsystem requirements and identify requirements that must be deferred to a higher level of integration for verification. Verification tests must also include demonstration of compliance to ICD agreements with other subsystems.

The SIM works with subsystem managers in developing the subsystem verification plan, and to identify additional requirements derived from the planned test program and any additional interface agreements that are needed. These could include additional hardware or software functionality needed to support verification tests or test units or simulators delivered between subsystems to support functional tests.

The I&T Manager is responsible for developing the Camera Verification Test Plan (VTP) Ref. [8], that incorporates all residual subsystem requirements verification tests, camera system requirements tests, as well as internal camera interface and external interface verification checks. This verification plan may also drive higher level interface agreements for test units or simulators. The VTP and any corollary interface agreements are Camera-level documents and are reviewed by the Camera CCB.

Each verification plan must include a verification cross-reference matrix listing each requirement, the method of verification (Analysis, Test, Inspection) and the level of integration at which the requirement is planned to be verified.

7.8. Support for Performance and Safety Assurance

7.8.1. Performance and Safety Assurance Management

The QA Manager and Safety Officer are responsible for developing and implementing the Camera Performance and Safety Assurance Plan Ref. [9]. This includes the processes for identifying, assessing, mitigating, and tracking system and personnel hazards, as well as standards for quality assurance. The SIM provides technical support in assessing system-level hazards and quality and reliability requirements, as derived from camera performance and operational requirements.

The SIM also supports the QA Manager and Safety Officer in assessing any requirements derived from either the hazard analysis process or the reliability assessment of camera systems and subsystems.

7.8.2. Problem and Discrepancy Resolution

The QA Manager is also responsible for developing quality assurance plans, which include processes for identifying, tracking and resolving manufacturing, integration and test discrepancies. While the QA Manager is responsible for dispositioning discrepancies and resolving problems and failures, the SIM supports the QA Manager in assessing the potential impact of the discrepancy or failure, trade-offs in resolving the issue, and the impact on the technical baseline.

8. System Engineering Methodology

8.1. Communication

8.1.1. Meetings

Team communication is facilitated through one on one discussions and charted forums for working issues and making decisions.

Table 3: Meetings Organized or Supported by Camera System Engineering

Forum	Membership	Purpose
LSST System Engineering Meeting	PSE(Chair), Camera, Telescope, Data Management System Engineers	Coordinate LSST requirements, flow down verification and system integration . Address technical issues, coordinate resolution, review technical trades & risks
Camera Systems Integration	SIM (Chair); controls, data flow, electronics, optics, structural, thermal systems engineers	Coordinate Camera requirements flow down; manage internal interface development; manage development of camera-level functional systems
Camera Integrated Project Teams	As assigned by the Project Manager	Address specific cross-Camera technical issues as chartered by the Project Manager
Change Control Board (CCB)	Project Manager, SIM, CEs, Requirement manager, QA Manager, subsystem managers	Approve controlled documentation, approve changes to program and technical baselines
Risk Review Board (RRB)	Project Manager, SIM, Risk Manager, QA Manager, subsystem managers	Approve risk mitigation activity

8.1.2. Issues and Action Item Lists

Issues and Action Items arising from the meetings and boards described above are tracked to closure, to ensure that resolution is achieved. A unified database of issues and action items is used through the JIRA tracking tool (Atlassian Software) to provide a single location for tracking. Items on the list are tracked with the following information: issue/action item, date opened, status, forum (in which meeting was it opened), title, description, person assigned to resolve, status date, status/resolution, estimated/actual completion date.

The Camera system engineering office tracks all issues and action items arising from these meetings, and works with subsystem personnel to resolve open actions and issues.

8.2. Programmatic Reviews

The Camera project supports reviews by the DOE Office of Science, following criteria defined by DOE Order 413.3. At these reviews, the camera team reports on overall project status as well as technical and programmatic progress. At each review the project presents designs, test and verification plans appropriate for the project development stage under review. The Camera system engineering team works with the Project Manager, along with corresponding LSST personnel to plan for these reviews. In preparation for these reviews, the SIM collects camera subsystem technical status, dispositions past action items, and tracks camera performance metrics.

The review committees develop and present to the project its specific recommendations, actions, and areas of concern. These actions are tracked by the SIM to ensure closure, and presented during the subsequent agency review. The DOE reviews include Critical Decisions 1, 2, 3, and 4.

Table 4: Camera External Programmatic and Technical Reviews

DOE Critical Decision Milestone	Purpose
CD-0	Approve mission need
CD-1	Approve alternate selection and cost range
CD-2	Approve performance baseline
CD-3	Approve start of construction
CD-4	Approve project completion

8.3. Technical Reviews

8.3.1. Subsystem Technical Review Cycle

The systems engineering process utilizes technical reviews to promote communication and guidance among the camera project's distributed team. During the project lifecycle various internal reviews are convened and managed by the project manager for the Camera and its subsystems. For these reviews, technical experts with relevant expertise are called upon to review designs, plans, and implementations. These reviews generate formal notes and action items, which are presented at subsequent agency reviews, as appropriate.

Peer reviews are conducted at key development stages, as shown in

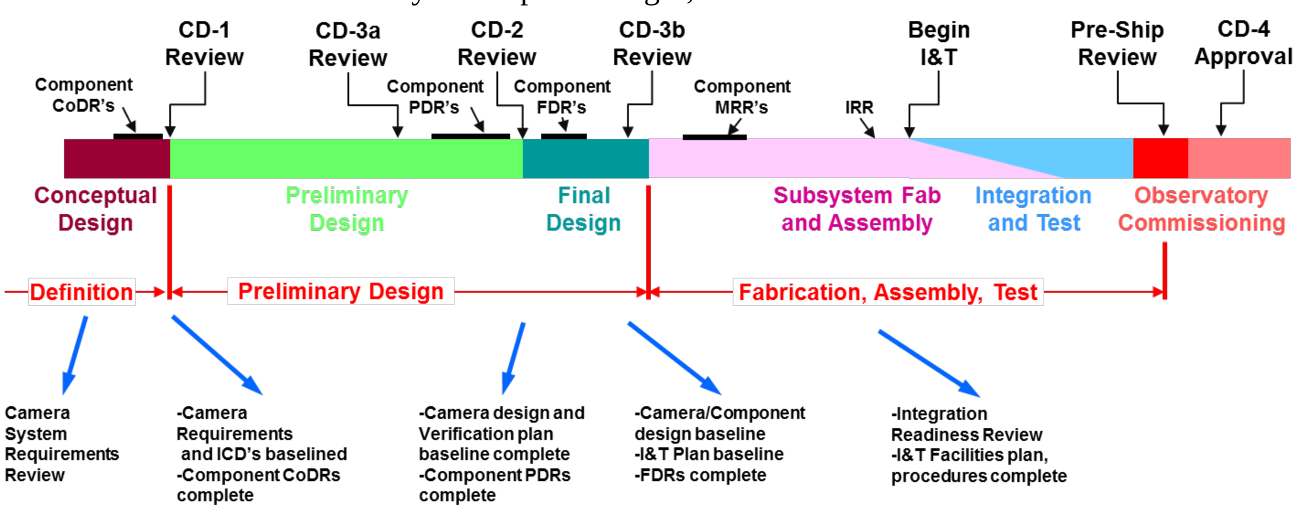

Figure 3. The project manager may also convene other peer reviews on an ad hoc basis.

8.3.2. Review Content and Expectations

While the technical review cycle described above is internal to the camera project, the reviews are used for guiding and tracking the development and implementation of subsystem component design. As such, the outcomes of the review are tracked and made known at external and other reviews. To ensure uniformity and consistency in the review process, the SIM has defined the content and expectations of the reviews. These are described in the Camera Design Review Plan Ref. [10].

Table 5: Camera Internal Technical Reviews

Technical Review Milestone	Purpose
System Requirements Review (SRR)	Approve the functional and performance requirements of the camera
Development Reviews	Approve plans for mitigating subsystem development risk, including prototyping and applied design efforts; review risk mitigation activities and schedule to assess their cost-effectiveness and timeliness in addressing development risk
Conceptual Design Reviews (CoDR)	Approve the functional and performance requirements of the subsystem hardware Approve hardware engineering specifications and conceptual design Approve R&D plans
Preliminary Design Reviews (PDR)	Approve the preliminary design and compliance to requirements Approve start of detail drawings Approve fabrication of test articles and placement of long-duration procurements
Final Design Reviews (FDR)	Approve the final design, cost and schedule Approve completion of detail drawings Approve start of procurement
Manufacturing Readiness Reviews (MRR)	Approve start of subsystem fabrication Approve start of subsystem verification testing program
Integration Readiness Review (IRR)	Review plans and procedures for system-level integration and verification testing Approve the start of system-level integration
Pre-Ship Review (PSR)	Review that all requirements have been verified Approve shipment of the Camera