Large Synoptic Survey Telescope Specification	Document # **LCA-68-D** Author(s) John Ku Martin Nordby	Status LSST Camera APPROVED Effective Date: 18 July 2015
	Subsystem/Office Systems Integration	

Document Title

LSST Camera Loads Specification

1. Change History Log

Revision	Effective Date	Description of Change
B	24 Oct 2011	Finalized for CD-1 Review
C	8 Feb 2013	Title WAS "LSST Camera Environmental Specification" IS "LSST Camera Loads Specification" Updated all seismic loads in Section 12 to reflect changes to higher-level requirements described in Ref [2]; this was captured in, and approved by, Redline LCN-1033 Removed section describing factors of safety; this has been moved to LCA-280, "Camera Mechanical Standards" document
D	18 July 2015	Rev D started since Rev C draft was posted for PDRs, FDRs, and CD-2 Review. Off-telescope seismic vertical accelerations were 1.5/0.6 g, are 1.6/0.5 g per 2014 revision of SLAC Seismic Criteria (see LCA-69 for analysis) Baseline release with LCN-1371.

2. Contents

3. Scope

This document serves as an addendum to Ref [1], LCA-48, the "LSST Camera Specification." It is a compilation of all acceleration load cases to be used for the design of the LSST Camera and its subsystems. This includes load cases to be used for subsystem components and should be referenced by subsystem specifications. Ref [1] takes precedence if any conflicts arise, but this document governs and takes precedence over all Camera subsystem specifications.

Load cases have been gleaned from a number of sources, and the analysis and reduction of these cases is detailed in Ref [2], LCA-69, "LSST Camera Environmental Specification Supporting Analysis". See this reference for additional information, commentary, and notes on applying the cases in analysis.

4. Applicable Documents

The following documents are applicable to the use of this specification

[1] LCA-48, "LSST Camera Specification"
[2] LCA-69, "LSST Camera Environmental Specification Supporting Analysis"
[3] LCA-280, "LSST Camera Mechanical Standards"
[4] LCA-10031, "Mechanical Standards: Factors of Safety"

5. Acronyms

CCS	Camera Coordinate System
DOF	Degrees of Freedom
g	acceleration due to gravity
Hz	Hertz (cycles/sec)
LSST	Large Synoptic Survey Telescope
TBD	To Be Determined
TBR	To Be Resolved

6. Overview

The Camera and its constituent components are subject to five classes of inertial accelerations: static, dynamic re-pointing, integration and handling, transportation, and seismic. For each class of loads, the camera and its components must be able to survive the resultant stresses and deflections, while for the operational load cases, they must also fully function or perform to specification. The following sub-sections describe the five classes of loads and the requirements placed on the camera when subject to those accelerations.

These load classes are defined as mutually-exclusive load sets. Furthermore, a number of load cases are defined for each class of loading. These, also, are mutually exclusive. Thus, load cases should not be added together or in any way combined, but a component should be analyzed for each load case individually.

Note that gravity is already included for each load class and that all load orientations are in the Camera Coordinate System (CCS), as defined in Ref. [3], LCA-280, "Camera Mechanical Standards," unless specifically defined otherwise.

7. Load Cases for Compact Components

The design load limit for compact camera sub-assemblies and components with natural frequencies above 40 Hz is 5 g acceleration in any orientation. The component must be able to fully function and

meet all performance requirements when exposed to this acceleration, when powered on or off over its entire working temperature range. This is in lieu of all other loading requirements, and is intended to bound the worst-case accelerations of the many load cases described below.

8. Operational Load Cases

The camera and its constituent components must meet all performance requirements when exposed to the static pointing load cases listed in Table 1. The Filter Exchange system must also be able to support a filter while exposed to any combination of loads listed in the table, with a filter either in the on-line position or stored in the Carousel. However, the system need only operate while subject to the final four load cases.

Operational Load Cases															
	Camera and Subsystems											Auto Changer, Carousel			Filter Loader
Load Case	Op-1	Op-2	Op-3	Op-4	Op-5	Op-6	Op-7	Op-8	Op-9	Op-10	Op-11	Op-12	Op-13	Op-14	Op-15
X	+1.00	+1.00	+1.00	+1.00	+0.00	+0.00	+0.00	-1.00	-1.00	-1.00	-1.00	+0.00	+0.00	+0.00	+0.00
Y	+0.00	+0.00	-1.00	-1.00	+0.00	-1.00	-1.00	+0.00	+0.00	-1.00	-1.00	+0.00	-1.00	-1.00	-1.00
Z	+0.00	-1.00	+0.00	-1.00	-1.00	+0.00	-1.00	+0.00	-1.00	+0.00	-1.00	-1.00	+0.00	-1.00	+0.00

Values are in g's, where 1 g = 9.81 m/sec^2 Orientations are with respect to the Camera Coordinate Systems (CCS)

Table 1: Camera and component operational load cases

9. Re-Pointing Load Cases

The camera and all its subsystem components shall be able to fully function, but not necessarily meet all performance requirements when subjected to the re-pointing load cases listed in Table 2. This encompasses the worst-case load envelope due to changes in both the gravity vector and accelerations due to angular velocities and accelerations of the telescope during re-points. The Filter Exchange system mechanisms shall also be capable of fully functioning over the full range of motion while subject to these loads, but only while in an X-axis horizontal orientation, as the load cases define.

Re-Pointing Load Cases														
	Camera and Subsystems											Exchange System		
Load Case	Repoint-1	Repoint-2	Repoint-3	Repoint-4	Repoint-5	Repoint-6	Repoint-7	Repoint-8	Repoint-9	Repoint-10	Repoint-11	Repoint-12	Repoint-13	Repoint-14
X	+1.10	+1.00	+1.10	+1.10	+0.00	+0.00	+0.00	-1.10	-1.10	-1.10	-1.10	+0.10	+0.10	-0.10
Y	+0.00	+0.00	-1.10	-1.10	+0.00	-1.10	-1.10	+0.00	+0.00	-1.10	-1.10	+0.10	-1.10	-1.10
Z	+0.00	-1.10	+0.00	-1.10	-1.10	+0.00	-1.10	+0.00	-1.10	+0.00	-1.10	-1.10	+0.10	-0.10

Values are in g's, where 1 g = 9.81 m/sec^2 Orientations are with respect to the Camera Coordinate Systems (CCS)

Table 2: Camera and component re-pointing load cases

10. Integration and Handling Load Cases

Camera components, sub-assemblies, and the integrated cryostat and camera shall be capable of surviving crane lift and handling loads listed in Table 3, when supported from their normal mount points and from any auxiliary handling or support points or in alternate orientations. For all components in the cryostat and the full cryostat assembly, all systems must be capable of surviving the handling loads while the cryostat is evacuated and cold, as well as at room temperature.

Lifting and handling fixtures and storage and transport containers shall be designed to safely support all camera hardware when subject to the loads listed in Table 3.

Integration and Handling Load Cases				
Load Case	Handling-1	Handling-2	Handling-3	Handling-4
Transverse	+0.00	+0.00	+0.25	-0.25
Gravity Direction	-1.25	-1.25	-1.25	-1.25
Direction of Motion	+0.25	-0.25	+0.00	+0.00

Values are in g's, where 1 g = 9.81 m/sec^2 Orientations are with respect to the Camera Coordinate Systems (CCS)

Table 3: Camera and component integration and handling load cases

Subsystems must also identify any additional loading other than these inertial loads that may be applied to their hardware during assembly, test, and integration. These include forces and moments due to bolt torquing, forces applied as part of the assembly process, and any temporary forces.

Orientations: note that during integration and handling, subsystem components and assemblies may be oriented in alternate orientations and be exposed to other gravity and inertial accelerations. Subsystems are responsible to identify and analyze any such handling orientations that may define a maximum loading for a component.

Support configurations: note that during integration and handling, both the camera assembly and subsystem components may be supported in configurations with load paths that are not standard for normal camera operations. Subsystems and I&T groups are responsible to identify all such configurations and analyze hardware responses to the load cases defined in the above table for each applicable support configuration.

Partial states of integration: note that during camera and component integration, assemblies may be subject to the load cases in Table 3, but in partial states of assembly, or while mounted to assembly fixtures. Subsystem and I&T groups are responsible to identify all such states of partial assembly and analyze the response of both camera hardware and fixtures to the load cases listed.

11. Transportation Load Cases

Camera components and assemblies shall be designed to survive transportation loads listed in Table 4, or be shipped in special containers and/or transported on "Air-Ride" trucks that include an isolation system. See Ref [2] for alternative load cases for shock-isolated transport load cases.

Containers and support stands with shock isolation systems shall be capable of surviving the shipping loads listed in Table 4, while meeting its load- and shock-transmitting requirements for the hardware being shipped.

Transportation Load Cases								
Load Case	Transport-1	Transport-2	Transport-3	Transport-4	Transport-5	Transport-6	Transport-7	Transport-8
Conventional Transport								
Transverse	+0.00	+0.00	+0.61	-0.61	+0.00	+0.00	+0.61	-0.61
Gravity Direction	-4.12	-4.12	-4.12	-4.12	+2.12	+2.12	+2.12	+2.12
Direction of Travel	+2.22	-2.22	+0.00	+0.00	+2.22	-2.22	+0.00	+0.00
Air-Ride Truck Transport Option								
Transverse	+0.00	+0.00	+0.61	-0.61	+0.00	+0.00	+0.61	-0.61
Gravity Direction	-2.00	-2.00	-2.00	-2.00	+0.10	+0.10	+0.10	+0.10
Direction of Travel	+2.22	-2.22	+0.00	+0.00	+2.22	-2.22	+0.00	+0.00

Values are in g's, where 1 g = 9.81 m/sec^2 Orientations are with respect to the Camera Coordinate Systems (CCS)

Table 4: Camera and component transportation load cases

12. Seismic Accelerations and Load Cases

The Camera and all subsystem components that form part of the on-telescope camera assembly shall be designed to withstand the "Operable" seismic load cases described in Table 5 with no yielding, structural failure or other damage or loss of function. Loads are to be analyzed individually and not combined. Analysis of these load cases should use the operational-seismic factors of safety described in Ref. [3], LCA-280, "Mechanical Standards," and Ref. [4], LCA-10031, "Factors of Safety."

All components internal to the on-telescope camera structural envelope shall be designed to survive the "Recoverable" load cases described in Table 5 with no ultimate or structural failure, damage to optical elements or detector plane integrity, or damage requiring a full subsystem re-build. Loads are to be analyzed individually and not combined. Analysis of these load cases should use the survival-seismic factors of safety described in Ref. [3], LCA-280, "Mechanical Standards," and Ref. [4], LCA-10031, "Factors of Safety."

All components that form part of the structural envelope of the on-telescope camera shall be designed to survive the "Survival" load cases described in Table 5 with no ultimate failure, rupture, fracture, or

separation of components from the integrated camera. Loads are to be analyzed individually and not combined. Analysis of these load cases should use the survival-seismic factors of safety described in Ref. [3], LCA-280, "Mechanical Standards," and Ref. [4], LCA-10031, "Factors of Safety."

During all stages of integration and test and in all standard off-telescope orientations, the Camera, its sub-assembly components, and all loaded integration and test fixtures shall be designed to withstand the "Off-Telescope" seismic load cases described in Table 5 with no yielding or other damage. Loads are to be applied in the combinations listed, for all expected orientations of the component. Analysis of these load cases should use the operational-seismic factors of safety described in Ref. [3], LCA-280, "Mechanical Standards," and Ref. [4], LCA-10031, "Factors of Safety."

All off-telescope camera support hardware, including electronics racks, camera cable runs, and refrigeration system and utilities installations, shall be designed to withstand the "Off-Telescope" seismic load cases described in Table 5 with no yielding or other damage. Loads are to be applied in the combinations listed. Analysis of these load cases should use the operational-seismic factors of safety described in Ref. [3], LCA-280, "Mechanical Standards," and Ref. [4], LCA-10031, "Factors of Safety."

These requirements are explicitly waived for four transient or temporary configurations:

- Filter exchange system hardware does not need to be safe against seismic loads during operation.
- Camera components may be in a configuration not safe to seismic loading for at most 1 hour during routine maintenance of the Camera.
- Camera components may be in a configuration not safe to seismic loading for at most 6 hours during integration or standard yearly servicing operations of the Camera.
- Planned maintenance activities of the Camera that put it in a seismically unsafe configuration for more than 6 hours must be reviewed and approved.

Table 5: Camera and component seismic load cases

Load Case	On-Telescope				Off-Telescope	
	Operable	Recoverable	Survival		Seismic-1	Seismic-2
Transverse	+2.42	+3.70	+5.70	**Transverse**	+0.85	+0.85
+Z-direction	+0.61	+1.17	+2.04	**Vertical**	+1.60	+0.50
-Z-direction	-1.44	-1.83	-2.45			
Referenced to Camera Coordinate System (CCS)				Referenced to gravity and mounting orientation		

Values are in g's, where 1 g = 9.81 m/sec^2