| | Document # | Status |
|---|---|---|
| Large Synoptic Survey Telescope<br>Camera Plan | **LCA-00040-D** | LSST Camera APPROVED<br>Effective Date 17 July 2018 |
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| | Subsystem/Office<br>Integration and Test | |

Document Title

# Camera Integration and Test Plan

## 1 Change History Log

| Revision | Effective Date | Description of Changes |
|---|---|---|
| A | Nov, 2011 | De facto release for CD-1 |
| B | August 2014 | Significant update - (for CD-2). |
| C | June 2015 | Significant update - (for CD-3). |
| D | July 17, 2018 | Significant Update - (for I&T - Integration Test Review).<br>Release per LCN-2035. |

## 2 Contents

# 3 Acronyms and Definitions

## 3.1 Acronyms

| | |
|---|---|
| BOT | Bench for Optical Testing |
| CAMs | Control Account Managers |
| CCOB | Camera Calibration Optical Bench |
| CMM | Coordinate Measuring Machine |
| DG | Development Group |
| EO | Electro-Optical |
| ESD | Electro-Static Discharge |
| ES&H | Environment, Safety and Health |
| GN2 | Gaseous Nitrogen |
| IG | Integration Group |
| ICD | Interface Control Document |
| I&T | Integration and Test |
| LSST | Large Synoptic Survey Telescope |
| ODM | Oxygen Deficiency Monitor |
| O&SHA | Operations and Support Hazard Analysis |
| PM | Project Manager |
| PS | Project Scientist |
| PSA | Performance and Safety Assurance |
| PSAP | Performance and Safety Assurance Plan |
| QA | Quality Assurance |
| SEMP | System Engineering Management Plan |
| SI | Systems Integration |
| SLAC | SLAC National Accelerator Lab |
| SMR | Spherically Mounted Retroreflector |
| SOP | Standard Operating Procedure |
| TBD | To Be Determined |
| TBR | To Be Resolved |
| TG | Testing and Data Analysis Group |
| UHV | Ultra High Vacuum |
| WBS | Work Breakdown Structure |
| WPC | Work Planning and Control |

## 4 Applicable Documents

[1] LCA-00226: LSST Camera Project Management Plan

[2] LCA-00038: LSST Camera System Engineering Management Plan

[3] LCA-00138: Camera Performance and Safety Assurance Plan

[4] LCA-00048: Camera Specification

[5] LCA-11685: Camera Integration and Test Flow Diagram

[6] LCA-10851: Camera I&T Fixture and Equipment Specification

[7] LCA-00283: Camera Verification Test Plan

[8] LCA-10734: Bldg 620 I&T Facility Specification

[9] LCA-10733: Bldg 620 I&T Facility Layout

[10] LCA-00279: Camera Contamination Control Plan

[11] LCA-10032: Camera Electro-Static Discharge Control Plan

[12] LCA-00031: Camera System Safety Program Plan

[13] SLAC-I-720-0A29Z-001-R023: SLAC Environment, Safety, and Health Manual

[14] LCA-00014: LSST Camera Hazard Analysis Report

[15] LCA 00015: Camera Hazard List

[16] LCA 00039: Camera Configuration Management Plan

## 5 Purpose and Scope

The purpose of this document is to define the integration and test planning activities for the LSST Camera.

The scope of the Camera Integration and Test Plan are outlined in Camera Project Management Plan (LCA-226) and the Camera Systems Engineering Management Plan (LCA-38) but are reiterated here for thoroughness.

The Camera Integration and Test Plan describes the plan for integrating and testing the Camera at SLAC. The plan includes details of the Integration and Test (I&T) organization and responsibilities along with major steps in the integration and test process. The plan also includes the flow of verification activities and responsibilities from Camera subsystem components up through the fully integrated Camera. Finally, the plan describes the I&T facilities and equipment to be used for the I&T process, and the plans for personnel and system safety during integration and test activities.

The 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.

# 6 I& T Subsystem Organization

## 6.1 I&T Organization and Management

The Camera Integration and Test Organization is comprised of several smaller subgroups – all under the control of I&T Management. The overall management structure of the I&T Organization is shown below. Working under, and reporting directly to I&T Management is an Integration Group, a Verification Analysis and Testing Group, and a Fixtures and Equipment Development Group. Each of the aforementioned groups is assigned an appropriate Lead and descriptions outlining the scope of work for the subgroup, and responsibilities of the leads are given below.

In general, the I&T Organization has a core staff that is dedicated to the I&T effort and is made up mainly of subsystem direct hires. Additionally, the core group is also able to draw upon resources from a variety of the other Camera Subsystems as well as the SLAC labor pool as needed. This might occur in a case where particular tasks require an individual flavor of expertise. It is anticipated that as individual subsystems approach completion, key members of those subsystems will transition onto the I&T team along with their associated subsystem knowledge.

The overall structure of the I&T organization is shown in Figure 1, below:

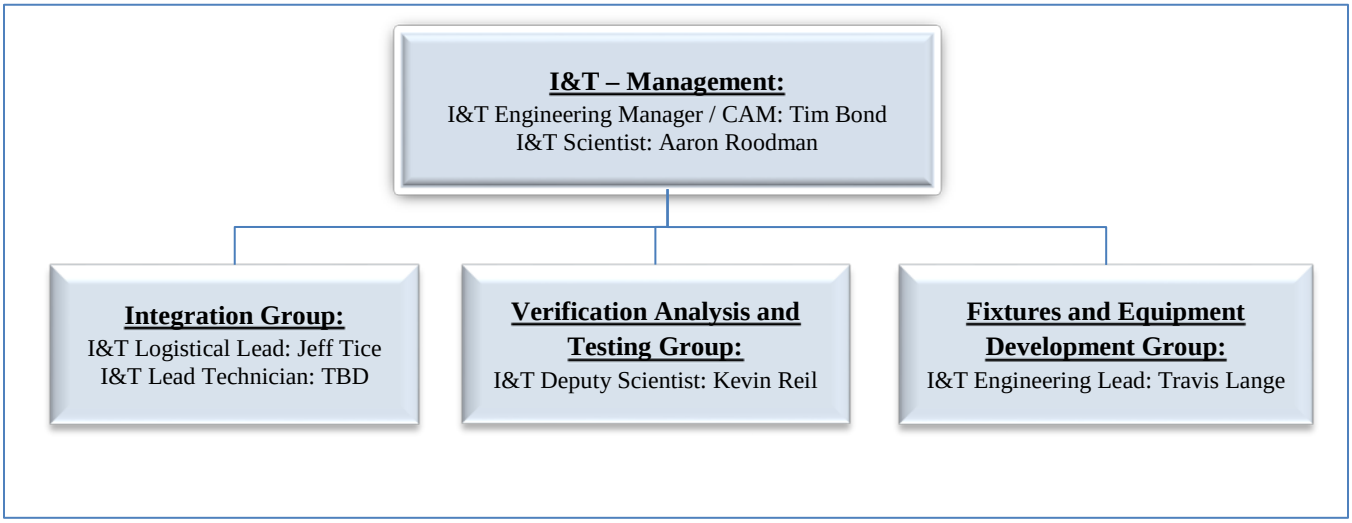


**Figure 1: I&T Organization chart.**

### 6.1.1 I&T Engineering Manager / CAM

The I&T Engineering Manager / CAM directs all aspects of the Camera integration and test process at SLAC. The I&T Engineering Manager reports directly to the Camera PM and acts as the I&T Subsystem Control Account Manager. Additional I&T Engineering Manager's responsibilities include, but are not limited to, the following:

- Subsystem coordination: work with the Camera PM and individual Subsystem Managers to identify subsystem deliverables for the camera, as well as fixtures and test equipment; track status on subsystem deliverables.
- Integration planning and execution: develop integration fixtures and procedures; plan the integration process and execute to the plan.

- System-level verification tests: plan and develop procedures using subsystem test procedures as a starting point; execute system-level tests; reduce test data to verify system requirements are met.
- Receiving tests: develop receiving tests for subsystem hardware; receive subsystem hardware and test data, perform tests, and store delivered test data.
- Facility management: manage and run all I&T related activities at SLAC, including activities within the clean room, control room, and ancillary support rooms; develop and manage clean and dirty stores and the inventory control system for the I&T subsystem.

### 6.1.2 I&T Scientist:

The I&T Scientist is responsible for closely monitoring the I&T design, construction and testing efforts and for performing analytical calculations and simulations necessary to support those efforts. The I&T Scientist serves as a key member of the I&T Team, and advises the Camera Project Scientist and Camera PM on I&T related matters that may affect the scientific performance of the instrument. Additional responsibilities of the I&T Scientist include, but are not limited to, the following:

- Communicates with the LSST Project Scientist and the LSST Project Science team to negotiate any revisions or clarifications to the Camera requirements.
- Modeling and analysis of the camera-level contributions to the integrated system image quality.
- Modeling and analysis of the integrated throughput of the camera.
- Modeling and analysis of the metrological procedures established to meet the flatness and alignment requirements of the focal plane.
- Modeling and analysis of contamination requirements and performance within the cryostat.
- Provide feedback to the System Integration Manager to ensure proper instrument and science simulations are conducted to enable verification and validation of requirements flow down.
- Work with the I&T Engineering Manager to evaluate the impact of revisions to I&T Subsystem requirements.

### 6.1.3 Integration Group - *I&T Logistical Lead*

The Integration Group is comprised of SLAC Technicians, Engineers, and Scientists and is the group responsible for the actual “hands on” assembly and testing of the Camera. This group is directed by the I&T Logistical Lead, who reports directly to the I&T Engineering Manager.

The I&T Logistical Lead will coordinate all work performed within the IR2 / Clean Room Facility at SLAC. The I&T Logistical Lead will directly supervise all clean room staff and coordinate the work of all others while within the facility. They are responsible for ensuring that all work is planned properly, and authorized, and serve as the final authority to release work to be completed.

The I&T Lead Tech will be responsible for oversight of all other technicians within the clean room during the course of the day. Any issues that arise will be reported to the I&T Lead Tech for determination of proper disposition. The I&T Lead Tech will report directly to the I&T Logistical Lead, or the I&T Engineering Manager in the Logistical Lead’s absence.

The I&T Logistical Lead will assume responsibility for day-to-day tactical planning of work at the IR2 / Clean Room Facility. This includes planning test activities, coordinating scientists and others in executing the tests and assessing the results. The I&T Logistical Lead is responsible for implementing the I&T Inventory Control plan and is the point of contact for I&T Inventory Control.

### 6.1.4 Verification Analysis and Testing Group - *I&T Deputy Scientist*

The Verification Analysis and Testing Group is comprised of SLAC Scientists and Engineers and is the group responsible for performing the analysis of the Camera verification test data. This group is directed by the I&T Deputy Scientist, who reports directly to the I&T Scientist, but works closely with the I&T Engineering Manager.

The I&T Deputy Scientist will manage the development of software used to analyze the results of camera tests, including determining whether a test has been passed, and verification status of requirements. The I&T Deputy Scientist works with outside Subsystem Managers and other Scientific Leads in using subsystem test and test analysis software when possible. They are responsible for developing test scripts, providing middleware and specifying hardware for data handling and storage of I&T and delivered subsystem test data.

In addition, they will develop web interface software and databases and search software for searching and viewing test data and results. They will interface with the eTraveler and eLog development groups to ensure that the infrastructure is available and functioning to meet I&T needs.

### 6.1.5 Fixtures and Equipment Development Group - *I&T Engineering Lead*

The Fixtures and Equipment Development Group is comprised of SLAC Engineers, Designers, Scientists, and Technicians and is the group responsible for designing, prototyping, detailing, fabricating, and assembling all of the fixtures and test equipment required by the I&T group to complete their work. This includes developing procedures for calibrating and proof testing the equipment, as needed, as well as operating procedures for using the equipment both during I&T and during subsequent maintenance work on the summit, after delivery. This group is directed by the I&T Engineering Lead, who reports directly to the I&T Engineering Manager.

The I&T Engineering Lead will provide the day to day direction and oversight to the group, and will work in close contact with the I&T Engineering Manager, and Scientific Lead to help ensure all provided equipment is on time, on budget and meets the established specifications. They will be the primary point of contact for planning the work and will work closely with the Safety Officer and QA Manager in reviewing work plans for purposes of authorizing the work. They will interface/coordinate with the I&T Logistical Lead in order to facilitate the releasing of work orders.

# 7 I&T Subsystem Methodology I: Camera Integration and Test Sequences

## 7.1 I&T Process Flow

I&T's role in the LSST Camera development is to assemble and test the final Camera assembly itself. Once subsystems complete verification of their deliverables, the integration of those components into the final Camera assembly can begin. The Camera assembly follows the high-level sequences shown below in Figure 2 and Figure 3 (Note: Details have been omitted; these figures are meant to give a general overview of the process).

The integration sequence proceeds on two parallel paths for much of the initial integration effort. The work depicted in Figure 2 is intended to run in parallel with the first steps in Figure 3 labeled "Camera Body / Shutter / Filter Integration". These parallel integration activities converge when the fully loaded and tested Cryostat is inserted into the completed Camera body. From that point onwards, the Camera behaves as a whole.

### 7.1.1 Overview: Cryostat Integration

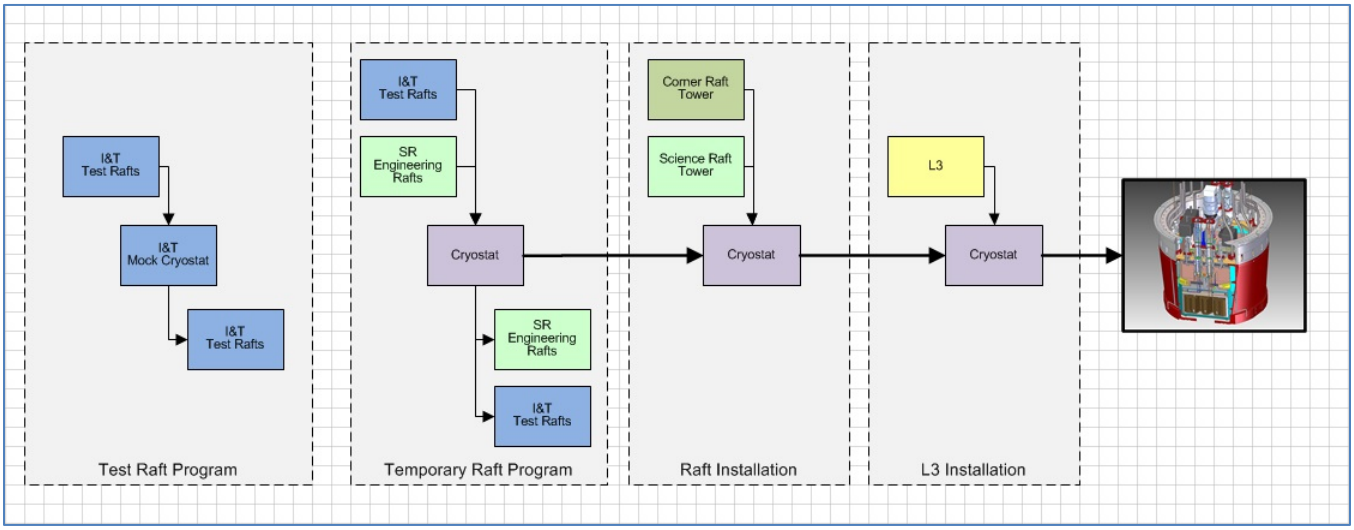


**Figure 2: Cryostat Integration**

The integration of the Cryostat components is performed according to the following high level steps:

- Pathfinder / Test Raft Program:
  - A set of 9 test rafts are installed/removed from the mockup cryostat.
  - Used for early qualification of the Raft Tower Modules installation and removal procedures and equipment (Integration Gantry).
  - Allows for limited early operation of the metrology bench.
- Temporary Raft Program:
  - Used for early qualification of the metrology process.
  - Uses the actual Cryostat and grid/internals.
  - Allows full Electro-Optical (EO) testing to occur prior to Science Raft installations.
- Production Raft Installation:
  - Production Science Rafts & Corner Rafts are installed.
  - Raft installation proceeds in three stages, with EO & metrology testing after each:

        - Stage 1: Total of 2 Science Rafts installed.
        - Stage 2: Total of 9 Science Rafts installed.
        - Stage 3: Total of 4 Corner Rafts & 21 Science Rafts installed.
    - Staged installation allows for repeated testing, while limiting the number of thermo-vacuum cycles.

- L3 Installation:
    - Figured L3 integrated after all Bench for Optical Testing (BOT) and metrology tests are completed.

### 7.1.2 Overview: Camera Integration

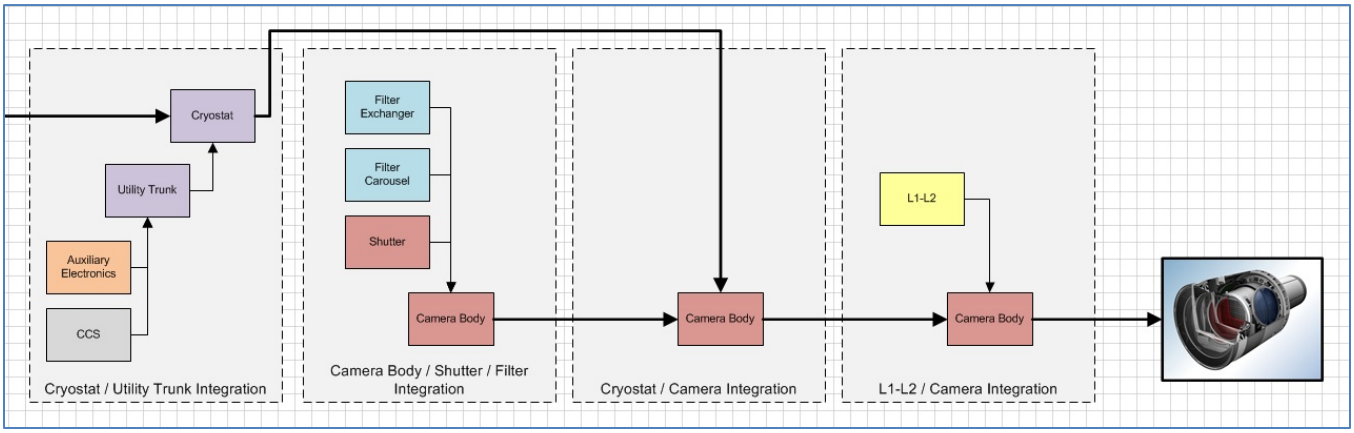


**Figure 3: Camera Integration**

The final integration of the Camera is performed according to the following high level steps:

- Cryostat / Utility Trunk population and integration:
    - Auxiliary electronics and computer control systems installed into trunk structure.
    - Utility Trunk structure mounted onto rear of cryostat.
- Camera Body / Shutter / Filter Integration:
    - Build and qualification of the camera body:
        - Proof testing of the camera back flange.
        - Temporary fit up of shrouds.
    - Installation of the carousel, auto changer, filter loader, and shutter.
    - Qualification testing:
        - Tests of carousel, auto changer, and filter loader.
        - Tests of shutter.
- Installation of the closed cryostat/utility trunk into camera body.
- Integration of the L1-L2 assembly onto the camera body:
    - Use of laser tracker / spherically mounted retroreflector (SMRs) and faro arm coordinate measuring machine (CMM) for the final placement.

### 7.1.3 Detailed Process Flow Sequences

For in-depth planning and development purposes, the entire work flow sequence of the assembly of the LSST Camera shall be predetermined and transcribed at a very high level of detail. The Camera Integration and Test Flow Diagram (Ref [5]) captures this sequencing and the document will be placed

into configuration control. The level of detail is appropriate enough to identify individual components or subassemblies very specifically (i.e. by drawing number).

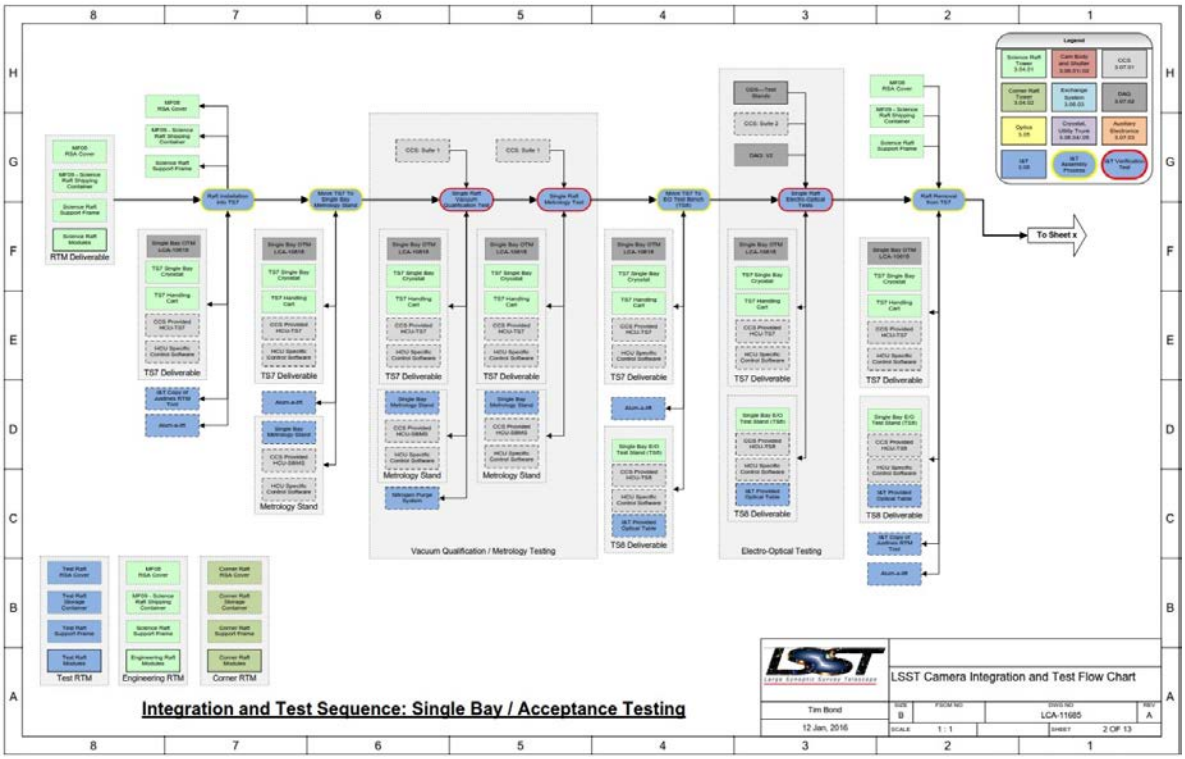


**Figure 4: Example of page from LCA-11685 showing flow sequence.**

The Flow Diagram is used to identify the exact location and time in the I&T sequence at which individual Camera components will be needed and/or expected. This includes all of Camera components as well as additional deliverables from the associated subsystems. Additional deliverables may include special fixtures specific to Camera hardware deliverables, and any temporary “engineering level" operating or test equipment. The workflow diagram functions as a tool to help identify additional elements needed from subsystems and to ensure all elements are identified in the appropriate Interface Definition Drawing (IDD) with I&T.

The work flow diagrams will also identify the individual verification tests that occur within the assembly sequence and the point between assembly steps at which each test will occur. The diagram will function as an effective tool for identifying all required I&T fixtures and jigs – both required from the subsystems, and those developed by I&T. This information will be used to populate the I&T Fixtures and Equipment List (see Sec 10.2).

## 7.2 Process Validation Plans

For the integration and test processes identified above, precursor demonstration tests and pathfinder units are used for validating some of the more difficult (high risk) integration or test processes. Working with these early pathfinder units reduces risks in two ways. First, they reduce the risk of failure or damage to components during the “for-the-record” process using real hardware. Second, the pathfinder units reduce the potential for lost time and re-work costs due to circumstances that could not be foreseen but are caught as part of the validation process.

These validation tests are in addition to the verification tests performed at the subsystem level, and involve pathfinder hardware of some kind. Precursor pathfinder and test units are listed in Table 1, along with a description of the step being validated and reduction in risk to elements of the full sequence shown above.

**Table 1: Validation steps during the integration and test process**

| Validation Steps During the I&T Process | | |
|---|---|---|
| **I&T Process** | **Validation Step** | **Risk Reduction** |
| **1. Raft tower integration** | | |
| Integrate Sci, Crnr RTM | Insert and measure location of Sci and Crnr Test Rafts | Use insertion gantry to integrate test rafts to check functionality and process steps |
| Remove Sci, Crnr RTM | Remove Test Rafts while surrounded by neighbors | Check removal process and any misalignment problems during removal |
| Interconnect RTM to Auxiliary Electronics | Test RTMs using pig-tails on vacuum feedthroughs during single-bay tests | Ensures that all RTMs perform to spec using the actual power and signal lines |
| **2. Cryostat close-out and utilities integration** | | |
| Close cryostat front end | Install L3 optical flat during early testing to check process steps and vacuum integrity | Reduces risk of damage to lens by proving out installing and removing procedures |
| Close cryostat back end | Install vacuum feedthroughs with pigtails prior to Test Raft insertion; vac test and continuity check | Verifies performance and functionality of all feedthroughs prior to inserting RTMs |
| **3. Camera preparation** | | |
| Assemble, proof test camera body | Camera body assembly fit-check during fabrication | Early measurement of as-built tolerances on key interface features |
| Assemble, proof test camera body | Proof test of camera body assembly using load jig at interface points | Correlate with FEA predictions to validate structural behavior |
| Assemble, proof test camera body | Pressure test camera body assembly with blank-off flanges | Checks structural integrity prior to mounting high-value hardware |
| Install cable ways, purge lines | Use camera mock-up to check cable routing, access | Checks real-world access for routing cables and working in the camera |
| **4. Exchange system integration** | | |
| Integrate, test carousel to back flange | Fit-check carousel on dummy back flange during assembly | Check fit of Carousel to back flange |
| Integrate, test Auto Changer to front flange and Carousel alignment | Pre-assemble entire exchange system before delivery | Confirm adjustment capability and adequate fit-up of assemblies |
| **5. Shutter installation** | | |
| Integrate, test shutter | Prove out insertion/extraction process prior to mounting cryostat | Proves out processes before L3 lens is present, reducing risk of damage |
| **6. Utilities interconnection** | | |
| Integrate, test camera utilities systems | Run Shutter, Exch Sys, and Purge system with final HCU's in test rack | Allows for full system verification with actual controls/aux elec hardware w/out Utility Trunk mounted yet |
| **7. Optics integration** | | |
| Load filters in Carousel | Insert Dummy Filters during Exch Sys and Cryostat integration | Checks full functionality of system and filter path with all components in place |

# 8 I&T Subsystem Methodology II: Camera Verification Planning

## 8.1 Verification Flow

The Camera requirements analysis and flow-down processes as well as the associated requirements verification activities are represented with the standard systems engineering V-diagram (see Figure 5). Details of the Camera requirements derivation methodologies are given in the LSST Camera Systems Engineering Management Plan (Ref [2]).

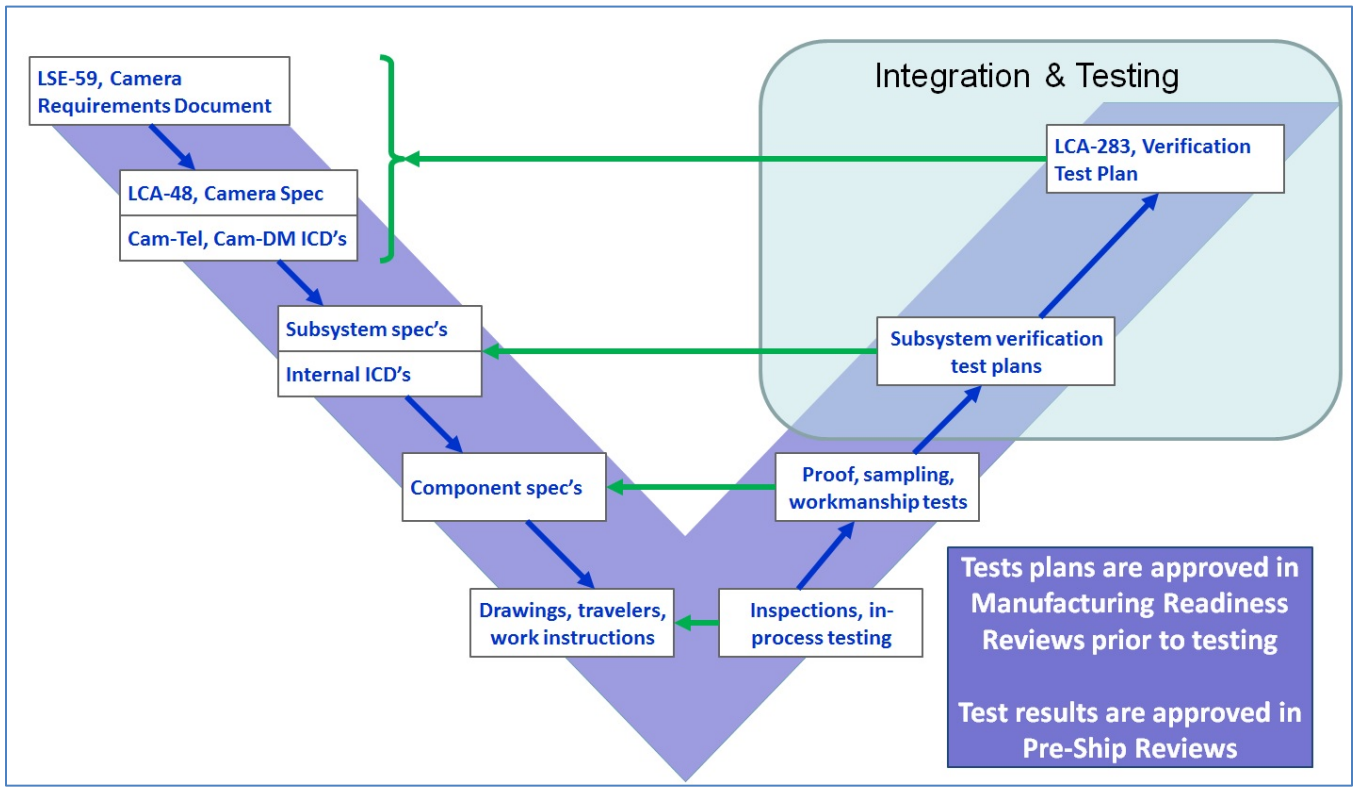


**Figure 5: Systems Engineering V-Diagram.**

The starting point for the I&T Verification activities is LSST Camera Specification (Ref [4]). The I&T subsystem is responsible for verification of the requirements within this specification.

Verification of camera and subsystem requirements begins early in the fabrication, assembly, and integration process, at the subsystem and component level. Some of this verification occurs well before the start of formal I&T work. However, it is important to understand the flow of verification activities from the subsystems on up to full system-level verification.

Furthermore, comparable design qualification testing occurs at the subsystem level, either using early prototypes or first-article units. These qualification tests are typically more rigorous than required to show that the design is robust and to increase the probability of success of subsequent production units.

The vast majority of subsystems should arrive at I&T fully verified and qualified; however, there may be subsystem specifications that will require verification at the full camera assembly level. These requirements will be identified to I&T and will be incorporated into the I&T testing and verification process.

Verification at the full-up camera level begins early in the integration process and proceeds through all phases of the assembly.

## 8.2 Camera Verification Plans

Verification tests have been developed to demonstrate compliance with the LSST Camera Specification (Ref [4]). In some cases, a test is designed to verify a single requirement. In other cases, a test is designed to verify groups of requirements.

Tests are collected together to define test set-ups and required equipment. The following sections are organized by test set-up, showing how tests are grouped. These test stations, their functionality and performance, and the equipment associated with them are all described in detail in the Camera Verification Test Plan (Ref [7]).

Individual Raft Electro-Optical Testing

A test stand will be developed for the sole purpose of confirming that the electro-optical requirements of a single raft tower module are verified (and consistent with previous Brookhaven National Laboratory measurements). The requirements that will be verified by this system are:

- Sensor Cross Talk
- Gain Stability
- Charge diffusion / charge transfer efficiency
- Full well measurements and linearity measurements

Detector Plane Metrology Test Stand (BOT)

A test stand will be developed for the purpose of measuring the flatness of the camera focal plane to a very high degree of precision (micron level). The requirements that will be verified by this system are:

- Detector plane flatness, profile
- Temperature induced motions of the detector plane

Bench for Optical Testing (BOT)

A test stand will be developed for the purpose of performing electro-optical tests of the loaded cryostat focal plane. A variety of tests will be performed, and the requirements that will be verified by this system are:

- Cryostat functional test
- Loaded cryostat thermal functional and performance
- Raft-to-raft crosstalk and removal
- Repeat of subsystem electro-optical tests, :excluding quantum efficiency testing

Integration Support Stand

An integrated support stand is needed for holding the Camera during the majority of its assembly and test processes. The integrated support stand will have functionality necessary to allow the verification of the following requirements:

- Integrated utility trunk thermal performance test
- Integrated camera functional test
- Mass properties measurement
- Modal survey and response to vibration
- Optical element survey and alignment

- Gravitational flexure of optical elements
- Temperature-induced motions of optical elements
- Camera and subsystem interface verification measurement

Camera Calibration Optical Bench (CCOB)

The Camera Calibration Optical Bench (CCOB) will be developed as an addition to the integration support stand for the purpose of performing verification activities specific to the following requirements:

- Raft-to-raft cross talk and removal
- Optics and detector plane alignment
- Integrated optical throughput

Subsystem Tests Used to Verify Camera-Level Requirements

There are a variety of tests that can and will be performed at the subsystem level for verification of Camera-level requirements. Some of those tests include:

- Optics subsystem: lens and filter null tests; lens and filter optical transmission; filter transmission and band-pass
- Science Raft Tower Module subsystem: CCD electro-optical testing
- Camera Body and Shutter subsystem: Shutter functional test
- Other subsystem functional testing

# 9 I&T Subsystem Methodology III: Ancillary Methodologies

## 9.1 Test System & Support Equipment Development:

The I&T subsystem will develop hardware in two general categories:

- Hardware used for handling during the assembly process.
- Hardware used for testing during the verification process.

I&T hardware development efforts will conform to the design and development phases described in the Systems Engineering Management Plan (LCA-00038), Section 8.3, and will meet the design review criteria outlined in the Camera Design Review Plan (LCA-98), Section 8.6. The Design Review Plan allows individual hardware systems to progress through their own individual design/development phases, thus unlinking their individual design reviews.

A graphical representation of the I&T subsystem review process is given in Figure 6 below:

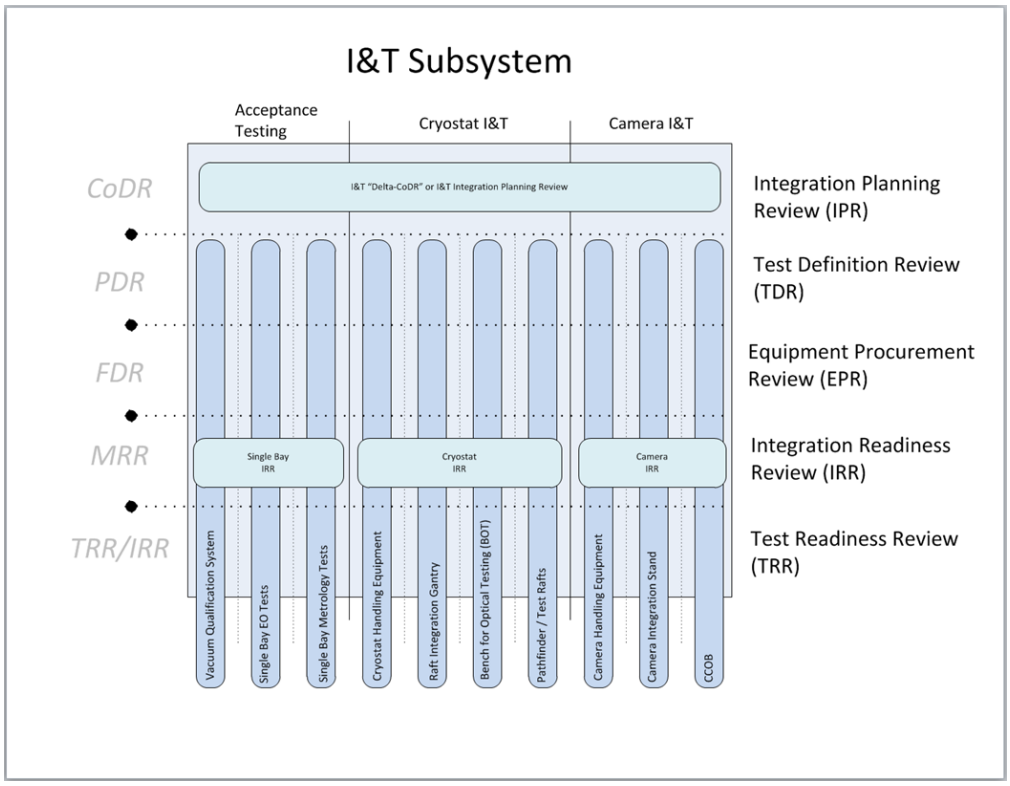


**Figure 6: I&T Review Phases**

The I&T reviews shown above mark the transitions between the following I&T subsystem development phases:

Integration and Test Planning Phase:

- Culminates in an Integration Planning Review.
- Similar in nature and scope to a CoDR for associated Camera hardware. See LCA-98 for the scope of a CoDR review.
- This review encompasses all of the I&T subsystem efforts.

Individual Hardware Subsystem - Test Definition Phase:

- Culminates in a Hardware Subsystem Test Definition Review.
- Similar in nature and scope to a PDR for associated Camera hardware. See LCA-98 for the scope of a PDR review.
- Review is focused on the individual I&T hardware system.

Individual Hardware Subsystem - Equipment Procurement Phase:

- Culminates in a Hardware Subsystem Equipment Procurement Review.
- Similar in nature and scope to an FDR for associated Camera Hardware. See LCA-98 for the scope of an FDR review.
- Review is focused on the individual I&T hardware system.

Individual Hardware Subsystem - Test Readiness Phase:

- Culminates in a Hardware Subsystem Equipment Procurement Review.
- Similar in nature and scope to a Pre-ship Review for Camera hardware. See LCA-98 for the scope of a PSR review.
- Review is focused on the individual I&T hardware system.

Integration and Test Subsystem - Internal Readiness Review Phase:

- Culminates in a series of Integration and Test Internal Readiness Reviews.
- Similar in nature and scope to the MRR for associated Camera Hardware. See LCA-98 for the scope of an MRR review.
- Encompasses several of the I&T hardware system development efforts.
- Readiness review of all hardware and processes for assembly and testing of the designated Camera hardware (i.e. Cryostat I&T, Camera I&T, or Single Raft Acceptance Testing).

## 9.2 Work Planning and Control

All work performed by members of the I&T subsystem will conform to the SLAC standards for Work Planning and Control defined in Chapter 2 of the SLAC Environment, Safety, and Health Manual (Ref [13]). Per the ES&H Manual:

“Work planning and control (WPC) is the use of formal, documented processes for identifying and mitigating risks when planning, authorizing, releasing, and performing work. The purpose of WPC is to ensure adequate protection of workers, the public, and the environment, which would otherwise be put at risk by inconsistent and inadequate planning, authorization, and control.

It applies to all workers (including SLAC employees, subcontractors, users, students, interns, department associates, and Department of Energy [DOE] employees); their supervisors; field construction and service managers; and area and building managers.

All work must first be planned, then authorized, and finally released.”

### 9.2.1 Work Planning and Authorization:

Controlled activities of each I&T worker must be planned and authorized. Planning may occur through a combination of employee/supervisor efforts, and authorization must be established from the worker’s supervisor (or manager) prior to start of work. Work shall be authorized through one or more of the following documents:

- *Activity Training Assessment (ATA):* For routine activities, work is authorized by an ATA created and kept by each worker and reviewed and signed by his or her supervisor. The worker and supervisor review ATAs at least once annually or when change in worker activity warrants an update. For non-routine activities, task-specific procedures assigned to approved personnel act as documentation of work authorization.
- Work Order / eTraveler: For many specific I&T tasks, authorization is documented by an eTraveler, which lists the work procedure, authorized personnel, and the hazards and mitigations associated with the task. Work without authorization is considered a serious violation of established protocols and can end in disciplinary actions.
- Job Safety Analyses (JSA): Work authorization through use of a Job Safety Analysis is required for non-routine tasks in the clean room not covered by an eTraveler.
- Work Integration Plan (WIP): A Work Integration Plan is required when the task warrants more than one SLAC safety-related permit, (Hot Work Permit, Confined Space Entry Permit, Elevated Surface Working Plan, or Excavation Permit), or when the task requires the coordination of workers from more than two SLAC organizations.

The Camera Safety Officer will see to the completion of JSAs and WIPs. Where appropriate, the Camera safety officer will review Work Orders / eTravelers, and has the authority to reject them based upon safety concerns. Also where appropriate, the Quality Assurance Officer will review Work Orders / eTravelers, and has the authority to reject them based on QA standards established in the Camera Performance and Safety Assurance Plan (Ref [3]).

### 9.2.2 Work Release:

Controlled activities of each I&T worker must be released before the commencement of the actual work. This will typically occur on each work day by the I&T Logistical Lead (or relevant "area manager") for the purposes of compliance with Ref. [13], Chapter 2, "Work Planning and Control." Most work release will be sought and granted verbally during pre-shift meetings; release through email and other communications may, at the discretion of the I&T Logistical Lead, be allowed. Work performed without release is absolutely prohibited.

### 9.2.3 Work Orders / eTraveler

Work Orders are procedures that involve the handling of Level I and/or Level II parts:

- Level I Parts – Actual Camera hardware: These parts require the establishment of special handling, packaging and shipping procedures (documented in eTravelers).
- Level II Parts – Parts that touch Camera hardware (i.e. Lifting fixtures, support tooling): These parts are not as critical in handling but still require established handling procedures (documented in eTravelers).

The established procedures will be entered into the eTraveler system. All Work Orders are authorized by the Responsible Manager(s) prior to release / implementation.

Work orders / eTravelers will provide the following minimum information:

- Date issued
- Level of part (Level I or Level II)
- SLAC personnel issuing the part
- Part description (LCA # of part or BOM number, kit or single assembly)
- Next Assembly

- Part quantities issued
- Lot and Date codes (if applicable)
- Subsystem or vendor that delivered the part to SLAC (POC from subsystem or vendor)
- Detail description of work to be performed (this is a line by line detail description of how to perform that specific operation)
- Prior Approval by Responsible Manager(s)
- Prior approval by Safety Officer (if applicable)
- Prior approval by QA (if applicable)
- Condition of part(s)
- Post Approval by Responsible Manager(s) (make sure the work was done per Work Order)
- Comments

### 9.3 Standard Operating Procedures:

Many I&T operational procedures or protocols will be relatively simple and/or repetitive in nature. These procedures will be conducted according to a set of well-defined Standard Operating Procedure (SOP) documents.

For example, a procedure will be defined for the cleaning of an individual part prior to moving the part into the IR2 Clean Room Facility. This procedure will be somewhat generic in nature and likely applied to a large number of parts over the life of the project. Rather than repeat the entire procedure for each of those parts in an associated eTraveler, an SOP can be referenced from and electronically linked to the part's eTraveler.

The part cleaning SOP is an example of a procedure written to satisfy general Camera operations requirements, namely, requirements from the Contamination Control Plan (Ref [10]) . Additional operations requirements driving and/or affecting SOP development flow from the following documents:

- The Electrostatic Discharge Control Plan – Ref [11]
- The Performance and Safety Assurance Plan – Ref [3]
- The System Safety Program Plan – Ref [12]
- The Hazard Analysis Report – Ref [14]

The following is an initially anticipated list of SOPs identified for use during the I&T of the Camera (and will include the following as a minimum):

1) Cleaning of Parts and Components (LCA-13482):
    - Ingress of small parts through "gowning area".
    - Ingress of large parts through front bay doors.
    - Bagging of parts for outside storage.
2) Clean Room Contamination Protocols (LCA-13483):
    - Gowning
    - General clean room principles
    - Banned items / behavior
3) Clean Room ESD Standard Practices and Procedures (LCA-13484):
    - ANSI.s2020 Standard practices
    - ESD Protected areas.
    - Proper grounding techniques.

- Packaging, storage, and handling

4) Emergency Protocols (LCA-13485):
    - Fire
    - Oxygen deficiency
    - Power outage
    - Earthquake
5) Machine Protection Procedures (LCA-13486):
    - Includes cases and procedures to follow during an emergency.
6) Material Handling Procedures (LCA-13487):
    - Critical Lifts (both large dollar value at risk and large mass)
    - Prime movers
    - Carts
7) Inventory Control Procedures (LCA-13488):
    - Checking items into inventory control
    - Finding item within inventory control (includes all associated information - i.e. location)
    - Moving items within inventory control
8) eTraveler Usage Procedures (LCA-13489):

### 9.4 Training:

All I&T personnel working on the Camera shall successfully complete any training required for the type of work identified. Training requirements for personnel are determined by the Camera Safety Officer. Much of that training can be accomplished via standard SLAC-provided occupational-safety and hardware-protection training. Examples of this training includes but are not limited to:

- Work off a ladder with feet >48 inches off the floor: SLAC course 293, Ladder Safety.
- Perform work on systems requiring lockout/tagout: SLAC courses 157 and 157-PRA, Control of Hazardous Energy and Practical Exam.
- Work with cryogens, nitrogen, or non-life-supporting gases: SLAC course 170, ODH and Cryogen Training.
- Operate a hoist or a crane: SLAC course 280 and 280-PRA, Hoisting/Rigging and Practical Exam.
- Work with ones feet >48 inches from the floor on an unguarded surface: SLAC course 200, Fall Protection/Authorized Training (Core).
- Handling radioactive sources: SLAC courses 116/116-PRA, Radiation Worker II Training and Practical, and (for tenders/owners) 118, Source Custodian Training.

Additional training specific to (and in support of) the LSST Camera integration and testing will be provided via two courses identified and developed by the I&T Subsystem. Those courses are:

- Clean Room Safety and Standard Operating Procedures training (covers many of the topics discussed in the general SOPs identified above).
- LSST-Camera ESD training (covers topics discussed in the “Clean Room ESD Standard Practices and Procedures “SOP and is needed for working on ESD sensitive equipment or in an ESD Area).

All I&T Subsystem employees entering the clean room shall be up-to-date with Employee Orientation to Environment, Safety and Health and General Employee Radiation Training. Non-employees shall complete the SLAC Safety Orientation for Non-SLAC Employees.

Any task-specific training required for hardware protection is specified on the eTraveler for that particular task.

### 9.5 Inventory Control:

The I&T subsystem plans to use the SLAC developed eTraveler system for Inventory Control. The eTraveler system will capture all controlled hardware needed for building the Camera (controlled Hardware - both Level I and Level II as defined in Section 9.2.3 above). Consumables and non-controlled hardware will not be captured on the eTraveler system and thus will not be recorded within the I&T Inventory Control system.

The eTraveler system is capable of recording a variety of properties for any of its database entries. Thus, selection and use of the proper fields for properties will facilitate simple and efficient inventory control activities for monitoring or tracking of items.

The following are examples of fields that can be used for tracking and storing of controlled parts in the eTraveler system:

- Status – Checked in / Checked out
- Shipping tracking number
- Date received (SLAC)
- Level of Part (Level I or Level II)
- Part description (LCA # of part or BOM number, kit or single assembly)
- Part quantities
- Lot and Date codes (if applicable)
- Subsystem or vendor delivering the part (POC from subsystem or vendor)
- SLAC personnel receiving the part and placing in storage (reported by)
- Authorizing Inventory Control personnel (approves part to be stored)
- Visual inspection of part or shipping container if not removing part
- NCR number if parts is received damaged
- Location of part to be stored
- Condition of storage (i.e. nitrogen purge set points, in original shipping container)

The process of checking in or checking out a component from inventory will be accomplished via a standardized eTraveler. The eTraveler system will also be developed to provide simple user interfaces that allow individuals to search the database for the purposes of inventory control. Examples of such interfaces include:

- An interface for listing all components located within one location.
- An interface for providing a location history of a particular component.
- An interface for providing all components having been under a particular subsystem’s control.

Camera parts will typically be stored in the cleanroom at IR2. The cleanroom is a controlled area with a keycard entry. Only authorized personnel can enter the cleanroom at IR2. Table 2 shows the locations of additional storage for controlled parts.

**Table 2: Inventory Storage Location:**

| Sub-System | Space Needed Location | | Activities to be done | Comments |
|---|---|---|---|---|
| | Building | Room | | |
| I&T | IR2 | Clean Room (Ante Room) | Clean Storage - "High Value" | Shared (w CR) Nitrogen Purged Cabinet |
| I&T | IR2 | Clean Room (High Bay) | Clean Storage - Small Inventories | Dedicated cabinets along west wall |
| I&T | IR2 | Clean Room (High Bay) | Clean Storage - Science Rafts | Dedicated area in high bay of clean room |
| I&T | IR2 | Clean Room (High Bay) | Clean Storage - Camera Parts | Dedicated area in high bay of clean room |
| I&T | IR2 | Area behind tunnel pillar | Misc I&T Handling and Processing | Staging / Prep area for general I&T activities (some tools) |
| | | | | |
| I&T | #33 | High Bay | Clean Storage - Large Fixtures | TBD - High bay area between clean room and loading doors |
| | | | | |
| I&T | IR12 | Storage Area | Storage of large fixtures | TBD - currently under investigation |

## 9.6 External Subsystem Acceptance / Receiving:

**TBD** – *As per established for camera subsystem requirements verification.…*

## 9.7 Quality Assurance & Non-Conformance Reporting:

### 9.7.1 Quality Assurance (QA)

**TBD** - Quality assurance support is provided by the Camera Quality Assurance Manager and will conform to the standards established by the Camera Performance and Safety Assurance Plan – Ref [3].

### 9.7.2 Non-Conformance Reports (NCR)

**TBD** - *As per established for general LSST Camera nonconformance reporting*.

**TBD** – *Non-Conformance reporting will be handled by the eTraveler system.*

## 9.8 Communications:

The direct communications of relevant information within the I&T subsystem will in general be accomplished via one of two forms:

- Interpersonal communications via meetings and email.
- General dissemination of information via intranet tools.

Weekly I&T Subsystem Meetings

All I&T Subsystem staff will meet weekly to discuss all ongoing I&T related activities. The I&T Engineering Manager (or a designate) will chair the meeting and all I&T staff are expected to attend. Members of the Camera team outside of the I&T subsystem group are welcomed to participate and outside members are encouraged to attend if they desire to discuss a particular I&T related topic. The outside member is asked to submit the topic to the chair prior to the meeting; however, opportunities to raise a particular topic will be provided at the end of the first half of the meeting

The second half of the weekly meeting will be dedicated to discussing the near term logistics of the core I&T team. Action items will be identified, discussed and assigned, and near-term priorities will be established and tracked.

During the assembly and testing of the Camera, some members of the core I&T team may be excused from attending the weekly meeting as other I&T priorities dictate and with the approval of the I&T Engineering Manager.

Daily I&T WPC Meetings

During assembly and testing of the Camera, a daily (morning) meeting will be held to discuss the coordination of that day's work. This meeting will generally be an open forum for any issues that affect the short term (day-to-day) activities of the group and will stay focused on those activities/issues.

The meeting will be chaired by the Logistical Lead (or his designate) and will include all staff working on the Camera that day as a minimum. The I&T Engineering Manager, I&T Scientist, I&T Deputy Scientist, and I&T Engineering Lead will attend as needed, and all additional I&T subsystem staff are welcome to attend for informational purposes. Members of the Camera team outside of the I&T subsystem will be invited as required.

The meeting will be brief and the following topics will be covered:

- The previous day's activities and status on those activities (~5 min).
- The current day's planned activities (~10 min).

Any topics raised requiring more thorough discussion are identified for a breakout group and scheduled for discussions after the ~15 minute meeting completes.

Weekly I&T WPC Meetings

During assembly and testing of the Camera, a weekly (Monday) meeting will be held to discuss the coordination of that week's work. This meeting will generally be an open forum for any issues that affect the longer term (weekly or longer timescale) activities of the group and can be used to raise more global issues.

The meeting will be chaired by the Logistical Lead (or his designate) and will include all staff working on the Camera that week as a minimum. The I&T Engineering Manager, I&T Scientist, I&T Deputy Scientist, and I&T Engineering Lead will attend as needed, and all additional I&T subsystem staff are welcome to attend for informational purposes. Members of the Camera team outside of the I&T subsystem will be invited as required.

The meeting will be one hour long and the following topics will be covered:

- The previous week's activities and status on those activities (~20 min).
- The current week's planned activities (~40 min).

Intranet Tools

Members of the I&T team are encouraged to use the tools available for dissemination of information to the larger I&T group. This includes use of email for more targeted discussions and the use of Confluence or Docushare for larger audiences / discussions. Both Docushare and Confluence are discussed in Section 10.4 below.

# 10 I&T Subsystem Infrastructure

## 10.1 Facilities

The vast majority of the Camera integration and test work will occur in the Clean Room Facility within IR2-Building #620 at SLAC. Additional "overflow" work will occur within Building #33 (both inside and outside of its associated clean room) and temporary storage of some of the larger I&T large fixtures is anticipated in IR12-Building #720. Table 3 lists planned I&T activities and their locations.

**Table 3: I&T Subsystem Activities and Locations**

| Sub-System | Space Needed Location | | Activities to be done | Comments |
|---|---|---|---|---|
| | Building | Room | | |
| I&T | IR2 | Clean Room (High Bay) | Camera I&T | All work required for the camera integration and test process |
| I&T | IR2 | Clean Room (High Bay) | Cryostat I&T | All work required for the cryostat integration and test process |
| I&T | IR2 | Clean Room (Ante Room) | Raft Acceptance Testing | All raft acceptance testing - both EO & Metrology |
| | | | | |
| I&T | IR2 | Clean Room (Ante Room) | Clean Storage - "High Value" | Shared (w CR) Nitrogen Purged Cabinet |
| I&T | IR2 | Clean Room (High Bay) | Clean Storage - Small Inventories | Dedicated cabinets along west wall |
| I&T | IR2 | Clean Room (High Bay) | Clean Storage - Science Rafts | Dedicated area in high bay of clean room |
| I&T | IR2 | Clean Room (High Bay) | Clean Storage - Camera Parts | Dedicated area in high bay of clean room |
| | | | | |
| I&T | IR2 | Area in front of loading door | Shipping and Receiving | "Temporary" intermittent use of area (temp due to sharing with LZ project) |
| I&T | IR2 | Area behind tunnel pillar | Misc I&T Handling and Processing | Staging / Prep area for general I&T activities (some tools) |
| | | | | |
| I&T | #33 | High Bay | Clean Storage - Large Fixtures | TBD - High bay area between clean room and loading doors |
| I&T | #33 | Clean Room | Misc Assembly and Testing | TBD - |
| I&T | #33 | Clean Room | ComCam - assembly and test | TBD - currently no DAQ/CCS support |
| | | | | |
| I&T | IR12 | Storage Area | Storage of large fixtures | TBD - currently under investigation |

### 10.1.1 IR2 / Clean Room Facility

Building #620 is located on the PEP Road on the east side of the SLAC property (Figure 7). The facility is located with the SLAC controlled access gate, and key cards are required for admittance.

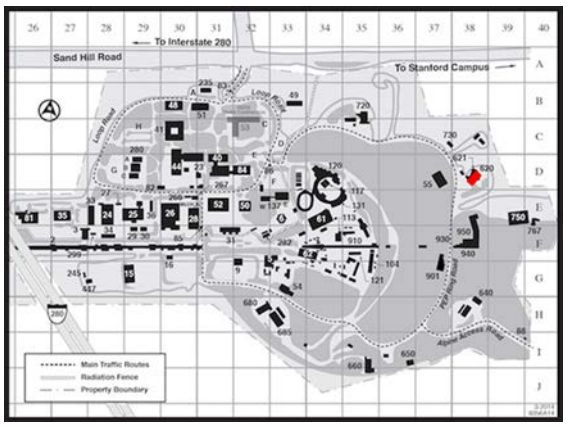


**Figure 7: SLAC Site (Building 620 Indicated in Red)**

### *10.1.1.1 IR2 Layout*

SLAC's IR2 Building contains several rooms within the Clean Room Facility, along with an additional utility room, server room, and control room. Figure 8 shows a floor plan of the Clean Room Facility at IR2.

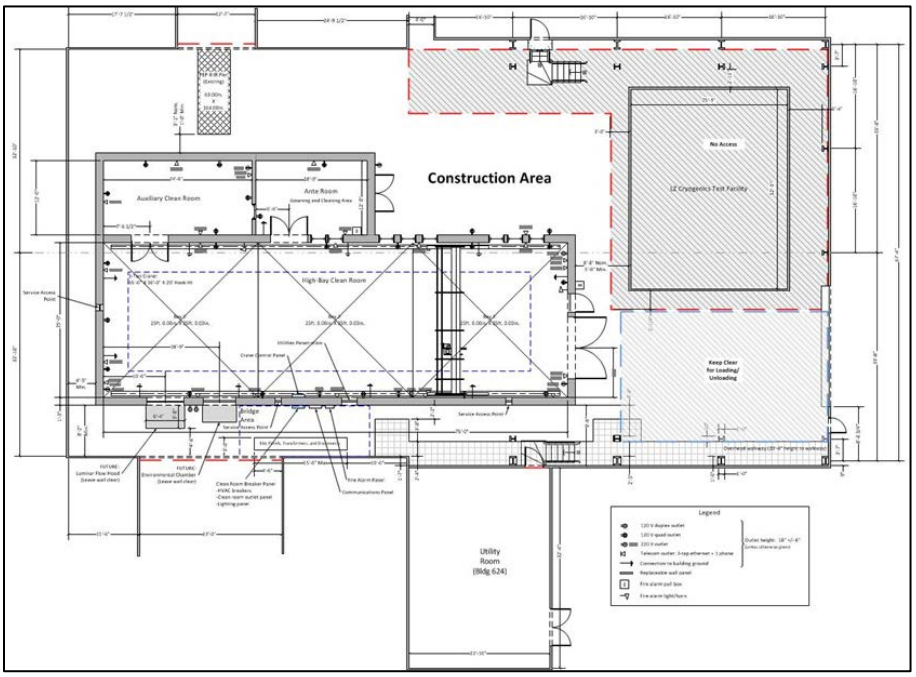


**Figure 8: IR2 / Clean Room Facility Layout**

### *10.1.1.2 Clean Room Facility: High Bay*

The 25' x 75' high bay contains the assembly area for the cryostat and utility trunk as well as several fixtures used in I&T to integrate and test the complete Camera. The high bay is certified as an ISO 6 class environment (FED-STD-209 Class 1000 equivalent). It contains a 5 ton overhead crane with a 20' hook height and a 16' x 60' coverage area, per Ref. [5].

The general purpose entrance to the high bay will be through the gowning room. There are also two doors on the east side of the room; a 3’ wide x 6’-8” high emergency exit door with crash bar, and a 10’ wide by 10’ high equipment access door.

### *10.1.1.3 Clean Room Facility: Auxiliary Room*

The 12’ x 24’ auxiliary room contains the assembly area for the corner raft as well as the I&T fixtures for both corner and science raft acceptance. The auxiliary room is certified as an ISO 6 class environment (FED-STD-209 Class 1000 equivalent). It is only accessible from the high bay through 6 ft. wide by 6’-8” high double doors.

### *10.1.1.4 Clean Room Facility: Gowning Room / Ante Room*

The 12’ x 18’ gowning room is the primary entrance for both personnel and material. It is used to prepare and gown authorized users and their guests to enter the clean areas. The gowning room is certified as an ISO 6 class environment (FED-STD-209 Class 1000 equivalent). A 6’x 8’ doorway allows users with card access to enter the gowning room, and from there another 6’x 8’ doorway allows entry to the high bay.

There are bins containing all required gowning items and a rack for reusable coveralls. A cleaning station is available for cleaning the small parts and tools that will be brought into the high bay through the gowning room.

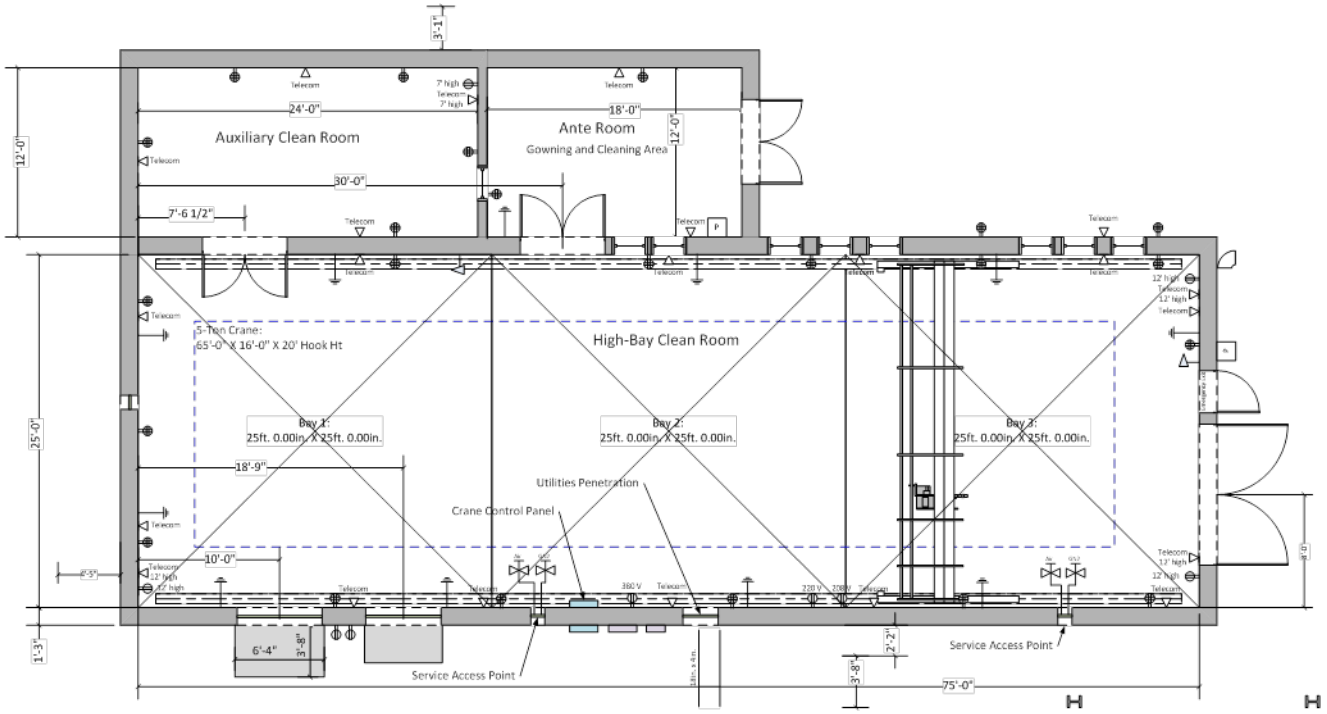


**Figure9: LSST Camera Clean Room at SLAC (Plan)**

### *10.1.1.5 Utility Room (Bldg 624)*

The utility room is an ~ 23’ x 32’ room adjacent to building 620 containing the cryostat refrigeration ground units, chilled water and a liquid nitrogen dewar. The room is accessed via a short flight of stairs from building 620. There are no cleanliness standards associated with this room.

### *10.1.1.6 Control Room*

The control room is the office space adjacent to the building 620 high bay containing the computers and monitors for data visualization. Additionally, there is a server room containing the networking racks and the DAQ system, as well as a conference room. The room is accessed from outside the building, via a card reader-controlled door, or from a set of stairs from the building 620 high bay. Figure 10 shows a layout of this room.

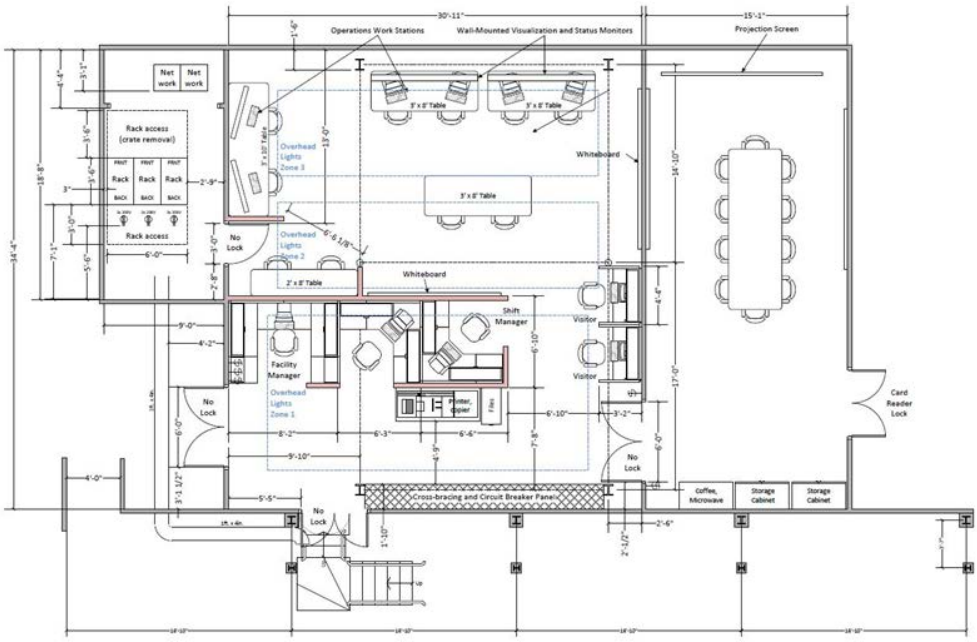


**Figure 10: Ref. [6] LSST Camera Control Room at SLAC (Plan)**

### *10.1.1.7 Storage*

There is space for storage in building 620, both within the clean room as well as the areas outside the clean room. Additionally, there will be storage area in other buildings on the SLAC campus for large fixtures and for use in staging equipment. The LSST Camera project will work with SLAC management to determine additional storage locations as needed.

### *10.1.1.8 IR2 Clean Room Requirements and Capabilities*

The I&T facility requirements and capabilities are defined in the Bldg 620 I&T Facility Specification – Ref [8]. This includes requirements associated with architecture, cleanliness, utilities, heating, ventilation and air conditioning, power, telecom, and monitoring conditions of the facility.

The Bldg 620 I&T Facility Layout (Ref. [9]), is a complete layout of the full complex showing the size and locations of all aspects of the facility.

The ISO 6 (FED STD-209 class-1000) clean room is equipped with the air filtering and handling, electrical power, material handling, environmental monitoring, storage, and computing equipment required for the integration and test of the Camera and Camera components. The clean room is comprised of a 25' x-75' high bay, a 24' x 12' auxiliary clean room, and an 18' x 12' ante room. Primary entry and exit to the clean room is through the ante room, where gowning and materiel cleaning is performed. Emergency exits and a loading door for large items are located on the east side of the high bay. The clean room is serviced by a 32' x 23' utility room located in adjacent building 624.

The clean room power is supplied by one 480V-380Y/220V VAC 3-phase 45 kVA circuit, one 220 VAC 30-Amp circuit, one 208 VAC 3-phase 20-Amp circuit, and fifteen 120VAC 20-Amp circuits (via 25 outlets). Gas systems serving the room include a 20 cubic feet per minute of filtered, low-oil (ISO 8573-1 class 2.2.1) compressed air and 30 liters per minute of dry nitrogen through two taps in the high bay and one in the auxiliary clean room. Cooling water is supplied at a minimum of 10 gallons per minute.

### 10.1.2 Building #33 (with Clean Room)

Building #033 is a 12,545 sq. ft. building with a 15-ton bridge crane (covers full building layout) with a large clean room built in 2001 for the GLAST/Fermi LAT project. The clean room is a Federal Standard 209E Class 100,000 or ISO Class 8 specifications compliant to industries standard and is around 4000 square feet of area. The Camera Project plans to use inside the clean room around 900 sq. ft. of area, 500 sq. ft. Room 100 (not in cleanroom) and around 1,000 sq. ft. of area in the high bay (Figure 11).

I&T plans to use a large portion of the high bay area for staging and storage of components that can be worked on and pre-tested in this area prior to use/integration at IR2.

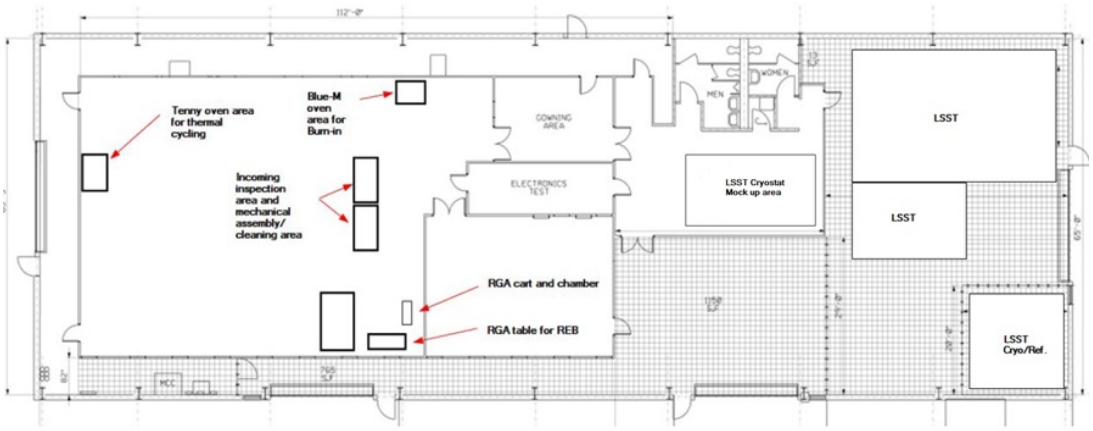


**Figure 11: Building #33 Layout**

### 10.1.3 IR12 - Storage

Building #720 is located on the PEP Road on the east side of the SLAC property (Figure 12). The facility is located within the controlled access gate, and key cards are required for access into the SLAC radiation area. The building also has an Omni lock. Here the project has around 1500 sq. ft. of area for shipping containers storage and large support equipment (bagged) during the assembly of the Camera.

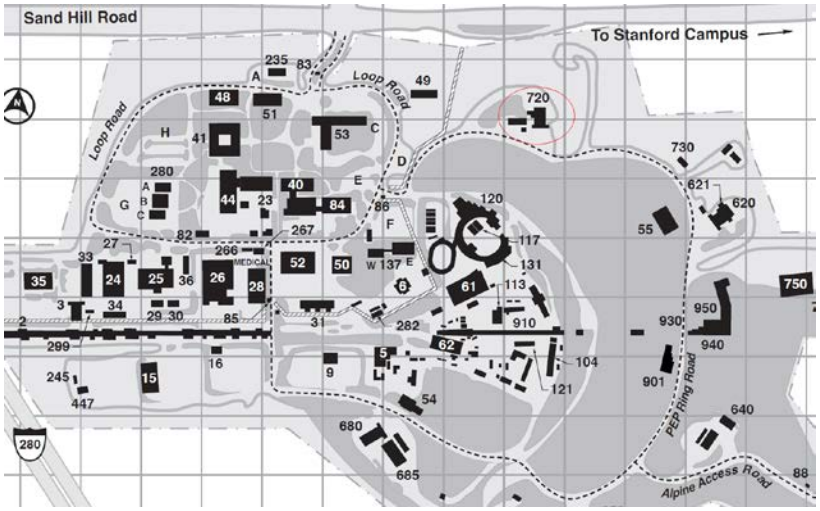


**Figure 12: Building #720 Location**

### 10.1.4 IR2 Clean Room Facility Access

Access to the clean room is controlled by a nested set of access-control zones. Building 620 and outer rooms will be controlled by radio-frequency identification (RFID) card access as is the clean room. Access is assigned by the clean room operations manager to workers who successfully complete Clean Room Safety and Standard Operating Procedures training.

"Piggy-backing" during entry is prohibited: each worker shall use the clean room RFID reader upon entry, even if the door is opened by another entrant. The list of individuals is maintained by the operations manager.

Qualified and trained I&T employees may enter the clean room during normal working hours as long as there are a minimum of two people present.

## 10.2 Fixtures and Support Equipment:

### 10.2.1 Process Identified Support Equipment and Fixtures

All fixtures, stands, supports, special handling hardware, and other equipment needed for the integration and testing of the Camera will be identified in the I&T Flow Sequences Diagram (Ref [5]), acknowledging the assembly point at which they are required. Once the need for a specific piece of equipment has been recognized in the I&T Sequencing Flow Diagram, the component is registered in the Camera I&T Fixture and Equipment Specification (Ref [6]) along with any additional information pertinent to the component.

The Camera I&T Fixture and Equipment Specification is a complete list of all equipment and fixtures that will be used in the I&T process, along with information regarding the source of the hardware, the process step that the hardware is required, and a pointer to any additional documentation that will help clarify the hardware's purpose or specifications.

The full Camera I&T Fixture and Equipment Specification is under documentation control, but a sample of this list with the first few element registered is provided below in Figure 13:

Camera I&T Fixture and Equipment Specification LCA-10851-A

1. Summary Table of Fixtures and Equipment Eff Date: 0-Jan-00

Travis Lange Print Date: 12-Mar-16

| Fixture or Equipment | Providing Subsystem | 1. RTM Acceptance | 2. Cryostat Initial Testing | 2a. Mech. Test RTM Integration | 2b. Thermal RTM Integration | 2c. Eng-grade RTM Integration | 2d. Science RTM Integration | 2e. Crnr RTM Integration | 3. Cryostat Close-Out, Utilities Integration | 4. Camera Preparation | 5. Exchange System Integration | 6. Shutter Installation | 7. Cryo Integration to Camera | 8. Utilities Interconnection | 9. Optics Integration | 10. Final Test and Delivery | Maintenance | ICD / Specification | Type | Design Status | Model In CAD? | Included In Flow Chart? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| General Supports | | | | | | | | | | | | | | | | | | | Title | | | |
| Camera Integration Stand | I&T | | | | | | | | | X | X | X | | | X | X | X | LCA-11972 | I&T | 50% | Y | Y |
| Camera Integration Frame | I&T | | | | | | | | | X | X | X | | | X | X | X | LCA-11972 | I&T | 50% | Y | Y |
| Camera Saddle Support Stand | I&T | | | | | | | | | | | | X | X | | | | LCA-11975 | I&T | 50% | Y | Y |
| Duplicate Rotator | Tel | | | | | | | | | | X | X | | | X | X | | LSE-80 | SS | 50% | Y | Y |
| Camera lift fixture | CB&S | | | | | | | | | X | | | | | | X | X | LCA-284 | SS | | Y | Y |
| Utility Trunk support stand | Cryo | | | | | | | | X | | | | | | | | | LCA-10848 | SS | 0% | Y | Y |
| Utility Trunk lift fixture | Cryo | | | | | | | | X | | | | X | | | | X | LCA-10848 | SS | | N | Y |
| Cryostat Support Stand | I&T | | | | | | | | X | | | | | | | | X | LCA-11974 | I&T | 75% | Y | Y |
| Cryostat lift fixture (C-hook) | I&T | | | | | | | | X | | | | | | | | X | LCA-11973 | I&T | 75% | Y | Y |
| Cryostat Spreader Bar | I&T | | X | X | X | X | X | X | X | | | | | | | | | LCA-13351 | I&T | | N | Y |
| Bench for Optical Test Stand (BOT) | I&T | | | X | X | X | X | X | X | | | | | | | | X | LCA-11795 | I&T | 50% | Y | Y |
| Raft Tower Integration Gantry | I&T | | | X | X | X | X | X | | | | | | | | | X | LCA-11971 | I&T | 60% | Y | Y |
| Back Flange mounting hardware | I&T | | | | | | | | | X | X | X | X | X | X | X | X | LCA-284 | I&T | 0% | N | N |
| Science RTM Acceptance Equipment | | | | | | | | | | | | | | | | | | | Title | | | |
| CDS--Test Stand (+ V2 or V3 of software) | DAQ | X | | | | | | | | | | | | | | | | LCA-11683 | SS | | N | Y |
| Single-bay Raft Metrology HCU (+ Suite 1 of software) | CCS | X | | | | | | | | | | | | | | | X | LCA-317 | SS | | N | Y |
| Mechanical Test Rafts (8 SciRft + 1 CnrRft) | I&T | X | | X | X | | | | | | | | | | | | | LCA-11561 | I&T | 75% | Y | Y |
| Optical Table to support TS8 | I&T | X | | | | | | | | | | | | | | | | LCA-291 | I&T | 50% | Y | Y |
| Single-bay Metrology Stand | I&T | X | | | | | | | | | | | | | | | X | LCA-11753 | I&T | 75% | Y | Y |
| Single-bay Raft Installation Fixture | SRft | X | | | | | | | | | | | | | | | X | LCA-291 | SS | 0% | Y | Y |
| Alum-a-lift | I&T | X | | | | | | | | | | | | | | | X | | I&T | 0% | Y | Y |
| SciRft shipping container | SRft | X | | | | X | X | | | | | | | | | | X | LCA-291 | SS | | Y | Y |
| SciRft RSA Cover | SRft | X | | | | X | X | | | | | | | | | | X | LCA-291 | SS | | Y | Y |
| SciRft Tower Support Frame | SRft | X | | X | | X | X | | | | | | | | | | | LCA-291 | SS | | N | Y |
| TS7 Single Bay Dewar (with OTM) | SRft | X | | | | | | | | | | | | | | | | LCA-291 | SS | | Y | Y |
| Single-bay Electro-Optical Test Stand (TS8) | SRft | X | | | | | | | | | | | | | | | X | LCA-291 | SS | | Y | Y |
| TS7 Pump Cart (vacuum, cryo, PS and controllers) | SRft | X | | | | | | | | | | | | | | | | LCA-291 | SS | | Y | Y |
| Computer for TS7/TS8 | I&T | X | | | | | | | | | | | | | | | | | I&T | | N | N |
| Nitrogen Purge System | I&T | X | X | | | | | | X | | | | | | | | | | | | N | Y |
| Corner RTM Equipment | | | | | | | | | | | | | | | | | | | Title | | | |
| Crnr Raft Tower support frame | CRft | X | | | | | | X | | | | | | | | | X | LCA-292 | SS | | N | Y |
| Crnr Raft Tower lift fixture | CRft | X | | | | | | X | | | | | | | | | X | LCA-292 | SS | | N | N |
| Crnr Raft Tower RSA Cover | CRft | X | | | | | | X | | | | | | | | | X | LCA-292 | SS | | | |
| Crnr Raft Tower storage container | CRft | X | | | | | | X | | | | | | | | | X | LCA-292 | SS | | N | Y |
| Crnr Raft Single-bay Cryostat (modified TS7) | CRft | X | | | | | | | | | | | | | | | | LCA-292 | SS | | N | Y |

**Figure 13: I&T Equipment List LCA-10851**

A large portion of the I&T Fixtures and Equipment will be used in the clean room, but may not necessarily be stored within the clean room, due to space constraints. This equipment will be appropriately bagged and stored outside of the clean room in a dedicated area, controlled by the I&T Logistical Lead. Appropriate handling and cleaning procedures shall be followed for moving this equipment into or out of the cleanroom.

### 10.2.2 Additional I&T Subsystem Provided Support Equipment

Basic/general tools and equipment will be made available for use during the I&T process. These tools will be available both inside and outside of the clean room and will be under the control of the I&T Logistical Lead. Any tools used in the clean room will be cleaned with appropriate procedures, and will adhere to the strict clean room materials policies.

Areas outside of the clean room will be identified for general logistical staging, and for simple workshop procedures. Additional basic tools and machines for simple machining processes and day to day activities will be made readily available.

More complicated machining processes can be undertaken at the nearby SLAC machine shops or an alternative outside vendor may be utilized if advantageous with respect to time and costs. SLAC also has

nearby facilities with expertise in Ultra High Vacuum (UHV) and their cleaning facilities can be easily accessed.

Workstations will be provided for basic electrical / electronic type related activities. Also, computer workstations will be available with access to the SLAC network, both inside and outside of the cleanroom area. Clean room computers will adhere to the Contamination Control Plan (Ref [10]), and the Electro-Static Discharge (ESD) Control Plan (Ref [11]).

Specialized (or expensive) equipment will be under stricter control and will reside in dedicated storage under the control of the I&T Logistical Lead. The I&T Logistical Lead will schedule and monitor the use of such equipment and shall enforce specified operating procedure and certifications as necessary. Possible equipment that fall into the aforementioned category may include:

- Vacuum Cart with RGA.
- Welding equipment.
- Vacuum oven.
- Drill Press
- Faro Arm.
- Environmental Chamber.
- Laminar Flow Benches.

### 10.3 eTraveler

eTraveler is an eManufacturing system developed at SLAC to replace traditional paper travelers. It consists of a backend database and code, most of it in the form of web applications. It can be used to track any device through assembly and testing at all levels.

All the steps in a procedure are recorded in a database as are components and relationships between the components. In addition, it automatically records and links to test results including data products, and allows for user input like uploading pictures and documents and entering data at all steps either through eTraveler itself or through an integrated interface to the electronic logbook (eLog). Finally, eTraveler keeps a complete history of locations for each component.

The users/operators interact with eTraveler through a web browser. However, there are also script interfaces to enable bulk operations like registering a large number of components in one operation.

A traveler definition in eTraveler is used to describe and control the steps in a procedure and acts on a specific hardware component. Creating a new traveler definition typically starts with the subject expert(s) describing the procedure to be embodied in the new definition in a spreadsheet (or any other convenient format). Then traveler developer translates this into a structured text file using the YAML data serialization language which then can be ingested into the eTraveler database.

The eTraveler system will be used by I&T for a variety of tasks:

- Inventory control: Since eTraveler keeps a complete history of locations for each component, inventory control of all controlled parts will be done exclusively through the eTraveler system.
- Accepting hardware: All hardware received by I&T will already have been entered into the eTraveler system by the respective subsystems. In addition, the I&T receiving process will be done using eTraveler.
- Tracking I&T test equipment: Components used for I&T test equipment will be entered into and tracked by eTraveler. Assembly procedures to make I&T test equipment will be done in eTraveler. Note, however, that a traveler in eTraveler can be a mixture of steps and records that we want to

capture electronically and references to external assembly and test documents. The level of details to be captured in eTraveler is decided by management.

- Camera procedures: All camera procedures will be done in eTraveler.
- Non-Conformance Reports (NCR): eTraveler supports two types of NCRs. From within eTraveler you can stop a step and initiate an NCR (which is in fact a new traveler) if you have the correct permissions. This enables the appropriate person to approve things like repeating a step, redoing part of the procedure or ending the procedure. There is also an NCR traveler which documents the NCR process itself. It is meant to be initiated in all cases of an NCR including when the NCR happened in a paper traveler outside of eTraveler. It will detail the problem, any analysis done, approved action and it comes with a signature process.
- Camera verification and test data: Any I&T test data will be taken and tracked using eTraveler and be extracted for verification purposes either using eTraveler itself or (see below) the Data Portal.

eTraveler ties together information about hardware, test and assembly information and test data. Subsystem-friendly views of this information are being implemented in a Data Portal. It will have a series of custom views extracting and displaying information from multiple sources (eTraveler, Data Catalog, eLog). This provides maximum flexibility for the many different users.

We therefore anticipate making a series of views for supporting tasks like inventory control and verification of requirements. Finally, we are planning on a visualization of the hardware hierarchy using a tree-like structure to both give a convenient overview of the state of the camera integration and the capability to drill down to specific hardware components with corresponding links to eTraveler information.

### 10.4 Confluence / Docushare

Confluence and Docushare are a powerful set of Content Management System (CMS) tools that are provided by SLAC and will be fully utilized by the I&T team.

Confluence is a collaborative tool that facilitates real time sharing of data and information. The tool allows real time interchanging of information between team members by enabling individuals to create, organize, share and discuss their work with other camera team members with a simple WYSIWYG interface. The tool will also serve as a data portal for archived reference information. The I&T subsystem will post all meeting minutes, monthly reports, design/development information, and test analysis results to the confluence site in order to dissemination information as easily/quickly as possible.

Docushare is a Content Management System that will be used mainly for document management. It is a web-based content management application that allows team members to submit (or access) revision controlled documents . All team members will have access to Docushare and can download and upload documents, as well as search for desired information within collections. All camera document under revision control will be located on the Docushare site.

### 10.5 Security

All hardware used and/or handled by the I&T team will be under inventory control and thus inherently located within a secure location. Hardware will be transported between secure locations in accordance with controlling documents and will be under the direct supervision of an I&T team member during the move.

The SLAC campus is a secure site and access is restricted to SLAC employees, SLAC approved contractors and SLAC qualified guests. In addition to the general campus SLAC security level, there is an additional level of security associated with entrance to the key controlled region.

Building #620 is located in a key card controlled portion of the SLAC campus. Entrance to building #620 and the clean room proper, are also controlled via key card each with increasingly limited number of authorized users. Access into the clean room is limited to only highly trained personnel needed for specific integration or hardware testing.

The IR2 clean room will be continuously monitored with a suite of cameras. Web cameras will provide documentation of the integration and testing of the camera and will also provide a record of all access and activities within the clean room. All camera components are controlled via the Computer Control System (CCS) which limits operation of the camera to a controlled list of users and only from inside the control room in B-620.

# 11 I&T Subsystem Documentation

The I&T Subsystem will adhere to all documentation policies established in the LSST Camera Configuration Management Plan (Ref [16]). Formal I&T Documentation will be captured, formatted appropriately, and checked into the LSST Camera Docushare system and placed under revision control.

## 11.1 I&T Plans (Level 3 Configuration Control)

These are high level documents that establish the plans and activities that the I&T subsystem will adhere to while performing all I&T work. Two of these documents are under Level 3 Configuration control (as defined in the Configuration Management Plan):

- I&T Plan: LCA-40
- Verification Test Plan: LCA-283

Any changes to these documents will require the approval of a larger group of reviewers as defined in the Configuration Management Plan. All additional I&T Plans will be placed under Level 4 Configuration Control.

## 11.2 I&T Subsystem ICD Documents (Level 3 Configuration Control)

All of the I&T Interface Control Documents (ICD) with outside subsystems are under Level 3 Configuration Control. Any changes to these documents will require the approval of a larger group of reviewers as defined in the Configuration Management Plan .

## 11.3 I&T Specifications Documents (Level 4 Configuration Control)

All developed I&T hardware (handling equipment and test systems) will be designed to a defining specification document. These documents will be placed under Level 4 Configuration Control. Any changes to these documents will require the approval of the I&T Engineering Manager, and the I&T Scientist. The Camera Systems Engineer will be copied for review purposes only.

## 11.4 All Remaining I&T Documents (Level 4 Configuration Control)

All of the remaining I&T Subsystem Documentation shall be under Level 4 Configuration Control. Any changes to these documents require the approval of the I&T Subsystem Manager. These documents include the following

- Additional I&T Plans.
- I&T Standard Operating Procedures
- I&T Technical Drawings.
- I&T Equipment Operations Manuals
- All additional documents.

# 12 Safety

## 12.1 Safety Plans

Safety of personnel and camera systems is paramount in all operations associated with the I&T effort. The development and use of all facilities, equipment, and work planning for I&T is governed by the plans laid out in the Camera Performance and Safety Assurance Plan (Ref [3]). In particular, since all I&T work is performed at SLAC, the PSAP calls out that all systems and operations meet specific requirements detailed in the SLAC Environment, Safety, and Health Manual (Ref [13]).

All I&T processes and plans are subjected to the hazard analysis process invoked in the Performance and Safety Assurance Plan (Ref. [3]), and detailed in the LSST Camera System Safety Program Plan (Ref [12]). Camera I&T plans and equipment undergo a hazard analysis process to identify mishap risks of the fully integrated camera as well as partial sub-assemblies. These hazards are captured in the Camera Hazard Analysis Report (Ref [14]), and further detailed in the Camera Hazard List (Ref [15]).

Integration, handling, and testing processes are further reviewed and assessed for mishap risk in the development of the Operations and Support Hazard Analysis (O&SHA, Ref. [16]). This captures hazards specific to I&T processes, and results in the definition of clear controls and mitigation activities needed to reduce the probability of the hazards coming to pass. All such mitigation activities are further detailed in specific work instructions that are developed, then reviewed as part of the approval process for the work.

## 12.2 Personnel and Equipment Safety

A human hazard is any real or potential condition that can cause injury, illness, or death to personnel. For Camera I&T (as with most engineering operations) hazards are most often associated with the unplanned failure of a component, misuse of equipment, non-standard operations, or the introduction of unforeseen outside influences including other hardware or systems, personnel, or environmental conditions. Threats to personnel safety in the clean room are similar to those found anywhere at SLAC, specifically:

**Thermal**: injury from heat and cold

**Pressure**: injury from flying debris from over-pressure and rupture

**Mechanical**: injury from collision, dropping, pinching by objects

**Structural** (seismic): injury from building collapse or failure

**Electrical**: injury or death from shock, arc-flash, and startling from power excursion

**Environmental**: injury or death from oxygen deficiency

**Fire**: injury or death from conflagration

**Materials**: injury or illness from toxin exposure

Though these hazards and their mitigations are addressed in more detail in Ref. [14] and Ref. [16], five items posing particular mishap risk across a wide range of integration and test activities have been identified. Each of these warrants broader program-level attention to ensure that risks to personnel and hardware are minimized throughout the I&T endeavor. The following sections describe these hazards and discuss the programs to address them.

### 12.2.1 Oxygen Deficiency

The camera volume is purged with a gaseous nitrogen (GN2) purge gas and GN2 is also used to provide a dry, clean environment for storing clean hardware and during certain integration activities. Thus, oxygen-deficient volumes will be present in the I&T facility. This hazard is addressed with oxygen deficiency monitoring (ODM) devices within the clean room facility. Portable monitors are placed adjacent to GN2 activities, and personnel are trained to move away from areas during monitor alarms before abating the oxygen-deficiency hazard.

### 12.2.2 Contamination

The camera lens optical surfaces and the sensor surfaces are sensitive to both particulate and non-condensable vapor residue contamination. The Camera Contamination Control Plan (Ref [10]) addresses the development of allowable contamination levels and requirements on cleanliness levels and contamination controls needed during I&T activities. This is used for motivating facility requirements as defined in Ref [8] and standard operating procedures to address maintenance of the clean room.

### 12.2.3 Electro-Static Discharge

The CCD sensors and support electronics are sensitive to damage from electro-static discharge (ESD). The Camera Electro-Static Discharge Control Plan (Ref [11]) was developed to address this mishap risk, by levying requirements on facilities and handling processes where ESD controls are needed. These have been addressed in the design of the facility as described in Ref [8]. ESD control is included in standard operating procedures for handling of ESD sensitive hardware.

### 12.2.4 Handling

Handling hazards and mishap risks abound during I&T activities. These are associated both with risk of damage to camera hardware and with risk of personnel injury. All handling hazards are addressed through the work planning and control processes described in Ref. [3]. In short, all work processes—including handling and moving processes—are planned ahead of time, reviewed and approved, then released for execution. Frequently occurring handling processes are subject to standard operating procedures (SOPs), while special handling operations are covered by specific work processes.

### 12.2.5 Hoisting and Rigging

Crane lift operations of camera hardware is a subset of the larger group of handling procedures. These involve use of a crane and possible below-the-hook lift fixtures and mounted equipment. Such operations are subject to the same work planning and control methodology as other handling operations, with the addition of other lift planning information as required by SLAC ES&H requirements as defined in Camera material handling protocols incorporating the requirements of Ref [13], Chapter 41, “Hoisting and Rigging.”

## 13 Summit Maintenance Facility

Three locations are available for camera maintenance on the summit. These are the clean room, an adjacent white room and the dome floor. The clean room is not large enough for the entire camera. Rather, the cryostat can be removed from the camera in the white room and taken into the clean room for any cryostat maintenance such as RAFT tower replacement. Camera body work can take place in the white room and full camera testing will need to be performed on the dome floor due to space constraints.

TBD

(Add a layout of summit and better define dome floor )

## 14 Camera Transport

LSST Camera I&T is responsible for the design and construction of the camera shipping container(s). Many details for shipping remain to be decided but it is expected that the camera will either be shipped as a single unit; or L1/L2 will be removed and shipped in a container it arrived in and the remainder of the camera shipped in a separate container.

In either case the shipping containers will be equipped with shock protection and telemetry monitors including accelerometers, temperature and humidity. Shipping containers will be “dual layered” to help maintain cleanliness and robustness.

TBD

Camera configuration during shipping

Plans and sequence required to properly box and ship the camera

Other equipment being shipped and general configuration

Planned modes of transportation (truck , train air, boat)

Shipping container: general requirements; lift and hold down points; shock protection

Instrumentation and recording