Large Synoptic Survey Telescope	*Document #* **LCA-10031-A** *Author(s)* Martin Nordby John Ku *Subsystem/Office* Systems Integration	*Status* LSST Project APPROVED Effective Date 26-Mar-13

Document Title

LSST Camera Mechanical Standards: Factors of Safety

Purpose

This serves as an addendum to LCA-280, "LSST Camera Mechanical Standards." It provides a means to calculated factors of safety to be used in the analysis and testing of camera hardware, factoring in the material used, the criticality of the application, and the load case the component is subject to.

Definitions

Applicable Documents

LCA-280	LSST Camera Mechanical Standards
LCA-138	LSST Camera Performance and Safety Assurance Plan

Change Log

	Revision A
26-Mar-13	Baseline release. Reviewed under LCN-1023.
11-Oct-12	>Cleaned up and finished tweaking; sent for final review and approval
20-Sep-12	>Started separate tables on different tabs, one for each load case; tweaked base-mounted seismic multipliers to match operational seismic (reduces number of unique load cases)
18-Sep-12	>Fixed error in 'Pressurized component, no test' factor. Resulting factor of safety was 1.4, now corrected to 3.0 for ductile metals, per SLAC code compliance >Re-organized materials and use/application tables to be in order of ascending criticality, so resulting factor of safety tables are better organized
17-Sep-12	>Changed buckling test factor from 1.20 to 1.25;
1-Aug-12	>Created this as a configuration-controlled document

2. Factor of Safety Calculator

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Select Mat'l, Use, and Load Case	Yld	Ult	Test	
1-Ductile: proof test	1.25	1.40	1.20	Material/Configuration (Pick only 1)
D-Pressurized component w/ test[A]	1.60	1.71	0.92	Use/Application (Pick only 1)
a-Normal operations: as-installed	1.00	1.00	1.00	Load Case/Configuration (All that apply)
Factors of Safety:	**2.00**	**2.40**	**1.10**	Use these factors for analysis and testing

Multipliers that are used for calculating factors of safety, above					Ref
Material/Configuration (Pick only 1)				Includes brittleness, spread of properties, qual process	
1-Ductile: proof test	1.25	1.40	1.20	Metals; tested to proof levels to qual design	[6]
2-Composites: uniform		1.50	1.20	Region w/no geometric or manufac discontinuities	[6]
3-Bonds to glass		2.00	1.20	Bonds qualified by test	[6]
4-Composites: discontinuous		2.00	1.20	Region of a composite with geometric discontinuiti	[6]
5-Bonds to other materials		2.00	1.50	Bonds qualified by test	[6]
6-Ductile: qual by analysis	2.00	3.00	na	Metals; final config not tested to proof levels	
7-Brittle materials		3.00	1.20	Materials with little capacity for plastic flow	
8-Glass		5.00	2.00	Under pressure or not	[6]
9-Bolted joint		2.00	na	Joint gapping or slipping	
10-Buckling		3.00	1.25	Column or panel buckling	
11-					
Use/Application (Pick only 1)				Component criticality level	
A-Low criticality comp	1.00	1.00	1.00	Multiply-redundant item	
B-Med criticality comp	1.10	1.10	1.10	Secondary struc element, redundant item	
C-High criticality comp	1.20	1.20	1.20	Single-failure point, primary struc element	
D-Pressurized component w/ test[A]	1.60	1.71	0.92	Component forming part of pressure envelope	[4, 6, 10]
E-Lifting device w/ test	1.60	1.71	1.04	Below-the-hook lifting fixture	[7, 8, 9]
F-Fixture, transport container	1.60	1.71	1.04	Floor-mounted, transport fixtures, containers	
G-Pressurized component no test	2.00	2.14	na		[4, 6, 10]
H-					
Load Case/Configuration (All that apply)					
a-Normal operations: as-installed	1.00	1.00	1.00	Gravity + operational loads + pressure	
b-Fixture operations: alt mounting	1.00	1.00	1.00	Alt gravity + operational loads + pressure	
c-Operational seismic: tel-mounted	0.80	0.80		Ops seismic + operational loads + pressure	
d-Survival seismic: tel-mounted		0.71		Surv seismic + operational loads + pressure	
e-Base-mounted seismic	0.80	0.80		SLAC/Summit seismic + oper loads + pressure	
f-Lifting/handling	1.00	1.00		Handling + any other applicable loads	
g-Transportation	1.00	1.00		Transport + any other applicable loads	
h-					

[A]: Applies for pneumatic testing; see references for hydraulic testing specifics

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3. FoS Table: Normal Operations

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Use with These Load Cases

Normal operations load cases, as-installed or in alternate configurations;
Lifting, handling, and transport load cases

		Use / Application								
	Material/ Config Multiplier	A-Low criticality comp	B-Med criticality comp	C-High criticality comp	D-Pressurized component w/ test[A]	E-Lifting device w/ test	F-Fixture, transport container	G-Pressurized component no test	H-	
Factors of Safety: Yield	Mult.	1.00	1.10	1.20	1.60	1.60	1.60	2.00		<<< Use/Application Mult
1-Ductile: proof test	1.25	1.25	1.38	1.50	2.00	2.00	2.00	2.50		Load Case Mult(Yield): 1.00
2-Composites: uniform	0.00									
3-Bonds to glass	0.00									
4-Composites: discontinuous	0.00									
5-Bonds to other materials	0.00									
6-Ductile: qual by analysis	2.00	2.00	2.20	2.40	3.20	3.20	3.20	4.00		
7-Brittle materials	0.00									
8-Glass	0.00									
9-Bolted joint	0.00									
10-Buckling	0.00									
11-										

Factors of Safety: Ultimate	Mult.	1.00	1.10	1.20	1.71	1.71	1.71	2.14		<<< Use/Application Mult
1-Ductile: proof test	1.40	1.40	1.54	1.68	2.40	2.40	2.40	3.00		Load Case Mult (Ult): 1.00
2-Composites: uniform	1.50	1.50	1.65	1.80	2.57	2.57	2.57	3.21		
3-Bonds to glass	2.00	2.00	2.20	2.40	3.43	3.43	3.43	4.28		
4-Composites: discontinuous	2.00	2.00	2.20	2.40	3.43	3.43	3.43	4.28		
5-Bonds to other materials	2.00	2.00	2.20	2.40	3.43	3.43	3.43	4.28		
6-Ductile: qual by analysis	3.00	3.00	3.30	3.60	5.14	5.14	5.14	6.42		
7-Brittle materials	3.00	3.00	3.30	3.60	5.14	5.14	5.14	6.42		
8-Glass	5.00	5.00	5.50	6.00	8.57	8.57	8.57	10.70		
9-Bolted joint	2.00	2.00	2.20	2.40	3.43	3.43	3.43	4.28		
10-Buckling	3.00	3.00	3.30	3.60	5.14	5.14	5.14	6.42		
11-										

Factors of Safety: Test	Mult.	1.00	1.10	1.20	0.92	1.04	1.04	na		<<< Use/Application Mult
1-Ductile: proof test	1.20	1.20	1.32	1.44	1.10	1.25	1.25			Load Case Mult (Test): 1.00
2-Composites: uniform	1.20	1.20	1.32	1.44	1.10	1.25	1.25			
3-Bonds to glass	1.20	1.20	1.32	1.44	1.10	1.25	1.25			
4-Composites: discontinuous	1.20	1.20	1.32	1.44	1.10	1.25	1.25			
5-Bonds to other materials	1.50	1.50	1.65	1.80	1.38	1.56	1.56			
6-Ductile: qual by analysis	na									
7-Brittle materials	1.20	1.20	1.32	1.44	1.10	1.25	1.25			
8-Glass	2.00	2.00	2.20	2.40	1.84	2.08	2.08			
9-Bolted joint	na									
10-Buckling	1.25	1.25	1.38	1.50	1.15	1.30	1.30			

Use with These Load Cases Normal operations load cases, as-installed or in alternate configurations; Lifting, handling, and transport load cases	Material/ Config Multiplier	A-Low criticality comp	B-Med criticality comp	C-High criticality comp	D-Pressurized component w/ test[A]	E-Lifting device w/ test	F-Fixture, transport container	G-Pressurized component no test	H-
11-									

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4. FoS Table: Operational Seismic

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Use with These Load Cases

Operational seismic load cases, on telescope;
Base-mounted seismic for equipment at SLAC or on the summit

		Use / Application								
	Material/ Config Multiplier	A-Low criticality comp	B-Med criticality comp	C-High criticality comp	D-Pressurized component w/ test[A]	E-Lifting device w/ test	F-Fixture, transport container	G-Pressurized component no test	H-	
Factors of Safety: Yield	Mult.	1.00	1.10	1.20	1.60	1.60	1.60	2.00		<<< Use/Application Mult
1-Ductile: proof test	1.25	1.00	1.10	1.20	1.60	1.60	1.60	2.00		Load Case Mult(Yield): 0.80
2-Composites: uniform	0.00									
3-Bonds to glass	0.00									
4-Composites: discontinuous	0.00									
5-Bonds to other materials	0.00									
6-Ductile: qual by analysis	2.00	1.60	1.76	1.92	2.56	2.56	2.56	3.20		
7-Brittle materials	0.00									
8-Glass	0.00									
9-Bolted joint	0.00									
10-Buckling	0.00									
11-										

Factors of Safety: Ultimate	Mult.	1.00	1.10	1.20	1.71	1.71	1.71	2.14		<<< Use/Application Mult
1-Ductile: proof test	1.40	1.12	1.23	1.34	1.92	1.92	1.92	2.40		Load Case Mult (Ult): 0.80
2-Composites: uniform	1.50	1.20	1.32	1.44	2.06	2.06	2.06	2.57		
3-Bonds to glass	2.00	1.60	1.76	1.92	2.74	2.74	2.74	3.42		
4-Composites: discontinuous	2.00	1.60	1.76	1.92	2.74	2.74	2.74	3.42		
5-Bonds to other materials	2.00	1.60	1.76	1.92	2.74	2.74	2.74	3.42		
6-Ductile: qual by analysis	3.00	2.40	2.64	2.88	4.11	4.11	4.11	5.14		
7-Brittle materials	3.00	2.40	2.64	2.88	4.11	4.11	4.11	5.14		
8-Glass	5.00	4.00	4.40	4.80	6.86	6.86	6.86	8.56		
9-Bolted joint	2.00	1.60	1.76	1.92	2.74	2.74	2.74	3.42		
10-Buckling	3.00	2.40	2.64	2.88	4.11	4.11	4.11	5.14		
11-										

Factors of Safety: Test	Mult.	1.00	1.10	1.20	0.92	1.04	1.04	na		<<< Use/Application Mult
1-Ductile: proof test	1.20	0.00	0.00	0.00	0.00	0.00	0.00			Load Case Mult (Test): 0.00
2-Composites: uniform	1.20	0.00	0.00	0.00	0.00	0.00	0.00			
3-Bonds to glass	1.20	0.00	0.00	0.00	0.00	0.00	0.00			
4-Composites: discontinuous	1.20	0.00	0.00	0.00	0.00	0.00	0.00			
5-Bonds to other materials	1.50	0.00	0.00	0.00	0.00	0.00	0.00			
6-Ductile: qual by analysis	na									
7-Brittle materials	1.20	0.00	0.00	0.00	0.00	0.00	0.00			
8-Glass	2.00	0.00	0.00	0.00	0.00	0.00	0.00			
9-Bolted joint	na									

Use with These Load Cases Operational seismic load cases, on telescope; Base-mounted seismic for equipment at SLAC or on the summit	Material/ Config Multiplier	A-Low criticality comp	B-Med criticality comp	C-High criticality comp	D-Pressurized component w/ test[A]	E-Lifting device w/ test	F-Fixture, transport container	G-Pressurized component no test	H-
10-Buckling	1.25	0.00	0.00	0.00	0.00	0.00	0.00		
11-									

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5. FoS Table: Survival Seismic

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Use with These Load Cases

Survival seismic load cases, on telescope

	Material/ Config Multiplier	Use / Application: A-Low criticality comp	B-Med criticality comp	C-High criticality comp	D-Pressurized component w/ test[A]	E-Lifting device w/ test	F-Fixture, transport container	G-Pressurized component no test	H-	
Factors of Safety: Yield	Mult.	1.00	1.10	1.20	1.60	1.60	1.60	2.00		<<< Use/Application Mult
1-Ductile: proof test	1.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00		Load Case Mult(Yield): 0.00
2-Composites: uniform	0.00									
3-Bonds to glass	0.00									
4-Composites: discontinuous	0.00									
5-Bonds to other materials	0.00									
6-Ductile: qual by analysis	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
7-Brittle materials	0.00									
8-Glass	0.00									
9-Bolted joint	0.00									
10-Buckling	0.00									
11-										

Factors of Safety: Ultimate	Mult.	1.00	1.10	1.20	1.71	1.71	1.71	2.14		<<< Use/Application Mult
1-Ductile: proof test	1.40	0.99	1.09	1.19	1.70	1.70	1.70	2.13		Load Case Mult (Ult): 0.71
2-Composites: uniform	1.50	1.07	1.17	1.28	1.83	1.83	1.83	2.28		
3-Bonds to glass	2.00	1.42	1.56	1.70	2.43	2.43	2.43	3.04		
4-Composites: discontinuous	2.00	1.42	1.56	1.70	2.43	2.43	2.43	3.04		
5-Bonds to other materials	2.00	1.42	1.56	1.70	2.43	2.43	2.43	3.04		
6-Ductile: qual by analysis	3.00	2.13	2.34	2.56	3.65	3.65	3.65	4.56		
7-Brittle materials	3.00	2.13	2.34	2.56	3.65	3.65	3.65	4.56		
8-Glass	5.00	3.55	3.91	4.26	6.08	6.08	6.08	7.60		
9-Bolted joint	2.00	1.42	1.56	1.70	2.43	2.43	2.43	3.04		
10-Buckling	3.00	2.13	2.34	2.56	3.65	3.65	3.65	4.56		
11-										

Factors of Safety: Test	Mult.	1.00	1.10	1.20	0.92	1.04	1.04	na		<<< Use/Application Mult
1-Ductile: proof test	1.20	0.00	0.00	0.00	0.00	0.00	0.00			Load Case Mult (Test): 0.00
2-Composites: uniform	1.20	0.00	0.00	0.00	0.00	0.00	0.00			
3-Bonds to glass	1.20	0.00	0.00	0.00	0.00	0.00	0.00			
4-Composites: discontinuous	1.20	0.00	0.00	0.00	0.00	0.00	0.00			
5-Bonds to other materials	1.50	0.00	0.00	0.00	0.00	0.00	0.00			
6-Ductile: qual by analysis	na									
7-Brittle materials	1.20	0.00	0.00	0.00	0.00	0.00	0.00			
8-Glass	2.00	0.00	0.00	0.00	0.00	0.00	0.00			
9-Bolted joint	na									

Use with These Load Cases
Survival seismic load cases, on telescope

	Material/ Config Multiplier	A-Low criticality comp	B-Med criticality comp	C-High criticality comp	D-Pressurized component w/ test[A]	E-Lifting device w/ test	F-Fixture, transport container	G-Pressurized component no test	H-
10-Buckling	1.25	0.00	0.00	0.00	0.00	0.00	0.00		
11-									