Large Synoptic Survey Telescope Camera Plan	Document No. **LCA-98-E**	Status LSST Camera APPROVED Effective Date: 13 Apr 2017
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Document Title **Camera Design Review Plan**		

1. Change History Log

Revision	Effective Date	Description of Changes
A	08 May 2012	Added Section 8.8 "Delta Review;" augmented Section 8.3 with additional PDR deliverables information Reviewed under change notice LCN-1011.
B	20 Feb 2013	Augmented Section 8.4 "Final Design Review" and Section 8.5 "Manufacturing Readiness Review" with additional review deliverables; added missing document numbers in Section 3, "Applicable and Related Documents;" Added detail to Section 8.8 "Safety Reviews" to clarify applicability and deliverables for each type of subject-matter review Updated disclaimer in footer. Reviewed under change notice LCN-1022.
C	21 March 2014	Updated all sections to cover electrical, mechanical and software requirements. Updated all sections to cover project current system engineering based requirements. Reviewed under change notice LCN-1080.
D	16 April 2015	Updated deliverables and presentation material for the final design review (Section 8.4). Added section on peer reviews (Section 8.9). Reviewed under change notice LCN-1246.
E	April 13, 2017	Added Integration and test specific review cycles. Reviewed under change notoce LCN-1782.

2. Contents

3. Applicable and Related Documents

[1] LCA-99, "Camera Design Review Report Form"
[2] LCA-101, "Camera Design Review Attendance Record"
[3] LCA-226, "Camera Project Management Plan"
[4] LCA-38, "Camera System Engineering Management Plan"
[5] LCA-138, "Performance and Safety Assurance Plan"
[6] LCA-29, "Camera Risk Management Plan"
[7] LCA-14, "Camera Preliminary Hazard Analysis"
[8] LCA-15, "Camera Hazard List"

4. Guiding Principles of Reviews

Design reviews provide an independent assessment of the continuing ability of the program to meet its technical and programmatic commitments and to provide value-added assistance to the program manager. For the Large Synoptic Survey Telescope (LSST) Camera reviews will occur throughout the life cycle of the program and consists of periodic independent reviews.

Reviews are a resource offering an opportunity to add value to the products and to the sharing of knowledge by inviting outside experts that can provide confirmation of the approach and/or recommend options. They serve as a tool for communication by formally providing an opportunity to organize, assess, and communicate critical data and information.

This document provides the LSST Camera technical staff with the guidelines for design reviews as discussed in the Camera "Systems Engineering Management Plan," LCA-38. The design review's minimum requirements for its technical and programmatic deliverables are provided, establishing roles

and responsibilities of the presenters and the review committee. It also defines what role the review process plays in authorizing the transition to the next phase of the technical deliverable. (Safety and QA attendance)

5. Major Classes of Reviews

The objectives and salient features of major review classes are provided to guide program/project managers in the formulation and implementation of a series of hierarchical reviews. Reviews provide the opportunity to confirm the approach or offer options, if needed, and communicate progress and risks toward meeting the success criteria. The output of these reviews (i.e., assessments, options, recommendations, and decisions) flow as inputs into subsequent reviews as appropriate to ensure alignment between providers, customers, and stakeholders, and ensure proper disposition of issues. It is up to the Project Manager or System Engineer to propose options to combine reviews to providers, customers, and stakeholders, provided that the objectives of each are met. The goal is to maximize the probability of mission success through added value and efficiencies. The major classes of reviews are:

- System Requirements Review (SRR)
- Conceptual Design Review (CoDR)
- Preliminary Design Review (PDR)
- Final Design Review (FDR)
- Manufacturing Readiness Review (MRR)
- Test Readiness Review (TRR)
- Pre-Ship Review (PSR)
- Safety Review (SR)
- I&T Reviews

6. Roles and Responsibilities

6.1. Review Moderator

The Review Moderator organizes and plans the review and

- Is responsible for forming an appropriate review committee.
- Initiates the design report, completing the table and writing the purpose/goal of the review.
- Identifies special boundary conditions for the review or caveats.
  - Schedule constraints may necessitate proceeding to a design review to obtain approval for fabrication or procurement, prior to meeting all of the design review deliverables. These special boundary conditions shall be approved by the Camera Project Manager.
  - Technical areas covered by the review should be clearly described to prevent confusion from the review committee and shall be approved by the Camera Project Manager
- Works with the technical team to create an appropriate agenda that meets the review deliverables as outlined in this document.
- Is responsible for obtaining the final report from the committee and posting it to DocuShare.
- Sends out the review announcement to the camera mailing list and the links to the formal documentation.
- Sends out the review password and site for the review material.
- Provides opening statement and slides explaining the goal and providing instructions to the review committee and audience.

- Is appointed by the Camera Project Office or the System Engineering Office.
- Ensures that the attendance is recorded on form LCA-101 and attaches it electronically to the final design report.
- Leads the executive sessions throughout the reviews.

6.2. Review Committee Chair

The Review Committee Chair (s) serves as the primary point of contact with the review committee or focused technical area committee sub-team and

- Is responsible to collect questions and requests ahead or during (for multiple day reviews) the review that require additional material to be generated to address concerns
- Is responsible to present findings, request for actions and recommendations during the close-out session at the end of the review.
- Is appointed by the Review Moderator

6.3. Review Committee

Review teams shall consist of knowledgeable, independent experts from outside the advocacy chain of the program. Evaluation supports the approval subprocess by providing findings and supporting data necessary to arrive at decisions either to proceed or not to proceed with subsequent portions of program life cycles. Evaluation during formulation assesses whether programs support the Agency goals and strategic planning and that programs can be successfully conducted within allocated resources and applicable constraints. Evaluation during implementation assesses whether programs are being successfully executed according to plans and provides recommendations for enhancing the technical and programmatic performance of programs. The Review Committee:

- Is selected by the Design Review Moderator and approved by the Project Manager.
- Will have a designated chairperson who will be the editor of the Design Review Report (form LCA-99).
- Consists of at least one external reviewer and a safety officer.
- Provides verbal and written feedback to the project on whether the subsystem has successfully demonstrated their technical and programmatic readiness as described in this document. Completes LCA-100 documenting their assessment.

6.4. System Engineering

- The System Engineering office verifies that the Design Review Plan (LCA-98) is being executed and maintains the plans and forms to support the reviews.
- It tracks the “request for actions” (RFAs) and reports summary status to the Camera Project Office.
- Ensures that these action items are closed out in a timely fashion as necessitated by the review committee.

7. Procedure

7.1. Presentation Materials and Support Documentation

- All reviews shall be prepared using the latest review template (.dot) document.
- First slide (title/cover) shall contain the title of the review, the preparer’s name and the date of the review.

- The presentation(s) shall cover all the applicable deliverables as stated in this document.
- Presentation material will be distributed in advance of the review. Preferably a few days before the review.
- All presentation material and supporting documents will be posted to the LSST Camera Confluence Website and will be viewable to both the reviewers and the LSST team members.
- Presentation materials shall be posted to DocuShare, using Camera controlled numbers (a.k.a." "LCA-" numbers) and released as records after completion of the review.
- The committee's draft report, attendance and agenda will be posted to the LSST Camera Confluence Website and will be viewable to both the reviewers and the LSST team members.

7.2. Design Review Report

- The Design Review Report is completed by the review committee and the moderator and posted on DocuShare.
- The Design Review Report should use a Camera controlled number (a.k.a." "LCA-" number) and released as a record after completion and submittal of the report.
- Purpose/Goal of the Review – to be completed by the review moderator prior to the start of the review. Lists special boundary conditions for the review.
- Introduction and Outcome Summary of the Review – to be completed by the review committee. Overall impression and general conclusions. Final recommendation to proceed to the next phase of the project.
- Request for Action (RFA) will be completed by the review committee, and tracked by the System Engineering team:
  - Tier 1 – Immediate RFA: these items require immediate formal action and closure in writing prior to receiving approval to move into the next phase of the project.
  - Tier 2 - RFA: these items require formal action and closure in writing prior the next review.
  - Tier 3 - Concerns: these are comments or "soft" recommendations that require action by the design/engineering team, but a response is not required to approve the review.
- Observations – these are general comments and require no response.

7.3. Announcement and Attendance

- Announcements will be made in advance of the review. Preferably one month prior to the date of the review.
- Announcements will be sent to the Camera mailing list (lsst-camera@lsst.org).
- Attendance records will be kept and posted on DocuShare, preferably appended to the Design review Report.

8. Review Deliverables

The following list is intended to provide the external project reviewers the minimal technical and programmatic content required to meet the design review deliverables. These are split out one on each page to allow for easy use during a review. The integration and test sub-system is expected to follow a different set of review defined in section 8.6 in lieu of the CoDR, PDR and FDR.

Vendor Reviews will be conducted as negotiated by the sub-contract. However, it is highly recommended to have vendor reviews to cover at least the following if applicable:

- Preliminary Design Review
- Final Design Review

- Manufacturing Readiness Reviews/Test Readiness Reviews

Vendor reviews are exempt from several items as described in section 8.11

8.1. System Function Requirements Review

- Camera level requirements
- Goal:
  - Approve the objectives/functionality and performance requirements of the Camera.
- Presents the following
  - Science including breadth of applications possible with the Camera.
  - Objectives/Functionality and the requirements of the system:
    - Camera Level Requirement Document complete and ready for sign off.
  - Requirement Margins.
  - Operations.
  - Reliability.
  - Traceability to Science Requirements.
  - Validation Process.
  - Verification Process.
- After closure of action items, this approves the baseline Camera level requirements, and continuation of engineering specifications and component conceptual designs.

8.2. Conceptual Design Review

The Conceptual Design Review (CoDR) is the first of the 5 major sub-system reviews and is a technical and programmatic review of the functionality and requirements of the deliverables. The presenters should demonstrate that functionality and requirements are well understood, including the impacts of requirements that are unresolved, as well as that the conceptual design meets these requirements. Also, a clear understanding of the interfaces and requirements that will be levied by these should be shown. The CoDR is conducted when the design is a minimum of 15% complete and should occur early enough that the concept can be modified without a major impact to the program. The review should present the major design alternatives considered, the relative risk for each and the justification for the selection.

Conceptual Design Reviews shall contain the following scope items and address these issues:

- Sub-System or Hardware Specific.
- Goal:
  - Approve the objectives/functionality and performance requirements of the hardware.
  - Approval of the related sub-system specifications & conceptual design.
  - Approval of development plans to fabricate prototypes.
- Presents the following:
  - Key requirements/specification:
    - Specification spreadsheets have been completed and have been reviewed by the system engineering office for CoDR readiness. All of the specification terms have been identified and the driving requirements are defined.
    - Risk has been accessed on specifications that are to be resolved (TBR) or to be determined (TBD), or with other issues.
    - Includes traceability and validation and verification process.
  - Risk Registry completed (including mitigation of technical, cost & schedule risk).
  - Conceptual design that meets the requirements.
  - New technologies developed or well understood R&D plan and risk assessment:
    - “Proof of Concept” Models.
  - Development plans & progress including rationale.
  - Engineering analyses to support conceptual design.
  - Major system interface points identified, both organizational and technical:
    - Control system implementation plan recommended.
  - Major design alternatives considered (Value Management).
  - Consideration for quality control, reliability.
  - Completed Hazard List. Identify planned hazard reports.
  - Cost & schedule update.
- After closure of immediate request for action by the System Engineering team this provides final approval of the CoDR specifications and conceptual design approach. Project management approves funds to start preliminary design phase.

8.3. Preliminary Design Review

Preliminary Design Reviews (PDR's) are the second of the 5 major sub-system reviews and are a technical and programmatic review of the basic design approach to assure the approach will meet the technical requirements and to ensure the integrity of the selected design. Verification planning, cost and schedule, and interface compatibility are also addressed during the review. The PDR is conducted when the design is a minimum of 50% complete.

The Preliminary Design Reviews shall contain the following scope items and address these issues:

- **Scope:**
  - System or Hardware Specific design.
  - Final design details at the component level are not required.
- **Goal:**
  - Approval of the preliminary design, with confirmation that it meets all technical requirements and interface agreements
  - Assessment of the viability of verification test plans
  - Approval to complete final design and start detail drawings.
  - Approval to fabricate test articles
  - Approval to place long duration procurements.
- **Presents the following:**
  - Sub-system current organizational structure and team
  - Sub-system current scope and deliverables
  - Science/technical objectives, requirements, general specification.
  - Subsystem and lower-tier Specification: show that requirements phase 1 and 2 are complete, traced, validated, and released, including verification plans; closure plans for all TBD's and TBR's should be presented
  - Subsystem interfaces, organizational and technical: show that ICD's are complete at PDR level and released
  - Preliminary design that meets the requirements: includes design studies, block diagrams, use cases and sequence diagrams, as appropriate for all mechanical, electrical and software aspects.
  - Engineering analyses: show predicted performance and expected margin to every requirement. Show assumptions and describe limitations of current state of the analyses. Show stresses and margins against allowable limits for all key components and a draft list of critical items and single-failure point items and their analysis as defined in LCA-280, Mech Spec.
  - Past Prototyping: show summary of prototype design and present test result performance against requirements
  - Upcoming Prototyping and first articles: show detailed design and test plan. It should be clear to the reviewer what the planned prototype are aiming to address.
  - Fabrication, assembly, and test plans: show manufacturability with vendor information when applicable, high level assembly procedures and high level test plan for final hardware
  - Quality and reliability: show parts selection, inspection, process control, and test plans
  - Risk Analysis: show current risk assessment and mitigation of technical, cost & schedule risk. Link to previously presented prototyping effort.
  - Updated Hazard List and drafts of any hazard reports.
  - Hazard controls: show analysis of design for engineering controls, administrative controls and design based mitigations
  - Cost and schedule

  - Summary of resolution of request for action from previous reviews since CoDR (Tier 1 and Tier 2)
- **Deliverables:**
  - Updated LCA-277 Design Report Chapter related to area being reviewed
  - Sub-system specification: spreadsheet with all Phase 1 and Phase 2 requirements complete and all phase 1 requirements verification method complete
  - Design and specification lower tier documents: All specifications should be listed and numbered. All specifications related to phase 1 sub-system requirements should be resolved
  - Allocation documents when applicable: All phase 1 specifications covering performances across lower tier components should have a supporting allocation document (generally a spreadsheet)
  - Interface documents and drawings: All identified interface documents should exist (no place holders). All interface documents to other sub-systems or components already at FDR or expected to be purchased as long duration items should be complete.
  - Testing and verification documents: Finalized test reports documents from past prototypes. Production preliminary test procedures for long duration items.
  - Updated 3D CAD model if applicable: CAD model should be compatible with the overall camera model for incorporation.
  - Drawings: preliminary drawings of major components, final drawings of long duration items to be purchased
  - Schematics and layout: Preliminary schematic of major electronics systems, final schematic and layout or long duration items.
  - Software functional architecture and infrastructure (OSI model summary).
  - Risk registry: risk registry spreadsheet (LCA-30) with current assessment, status dated to less than a month, schedule and cost residual
  - Hazard registry: updated hazards spreadsheet (LCA-15) with current assessment and status dated to less than a month
  - Updated LCA-14 Preliminary Hazard Analysis (PHA) section related to area being reviewed
  - Updated Camera Hazard Report for hazards qualifying under LCA-31-A, the SSPP, section 8.2.1.1. The report should follow the template defined in LCA-16.
  - Resolution in the LSST Camera Action Item tracking tool of all previous reviews since CoDR Tier 1 and Tier 2 RFA related to the sub-system.
  - Printout of the most up to date schedule and Detail Cost Estimate (DCE)
  - Updated BOE spreadsheet.
  - Printout of the Baseline Change Requests to date.

After closure of action items, preliminary design approved and long duration items can be purchased. Move to final design.

8.4. Final Design Review

Final Design Reviews (FDR's) are the third of the five major reviews and are generally held when subsystem designs are 90% complete. FDR's are a technical and programmatic review to provide assurance that the completed design of the selected configuration meets all functional and performance specifications as well as interface agreements. The technical areas addressed during the review include the design configuration and integrity of the selected design; verification planning, requirements, and compliance; operations planning and requirements; lab and observatory support equipment requirements and specifications; and systems compatibility.

Final Design Reviews shall contain the following scope items and address these issues:

- **Scope:**
  - Component specific analysis and design.
  - Performance analysis and design details at the component level are required
- **Goal:**
  - Approval of the final design, cost and schedule.
  - Approval to complete detail and assembly drawings.
  - Approval to start procurement and fabrication, including detailing and fabrication of fixtures, test equipment, and fabrication procedures
- **Presents the following:**
  - Sub-system current organizational structure and team and proposed team if different during fabrication. Demonstrate readiness to transition from design to fabrication.
  - Sub-system current scope and deliverables
  - Final design that meets the requirements: drafts of all key/high-value components and assemblies, along with a complete indented drawing list, complete set of use cases and sequence diagrams for all mechanical, electrical and software aspects.
  - Sub-system compliance matrix for all requirements. Compliance can be kept at a pass fail level and expected performance presented when available. For pass fail only compliance, be prepared to answer question on why the requirement is expected to be met
  - Engineering analyses: description of the analyses conducted and predicted performance and margins when available. This should include tabulation of stresses and margins against allowable limits for all components and a complete list of critical items (as defined in LCA-280, Mech Spec), their analysis, and fabrication and test plans.
  - Prototype test results: results of development testing to demonstrate functionality and/or technology readiness needed for start of production; include margins to requirements
  - Fabrication, assembly, and test plans: list of procedures, fixtures, and flow of work for component and sub-system fabrication, assembly, and test; rough drafts of key procedures
  - Operations and maintenance plans: draft, including list of operating and maintenance procedures
  - Quality assurance plans: include requirements for parts and material selection, inspection, and process control during manufacturing
  - Updated Risk analysis: technical, cost and schedule risks, with focus on manufacturing risks
  - Final Hazard Analysis and Hazard List: updates to FHA and Hazard List reflecting final design
  - Final design of hazard controls: design and analysis of all controls for identified hazards
  - Close-out of safety reviews: reports from reviews by subject-matter-experts (see Section 8.8)
  - Cost and schedule: includes Earned value performance, estimated cost to completion and list of Baseline Change Requests to date.
  - List of identified outstanding problem areas/open issues
  - Summary of resolution of request for action from previous reviews since PDR (Tier 1 and Tier 2)

- **Deliverables:**
  - Updated Final Design Report Chapter related to area being reviewed
  - Sub-system specification: spreadsheet with all requirements complete and all requirements verification method complete
  - Sub-system compliance matrix for all requirements. When available, add traceability information and expected margin
  - Design and specification lower tier documents as needed
  - Updates to allocation documents when applicable: mass budget (LCA-119), power budget (LCA-275), image quality budget (LCA-17), read noise (LCA-32), timing (LCA-28), crosstalk (LCA-10033), gain stability (LCA-10065) and throughput (LCA-18) must be updated to reflect the final design. Inputs should have been provided to the system engineering team with lower level breakdown for incorporation or update in the camera document.
  - Tolerance study and stackup documentation compared to requirements when applicable
  - Draft engineering note to be submitted for a peer review on structural analyses for critical items.
  - Interface documents and drawings: All identified interface documents should exist and be complete and released with clear deliverables.
  - Testing and verification documents: Finalized test reports documents from past prototypes if applicable.
  - Updated 3D CAD model if applicable: CAD model should be compatible with the overall camera model for incorporation.
  - Drawings: drawings of critical components and assemblies should be available.
  - Schematics and layout: schematic of electronics systems and layout of critical boards or board section should be available.
  - Software final functional architecture and infrastructure (OSI model summary).
  - Bill of material of key components contamination assessment report if inside the cryostat.
  - Risk registry: risk registry spreadsheet with current assessment, status dated to less than a month, schedule and cost residual
  - Hazard registry: updated hazards spreadsheet (LCA-15) with current assessment and status dated to less than a month
  - Updated LCA-14 Hazard Analysis section from the PHA version related to area being reviewed (document to become the Final Hazard Report or FHA)
  - Updated Camera Hazard Report for hazards qualifying under LCA-31-A, the SSPP, section 8.2.1.1. The report should follow the template defined in LCA-16.
  - Draft Operational Hazard Analysis section related to area being reviewed
  - Resolution in the LSST Camera Action Item tracking tool of all previous reviews since PDR Tier 1 and Tier 2 RFA related to the sub-system.
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- **Optional Deliverables (good to have but not required):**
  - Design and specification lower tier documents: All specifications should be listed and numbered. All specifications should be resolved
  - Allocation documents when applicable: All specifications covering performances across lower tier components should have a supporting allocation document (generally a spreadsheet) to support the roll up and verification matrix

After closure of action items, final design is approved; detail drawings and assemblies can be completed, items can be purchased, and part fabrication can begin

8.5. Manufacturing Readiness Review

Manufacturing Readiness Reviews (MRR's) are the fourth of the five major subsystem-level reviews. MRR's are generally held as needed prior to the start of manufacturing and testing of major subsystem assemblies. MRR's are largely technical reviews, but include assessment of the planned cost, schedule, and personnel needs to complete the manufacturing processes that are covered. These are ad hoc reviews in that the number and extent of subsystem MRR's depend on the nature of the design and manufacturing plans. However, at least one MRR is expected for each subsystem, with MRR's recommended for every major deliverable assembly

Manufacturing Readiness Reviews shall contain the following scope items and address these issues:

- **Scope:**
  - Part and sub-assembly specific fabrication and assembly material
  - Manufacturing and test procedures at the part and sub-assembly level are required
- **Goal:**
  - Approval of plans and procedures for manufacturing sub-assemblies
  - Approval to start manufacturing
  - Either approval to proceed with power-on testing of completed assemblies or establishment of a required set of Test Readiness Reviews
- **Presents the following:**
  - Status of Sub-assembly and detail drawings
  - Status of bill of material and part list with contamination assessment if inside the cryostat
  - Status of fixture and equipment drawings and specifications: final drafts of drawing for assembly, test, and handling fixtures; specifications or drawings for assembly and test equipment
  - Status of Procedures and travelers. Present verification test plans and inspection and test
  - Manufacturing workflow plans: present final plans for manufacturing, including scheduling, personnel needs, time-and-motion studies, floor space requirements, facilities requirements and procedures (e.g.: clean room protocols) Status of procurement and manufacturing: update on procurements and how they support manufacturing workflow plans
  - Status of safety documents: close-out of Hazard Reports; draft sections for Operating and Support Hazard Analysis as required
  - Review closure of action items from the FDR
  - Updated Risk analysis: include manufacturing risks
  - Cost and schedule update: updates based on manufacturing workflow plan details
- **Deliverables:**
  - Final Drawings for all mechanical items
  - Final GERBER design files for all electronics items
  - Assembly drawings where applicable
  - Bill of material and part list for all components with contamination assessment if inside the cryostat
  - Quotes or purchase order description for procured items (including computing infrastructure items for software deployment)
  - Procedures and travelers: final drafts of fabrication and assembly procedures and travelers, including in-process inspection steps, equipment used
  - Verification Test Plan: released plan describing all tests for verifying subsystem requirements and interfaces; includes description of end item data package to be delivered
  - Inspection and test procedures: plans and final drafts of procedures for acceptance and verification tests

- Manufacturing workflow plans: final plans for manufacturing, including scheduling, personnel needs, time-and-motion studies, floor space requirements, facilities requirements and procedures (e.g.: clean room protocols)
- Safety documents: close-out of Hazard Reports; draft sections for Operating and Support Hazard Analysis as required
- Resolution in the LSST Camera Action Item tracking tool of all previous reviews since FDR Tier 1 and Tier 2 RFA related to the sub-system.
- Printout of the most up to date schedule and Detail Cost Estimate (DCE)
- Updated BOE spreadsheet.
- Printout of the Baseline Change Requests to date.

After closure of action items, this approves the start of component/sub-assembly manufacturing, assembly, and test, unless otherwise modified by requirements for a Test Readiness Review

8.6. Integration and test reviews

The Integration and Test (I&T) sub-system is different from other sub-systems and have has a different development cycle than the rest of the sub-systems. The review cycle for I&T should be more targeted and the following review are to be used instead of the standard CoDR, PDR and FDR:

8.6.1 Integration Planning Review (equivalent to CoDR)

The integration planning review is a conceptual design review intended to define the high level integration process flow and provide a walk through both the plans that support the work and the design for equipment, software and databases to be used in carrying out the work.

- **Scope:**
  - Integration process flow
  - Plans to support the work
  - Conceptual design for the equipment, software and databases to be used
- **Goal:**
  - Approval of the high level integration process flow
  - Approval of the related equipment specifications & conceptual design.
  - Approval of development plans to fabricate prototypes.
- **Presents the following:**
  - Lay out I&T plans and infrastructure: I&T Plan, Verification Test Plan, S.O.P.s spawned by these, clean room, logistical infrastructure expected to be worked on (e.g.: inventory control)
  - I&T sequence flow: walk through the flow of I&T activities
  - Walk through rough physical layout of major I&T steps in the clean room
  - For each I&T major block of work, define:
    - Work activity steps,
    - Who is supplying what
    - Conceptual design of all I&T-supplied equipment along with rough supporting analysis as needed (e.g.: far-field stresses, deflections, basic thermal analysis of test set-up, …)
    - ICD-related requirements on subsystem-supplied equipment
    - Expectation on what and how subsystem hardware will be delivered
  - Risk Analysis: show current risk assessment and mitigation of technical, cost & schedule risk. Link to previously presented prototyping effort.
  - Updated Hazard List and drafts of any hazard reports.
  - Hazard controls: show analysis of design for engineering controls, administrative controls and design based mitigations
  - Cost and schedule Updates
- **Deliverables:**
  - Draft requirements document for each equipment involved
  - Interface documents and drawings with other sub-systems: All identified interface documents should exist (no place holders). All interface documents to other sub-systems or components already at FDR or expected to be purchased as long duration items should be complete.
  - Risk registry: risk registry spreadsheet (LCA-30) with current assessment, status dated to less than a month, schedule and cost residual
  - Hazard registry: updated hazards spreadsheet (LCA-15) with current assessment and status dated to less than a month

- Updated Camera Hazard Report for hazards qualifying under LCA-31-A, the SSPP, section 8.2.1.1. The report should follow the template defined in LCA-16.
- Resolution in the LSST Camera Action Item tracking tool of all previous I&T reviews
- Printout of the most up to date schedule and Detail Cost Estimate (DCE)
- Updated BOE spreadsheet.
- Printout of the Baseline Change Requests to date

8.6.2 Test Definition Review (equivalent to PDR)

The Test Definition Reviews are targeted reviews of one integration/test activity and the associated equipment. The review focusses on a particular piece of equipment, but also provides the context in which the equipment is used. The goal is to present the preliminary design and implementation of the equipment in the broader I&T context and receive approval to complete the final design and prepare for procurement.

- **Scope:**
  - Equipment Design including hardware, software and databases
  - Equipment detailed Test activity
- **Goal:**
  - Approval of the preliminary equipment design, with confirmation that it meets all technical requirements and interface agreements
  - Assessment of the viability of associated test activities
  - Approval to complete final design and start detail drawings.
- **Presents the following:**
  - How the equipment is used in the verification test/integration process: what requirements is it verifying, roughly how does it function and how is it used
  - Use of the equipment in the I&T sequence: how does the equipment fit in physically and logistically into the sequence; lay out a progression of the work activities, associated procedures, and where the equipment (and other equipment) fits into the process
  - Requirements: requirements from the Verification Test Plan; interface requirements agreed on in ICDs with subsystems, and any operational req's
  - Preliminary design: mechanical, control system design; data acquisition plans; interfaces to camera hardware
  - Supporting analyses: preliminary structural and/or thermal analysis showing that the design meets its requirements; lay out load cases and handling/support configurations and mount points that may not be standard and show effect on camera hardware
  - Operating hazards: list hazards associated with operating this equipment (to personnel and camera hardware)
  - Verification testing using the equipment: show expected test data and downstream analysis to establish verification
  - Remaining/open issues: items yet to resolve, especially if it involves subsystem hardware
  - Risk Analysis: show current risk assessment and mitigation of technical, cost & schedule risk. Link to previously presented prototyping effort.
  - Updated Hazard List and drafts of any hazard reports.
  - Hazard controls: show analysis of design for engineering controls, administrative controls and design based mitigations
  - Cost and schedule Updates

- **Deliverables:**
  - Preliminary requirements document for relevant equipment
  - Interface documents and drawings with other sub-systems: All identified interface documents should exist (no place holders). All interface documents to other sub-systems or components already at FDR or expected to be purchased as long duration items should be complete.
  - Risk registry: risk registry spreadsheet (LCA-30) with current assessment, status dated to less than a month, schedule and cost residual
  - Hazard registry: updated hazards spreadsheet (LCA-15) with current assessment and status dated to less than a month
  - Updated Camera Hazard Report for hazards qualifying under LCA-31-A, the SSPP, section 8.2.1.1. The report should follow the template defined in LCA-16.
  - Resolution in the LSST Camera Action Item tracking tool of all previous I&T reviews relevant to the equipment and associated test since the Integration Planning Review
  - Printout of the most up to date schedule and Detail Cost Estimate (DCE)
  - Printout of the Baseline Change Requests to date

8.6.3 Equipment Procurement Review (equivalent to FDR)

The Equipment Procurement Review is a detailed review of equipment design and analysis at the component and part level. This can also serve as a procurement review for the pieces of hardware in lieu of an MRR.

- **Scope:**
  - Equipment Design including hardware, software and databases
  - Equipment detailed Test activity and processes
- **Goal:**
  - Approval of the final equipment design, with confirmation that it meets all technical requirements and interface agreements
  - Approval of the associated test activities
  - Approval to start procurement and fabrication of the relevant equipment.
- **Presents the following:**
  - Review of Test Definition Review plans and processes: point out any changes to I&T process flow and how the equipment will be used
  - Requirements: final list of requirements and interface definitions
  - Design and analysis: final design and detailed analysis showing compliance with all requirements and to LCA-280 “Mech Standards.” This may also include review of analysis done to demonstrate compliance for safety review (e.g.: hoisting and rigging review of under-the-hook lifting devices)
  - Procurement/fabrication plans:
    - Review of procurement spec and SOW, if applicable
    - Discuss provisions for verification testing by contractor and/or any acceptance testing at SLAC
    - Lay out plans for validating that the final assembled hardware actually performs as required and that it is ready for use on camera hardware (this essentially lays out a road map for getting to the Test Readiness Review for the equipment)

- Risk Analysis: show current risk assessment and mitigation of technical, cost & schedule risk. Link to previously presented prototyping effort.
- Updated Hazard List and drafts of any hazard reports.
- Hazard controls: show analysis of design for engineering controls, administrative controls and design based mitigations
- Cost and schedule Updates

- **Deliverables:**
  - Final requirements document for relevant equipment
  - Tolerance study and stackup documentation compared to requirements when applicable
  - Draft engineering note to be submitted for a peer review on structural analyses for critical items.
  - Interface documents and drawings: All identified interface documents should exist and be complete and released with clear deliverables.
  - Testing and verification documents prior to use of the equipmnt: Finalized test reports documents from past prototypes if applicable.
  - Updated 3D CAD model if applicable: CAD model should be compatible with the overall camera model for incorporation.
  - Drawings: drawings of critical components and assemblies should be available.
  - Schematics and layout: schematic of electronics systems and layout of critical boards or board section should be available if applicable.
  - Software final functional architecture and infrastructure (OSI model summary).
  - Bill of material of key components and contamination assessment report.
  - Risk registry: risk registry spreadsheet (LCA-30) with current assessment, status dated to less than a month, schedule and cost residual
  - Hazard registry: updated hazards spreadsheet (LCA-15) with current assessment and status dated to less than a month
  - Updated Camera Hazard Report for hazards qualifying under LCA-31-A, the SSPP, section 8.2.1.1. The report should follow the template defined in LCA-16.
  - Resolution in the LSST Camera Action Item tracking tool of all previous I&T reviews relevant to the equipment and associated test since the associated test Definition Review
  - Printout of the most up to date schedule and Detail Cost Estimate (DCE)
  - Printout of the Baseline Change Requests to date

8.6.4 Integration Readiness Review

The Integration Readiness Review is a planning review intended to finalize the high level integration and test process workflow, facilities and infrastructure needed to support the work, and establish a plan to complete Test Readiness Reviews of all activities and equipment that comprise the workflow. There may be one or two IRRs, depending on the modularity of the work organization.

- **Scope:**
  - Final integration process workflow for the scope of the work being reviewed

  - Final designs and operations plans of fixtures, equipment, software, and databases supporting the workflow
  - Processes used in completing the scope of work
- **Goal:**
  - Approval of the final process workflow
  - Approval of the plans for using the equipment and the plans for completing activity Test Readiness Reviews
  - Approval of a complete procedure list, plans to complete all procedures, and procedure and equipment validation plans
- **Presents the following:**
  - Final I&T process workflow for the scope of work covered in the review
  - Final facilities and infrastructure definitions, status to completing all needed infrastructure, and standard operating procedures for using it (including clean room, IT infrastructure, inventory control plans, storage, and any other physical or logistical infrastructure)
  - Final I&T Plan, Verification Test Plan
  - Physical layout and sequencing of process workflow steps
  - Risk analysis updates: show current risk assessment and plans for mitigation of technical, cost & schedule risk
  - Hazard analysis updates: plans for closing out all hazards to the appropriate procedures
  - Cost and schedule updates
- **Deliverables:**
  - Complete list of all procedure and their status
  - List of all fixtures, test equipment, and camera components, and who is supplying what
  - Final design of all I&T-supplied equipment and plans for how it will be used
  - Final plans on what and how subsystem hardware will be delivered
  - Risk registry: risk registry spreadsheet (LCA-30) with current assessment, status dated to less than a month, schedule and cost residual
  - Hazard registry: updated hazards spreadsheet (LCA-15) with current assessment and status dated to less than a month
  - Updated Camera Hazard Report for hazards qualifying under LCA-31-A, the SSPP, section 8.2.1.1. The report should follow the template defined in LCA-16.
  - Resolution in the LSST Camera Action Item tracking tool of all previous I&T reviews relevant to the equipment and associated activity
  - Printout of the most up to date schedule and Detail Cost Estimate (DCE)
  - Printout of the Baseline Change Requests to date

8.6.5 Test Readiness Review

The Test Readiness Reviews are targeted reviews of one or more integration/test activities and the associated equipment and processes. The review focusses on a particular piece of equipment and its use, but also details all aspects of the context in which the equipment is used. TRRs are generally held as needed prior to the start of integration and testing of camera components using that equipment. TRRs are largely technical reviews, but can include assessment of the planned schedule and personnel needs to support use of the equipment in the broader context of the I&T process. The number and extent of I&T

TRRs depend on the final configuration of the I&T plans and equipment, but the expectation is that all equipment has been built and validation tests completed, using completed process travelers.

- **Scope:**
  - Integration and test equipment design and process validation results for the activities and equipment under review
  - Integration and test procedures for all processes associated with the activities and equipment under review
- **Goal:**
  - Approval to use validated fixtures, equipment and procedures for integration and test of camera components
  - Approval to start the integration and test process flow that covers the scope of the review
  - Either approval to proceed with power-on testing of integrated assemblies or establishment of follow-on Test Readiness Reviews
- **Presents the following:**
  - Completed I&T workflow plans covering the full scope of work, including the following: receiving, cleaning, integration, assembly, inspection, operation, testing, handling, storage, and shipping
  - Design, functionality, and operations procedures for fixtures and test equipment, including any delivered by subsystems, including any test scripts and eTravelers
  - Description of all delivered subsystem components and their configuration, including verification test results
  - Results of validation testing, demonstrating that equipment functions as needed and includes adequate controls for operations and equipment safety
  - Completed and validated integration and test procedures and travelers to be used
  - Final Operating and Support Hazard Analysis entries for work within the scope of the review
  - Review closure of action items from the Equipment Procurement Review and Integration Readiness Review
  - Updated Risk analysis: include manufacturing risks
  - Hazard analysis updates: plans for closing out all hazards to the appropriate procedures
  - Cost and schedule updates
- **Deliverables:**
  - Complete list of all procedure and their status
  - List of all fixtures, test equipment, and camera components
  - Final design of all I&T-supplied equipment and plans for how it will be used
  - Final plans on what and how subsystem hardware will be delivered
  - Risk registry: risk registry spreadsheet (LCA-30) with current assessment, status dated to less than a month, schedule and cost residual
  - Hazard registry: updated hazards spreadsheet (LCA-15) with current assessment and status dated to less than a month
  - Updated Camera Hazard Report for hazards qualifying under LCA-31-A, the SSPP, section 8.2.1.1. The report should follow the template defined in LCA-16.
  - Resolution in the LSST Camera Action Item tracking tool of all previous I&T reviews relevant to the equipment and associated activity
  - Printout of the most up to date schedule and Detail Cost Estimate (DCE)
  - Printout of the Baseline Change Requests to date

After closure of action items, this approves the start of integration and test processes associated with the scope of the review, unless otherwise modified by requirements for follow-on Test Readiness Review

8.7. Pre-Ship Review

Pre-Ship Reviews shall contain the following scope items and address these issues:

- **Scope:**
  - System level verification that the unit is ready to be delivered
  - Commissioning and operation documentation is required
- **Goal:**
  - Approve that the system to be shipped is ready
  - Accept the verified performance of the system to be shipped
- **Presents the following:**
  - Verification matrix against all requirements: present performance, functional and interface requirement verification results.
  - Present shipping method compliance against requirement. This includes environmental requirements.
  - Present commissioning and operation workflow plan after delivery.
  - Present status of traveler documentation for the item.
  - Status of safety documents: close-out of Hazard Reports for operation
  - Review closure of action items from the MRR
  - Updated Risk analysis: include shipping, commissioning and operation risks
  - Cost and schedule update: updates based on commissioning and operation workflow plan details
- **Deliverables:**
  - Functional and performance requirement verification matrix for the sub-system
  - Interface requirement verification matrix for the sub-system
  - Item data package with all test data required to be delivered by interface requirements.
  - Shipping workflow plans and paperwork: shipping schedule, status of necessary approval as well as drawings and any specifications of the shipping container.
  - Commissioning workflow plan.
  - Operation plan or user manual.
  - Safety documents: close-out of Hazard Reports; draft sections for Operating and Support Hazard Analysis as required
  - Resolution in the LSST Camera Action Item tracking tool of all previous reviews since MRR Tier 1 and Tier 2 RFA related to the sub-system.

8.8. Safety Reviews

Subject-matter-specific Safety Reviews are held as part of the run-up to a subsystem's FDR. These reviews constitute one part of the ES&H program at SLAC and have been adopted by the LSST Camera to assure that subsystem designs and equipment that is delivered to SLAC meet or exceed DOE ES&H requirements. Thus, these form part of the ES&H assurance and review processes for all subsystems, regardless of the origin of the design and hardware. This SLAC "Experimental Project Review Process" is defined and described in Chapter 1 of the SLAC ES&H Manual, referred to in Ref. [5], the Camera Performance and Safety Assurance Plan.

Safety Reviews are technical reviews addressing the personnel hazards and equipment protection issues associated with subsystem design, manufacture, assembly and test, and operation. They are intended to provide assurance that hazards have been sufficiently analyzed, that appropriate controls are planned to mitigate or eliminate the hazards, and that the activity conforms to SLAC ES&H policies.

There are 11 subjects that may warrant review of a subsystem. Safety Reviews shall contain the following scope items and address these issues, depending on the subject of the review:

Earthquake Safety (Opt, Exch, Cryo, CB&M, I&T): subsystem seismic loading; analysis to demonstrate that design can survive seismic loads; any secondary seismic hazards and mitigations

Electrical Safety (SRft, CRft, PCM, I&T): electrical standards used; design of electrical circuits and test equipment; over-current protection and grounding design details; personnel protection; test plans

Environmental Safety (Cryo, I&T): hazardous materials being used and containment systems; plans for storing and using materials during assembly; transport plans

Fire Protection Safety (Cryo, I&T): flammable materials inventory; ignition sources; plans for reducing risk of fire hazard

Hazardous Experimental Equipment (Opt, Exch, Shutter, CB&M, Cryo): identification and control of hazardous energy sources; personnel protection plans; personnel and equipment hazards and mitigation/controls

Hoisting and Rigging Safety (Opt, I&T): hoisting and rigging plans; design, analysis, and test plans for lift fixtures and rigging

Radiation Safety (I&T): radiation sources and levels; plans for control of radioactive materials; plans for personnel protection

Pressure Vessel Safety (CB&M, Cryo): MAWP/MOP assessment; analysis to demonstrate that design can withstand MAWP; fabrication and test plans; materials and joining details

Laser Safety: Not Applicable

Non-ionizing Radiation Safety: Not Applicable

As Low As Reasonably Achievable (ALARA): Not Applicable

8.9. Delta Reviews

At times, intermediate reviews are needed to assess and approve changes to requirements, designs, or plans. These so-called "delta" reviews are ad hoc, and are generally needed when the changes are of sufficient magnitude that they affect multiple interfaces, include changes to the design of entire sub-assemblies, or impact entire classes of requirements or their verification.

- **Scope:**
  - Sub-Assembly or Component Specific.
  - Review charge dependent
- **Goal:**
  - Approval of changes to the baseline design and/or requirements, with confirmation that the changes meet all technical requirements and interface agreements
  - Approval to re-enter the design development path towards the next full review, fully incorporating the changed baseline; this may include approval of additional development work or modifications of existing prototype hardware
- **Presents the following:**
  - Changes to requirements and their impact on higher level requirements
  - Changes to the design, rationale for the changes, and evidence that the modified design meets the requirements: includes design studies of change impacts, and modifications of existing design documentation as appropriate
  - Value engineering: results of trade studies and other alternative evaluations to justify the rationale for the changes; this should include impacts on cost, schedule, technical performance, and risk
  - Engineering analyses: updated analyses to reflect design changes, along with impact on predicted performance and margins to requirements
  - Subsystem interfaces: changes to interfaces and ICD's, along with impacts on opposite side of the interface
  - Fabrication, assembly, and test plans: impact of changes on manufacturing plans and processes
  - Assessment of the impact of changes on risk exposure, identified and new hazards and their mitigations, hazard control and protection plans, reliability of the system and components
- **Deliverables:**
  - As required by the charge. Generally they should be a subset of the deliverables listed under the previous major review as defined in section 8.2, 8.3, 8.4, 8.5 and 8.6 affected by the changes presented under this review

After closure of action items, approved to change design baseline and re-enter the design development path.

8.10. Analyses Peer Reviews

Peer Reviews for analysis efforts are required to ensure that model assumptions for boundary conditions, properties, load cases and results interpretation are appropriate. These peer reviews are meant to convey detailed analysis information that shows all needed analyses have been completed with adequate margins of safety. Minimum guidelines are given below for the reviews and reports, but peer review panels may request additional information.

8.10.1. Structural Analysis Peer Reviews

- **Scope:**
  - All structural analyses performed for the FDR, including Subsystem FEA models, detailed stress models, model/test correlation efforts, and hand calculations. All analysis results should show positive margins under the full set of load cases.
  - Accuracy of analysis performed. This can be in the form of heritage performance, in-house analysis standards, correlation to test, or conservative estimation. For example, in preliminary designs, model uncertainty factors may be used to account for unknown mass, material, or final design details. Moving into FDR, the analysis accuracy will be improved; the improvement should be quantified and explained.
- **Goal:**
  - Get peer review concurrence that a complete analysis was conducted for FDR and that all results show adequate positive margins. Provide assurance that the engineering note is ready for release. The engineering note should be a stand-alone document that conveys the analysis information requested.
- **Presents the following:**
  - Assumptions used during analysis. Assumptions include boundary conditions (joints, friction, fixed/free, rigid, etc.).
  - Model Checks. After an FEA model is created and before results are used from that model, model validity checks should be performed. Different kinds of model checks are described below. The analyst should present the information deemed necessary to validate the model.
    - Mathematical model validity checks. Typical checks include: 1) Unit enforced displacement and rotation, 2) Free-free dynamics with a stiffness equilibrium check, 3) unit gravity loading, and 4) unit temperature increase.
    - FEA model properties should be checked for modeling issues such as proper element selection, duplicate elements, element aspect ratios, element normal, coincident nodes, element connections, etc.
    - Other common sense checks should be performed. These include dimensional comparisons with the 3D CAD model, material property assumptions and properties, element properties, consistency of units, and results coordinate systems.
  - Load Cases. The load cases used in the analysis will be presented to ensure completeness. All load cases in the subsystem specification must be addressed. Any additional special load cases shall also be shown. Special load cases may include stages of integration where assemblies are handled or loaded in non-standard ways. Show all load case combinations used in determining structural behavior and margins (gravity, seismic, thermal, pressure, …)
  - Results. Stresses, displacements, forces and other results should be shown in a table format. The table should show the applied force, material allowable, safety factor, and minimum margin of safeties for yield and ultimate levels. Safety factors are up to the subsystem engineer to determine, based on LCA-10031. All margins of safety should be greater than 0.0.
  - Conclusions. A discussion of the results should lead to conclusions that the structure is capable of satisfying all its structural requirements.

- **Deliverables:**
  - Model and data that can be used and checked by the peer reviewer.
  - Engineering note describing assumptions and results. A MS Powerpoint presentation may satisfy this deliverable if it contains enough information as a stand-alone document.

8.10.2. Thermal Analysis Peer Reviews

- **Scope:**
  - All thermal analyses performed for the FDR, including subsystem thermal FEA models and hand calculations and any model/test correlation efforts.
  - Accuracy of analysis performed. This can be in the form of heritage performance, in-house analysis standards, correlation to test, or conservative estimation. This may include assessment of conservatism of convection boundary conditions, radiative emissivity estimates, and thermal contact joints, as well as material properties and their changes over the working temperature range.
- **Goal:**
  - Get peer review concurrence that a complete analysis was conducted for FDR and that all results show adequate thermal performance given the expected range of variation of boundary conditions and heat loads.
  - Provide assurance that the thermal design engineering note is ready for release. The engineering note should be a stand-alone document that conveys the analysis information requested.
- **Presents the following:**
  - Assumptions used during analysis. Heat loads and their variations (min, max, variations over time), conductive boundary conditions and their expected range (min and max for thermal contact joints), convective boundary conditions and flow characteristics (fluid and flow properties, expected variation in convection coefficient), and radiative boundary conditions and characteristics (view factors, min and max emissivities and materials/coating). Material properties and all steady-state and any transient analyses
  - Model Checks. perform thermal FEA model validity checks. Different kinds of model checks are described below. The analyst should present the information deemed necessary to validate the model.
    - Mathematical model validity checks. Typical checks include: 1) Total heat load, 2) Heat source/sink thermal equilibrium check.
    - FEA model properties should be checked for modeling issues such as proper element selection, duplicate elements, element aspect ratios, element normal, coincident nodes, element connections, etc.
    - Other common sense checks should be performed. These include dimensional comparisons with the 3D CAD model, material property assumptions and properties, element properties, and consistency of units.
  - Load Cases. The thermal load cases used in the analysis will be presented to ensure completeness. All load cases in the subsystem specification must be addressed, including any used for thermal distortion analyses. Any additional special load cases shall also be shown, including test configuration where hardware sees non-standard thermal environment.
  - Results. Temperatures, heat flow/flux, and temperature gradients. Results should include predicted variations due to extremes of the heat loads and thermal boundary conditions. This could be done by scaling results or running additional “hot-case” and “cold-case” analysis runs to bound the extreme thermal states, besides simply the nominal.

  - Conclusions. A discussion of the results should lead to conclusions that the component/assembly is capable of satisfying its thermal requirements and/or meeting performance requirements while in the specified environments and thermal conditions.
- **Deliverables:**
  - Model and data that can be used and checked by the peer reviewer
  - Engineering note describing assumptions and results. An MS Powerpoint presentation may satisfy this deliverable if it contains enough information as a stand-alone document.

8.11. Vendor Reviews

Vendor reviews are expected to be conducted by the project team per the negotiated sub-contract. Review scope, goal and deliverables for all vendor reviews shall follow the guidelines presented in previous section with the exception of the following:

Present the following:

- Hazards and safety material must be presented. Personnel safety of the vendor personnel is not required to be presented. However, equipment safety and any personnel safety potentially impacting project personnel is required.
- Cost is not required to be presented for firm fixed price contract. However, time and material contract must present cost update. Note that schedule is required to be presented in all cases.

Deliverables:

- The design review report chapter is not a vendor deliverable requirement and is being handled by the project relevant sub-system
- A risk registry must be available and delivered but is not required to be delivered as part of the project risk registry spreadsheet. It is the responsibility of the project relevant sub-system to update the project registry using the vendor specific registry.
- A hazard registry must be available and delivered but is not required to be delivered as part of the project hazard registry spreadsheet. It is the responsibility of the project relevant sub-system to update the project registry using the vendor specific registry.Personnel safety of the vendor personnel is not required to be captured as part of the hazards. However, equipment safety and any personnel safety potentially impacting project personnel is required
- The Hazard analysis section in LCA-14 is not a vendor deliverable requirement and is being handled by the project relevant sub-system
- Hazard report as applicable under LCA-31 and following the LCA-16 template are not a vendor deliverable requirement and are being handled by the project relevant sub-system
- Basis of estimate documentation (BOE) is not required for vendors.
- A Detailed Cost Estimate (DCE) document is not required for vendors, however a detailed schedule is required.
- Baseline change request form are not required for vendors. It is expected that any contract modification, approved deviation request, approved non-conformance are being tracked and handled through the relevant organization contracting office.