Large Synoptic Survey Telescope Camera System Plan	Document **LCA-10032-A**	Status LSST Camera APPROVED Effective Date: 26 Mar 2013
	Author(s) Martin Nordby Rick Van Berg	
	Subsystem/Office Systems Integration	
Document Title **LSST Camera Electro-Static Discharge Control Plan**		

1. Change History Log

Revision	Effective Date	Description of Changes
A	March 26, 2013	Baseline release. Reviewed under LCN-1023.

2. Contents

3. Acronyms and Definitions

3.1. Acronyms

ASIC	application-specific integrated circuit
CCD	charge-coupled device
EPA	ESD protected area
ESD	electro-static discharge
ESDS	electro-static discharge sensitive
FPGA	field-programmable gate array
GFCI	ground fault circuit interrupter
HBM	Human Body Model
LSST	Large Synoptic Survey Telescope
MOS	metal oxide semiconductor
PTG	point to electrical ground
RH	relative humidity
RTG	resistance to ground
TBD	To Be Determined
TBR	To Be Resolved

3.2. Definitions

ESD Protected Area (EPA): A designated environment provided with materials and equipment to limit electrostatic potentials

Human Body Model: The equivalent electric circuit, which simulates the discharge from a person delivered to the device; the model has a 100 pF capacitor that discharges through a 1.5 kΩ resistor and a switch into the device under test

4. Applicable Documents

[1] LCA-138, “LSST Camera Performance and Safety Assurance Plan”

[2] ANSI/ESD S20.20-2007, "ESD Association Standard for the Development of an Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment"

[3] ANSI/ESD STM 3.1, "Ionization"

[4] ANSI/ESD STM 97.1, "Floor Materials and Footwear—Resistance Measurements in Combination with a Person"

[5] ANSI/ESD S7.1, "Floor Materials—Characterization of Materials"

[6] ANSI/ESD S4.1, "Worksurfaces—Resistance Measurements"

[7] ANSI/ESD STM 4.2, "ESD Protective Worksurfaces—Charge Dissipation Characteristics"

[8] ANSI/ESD STM 12.1, "Seating"

[9] ANSI/ESD S1.1, "Wrist Straps"

[10] ANSI/ESD TR53, "Compliance Verification of ESD Protective Equipment and Materials"

[11] ANSI/ESD STM 2.1, "Garments"

[12] ANSI/ESD S541, "Packaging Materials for ESD Sensitive Items"

5. Purpose and Scope

This Plan documents the administrative and technical requirements of the electro-static discharge (ESD) Control Program used by the LSST Camera. This has been developed to support the assurance and process control plans established in Ref. [1] LCA-138, the "LSST Camera Performance and Safety Assurance Plan," and comply with the ESD control program requirements of Ref. [2] ANSI/ESD S20.20-2007, to ensure that the ESD sensitive items in the camera are fabricated, assembled, tested, handled, stored, and operated in a way that reduces the likelihood of damage or loss of function due to electrostatic discharge.

The requirements and programs in this plan apply to all manufacturing and test areas and operations where ESD sensitive items are handled, at all institutions working on Camera components. They apply for all ESD sensitive items susceptible to damage by electrostatic discharges greater than 100 volts Human Body Model (HBM), with the expectation that they adequately protect ESD sensitive devices down to 50 volts HBM.

6. Introduction

The LSST Camera design incorporates a number of electronic devices that are sensitive to damage from electro-static discharge (ESD). These include the charge-coupled devices (CCD's), the application-specific integrated circuits (ASIC's) in the front end electronics, and field-programmable gate arrays (FPGA's) both inside the cryostat and in support electronics. All can be damaged or destroyed by uncontrolled discharges during handling and testing.

In particular, the CCD is one of the most ESD-sensitive electronic components manufactured. Without ESD protection diodes, most scientific CCD's are susceptible to a discharge as small as 50 V. An ESD event can cause bus lines to melt, generate ESD craters, diode junction breakdowns, or insulator failure. Of these problems, dielectric damage is by far the most prevalent. (Scientific CCD's, Janesick).

Metal oxide semiconductor (MOS) devices are particularly susceptible to ESD damage because the energy stored in the gate-channel capacitance, when it has been brought up to breakdown voltage, is sufficient to blow a hole through the delicate dielectric gate oxide insulation. (The Art of Electronics, Horowitz and Hill)

7. Overview

This document defines the administrative and technical requirements that need to be met for all facilities handling ESD sensitive hardware. First, Section 8 specifies requirements for the identification and markingof ESD sensitive devices. Section 9 then details the requirements for the establishment of ESD-controlled areas, including detailed requirements on the equipment in the area, such as work surfaces, floor coverings, and equipment grounding. Section 10 addresses requirements for personnel who work in ESD-controlled areas, including both gowning requirements and standard procedures for handling devices. Personnel safety considerations are also addressed.

Sections 11 and 12 include ESD-control provisions that need to be included in work procedures. This first focuses on standard methods for safe handling, storage, and transport, then more general instructions for including ESD-control measures in assembly and test procedures that are developed for camera hardware production.

The final sections include requirements for managers of facilities where ESD sensitive devices are used. This includes requirements on an ESD training program for all personnel using the facility, and requirements and guidelines for establishing a compliance verification and auditing program to ensure that ESD controls are implemented and followed.

8. Identification of ESD Sensitive Items

ESD sensitive (ESDS) components and products must be known and clearly identified. Prior to the development of assembly or test processes, ESDS components must be identified by subsystem electrical leads and confirmed by the Camera Electrical Systems Engineer. This includes both parts as well as assemblies that include ESDS parts. As these parts enter higher levels of assembly, it can become difficult to identify that the assembly contains ESD sensitive parts, so it is essential that all levels of assembly be assessed from the lowest level up, so proper ESD control procedures and design elements can be included.

Once ESD sensitive items and assemblies are identified, they must be conspicuously labeled with ESD susceptibility symbols, either on the device or on the packaging or support housing holding the device. ESD sensitivity and control requirements must also be clearly marked on component and assembly drawings and procedures used in the handling and processing of the part and assembly.

Furthermore, test equipment and handling fixture designs need to include provision for controlling ESD. Thus, ESD control becomes a requirement for such fixtures and test equipment; this should be addressed at design and test reviews.

9. ESD Protected Areas

9.1. Areas

Areas where ESDS items are to be processed are defined as ESD protected areas (EPA's). EPA's shall be clearly identified and separated from the rest of the facility. Signs should be used to identify both the EPA and each workstation surface within the EPA, signifying that they are ESD-protected. EPA's should be clearly delineated by yellow floor tape, a partition, rope guard, or other means to fully describe the boundary of the EPA. Where the EPA adjoins high-use areas, partitions or physical barriers are strongly recommended.

Unprotected ESD sensitive devices shall only be handled in an EPA, by grounded, ESD certified personnel, using controlled processes and procedures in accordance with the requirements established in the following sections. ESDS items are to be opened or removed from protective containers only at an ESD protected workstation.

Where an EPA includes a laminar flow bench, hood, vacuum chamber, dark box, or other physical enclosure, care must be taken to clearly define the boundaries of the EPA relative to the enclosure. This is important to ensure that no ESDS device or tool is exposed to potentially ungrounded enclosures or ancillary hardware.

9.1.1. Personnel Access

Access to EPA's shall be limited to trained, equipped, and authorized personnel. Visitors to the EPA as well as untrained personnel must be escorted by ESD certified personnel. Personnel should never enter an ESD protected area without taking the proper precautions as defined in this Plan, and in no instance shall untrained visitors or personnel handle unprotected ESDS devices.

All personnel entering an EPA and working at an ESD protected workstation must be grounded appropriately. See Section 10 for details on personnel gowning and grounding. Personnel grounding devices shall be supplied to all personnel working with or handling ESDS items to prevent the accumulation of dangerous electrostatic charge levels. A grounding device shall be worn by all personnel coming within 1 meter (3.3 feet) of any unprotected ESDS items.

9.1.2. Air Ionizers

Necessary non-conductors in the environment cannot lose their electrostatic charge by attachment to ground. Ionization systems provide neutralization of charges on these necessary non-conductive items (circuit board materials and some device packages are examples of necessary non-conductors). Ionization systems should be used for dissipating charge in insulators. An air blower ionizer must be installed in a laminar flow bench, if used.

Ionizers shall have less than +/- 50 Volts offset voltage, qualified per Ref. [3], ANSI/ESD STM 3.1.

9.1.3. Conductors in an EPA

All conductors, including personnel, must be grounded in an ESD protected area. All tools and mechanical components (fixtures, gauges, support devices) that come in contact with the ESDS must be separately grounded.

Test equipment, power supplies, and ancillary test hardware (e.g.: vacuum pumps, ion gauges) that support testing of ESDS hardware should be physically located within the boundaries of the EPA and must be grounded to the same facility ground as the ESD protected work surface (see Section 9.4 on equipment and facilities grounding).

Essential materials and equipment under normal use shall not cause or generate static electrostatic fields of greater than +/- 2,000 volts/inch within 12 inches of unprotected ESDS devices. Nonessential and personal items shall not be placed on ESD protective work surfaces.

9.1.4. Insulators in an EPA

As insulators cannot be grounded, non-essential insulators should be removed from ESD protected areas and essential insulators have charges neutralized by before being used for work around ESDS items, and repeatedly during long periods of use.

Non-essential insulators (insulative items not required in the manufacturing process), including packaging materials, plastic clipboards, and personal items shall be removed from all ESD protected workstations. Process-required insulators are permitted at an ESD protective workstation as long as the measured electrostatic field does not exceed 2,000 volts/inch. If the measured field exceeds 2,000 volts/inch the process required insulator must be moved a minimum of 12 inches from the ESD sensitive device.

9.2. ESD Flooring

ESD protective flooring or floor mats shall be used in all EPA's. The resistance to ground (RTG) of the flooring—footwear system shall be less than 3.5×10^7 ohms. This is tested per Ref. [3], ANSI/ESD STM 97.1.

Candidate ESD-protective flooring (including floor mats, coverings, and finishes) must be qualified to ensure that its RTG meets these requirements. The qualification method should be based on Ref. [5], ANSI/ESD S7.1. For floor tiling, test tiles should include at least 10% of all floor tiles, with 5 readings on each tile. For protective floor coverings, conductive paint, and floor mats, test points should be uniformly distributed across the surface area. All samples are point to electrical ground referenced.

ESD flooring should be regularly cleaned and only with ESD cleaners that do not leave an insulative residue.

9.3. Work Surfaces

All work surfaces in an ESD-protected area shall be static dissipative and electrically connected to the common point ground. ESD protected work surfaces shall have a maximum RTG of 1.0×10^9 ohms, qualified according to Ref. [6] or [7], ANSI/ESD S4.1 or STM 4.2. If safety codes and/or other authorities require inclusion of a series resistor in the ground circuit, it is permitted.

The protective work surface shall be sufficiently large to encourage the resting of common hand tools on the protective surface rather than on an adjacent non-protected surface. ESD protected work surfaces should be clean and clear of unnecessary materials, particularly common plastics or any other electrostatic generating material.

The protective work surface shall not release particle contaminants and shall resist attack by common solvents or cleaners. Solvent resistance shall be determined during initial verification by exposing test specimens to 1-hour exposure to each of the solvents that can be expected to be used at the work station.

Any surfaces in an EPA that are not appropriately grounded shall be marked to indicate that they are not suitable for holding unprotected ESDS. These may include roll-around tool or equipment carts or temporary shelves.

9.4. Furniture

All furniture in an ESD-protected area shall be static dissipative and electrically connected to the common point ground, with a maximum RTG of 1.0×10^9 ohms, qualified per Ref. [8], ANSI/ESD STM 12.1 (for seating), and Ref. [6], ANSI/ESD S4.1 (for shelving and mobile work surfaces). Grounding can be accomplished either through dedicated grounding cables or static dissipative contact with the flooring or mats. This includes all furniture used by personnel in an EPA or for storing or processing unprotected ESDS devices in the EPA.

Furniture required to be static dissipative includes: stools, chairs, benches, permanent storage shelves, permanent storage cabinets, work benches and surfaces.

All furniture in and EPA should be stand-alone. Wall-mounted shelves and cabinets are not acceptable since they may be grounded through their mounting points to a non-local auxiliary ground at a different potential.

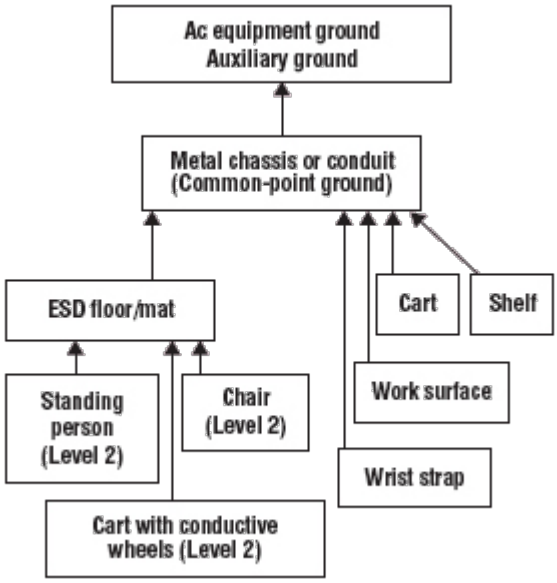

Figure 1: Grounding schematic for a generic ESD protected area

9.5. Equipment and Facilities Grounding

The preferred grounding practice in an EPA is to use the third wire AC line ground for grounding all items at the ESD-protected work station. See Figure 1 for a schematic. When a separate grounding line is present or used in addition to the equipment ground, it should be bonded to the equipment ground at each ESD-protected work station to minimize the difference in potential. The resistance of the conductor from this common point ground to the equipment ground (AC ground) should not be greater than 1.0 ohm.

All wrist strap connection points, test and support equipment, and work surfaces shall be connected to the work station common point ground. The connection point resistance to common point ground should not be greater than 1 ohm for every grounded item.

Ground points shall be tested before use or at a minimum daily for equipment being used continuously, to ensure that they are still connected to ground.

9.6. Humidification

The relative humidity (RH) should be maintained at 30% or higher in ESD-protected work areas. At levels below 30%, additional precautions shall be employed (e.g., air ionizers, humidifiers) while working on ESD sensitive hardware. If other precautionary methods are not available, work shall be halted until the required humidity level is obtained. Work on or around ESD sensitive hardware must cease if the RH drops to 25% or lower.

10. Personnel Grounding

10.1. Wrist Straps

Personnel shall wear grounding wrist straps snugly on skin, plugged into the common point ground of an EPA. The continuous electrical path from the user, through the wrist strap, directly to ground shall have a maximum resistance of 3.5×10^7 ohms. The wrist strap must be worn such that there is 360 degrees of contact with the user's skin. The wrist cord must be plugged into the common point ground plug that is located at every ESD protected work station.

Wrist straps shall be tested for proper function and logged at a wrist strap tester whenever used. Wrist strap systems must be qualified per Ref. [9], ANSI/ESD S1.1, Section 5.11 and verification testing must be compliant with Ref. [10], ESD TR53. Straps that fail their test must be removed from service and separated from the rest of the straps until they have been repaired and pass a re-test.

10.2. Footwear

ESD protective footwear is required, in addition to wrist straps. Protective footwear may use heel straps, toe straps, or conductive shoes. It must provide a continuous electrical path from the user, through the footwear and ESD protective flooring or mat directly to ground of less than 3.5×10^7 ohms.

Footwear shall be tested for proper function at start of use. Footwear systems must be qualified per Ref. [4], ANSI/ESD STM 97.1, and verification testing must be compliant with Ref [10], ESD TR53.

10.3. Garments and Gloves

Personnel shall wear static dissipative garments. ESD protective garments shall have a maximum RTG of less than 1 x 10^{11} ohms, qualified per Ref. [6], ANSI/ESD STM 2.1. ESD protective garments are used to shield ESDS from charges built up on insulative clothing. When worn, they should cover all personal garments above the wrist except at the neck area, and make intimate contact with the skin. Otherwise, the ESD garment becomes an isolated ungrounded conductor.

Personnel shall wear static dissipative gloves with a maximum RTG of less than 1 x 10^{11} ohms, qualified per Ref. [11], ANSI/ESD STM 2.1 . When in a clean room, they must also be clean room compatible. Nitrile or Polyurethane gloves are recommended. Note, rubber finger cots are not allowed, since they can build up electrostatic charge and introduce it into the ESDS if the rubber comes in contact with it.

10.4. Personnel Safety Considerations

The grounding of personnel around electrical line voltage is a possible hazard. Personal grounding should not be used when working around voltages over 250 VAC. Although personal grounding items may include a 1 Mega-ohm resistor to limit current to less than 0.5 mA, ground fault circuit interrupters (GFCI) should be used.

11. Handling, Storage, and Transport

ESD susceptible items handled, transported or stored outside an ESD protected area must be suitably protected, packaged, and marked.

11.1. Protection

ESDS devices should use shorting plugs to protect against possible charge build up during handling or transport. For the camera, only the CCD sensors require the use of shorting plugs, since assembled boards are only sensitive to ESD damage at unprotected component leads and not through external connector pins.

If the ESDS device is supported or mounted in a fixture or container, the fixture should be metallic. The fixture/container must have its own grounding point, to allow independent connection to a central ground point as it is being loaded or unloaded.

11.2. Packaging

ESDS devices shall be enclosed within ESD shielding bags or other sealed conductive container during storage or transportation outside an EPA.

Only new metallized shielding bags or other sealed container, qualified per Ref. [12], ANSI/ESD S541, shall be used to transport ESD sensitive devices from one EPA to another. ESD sensitive devices must be completely enclosed by the shielding bag, and removed from the packaging only at an ESD protected work surface by grounded employees.

Bags/material should be inspected for damage, tears, or scratches prior to use. Discard any damaged or torn bags.

11.3. Marking

To ensure that downstream users are aware that a device is ESD sensitive, the following labeling should be used to seal the metalized shielding bag that is used to store and ship all products.

ATTENTION
CONTENTS STATIC SENSITIVE
OBSERVE PRECAUTIONS FOR HANDLING ELECTROSTATIC DISCHARGE SENSITIVE DEVICES

Note that only ESD sensitive parts and assemblies should be so labeled. Simply marking everything as ESD sensitive, to play it safe or foster supposedly better handling practices is usually counterproductive.

12. Work Procedure Requirements

Work procedures for ESD sensitive parts and assemblies must clearly define ESD protections needed and safe handling and processes. Work procedures (a.k.a.: work processes, procedures, work instructions, travelers) should include the following:

Caution notices: visible cautions to focus attention on work process steps involving contact with ESD sensitive parts

Ground test steps: identify specific steps for checking potential to ground of personnel, equipment, or ESD sensitive devices

Safe handling instructions: process steps to ensure safe handling and packaging of ESD sensitive devices and assemblies, including instructions for unpacking

Test process steps: test procedures should include details to ensure that the test is set up and recovered from in a way that protects ESD sensitive parts. Topics to include are grounding and use of external power supplies, required ESD protections for other test electronics, and safe-to-mate procedures to use prior to connecting to ESD sensitive components (especially CCD's)

13. Personnel Training

ESD control and ESD protected area training must be conducted for all personnel involved in the fabrication, assembly, integration, and testing of any ESDS device or any assembly containing an ESDS device. Training and training logs must be handled by the manager of the facility containing the ESDS device and ESD protected areas. Topics that must be covered include:

Definition of ESD and how it affects the LSST camera, subsystem, and particular sub-assemblies and devices at their location

The importance of maintaining ESD control at all phases of work (fabrication, assembly, and testing) and all levels of assembly (part, component, sub-assembly, assembly)

Reviewing ESD sensitivities for all hardware in the facility

Knowledge of the camera and ESD control plans and related documents

Specific techniques and procedures for ESD control within the facility

Monitoring techniques in the clean room and in storage, handling, and shipping containers and fixtures

Personnel gowning procedures and rules for working in an ESD-controlled area:

Training must include an evaluation process for all personnel, such as a test, evaluation exercise, or walk-through of ESD control processes. A training log must be kept to record who was trained, when it was completed, and when the interval expires and refresher training is required.

14. Compliance Verification and Audit

Facilities containing ESD protected areas must develop procedures to verify that all ESD controls are in place and functioning, and a method to audit the processes being used over the course of work with ESDS devices. ESD control verification procedures should include the following:

Personnel training program: training materials, log, interval; should also include a means for identification of personnel who have been trained

Review of standard operating procedures: review of all procedures used in EPA's.

Testing program for ESD protected areas: includes test frequency and pass/fail criteria to check grounding of floor materials, work surfaces, tools, and equipment; include ionizers

List of approved ESD protective products: items and approvals for products and items commonly used in EPA's. This may include manufacturers of clean room garments, wrist straps, protective mats and surfaces, and other materials.