LARGE SYNOPTIC SURVEY TELESCOPE

Large Synoptic Survey Telescope (LSST)

Observatory System Specifications

Chuck F. Claver and the LSST Systems Engineering Integrated Project Team

LSE-30

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Change Record

Version	Date	Description	Owner name
1	5/23/2011	Initial draft for configuration control. Review comments and actions taken in this draft are found in Document---11071.	Chuck Claver
2	5/26/2011	Updated type and clarifications per May 25, 2011 CCB meeting. Affected requirements: OSS-REQ-0010, 0014, 0051, 0064, 0314, 0083, 0084, 0092, 0108, 0239, 0253, and 0259.	C. Claver
	10/15/2012	LCR-88; changes OSS-REQ-0267 (page 95), the system pixel noise from 10e- to 1.7e- per pixel visit.	C. Claver
	10/15/2012	LCR-103; Establishes new requirements for crosstalk amplitudes and correction OSS-REQ-0327-0330, 0346-0349 (pg 91-94)	C. Claver
	10/15/2012	LCR-86; Complete refactoring of photometric requirements (pg 97-102, 104)	C. Claver
	10/15/2012	LCR-84; Updates filling in TBDs in level 1 (pg 46-48) and level 2 (pg50-54) data quality metrics	C. Claver
	10/15/2012	LCR-113; Updates to EMI/Rfi requirements (pg 32)	C. Claver
3	2/14/2013	LCR-85; Redefinition of the seismic design criteria (pg 3, 9-10, 33)	George Angeli
4	10/8/2013	Incorporates all changes approved via LCRs 133, 145, 146, 148, and 153 and all amendments made to those LCRs by the CCB during the meetings held 10/2/2013 and 10/8/2013	B. Selvy
4.1	2/12/2014	Incorporates changes approved in LCR-166 regarding changing the reference to Document-8123 to LSE-180 in the Discussion of OSS-REQ-0194. Incorporates all changes approved in LCR-168 regarding barometric pressues in OSS-REQ-0010.	B. Selvy

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Introduction and Scope

This Observatory System Specifications document describes the functional and performance requirements and allocations needed to fulfill the system functionality and survey performance described by the ***LSST System Requirements Document*** (LSE-29). These specifications include those derived from the following activities and/or modeling tools:

- the reference system architecture consisting of 4 principle sites - summit, base, archive and headquarters
- the selection of the summit site on Cerro Pachón;
- the modeling the dynamic survey performance with the LSST Operations Simulator;
- the optical design optimization;
- the point source SNR analysis of the system throughput

In addition to the system specifications this document also includes required codes and regulations covering safety, construction, and other engineering standards.

Supporting Documents

- LSST Science Requirements Document (LPM-17)
- LSST System Requirements (LSE-29)
- LSST Systems Engineering Management Plan (LSE-17)
- LSST Change Control and Configuration Management Plan (LPM-19)
- LSST Risk Management Plan (LPM-20)

The LSST Observatory System Specifications

1 System Composition and Constraints

The LSST system will consist of facilities constructed at several sites in Chile and the United States. In this section we enumerate the planned facilities and their functions. The data processing functions at these facilities are further divided into "Centers" -- collections of closely related activities.

We specify the choice of the physical sites used for the system design. These choices imply specific constraints that impact the system requirements and design. The specific sites drive system architecture and connectivity specifications. The choice of the summit site, and the subsequent agreement with Chile, also determines particular requirements on the system components that are provided.

The LSST summit site selection process resulted in the choice of Cerro Pachón in Chile for the location of the observatory itself. The weather and astro-climate (seeing and cloud cover) of Cerro Pachón provide system constraints under which the survey design requirements must be met which in turns drives certain system specifications.

1.1 Facilities

ID: OSS-REQ-0001 **Last Modified: 4/21/2011**

Specification: The LSST Observatory shall be designed using the following four facilities; Summit Facility. Base Facility, Archive Facility, and Headquarters Facility. These are described below.

1.1.1 The Summit Facility

ID: OSS-REQ-0002 **Last Modified: 4/21/2011**

Specification: The LSST shall provide a "Summit Facility" to host the following functions and their associated maintenance activities:
1. Collection of the science data for the survey;
2. Collection of additional data required for photometric calibration; and
3. Control of the Observatory.

Discussion: The Summit Facility includes the main telescope and its enclosure, camera service areas, mirror coating systems, the auxiliary telescope and its enclosure, utility equipment, and all other infrastructure necessary to safely execute all the functions above and secure all LSST assets located on the summit. Summit Facility also must provide the space and functional equipment to safely maintain all the system assets operating on the site.

1.1.2 The Base Facility

ID: OSS-REQ-0003 **Last Modified: 10/7/2013**

Specification: The LSST shall provide a "Base Facility" to host the following functions and their associated maintenance activities:
1. The Primary Remote Observing facility to assist in the control of the Observatory;
2. Survey planning and performance monitoring;
3. Collection of newly acquired data for transfer to the LSST data archive;

4. Backup of all data - raw, engineering, and derived products;
5. Host Country Data Access Center, as defined below; and
6. Control of Data Management operations (secondary location).

Discussion: The Base Facility may be a single structure or a series of co-located buildings that provides the personnel offices, computer equipment, and other specialized infrastructure necessary to safely execute all the functions above and to secure all LSST assets located at the Base.

1.1.3 The Archive Facility

ID: OSS-REQ-0004 **Last Modified: 5/20/2011**

Specification: The LSST shall provide an "Archive Facility" to host the following functions:
1. Ingest and daily reprocessing of all raw science data;
2. Archiving of all data - raw, engineering, and derived products;
3. Data Release Production;
4. Calibration Product Production;
5. Moving Object Production;
6. United States Data Access Center; and
7. Data Management Operations (secondary location).

Discussion: The Archive Facility includes the personnel offices, computer equipment, and other specialized infrastructure necessary to safely execute all the functions of the listed Centers and to secure all LSST assets located at the Archive.

1.1.4 The Headquarters Facility

ID: OSS-REQ-0005 **Last Modified: 9/16/2010**

Specification: The LSST shall provide a "Headquarters Facility" to host the following functions:
1. Survey planning and performance monitoring;
2. Management of community science input;
3. Overall Observatory and project administration;
4. Education and Public Outreach; and
5. Data Management Operations Center

Discussion: The function of Observatory and project administration includes the activities of a director, technical manager, business manager, and human resources, and covers all matters of compliance and reporting, interface to funding agencies, and management of the overall LSST Observatory and its operations world-wide.

The functions of Education and public outreach include the development of K-12 curricula, citizen science programs, and the necessary serving of LSST data to educators and the general public through a dedicated Data Access Center within, or in close proximity to, the Headquarters facility.

The Headquarters Facility includes the personnel offices, business equipment, and other specialized infrastructure necessary to safely execute all the functions above and to secure all LSST assets located at the Headquarters.

1.2 Sites

ID: OSS-REQ-0006 **Last Modified: 9/15/2010**

Specification: The LSST Observatory system shall be designed to safely meet its technical requirements and operational specifications with the above-defined Facilities constructed at the following physical locations ("Sites"):

1. Cerro Pachón in Chile for the Summit Facility;
2. The AURA Recinto in La Serena, Chile for the Base Facility;
3. The National Center for Supercomputing Applications (NCSA) in Urbana-Champaign, IL for the Archive Facility; and
4. A continental U.S. site for the Headquarters Facility.

1.2.1 Chilean Summit and Base Sites

ID: OSS-REQ-0350 **Last Modified: 2/5/2013**

1.2.1.1 Summit Site

ID: OSS-REQ-0007 **Last Modified: 10/18/2012**

Specification: The LSST observatory Summit Facility shall be located within the AURA property on Cerro Pachón (El Peñón), Chile, and shall meet all requirements for survey performance and operations at that site. All other functions of the Summit Facility shall be compatible with the defined weather, access, seismic and other site conditions provided below.

Summit Geographic Definitions

ID: OSS-REQ-0008 **Last Modified: 8/28/2010**

Specifications: When design considerations require the specification of the summit site location, the following definitions for elevation, latitude, and longitude shall be used:

Description	Value	Unit	Name
The operational summit elevation to be used for design purposes is **summitElevation.**	2650	Meters	summitElevation
The operational site latitude to be used for design purposes is **summit Latitude.**	-30.2444	Degrees	summitLatitude
The operational summit longitude to be used for design purposes is **summitLongitude.**	-70.7494	Degrees	summitLongitude

Summit Environment

ID: OSS-REQ-0009 **Last Modified: 12/1/2010**

Specification: All systems operating at the Summit Facility exposed to the external environment (includes the dome interior) shall meet all their functional and performance specifications for the Normal site conditions, shall operate in defined degraded modes under the Marginal conditions, and withstand without damage the non-operational Survival conditions provided below.

Normal Operating Conditions

ID: OSS-REQ-0010 **Last Modified: 12/1/2010**

Specification: The equipment and systems exposed to the external environment at the Summit Facilities shall meet all of their functional, performance, and operational specifications for the normal environmental conditions specified in the table below.

Discussion: These conditions correspond to the ~90% to 95% values of the weather distribution.

Description	Value	Unit	Name
The mean temperature for normal operations at the summit shall be **normTempMean**.	11.5	Celsius	normTempMean
The minimum temperature for normal operations at the summit shall be **normTempMin**.	-3.0	Celsius	normTempMin
The maximum temperature for normal operations at the summit shall be **normTempMax**.	19.0	Celsius	normTempMax
The rate of change for design purposes shall be **normTempGrad.**	0.7	C/Hour	normTempGrad
When design considerations require operational wind specifications all summit based systems shall use the extreme operational wind speed, **normWindMax**.	12	m/sec	normWindMax
When design considerations require humidity specifications all summit based systems shall use the normal maximal operational relative humidity (non-condensing) **normHumidityMax**	90	Percent	normHumidityMax
When design considerations require humidity specifications all summit based systems shall use the normal mean operational relative humidity (non-condensing) **normHumidityMean.**	40	Percent	normHumidityMean
When design considerations require barometric pressure specifications all summit based systems shall use the mean pressure **normBaroMean**.	750	milibar	normBaroMean
The maximum barometric pressure for normal operations at the summit shall be **normBaroMax** (TBR).	775	milibar	normBaroMax
The maximum barometric pressure for normal operations at the summit shall be **normBaroMin** (TBR).	725	milibar	normBaroMin

Marginal Operating Conditions

ID: OSS-REQ-0011 **Last Modified: 4/21/2011**

Specification: The equipment and systems exposed to the external environment at the Summit Facility shall be operable (not necessarily meeting all performance and functional requirements) over the range of marginal environmental conditions specified in the table below.

Discussion: These conditions correspond to the ~99% values of the weather distribution.

Description	Value	Unit	Name
The temperature rate of change for degraded operations is **marginalTempGradient**	2.0	C/Hour	marginaltempGradient
The maximum temperature for degraded operations at the summit shall be **marginalTempMax**.	30	Celsius	marginalTempMax

Description	Value	Unit	Name
The minimum temperature for degraded operations at the summit shall be **marginalTempMin**.	-5	Celsius	marginalTempMin
The maximum free air windspeed for degraded operations at the summit shall be **marginalWind**.	20	m/sec	marginalWind

Survival Conditions

ID: OSS-REQ-0012 **Last Modified: 5/25/2011**

Specification: The exterior of the Summit Facility and all hardware permanently located on the exterior shall be capable of surviving a constant wind speed of **survivalWindExterior.**

All equipment and systems at the Summit Facility, when exposed to the external environment (e.g. when the dome is open) shall survive the other environmental conditions specified in the table below.

Description	Value	Unit	Name
All hardware permanently located on the exterior of the Summit Facility shall be capable of surviving a constant wind speed of **survivalWindExterior.**	54	m/sec	survivalWindExterior
The equipment in the interior of the Summit Facility must be capable of surviving an exterior 10-second wind gust speed of **survivalWindGust.**	25	m/sec	survivalWindGust
The equipment in the interior of the Summit Facility must be capable of surviving a constant wind speed of **survivalWind.**	20	m/sec	survivalWind
All equipment at the Summit Facility must be capable of surviving a maximum non-condensing humidity of **survivalHumidity** without damage.	100	Percent	survivalHumidity
All equipment located at the Summit Facility must be capable of surviving an ambient air temperature of **survivalTemperature.**	-10	Celsius	survivalTemperature
The survival load on the Summit Facility due to snow shall be **snowLoading** (ref. Norma Chilena NCH 431).	200	kg/m^2	snowLoading
The survival load on the Summit Facility for ice on vertical surfaces shall be **iceLoading** (ref. Norma Chilena NCH 431)	22	kg/m^2	iceLoading

Transportation/Shipping Environment

ID: OSS-REQ-0013 **Last Modified: 5/18/2011**

Specification: Components of the LSST Observatory that are transported to Chile shall survive the shipping conditions described below.

Discussion: The shipping environment includes the general conditions when equipment is shipped to the summit. The equipment must remain undamaged after repeated shipments. Delivery is expected to be by plane or boat to Chile and then by road to the summit.

There is a tunnel on the road between the town of La Serena and the summit site on Cerro Pachon called the Puclaro Tunnel. Any equipment will have to pass through that tunnel. Its overall dimensions are given below.

Description	Value	Unit	Name
During transportation, the effective altitude can change between sea level and 3000m.	Sea level to 2700m	Meters	Altitude
The ambient temperature range or transportation to the summit is	-15C to +40C	Celsius	Temperature Range
The relative humidity range is from 10% to 100% with condensation for transportation to the summit	10% to 100%	Percent	Relative Humidity Range
Wind speed may reach up to 45m/s during transportation to the summit	45	m/sec	Wind Speed
Pressure will change during transportation to the summit from 1000mbar at sea level down to 750mbar at the summit	1000 to 750	milibar	Pressure
Containers have to be designed to limit water, dust, sand and insect access during transportation			Contamination
Dirt roads will be used during transportation to the summit with grades up to 16%	16	Percent	Roads
During transportation to the summit, some roads have vehicle weight restrictions. Gross Vehicle Weight GVW = TBD Weight/axle = TBD	TBD	kg	GVW
The container dimensions are limited by the Puclaro Dam tunnel (see figure 7) located on the road between La Serena and the summit.	9	Meters	Tunnel

Astro-Climate

ID: OSS-REQ-0015 **Last Modified: 8/5/2010**

Discussion: The selection of the summit site on Cerro Pachon implies a set of constraints relating to the astro-climate under which the survey performance requirements from the LSR must be met. These include atmospheric seeing, usable fraction of nights and cloud cover fraction, standard dark sky brightness, and standard atmospheric transparency.

Atmospheric Seeing

ID: OSS-REQ-0016 **Last Modified: 12/1/2010**

Specification: The LSST shall meet the survey performance requirements under the constraint of the atmospheric seeing on Cerro Pachon (El Penon) as specified in the table below.

Discussion: The values included here are direct DIMM measurements referenced to a wavelength of 500 nm. They do not represent the integrated delivered seeing over an 8.4m aperture or include affects from the outer scale.

Description	Value	Unit	Name
The first quartile of the seeing distribution shall be taken as **seeing1stQuartile**	0.58	ArcsecFWHM	seeing1stQuartile
The median of the seeing distribution shall be taken as **seeingMedian**	0.69	ArcsecFWHM	seeingMedian
The third quartile of the seeing distribution shall be taken as **seeing3rdQuartile**	0.84	ArcsecFWHM	seeing3rdQuartile

Cloud Coverage

ID: OSS-REQ-0017 **Last Modified: 12/1/2010**

Specification: The LSST Observatory shall meet the survey specifications under the assumed weather conditions recorded at Cerro Tololo Observatory from 1975 to 2005 for cloud cover and fraction of photometric and usable nights as defined in the table below.

Description	Value	Unit	Name
The historically monthly mean available time fraction that is considered "photometric" (i.e. cloudless) shall be taken as **photTimeFrac**	53	Percent	photTimeFrac
The historically monthly mean available time fraction that is considered usable (i.e. with clouds but observable, also called "spectroscopic") shall be taken as **usableTimeFrac**	85	Percent	usableTimeFrac

Standard Atmospheric Transmission

ID: OSS-REQ-0018 **Last Modified: 4/21/2011**

Specification: For the purpose of evaluating the system performance and the flow down of subsystem requirements the standard atmospheric transmission shall be calculated from the USAF MODTRAN model using the reference atmospheric parameters given in the table below.

Discussion: While the reference airmass is X=1, Collection-973 contains data files for other airmass values up to x=2.5. Document-3902 contains details on using MODTRAN to calculate the atmospheric transmission functions.
https://www.lsstcorp.org/docushare/dsweb/Get/Document-3902
https://www.lsstcorp.org/docushare/dsweb/View/Collection-973

Description	Value	Unit	Name
1976 US standard STP sea level pressure is **seaLevelPressure**.	1013	milibar	seaLevelPressure
The standard relative humidity percentage is **stpRelHumidity**.	15	Percent	stpRelHumidity
The standard typical Ozone level over northern Chile is **ozoneLevel**.	338	Dobson	ozoneLevel
Reference airmass for calculating the standard transmission function is **stdAirmass**.	1.0	Airmass	stdAirmass

Standard Dark Sky Emission

ID: OSS-REQ-0019 **Last Modified: 4/21/2011**

Specification: For the purpose of evaluating the system performance and the flow down of subsystem requirements the assumed sky brightness in each filter shall be as defined in the **darkSkyBrightness** table below.

Discussion: The details of the sky brightness model and assumptions used are given in Document-8857. The data file containing the assumed sky spectrum is found in Document-8817.

The value for the y-band is for the adopted baseline y4 filter.

The intense sky emission at the extreme red end of the LSST system response means this value could change significantly should a different y-band definition be adopted later.
https://www.lsstcorp.org/docushare/dsweb/Get/Document-8817
https://www.lsstcorp.org/docushare/dsweb/Get/Document-8857

Description	Value	Unit	Name
Integrated reference sky brightness in the u-band.	22.92	mag/SqArcsec	u_SkyBrightness
Integrated reference sky brightness in the g-band.	22.27	mag/SqArcsec	g_SkyBrightness
Integrated reference sky brightness in the r-band.	21.20	mag/SqArcsec	r_SkyBrightness
Integrated reference sky brightness in the i-band.	20.47	mag/SqArcsec	i_SkyBrightness
Integrated reference sky brightness in the z-band.	19.59	mag/SqArcsec	z_SkyBrightness
Integrated reference sky brightness in the y-band.	18.42	mag/SqArcsec	y_SkyBrightness

Usable Observing Time

ID: OSS-REQ-0020 **Last Modified: 5/3/2011**

Specification: The LSST system shall be designed for the expected average number of usable observing hours at the site, **nightDurationAvg**, the winter maximum, **nightDurationMax**, and the summer minimum, **nightDurationMin**.

Discussion: These values have been defined with reference to Nautical (12-degree) twilight and do not include the effects of weather.

These specifications are required for the design of the peak and average capacities of the Data Management system.

They also provide constraints for the definition of the non-observing-time budget for observing preparation, calibration, and maintenance activities together. During the period around winter solstice the scheduled maintenance and calibration activities will be defined such that they can be accommodated in short non-observing hours.

Description	Value	Unit	Name
The mean useable length of a night shall be taken as **nightDurationAvg.**	10	Hour	nightDurationAvg
The maximum useable length of a winter night shall be taken as **nightDurationMax**.	12	Hour	nightDurationMax
The minimum useable length of a summer night shall be taken as **nightDurationMin**.	8	Hour	nightDurationMin

1.2.1.2 Base Site

ID: OSS-REQ-0021 **Last Modified: 10/18/2012**

Specification: The LSST Base Facility shall be located at the AURA Recinto compound in La Serena, Chile. The facilities at the Base Site shall be designed to be consistent with existing conditions; where local standard construction codes are not sufficient, all equipment shall be designed to project-defined Seismic Specifications.

Discussion: The facilities at this site will be developed through new construction or through agreements that meet operational and functional requirements but take advantage of existing NSF and AURA infrastructure.

1.2.1.3 Seismic Design Parameters

ID: OSS-REQ-0344 **Last Modified: 10/18/2012**

[These requirements are under review and have not been formally adopted.]

Discussion: The LSST Summit and Base Facilities are located in Region-3, Chile; a known seismically active area. The requirements for seismic accelerations established here determine the probability for survival, recoverable and operable events as defined below.

As a result of the interactions of the dynamic characteristics (natural frequencies and damping) of the telescope mount and its components with the vibration frequencies of the seismic accelerations, the maximum accelerations of the telescope systems vary significantly according to their location on the telescope mount. Consequently, for all systems mounted to the telescope for all event levels, the design accelerations will be determined by the application of the appropriate seismic vibration spectrum to a finite element analysis (FEA) model of the telescope and its pier. These accelerations will be specified at the appropriate interfaces between subsystems and/or components.

Verification of these requirement will be by analysis or prototype. The implied accelerations are normalized to ductile materials and should be scaled to ASME standard safety factors for other material types (e.g. glass, carbon fiber etc..). Where a range of material strengths is possible verification analysis will use the minimum strength to determine compliance.

Survival Seismic Design Parameters

ID: OSS-REQ-0014 **Last Modified: 2/5/2013**

Specification:
All systems and/or components permanently located at the Summit or Base Facilities shall be designed to withstand the loads resulting from an earthquake up to the levels a 300-year return period seismic event and stay intact such that catastrophic failure is prevented and the hazards to personnel safety are either eliminated or reduced. The levels of a 300-year return period earthquake have a 9.5% probability of being exceeded in 30 years. The ground acceleration values corresponding to a 300-year return period earthquake are defined in the standards established in OSS-REQ-0095.

"Catastrophic failure" shall be defined as fracture or rupture that allows a significant element to separate and fall, or produces the possibility of personnel injury.

Discussion:
See discussion on design accelerations in "Seismic Design Parameters" (OSS-REQ-0344).

The return of the Summit or Base Facilities and their contents to "normal"operations following a "Survival" event will be assessed based on actual damage incurred.

Recoverable Seismic Design Parameters

ID: OSS-REQ-0342 **Last Modified: 10/18/2012**

Specification:
All systems and/or components permanently located at the Summit Facility shall be designed to operate without any permanent damage following a seismic event equivalent to a 20% probability of return over the specified design lifetime of the system and/or component.

"Permanent damage" shall be defined as any damage to optical elements, any yielding of primary structural components, damage where capital repair costs are in excess of $10M (TBR) or repair times longer than 6 months after access and damage assessment.

Discussion:
See discussion on design accelerations in "Seismic Design Parameters" (OSS-REQ-0344).

Operable Seismic Design Parameters

ID: OSS-REQ-0345 **Last Modified: 10/18/2012**

Specification: All systems and/or components permanently located at the Summit Facility shall be designed to operate without any significant damage following a seismic event with a return period equivalent to specified design lifetime of the system and/or component.

"Significant damage" shall be defined as any damage that cannot be repaired within the statistical allocation of the unscheduled down time defined in OSS-REQ-0082.

Discussion: See discussion on design accelerations in "Seismic Design Parameters" (OSS-REQ-0344).

1.2.2 Archive Site

ID: OSS-REQ-0022 **Last Modified: 9/14/2010**

Specification: The LSST Archive Facility shall be located at the National Center for Supercomputing Applications (NCSA) in Champaign-Urbana Illinois.

Discussion: The facilities at this site will be developed through new construction or through agreements that meet operational and functional requirements but take advantage of existing NSF and NCSA infrastructure.

1.2.3 Headquarters Site

ID: OSS-REQ-0023 **Last Modified: 12/1/2010**

Specification: The LSST Headquarters Facility shall be located in the continental United States of America. When design considerations require the specification of the site location, Tucson Arizona shall be used.

Discussion: The facilities at the selected site shall be developed through new construction or through agreements that meet operational and functional requirements.

2 Common System Functions & Performance

The requirements and specification called out in this section are common and apply across the LSST System. These requirements address the following topics:

1. Survey Scheduling and Management;
2. System Control;
3. System Monitoring and Diagnostics,
4. System Maintenance;
5. System Availability;
6. System Time References;
7. System Standards (including environmental and safety).

2.1 Survey Scheduling and Management

ID: OSS-REQ-0024 **Last Modified: 4/21/2011**

Specification: The LSST shall be capable of scheduling the survey observations in an automated maner based on several optimization parameters established to produce the Survey specifications defined in the LSST System Requirements (LSE-29) and maximize the operational efficiency. Through the parameters defined below, the LSST shall be capable of adjusting its observations and its scientific priorities if they should change before or during the survey. The System shall monitor survey progress and provide the necessary tools described below to evaluate performance.

2.1.1 Survey Scheduling

ID: OSS-REQ-0025 **Last Modified: 5/18/2011**

Specification: The Observatory Control System shall schedule the survey with the functionality detailed below.

2.1.1.1 Environmental Optimization

ID: OSS-REQ-0026 **Last Modified: 4/21/2011**

Specification: The survey scheduling shall be optimized against local environmental conditions to maximize the survey's scientific return. This optimization shall include the ability to adjust filters based on seeing conditions, the ability to avoid clouds with predefined opacity, and adjust to constraints derived from wind direction.

2.1.1.2 Multiple Science Programs

ID: OSS-REQ-0027 **Last Modified: 5/18/2011**

Specification: The survey scheduling shall be capable of optimizing scientific returns from multiple science priorities, numbering at least **nSciProp**.

Discussion: A science proposal will be defined by that include but are not limited to

- number of visits and distribution by filter;
- temporal of visit distribution and/or sequence definition;
- limits on astro-climate quality for observation;
- constraints on the location of visit fields;
- priority relative to other science proposals

Description	Value	Unit	Name
The minimum science proposal that the scheduling algorithm must be capable of optimizing over.	6	int	nSciProp

2.1.1.3 Parallax Factor Sampling

ID: OSS-REQ-0028 **Last Modified: 5/18/2011**

Specification: The scheduler shall enforce an even distribution of parallax factor over the sum of all visits in the 10-year survey.

2.1.1.4 Scheduling Assessment

ID: OSS-REQ-0029 **Last Modified: 12/1/2010**

Specification: The survey scheduling shall be adjustable based on periodic assessment of performance. This shall be done down to periods of 1 hour throughout the night and shall be based on actual accomplishments compared to objectives and current system technical performance.

2.1.1.5 Survey History Record

ID: OSS-REQ-0030 **Last Modified: 4/21/2011**

Specification: The LSST Scheduler shall maintain an independent record of all past observations and shall include Data Quality Assessment parameters determined by evaluation of the imaging data.

2.1.1.6 Temporal Visit Distribution

ID: OSS-REQ-0031 **Last Modified: 5/18/2011**

Specification: The scheduler shall be capable of enforcing 5 (TBR) defined temporal distributions of visits covering the fast sample area (defined in the SRD).

2.1.1.7 Visit Optimization

ID: OSS-REQ-0032 **Last Modified: 12/1/2010**

Specification: The survey schedule shall be optimized to maximize the number of scientifically useful visits per night.

2.1.2 Survey Planning and Performance Monitoring

ID: OSS-REQ-0033 **Last Modified: 12/1/2010**

Specification: The LSST shall provide the tools and administrative processes necessary to monitor the progress of the ongoing survey,provide reports on the progress of the survey, respond to feedback from the science community, and evaluate the impact of changing science priorities over the 10 year survey lifetime.

Discussion: It is expected that the performance of this task will require the use of detailed survey simulations in order to evaluate scheduling alternatives and optimize the future performance of the survey.

2.2 System Control

ID: OSS-REQ-0034 **Last Modified: 5/18/2011**

Specification: The LSST Observatory shall be implemented with a coordinated set of control software that will achieve the specified survey, as well as the necessary command, control and monitoring of all observatory functions and states across the Facilities.

Discussion: This control software includes both the Observatory Control System, which is responsible for sequencing activities associated with data collection and initial processing, and the control software for the Data Management system, which will be responsible for alert, data release, and calibration products productions, and archiving and serving data to users.

2.2.1 Control Capabilities

ID: OSS-REQ-0035 **Last Modified: 5/26/2011**

Specification: The LSST control capabilities throughout the system shall be designed to achieve the specified survey with an operating team consistent with the LSST Operations Plan. [document-7838] To control the system efficiently, safely and reliably, the control system shall include both local and remote control modes as specified in this section.
https://www.lsstcorp.org/docushare/dsweb/Get/Document-7838

2.2.1.1 Local Autonomous Administration of System Sites

ID: OSS-REQ-0036 **Last Modified: 5/18/2011**

Specification: Each site in the LSST Observatory shall be capable of local autonomous control and operation. The LSST System shall include the necessary provisions to function effectively when data connections to other sites of the Observatory are interrupted.

Discussion: By "Function effectively" it is understood that when data connections are lost that not system functions will be preserved. For example, the Base Facility cannot generate alerts within 60 seconds without the data coming from the Summit Facility and the Archive Facility cannot serve data it doesn't yet have. Further, regarding data management "effectively" means that the equipment operates normally, processes, and serves whatever data is available.

2.2.1.2 Remote Operation Capabilities

ID: OSS-REQ-0043 **Last Modified: 5/18/2011**

Specification: All LSST major subsystems and OCS shall be remotely operable from any of the LSST Facilities or other Project designated site (e.g. SLAC for camera troubleshooting).

Discussion: This provides the opportunity to establish a single operations center for the various system functions.

Remote operation of the telescope requires granting of permission by an operator who is present at the site, and must remain present during remote operation

It is expected that routine observing oversight of the observatory will be done from the Base Facility, with the exception of actions for which safety and/or equipment protection considerations require operator

presence on the summit. These restrictions will be documented in the LSST Safety Plan.

Summit Facility Operator

ID: OSS-REQ-0308 **Last Modified: 4/21/2011**

Requirement: A local operator shall be always available at the Summit Facility to regain local control when conditions or safety considerations merit.

Netwrok Security

ID: OSS-REQ-0309 **Last Modified: 4/21/2011**

Requirement: Remote operations shall comply with all LSST Corporation cyber security policies in effect at the time.

2.2.1.3 Observatory Safety System

ID: OSS-REQ-0321 **Last Modified: 5/20/2011**

Specification: Each Facility in the LSST Observatory shall implement a non-software based safety system(s) in areas where injury or harm to personnel and or equipment can occur.

2.2.1.4 Observatory Control System Definition

ID: OSS-REQ-0037 **Last Modified: 5/18/2011**

Specification: The Observatory Control System (OCS) is the primary high level supervisor and monitor for conducting the survey that shall consist of software subsystems that interact through a connectivity backbone layered on top of the observatory communications network.

Discussion: The OCS commands, monitors and controls all observatory activities, to achieve a safe and efficient observation environment.

Scope of Control

ID: OSS-REQ-0038 **Last Modified: 4/21/2011**

Specification: The OCS shall control and monitor all activities necessary for the acquisition of the survey and ancillary data. Additionally, the OCS shall provide high level control of the Data Management system's processing of new data from the observatory, including the selection of its operational mode consistent with each type of operational and maintenance data acquisition.

Discussion: The operational mode selection above is intended to encompass the choice of normal nightly science data acquisition, calibration data acquisition of various types, and diagnostic processes. The OCS will control the nightly start and stop of DM processing and overall system state changes, but it is not envisioned that it will exert fine-grained (e.g. per-exposure or per-visit) control of DM's activity.

Visit Sequencing

ID: OSS-REQ-0039 **Last Modified: 4/21/2011**

Specification: : The OCS shall include the ability to orchestrate a complete sequence of visits over any 24 hour time period. This master sequencer shall be capable of system action flow control as well as

system process synchronization and parallelization.

Discussion: OCS can be viewed as a sequencing engine for the execution of science, calibration, and engineering observations. The sequence of science observations are generated by the observatory scheduler based on observatory performance and project defined priorities. The master sequencer will include observatory configuration and target acquisition sequences, from an OCS master process sequencer.

Manual Visit Specification

ID: OSS-REQ-0040 **Last Modified: 12/1/2010**

Specification: The OCS shall be capable of accepting a full set of visit specifications from an external source. This shall include individual operator defined targets and a target list that is followed in order.

2.2.1.5 Subsystem Activation

ID: OSS-REQ-0041 **Last Modified: 5/19/2011**

Specification: Upon activation, each subsystem connected to the OCS architecture shall be able to initialize itself and be ready for communication with the OCS without further human intervention. This activation process shall take less **subSysStart** to complete..

Discussion: In the context of this requirement a subsystem refers to the three major subsystem of the LSST Observatory, Telescope, Camera, and Data Management. It can also include other subsystems of each of the three that are directly connected to the OCS architecture.

This does not place any requirements on the subsystem in terms of being ready to take data. For example, the Camera cool down (which requires activation) will take considerable longer than 1 minute.

This requirement assumes a "warm restart" or activation with the appropriate computer(s) up and running.

Description	Value	Unit	Name
The maximum time for a subsystem to execute a warm restart and regain connectivity with the OCS.	60	Seconds	subSysStart

2.2.1.6 Subsystem Initialization

ID: OSS-REQ-0307 **Last Modified: 5/23/2011**

Specification: Each subsystem when powered up shall be initialized into a known safe state without human intervention.

2.2.1.7 Subsystem Health and Welfare

ID: OSS-REQ-0042 **Last Modified: 5/20/2011**

Specification: Each LSST subsystem shall be responsible for maintaining its own technical heath, safety, and status without any other subsystem operational.

Discussion: The Observatory shall have independent safety systems but each subsystem shall include an initial level of autonomous safety for independent operation.

2.2.2 Standard Operating States

ID: OSS-REQ-0044 **Last Modified: 4/21/2011**

Specification: The LSST observatory system shall be designed and constructed to support the following operational states:

- Fully automated observing - used for most of the survey observing;
- Calibrate - used for special observing modes needed to calibration either the science data or other technical aspects of the observatory;
- Manual observing - used for specific non-scheduler driven observing to support system verification and testing or specialized science programs;
- Engineering and Maintenance

Note: The states need further definition in terms of access and safety requirements for each.

2.2.2.1 Automated Survey Observing

ID: OSS-REQ-0045 **Last Modified: 4/21/2011**

Specification: The LSST system shall be capable of operating in an automated operation state to perform the survey execution.

Discussion: The survey operation shall proceed under the conduct of the OCS utilizing the automated scheduler and its coordination capabilities with an operator available at the Summit Facility.

2.2.2.2 Calibration

ID: OSS-REQ-0046 **Last Modified: 10/27/2010**

Specification: In calibration state the LSST system shall be capable of performing a science calibration plan.

Discussion: The science calibration plan can include both the acquisition of specialized sky observations or instrumental characterization data (e.g. dome flats, dark and bias images).

2.2.2.3 Engineering and Maintenance

ID: OSS-REQ-0047 **Last Modified: 4/21/2011**

Specification: While in the engineering and maintenance state the LSST system shall provide the capabilities to support the activities comprising of access to maintenance plans, capturing relevant telemetry, executing sequences of tests, recording of associated activities, among others.

2.2.2.4 Manual Observing

ID: OSS-REQ-0048 **Last Modified: 4/21/2011**

Specification: The LSST Observatory shall be capable of executing manual or simple script driven observations.

2.2.3 Degraded Operational States

ID: OSS-REQ-0049 **Last Modified: 4/21/2011**

Specification: The LSST system shall support the modes of degraded operation enumerated below.

Discussion: For each type of degradation we specify the time for which we can tolerate an outage of that particular type. Longer outages are then assumed to cause unacceptable losses, and are then charged against the unscheduled downtime budget. The system should therefore be engineered to minimize the occurrences of outages longer than the specified durations.

This can lead to concrete requirements at lower levels. For instance, the fact that we are designing for two-day outages in Summit-Base and Base-Archive connectivity now requires us to minimize the number of outages longer than two days. This can be done, for instance, by requiring - at the subsystem level - the acquisition of redundant network links.

2.2.3.1 Summit Power Grid Loss

ID: OSS-REQ-0050 **Last Modified: 10/27/2010**

Specification: The summit Facility shall be capable of normal survey operations in the event of power loss from the grid for a minimum duration of **gridLossTime.**

Description	Value	Unit	Name
The minimum time between resupply of the Summit Facility backup power under continuous operation.	2	Days	gridLossTime

2.2.3.2 Summit-Base Connectivity Loss

ID: OSS-REQ-0051 **Last Modified: 5/25/2011**

Specification: The LSST shall be able to continue with automated survey observing in the event that the data communications between the Summit and Base sites are severed, for outages of less than **summitConnectivityLossTime**.

Discussion: The level of data quality monitoring provided during such degraded operation may be lower than normal, due to the lack of availability of Base resources for computing. However, at a minimum, data quality monitoring related to the health and welfare of the subsystems (see OSS-REQ-0065) and simple analytic functions of the "quick look" display (see OSS-REQ-0057) must be maintained.

Upon resumption of normal operations all normal science data processing, including full data quality assessment, must be completed on acquired during the outage.

The emphasis on automated survey observing here is meant to convey that other capabilities might be lost during such an outage, for instance the ability to reassess the progress of the survey, adjust scientific priorities, etc.

Description	Value	Unit	Name
Minimum duration of summit-base connectivity outage for which normal survey operation can be maintained	48	Hour	summitConnectivity LossTime

Summit Data Buffer

ID: OSS-REQ-0052 **Last Modified: 5/20/2011**

Specification: The LSST system shall provide a limited buffer of both raw image (science and wave front sensing images) and telemetry data to allow survey observations to proceed in the event of communications loss between the summit and base. The buffer(s) shall have sufficient capacity to store the raw pixel and telemetry data for at least the design outage time, **summitConnectivityLossTime**. Upon recovery from a communications interruption, it shall be possible to drain the buffer, in parallel with continuing normal operations, in no more than **summitBufferTransferTime**.

Discussion: Once the connectivity is restored it is expected that any data obtained during the outage will be transferred to the Base Facility and then forwarded to the Archive Facility where it will be processed for alerts (late) and the data base updated.

Discussion: This requirement does not imply completing the nightly reprocessing of 3 days worth of data at the Archive Facility within 24 hours.

Description	Value	Unit	Name
The maximumallowedtime to transmit entire pixel buffer in parallel with normal operations is **summitBufferTransferTime**.	24	Hour	summitBufferTransferTime

2.2.3.3 Base-Archive Connectivity Loss

ID: OSS-REQ-0053 **Last Modified: 4/28/2011**

Specification: The LSST system shall be able to conduct normal science operations in the event that data communication between the base and archive sites is lost, for outages of less than **baseConnectivityLossTime**.

Description	Value	Unit	Name
Minimum duration of base-archive connectivity outage for which normal survey operation can be maintained	48	Hour	baseConnectivityLossTime
Maximum time for recovery from a Base-Archive communications outage of length **baseConnectivityLossTime**.	24	Hour	baseConnectivityRecoveryTime

Base Data Buffer

ID: OSS-REQ-0054 **Last Modified: 10/7/2013**

Specification: The LSST system shall provide a limited buffer for data (raw, processed, and engineering) *en route* from the Base to the Archive Center, to allow science operations to proceed in the event of communications loss between the Base and Archive. The system shall have sufficient capacity to store all *en route* data for at least the design outage time, **baseConnectivityLossTime**.

Discussion: This requirement does not imply completing the nightly reprocessing of the buffered data at the Archive Facility within 24 hours once it is transferred.

Base Updating from Archive

ID: OSS-REQ-0055 **Last Modified: 10/7/2013**

Specification: Following an outage in Base-Archive connectivity not longer than **baseConnectivityLossTime**, all data transfer from Archive to Base shall be brought current within

baseConnectivityRecoveryTime, in parallel with the continuation of normal operations.

2.3 System Monitoring & Diagnostics

ID: OSS-REQ-0056 **Last Modified: 4/28/2011**

Specification: LSST Observatory shall monitor system and instrument performance on a regular (daily where appropriate) basis with the goal of detecting sudden as well as gradual performance changes.

Discussion: Data volume and rate drive the need for very summary or statistical representation of the information, thresholds and alarms, and the ability to drill down.

During routine observing hours the system will provide real time display(s) summarizing system performance. This includes real time display of the FPA image and basic image analysis including, but not limited to PSF measurements, background levels, amplifier noise and other image statistics.
.
During non-observing hours the primary activity shall be to review the quality control and performance parameters specified by the established baseline performance report against the current performance summarized in automated reports.

Sudden changes should be obvious from the near real time displays and image analysis – detecting long-term changes will require monitoring performance as a function of time.

2.3.1 Image Visualization

ID: OSS-REQ-0057 **Last Modified: 5/19/2011**

Specification: The LSST Observatory shall provide the means to display images from the FPA (including both science and wavefront sensors) in real time commensurate with the FPA readout, as well as from archived images. This "quick look" display shall support the following global functions:

- Pan/zoom quickly and easily to arbitrary resolution
- View from laptop/workstation or multi-monitor wall (albeit with performance trade-offs)
- Ability to view warning/quality flags via color coding, overlays or some other mechanism
- blink / compare images from at least two different exposures

2.3.1.1 Analytic Functions

ID: OSS-REQ-0058 **Last Modified: 4/28/2011**

Specification: The "quick look" display tool shall support as a minimum the following analytic functions:

- computation of basic statistics (mean, mode, SDEV, etc...) over an arbitrary region of pixel space
- line/column plot on any scale
- histogram of pixel values in an arbitrary region of pixel space
- basic PSF measurements (FWHM, second moments, radial plots profile fitting, etc...)
- simple arithmetic between arbitrary regions of two images
- overlaying the results of queries to the Engineering & Facility Database

2.3.1.2 Display Timing Performance

ID: OSS-REQ-0059 **Last Modified: 4/28/2011**

Specification: The "quick look" image display at the Summit and Base Facilities shall respond with the latency performance indicated below.

Discussion: these requirements only apply to "quick look" display located at the Summit and BAse Facilities when accessing data from either the base archive or the summit data buffer.

Description	Value	Unit	Name
Users at the Summit or Base facility shall be able to view the image data from the most recent exposure within **displayLatency** after the shutter has closed.	10	Seconds	displayLatency
Users shall be able to cycle through predefined views of the full image (e.g. bright or faint star optimized binned, bias map, noise map, etc.) within **viewCycleTime** between each.	2	Seconds	viewCycleTime

2.3.1.3 Image Data Sources

ID: OSS-REQ-0060 **Last Modified: 4/28/2011**

Specification: The "quick look" image display shall have access to image data from the following sources:

- the real-time pixel streams (raw or cross-talk corrected)
- the 2-day on Summit image buffer (from Summit and Base only)
- the image archive at the Base Facility
- the image archive at Archive Facility

2.3.1.4 Image Display Locations

ID: OSS-REQ-0310 **Last Modified: 5/19/2011**

Specification: "Quick look" image displays shall be locatde at a minimum at the following locations:

- Summit Facility Control Room
- Base Facility Control Room
- Archive Facility
- Headquarters
- Data Access Centers

2.3.2 Data Visualization

ID: OSS-REQ-0061 **Last Modified: 12/1/2010**

Specification: The LSST Observatory shall provide facilities (physical and software) for the visualization of a variety of types of data produced by the Observatory at the locations specified in OSS-REQ-0006, including:

- Catalog data derived from image analysis
- Calibration data and data products, including images and spectra from the ancillary telescopes and cameras in the Observatory
- Data quality metrics derived from the analysis of the Observatory's raw data
- Engineering and facilities data, including monitoring and diagnostic data from the Observatory and data processing systems
- Data processing metadata
- Selected reference datasets from external sources (e.g., astrometric catalogs)

These facilities shall provide for at least the following types of displays:

- Statistical, including histograms, correlation plots, and basic statistical data reductions on selected data
- Temporal, showing time histories of selected parameters and of statistical properties of acquired data
- Spatial, displaying data overlaid on associated images

2.3.3 Subsystem Telemetry

ID: OSS-REQ-0062 **Last Modified: 5/19/2011**

Specification: All LSST subsystems shall publish telemetry using the Observatory specified protocol (LSST Document-2233) containing time stamped structures of all command-response pairs and all technical data streams including hardware health, and status information.

Discussion: In the context of this requirement a subsystem refers to the three major subsystem of the LSST Observatory, Telescope, Camera, and Data Management. It can also include other subsystems of each of the three that are directly connected to the OCS architecture.

Hardware health and status information includes data regarding the correct functionality of all major internal components and sub-subsystems.

The data for the science, wavefront sensing, and raw guider images are not included in this requirement.
https://www.lsstcorp.org/docushare/dsweb/Get/Document-2233

2.3.3.1 Subsystem Metadata for Science Analysis

ID: OSS-REQ-0063 **Last Modified: 5/20/2011**

Specification: The subsystem telemetry shall include all required information (metadata) needed for the scientific analysis of the survey data.

Discussion: The specific metadata that each subsystem is required to produced will be detailed as part of the DM interface control definitions between the Camera, Telescope & Site, and OCS. Collection-1539 contains the lists of metadata for the EFD as it is developed.
https://www.lsstcorp.org/docushare/dsweb/View/Collection-1539

2.3.3.2 Subsystem State Notification

ID: OSS-REQ-0064 **Last Modified: 5/25/2011**

Specification: Each subsystem shall report changes in its internal state consistent with the significant state changes contained in the Observatory State Model in SysML.

Discussion: The state change notification include at least those states defined in OSS-REQ-0047, as well as the following additional states:

- System Reset
- Emergency Shutdown
- Standby / Idle
- Reconfiguring

2.3.3.3 Subsystem Status

ID: OSS-REQ-0065 **Last Modified: 6/23/2010**

Specification: Each LSST subsystem (or a small number of major subsystem components) shall assess and report an overall hardware health status.

Discussion: The primary purpose of these status indicators is for the OCS to be able to orchestrate normal operations and handle out of normal conditions.

2.3.3.4 Telemetry Database

ID: OSS-REQ-0195 **Last Modified: 5/18/2011**

Specification: The LSST System shall capture the telemetry data produced by every subsystem, organize it and make it available through an Engineering Facility Data Base (EFD).

Discussion: There will be two kinds of interfaces for querying the EFD. One is to obtain the current value of the telemetry, a real-time status of the system. The other one is for accessing the history of the telemetry. The access of large amount of history data may span through more than one distributed instance of the EFD, and such fact must be transparent to the user performing the query, as well as not having an impact on real-time operations.
https://www.lsstcorp.org/docushare/dsweb/View/Collection-677

Control Data

ID: OSS-REQ-0196 **Last Modified: 5/18/2011**

Specification: The telemetry data shall include reported values needed for the purpose of the real-time control of the observatory.

Engineering Data

ID: OSS-REQ-0197 **Last Modified: 5/18/2011**

Specification: The telemetry data shall include reported values needed for the purpose of the engineering activities.

Meta Data

ID: OSS-REQ-0198 **Last Modified: 5/18/2011**

Specification: The telemetry data shall include reported values needed for the purpose of the insertion of meta data alongside the science data.

Monitoring Data

ID: OSS-REQ-0199 **Last Modified: 5/18/2011**

Specification: The telemetry data shall include reported values needed for the purpose of the monitoring activities.

Telemetry Database Sizing

ID: OSS-REQ-0311 **Last Modified: 5/26/2011**

Specifications: The telemetry database shall be sized and support the bandwidths defined in the table (EFD_OSSparameters) below.

Discussion: The average rate **EFD_AvgRate** and the estimated data storage requirement i **EFD_DayStore** are supported in document 7722. There is another set of data (see document 7721) consisting of non-science images that are not permanently stored in the EFD that pushes the data rate transfer to **Blob_AvgRate**, for a combined rate of **NonScience_MaxRate**.
https://www.lsstcorp.org/docushare/dsweb/Get/Document-7721
https://www.lsstcorp.org/docushare/dsweb/Get/Document-7722

Description	Value	Unit	Name
Long-term mean ingest rate to the Engineering and Facilities Database required to be supported.	6.5	Mbit/sec	EFD_AvgRate
The minimum supported daily data volume of the engineering facility data base.	30	GBytes	EFD_DayStore
Long-term mean ingest rate to the Engineering and Facilities Database of non-science images required to be supported.	15.4	Mbit/sec	Blob_AvgRate
Maximum ingest rate to the Engineering and Facilities Database of non-science images required to be supported.	21.9	Mbit/sec	NonScience_MaxRate

Initiation of Telemetry Database

ID: OSS-REQ-0312 **Last Modified: 5/18/2011**

Specification: Collection and retention of telemetry data shall begin no later than the start of system integration in the Summit Facility.

Telemetry Database Retention

ID: OSS-REQ-0313 **Last Modified: 5/18/2011**

Specification: The data in the EFD shall be retained at least for the lifetime of the survey.

2.3.4 Subsystem Baseline Performance

ID: OSS-REQ-0066 **Last Modified: 5/19/2011**

Specification: Each subsystem shall provided a baseline of the as built performance as determined during acceptance testing and system integration & test.
Discussion: The baseline analysis is a deliverable of the subsystem and will be part of the acceptance process. It is expected that over time the observatory operations staff will modify and add to the analysis as knowledge of the subsystems improves.

2.3.5 Subsystem Performance Reporting

ID: OSS-REQ-0314 **Last Modified: 5/25/2011**

Specification: The LSST Observatory over the course of the 10-year survey shall monitor its performance with respect to its established baseline and report variances exceeding established thresholds.

2.3.6 Performance & Trend Analysis Toolkit

ID: OSS-REQ-0067 **Last Modified: 5/10/2011**

Specification: The LSST system shall provide a common tool kit for conducting performance analysis, including trending, on the telemetry captured in the Engineering & Facility Database.

Discussion: This tool kit will be part of the OCS.

2.3.7 Summit Environment Monitoring

ID: OSS-REQ-0068 **Last Modified: 4/28/2011**

Specification: The LSST Observatory shall monitor the local observing environment so that delivered data performances can be assessed against the state of the environment at the time the data were obtained. The monitoring shall include all natural elements that impact the image data quality and at a minimum shall include the following as detailed below:

- Cloud Coverage
- Meteorological Parameters
- Atmospheric Turbulence Structure
- Integrated atmospheric seeing
- Seismic activity

Discussion: The data generated from the Summit Environmental Monitoring is part of the recorded observatory telemetry streams (see OSS-REQ-0062).

2.3.7.1 Atmospheric Seeing

ID: OSS-REQ-0069 **Last Modified: 12/1/2010**

Specification: For the purpose of monitoring the system performance and optimizing its operation the LSST Observatory shall provide the necessary instruments to measure the atmospheric seeing independently from the main observing system.

2.3.7.2 Atmospheric Turbulence Structure

ID: OSS-REQ-0070 **Last Modified: 12/1/2010**

Specification: For the purpose of monitoring the system performance and optimizing its operation the LSST Observatory shall provide the necessary instruments to measure the structure of the atmospheric turbulence in at least **minTurbLayers** to an altitude of **minTurbHighAltitude**.

Description	Value	Unit	Name
The high altitude limit to which the atmospheric turbulent profile shall be measured shall be no less than **minTurbHighAltitude.**	20000	Meters	minTurbHighAltitude
The number of layers for which the atmospheric turbulence structure will be measured shall be at least **minTurbLayers**.	6	int	minTurbLayers

2.3.7.3 Cloud Mapping and Monitoring

ID: OSS-REQ-0071 **Last Modified: 5/19/2011**

Specification: For the purpose of monitoring the system performance and optimizing its operation the LSST Observatory shall provide the necessary instruments to provide a 2-D map of the cloud cover covering the visible sky centered on the Summit Site with a cadence equal to or faster than a standard visit. The could map shall as minimum the properties listed in the table below.

Description	Value	Unit	Name
The angular resolution of the all sky cloud map shall be at least **cloudMapResolution.**	1.0	Degrees	cloudMapResolution
The angular extent of the all sky cloud map centered on the zenith point shall be at least **cloudmapCoverage**.	150	Degrees	cloudMapCoverage

2.3.7.4 Weather and Meteorological Monitoring

ID: OSS-REQ-0072 **Last Modified: 12/1/2010**

Specification: The LSST Observatory on the summit shall provide local weather conditions that impact, and at a resolution consistent with, technical and scientific performance. This shall include, at a minimum,

Temperature
Humidity
Wind Speed
Wind Direction

2.3.7.5 Seismic Monitoring

ID: OSS-REQ-0073 **Last Modified: 12/1/2010**

Specification: The LSST Observatory shall provide and report real time monitoring of local summit seismic activity and a near real-time feed back on nearby seismic events to the local operators at the summit and base facilities.

2.4 System Maintenance

ID: OSS-REQ-0074 **Last Modified: 4/28/2011**

Specification: The LSST system shall be designed for maintainability of components, and a maintenance plan shall be implemented to achieve the required survey performance during the life span.

Discussion:
The concept of the maintenance comprises both the idea to facilitate the monitor/inspection/repair activities and the plan to perform the activities. The maintenance activities and the plan to perform them, shall be derived from documentation delivered as part of each subsystem.

Maintainability features in the designs shall include: the adoption of standard components where possible; use of software and utility systems to track and minimize the spare parts inventories; and technical training and tool sets for maintenance activities.

Specific standards and codes are detailed below in **System Standards.**

2.4.1 Predictive Maintenance

ID: OSS-REQ-0075 **Last Modified: 5/19/2010**

Specification: The LSST Observatory shall implement and maintain a comprehensive system-wide predictive maintenance program based on regular inspection and/or condition monitoring of all major sub-systems including enclosure, telescope, adaptive optics, and instrumentation.

Discussion: The goal is to detect and correct performance degradation and/or potential failures before these problems cause lost science time or significantly reduce system efficiency.

2.4.2 Preventive Maintenance

ID: OSS-REQ-0076 **Last Modified: 4/28/2011**

Specification: The LSST Observatory shall implement and maintain a comprehensive system-wide preventive maintenance program based on vendor recommendation.

Discussion: This program shall cover all major technical sub-systems including enclosure, telescope, active optics, instrumentation, and data processing hardware and software. The goal is to maintain system efficiency within specified ranges and maximize the time between failures.

2.4.3 Maintenance Activity Support

ID: OSS-REQ-0077 **Last Modified: 10/25/2010**

Specification: In support of all maintenance activity, both predictive and preventive, the LSST Observatory shall implement the following systems:

- Comprehensive problem reporting, tracking, and management system
- Work order driven preventive maintenance support system (usually known as CMMS for Computerized Maintenance Management System).
- Warehouse inventory and property control
- Document control center
- Analysis tools for supporting predictive maintenance.

2.4.4 Maintenance Reporting

ID: OSS-REQ-0078 **Last Modified: 10/25/2010**

Specification: For the purposes of monitoring technical performance, a set of automatic reports based on engineering telemetry shall be generated on a daily basis.

Discussion: The reports are based on device/mechanism usage, behavior of their parameters within specified limits, and correlation with common environmental conditions.
More detailed and specific reports can be generated using the tools specified in **Maintenance Activity Support**.

2.4.5 Maintenance Tracking and Analysis

ID: OSS-REQ-0079 **Last Modified: 5/19/2010**

Specification: The LSST Observatory shall maintain a permanent record of the description and time required to recover from all maintenance events.

2.5 System Availability

ID: OSS-REQ-0080 **Last Modified: 5/19/2011**

Specification: The LSST system shall have an availability for science and calibration observations, of at least **plannedAvailability** of observing nights of operation, within the specified performance limits defined under "Normal Operating Conditions" (see OSS-REQ-0010 above) and the allowed fractional cloud cover **cloudCoverFrac**, in order to achieve the goals given by the survey.

Discussion: An observing night is considered when weather conditions are within observable limits. Of those observing nights a percentage is allocated for scheduled downtime and another for unscheduled downtime.

Description	Value	Unit	Name
The minimum allowed fraction of available nights that can be used when all sources of down time are summed is **plannedAvailability**.	90	Percent	plannedAvailability
An night is considered "observable" when the fractional cloud cover is less than **cloudCoverFrac**.	62.5	Percent	cloudCoverFrac

2.5.1 Scheduled Down Time

ID: OSS-REQ-0081 **Last Modified: 8/5/2010**

Specification: The LSST shall meet the survey specifications allowing for **plannedDownTime** days of scheduled down time annually for maintenance and repair.

Description	Value	Unit	Name
Allowed down time for scheduled non-observing activities is **scheduledDownTime**.	14	Days	scheduledDownTime

2.5.2 Unscheduled Down Time

ID: OSS-REQ-0082 **Last Modified: 5/26/2011**

Specification: The LSST shall meet the survey specifications allowing for the equivalent of **unplannedDownTime** days for un-scheduled down time annually for maintenance and/or repair.

Discussion: The basis for allocating the unscheduled downtime uses "typical" observatory down time of 4% with 2% added to account for the single instrument of the LSST.

This down time covers only the ability to collect survey data.

Description	Value	Unit	Name
The allowed time the system can be down for unplanned events is **unplannedDownTime**.	21	Days	unplannedDownTime

2.6 System Time Reference

ID: OSS-REQ-0086 **Last Modified: 12/1/2010**

Specification: The LSST system shall provide an observatory wide standard time reference that shall be used by all subsystems where absolute and external time reference is required

2.6.1 Time Acuracy and Precision

ID: OSS-REQ-0087 **Last Modified: 12/1/2010**

Specification: All time tagged events reported both internally and externally by the LSST system shall be done with the timing accuracy and precision given in the table below**.**

Discussion: This implies that the observatory master clock is significantly better than the specifications for absolute accuracy (e.g. absolute accuracy of few mili-seconds) to allow latency in the various subsystems to meet this requirement.

Description	Value	Unit	Name
All time tagged events reported both internally and externally by the LSST system shall be done with an accuracy of **absTime**.	0.010	Seconds	absTime
All internal events within the LSST system shall be recorded with a precision relative to the master clock of **relTime**.	0.001	Seconds	relTime

2.6.2 Time Reporting Standard

ID: OSS-REQ-0089 **Last Modified: 10/7/2013**

Specification: The time reporting standard shall be International Atomic Time (TAI).

Discussion: TAI is a purely sequential time standard without leap seconds. It forms the basis of the Terrestrial Dynamic Time standard from which most other time references can be derived.

2.7 System Standards

ID: OSS-REQ-0090 **Last Modified: 5/26/2011**

Specification: The LSST shall be designed to meet the site based component and procedure standardization captured in the LSST System Standards document, LSE-XX. This document defines the component standards to be followed to ensure a minimum dispersion of final design elements across the LSST system, in particular at a single facility/site.

Discussion: The objective is to minimize the support equipment and specialized training necessary to maintain and operate different types of electronics, to minimize the types of tooling to service otherwise similar hardware, etc...

2.7.1 Environment

ID: OSS-REQ-0091 **Last Modified: 5/26/2011**

Specification: The LSST shall be developed and operated in compliance with all applicable local environmental, cultural, and permitting regulations for each relevant LSST site and location of work. All LSST development and operation shall comply with the LSST Environmental and Cultural Sensitivity Plan (Document-TBD) that describes in detail the LSST Policy and Procedure for adhering to local permitting requirements and other US Federal guidelines for extraterritorial projects. In addition to these local and international standards the LSST shall also comply with the following environmental parameters.

2.7.1.1 Electromagnetic Compatibility

ID: OSS-REQ-0343 **Last Modified: 9/26/2012**

Discussion: LSST consists of a collection of commercial and custom electronics supporting a single scientific instrument. Some parts of the instrument deal with exceptionally small electrical signals and are, thereby, susceptible to interference from neighboring equipment. Some parts of the instrument deal with large voltage and current changes and are, thereby, potential sources of interference. It is essential for robust operation of the Observatory that all electrical and electronic equipment be purchased, designed, fabricated and installed with this in mind.

Electromagnetic (RF) Emissions

ID: OSS-REQ-0092 **Last Modified: 10/8/2012**

Specification: The LSST Observatory shall not emit electromagnetic radiation on any frequency in accordance to FCC part 15 Class B standards that significantly interferes with itself (as defined by meeting its performance specifications) or the operation of any neighboring facility, not including the formal certification defined in those standards. All off-the-shelf electronic devices that are not compliant require suitable shielding or other mitigation. Custom designed LSST electronics shall take advantage of all reasonable good practices in design and fabrication to minimize interference.

Electromagnetic (RF) Suceptibility

ID: OSS-REQ-0326 **Last Modified: 10/8/2012**

Specification: The LSST Observatory shall not be susceptible to electromagnetic emissions consistent with FCC Part 15 Class A standards and commercial sources within and external to the Summit Facility, not including the formal certification defined in those standards. All off the shelf electronic components that are not compliant require suitable shielding or other mitigation. Custom designed LSST electronics will include all reasonable good practices in design and fabrication that minimize susceptibility.

Discussion: This requirement is meant to ensure the LSST design is robust against typical radio emissions in and around the Summit Facility (e.g. walkie talkie and cell phone transmissions).

2.7.1.2 Night Light Emission

ID: OSS-REQ-0093 **Last Modified: 4/28/2011**

Specification: During normal night time operation the LSST Summit Facility shall not generate detectable light pollution.

Discussion: The requirement is meant to both protect the scientific integrity of the LSST survey and also minimize the LSST's impact on neighboring observatories.

2.7.1.3 Radio Active Background

ID: OSS-REQ-0094 **Last Modified: 5/19/2011**

Specification: Charged particle events from radioactive material in the summit facility shall cause a background of no more than 0.01 (TBR) events/cm^2-sec on the detector plane.

Discussion: Additional work is necessary to derive the allocation from the telescope and camera.

2.7.2 Building Codes

ID: OSS-REQ-0095 **Last Modified: 2/6/2013**

Specification: All LSST facilities shall comply with the 2006 International Building Code and the accompanying 2006 International Mechanical/Plumbing Codes for the deisgn of the Summit Support Facility. These codes shall also apply to the LSST Base facility in Chile and the design of all U.S.-based facilities.

In addition, all LSST Facilities in Chile shall comply with the applicable *Norma Chilena:*

- NCH-431: "Earthquake resistant design of buildings";
- NCH-433: "Earthquake resistant design of buildings";
- NCH-2369: "Seismic design of industrial structures and installations"; and

with other related regulations regarding seismic design. In cases of conflicting requirements, the most stringent code shall govern.

2.7.3 Electrical and Controls Standards

ID: OSS-REQ-0096 **Last Modified: 4/28/2011**

Specification: For each system Facility the LSST shall develop and document standards for the following:

- Control Panels
- Electrical and Electromagnetic Compatibility
- Controllers and associated software
- Utility Connection
- Grounding

Summit Facility - Document-TBD
Base Facility - Document-TBD
Archive Facility - Document-TBD
Headquarters - Document-TBD

Discussion: The objective of these standards is to support efficient operations and minimize the dispersion of final design elements across the LSST system. This requirement will be applied at the facility/site level to account for differences in facility/site specific needs.

2.7.4 Minimum Design Lifetime

ID: OSS-REQ-0097 **Last Modified: 5/25/2011**

Specification: The LSST Observatory shall be designed for a minimum lifetime of **minDesignLife.**

Discussion: The minimum design lifetime includes the time from initial assembly during construction, 2 years of commissioning, and 10 years of survey operations.

Description	Value	Unit	Name
The minimum expected lifetime covering mid-construction through to the end of 10 years of survey operation is **minDesignLife**.	15	Years	minDesignLife

2.7.5 Safety

ID: OSS-REQ-0098 **Last Modified: 12/1/2010**

Specification: The LSST shall be designed to achieve the highest level of personnel health and safety performance in all phases of the project lifecycle. All aspects of the design and construction shall comply with the LSST Safety Policy, LPM-18. This policy defines the procedures for personnel and equipment safety throughout the design, construction, and operation phases of the project addressing working conditions and procedures, as well as the management structure and design features that impact safety throughout the LSST Project.

2.7.5.1 Safety Priorities

ID: OSS-REQ-0099 **Last Modified: 12/1/2010**

Specification: The safety priority within the entire LSST shall be (in priority order):
1. The protection of personnel;
2. The protection of the technical integrity of the LSST system and other equipment associated with its operation; and
3. The protection of scientific data.

2.7.5.2 Hazard Analysis and Safety Practices

ID: OSS-REQ-0100 **Last Modified: 4/28/2011**

Specification: The LSST system shall govern its hazard analysis and safety practices (see LPM-49) in an order of precedence as follows:

1. ***Design for Minimum Risk:*** The primary means for mitigating risk shall be to eliminate the hazard through design.
2. ***Incorporate Safety Devices:*** Protective devices shall be used as part of system design to reduce hazard risks to an acceptable level where possible. These devices shall be subjected to periodic functional tests and checks.
3. ***Provide warning Devices:*** when neither design or safety devices can effectively minimize a

hazard risk, devices shall be used to detect the hazard condition and alert personnel of its presence. These devices may include visual or audible alarms and/or movable or permanent signs.
4. ***Procedures and Training:*** Only when it is impractical to substantially eliminate or reduce the hazard, or where the condition of the hazard indicates additional emphasis, special operating procedures and training shall be used. All such procedures shall be fully documented.

https://www.lsstcorp.org/docushare/dsweb/Get/LPM-49

2.7.5.3 Safety Plan

ID: OSS-REQ-0101 **Last Modified: 12/1/2010**

Specification: Comprehensive safety plans shall be developed and implemented before construction starts at each of the 4 LSST system sites.

2.7.5.4 Operational Safety Plan

ID: OSS-REQ-0102 **Last Modified: 12/1/2010**

Specification: An operational safety plan shall be developed and implemented before the Commissioning phase starts.

2.7.5.5 Emergency Communications

ID: OSS-REQ-0103 **Last Modified: 12/1/2010**

Specification: The LSST shall be designed, and shall include, the necessary communication equipment to support the necessary machine and personnel communication in both normal and emergency operating conditions at the summit. Other LSST sites are not specifically addressed due to their proximity to normal municipality infrastructure and emergency response services.

Earthquake Display

ID: OSS-REQ-0104 **Last Modified: 5/19/2011**

Specification: The summit facility shall include a comfort display to present summit personnel with information on seismic activity monitored per OSS-REQ-0073 down to a level of 3 on the Richter scale.

Summit Radio Equipment

ID: OSS-REQ-0105 **Last Modified: 12/1/2010**

Specification: LSST shall include radio communication devices to support the personnel necessary to be on the remote summit site. This equipment shall be consistent with Summit radio infrastructure already in place.

2.7.6 Health

ID: OSS-REQ-0106 **Last Modified: 8/4/2010**

Specification: The LSST shall comply with all applicable local and national environmental and occupational health codes, regulations, and standards.

2.7.7 Security

ID: OSS-REQ-0107 **Last Modified: 4/28/2011**

Specification: The LSST shall provide a secure and safe environment for personnel, equipment, and data at each of its 4 operational sites throughout the full life cycle of the project.

2.7.7.1 Cyber Security Agency Requirements

ID: OSS-REQ-0108 **Last Modified: 5/25/2011**

Specification: The LSST shall comply with funding agency requirements for cyber security appropriate to the sensitivity of the project and the data it maintains and produces.

Discussion: This process requires an evaluation of the threat level and of the consequences of a compromise of security. The bulk of the project will generally be subject to security requirements for what is often called an "open/public/unrestricted" environment. In such an environment, the cyber security architecture focuses on maintenance of the integrity of the data and computing systems, and of system availability.

Any sensitive computing systems, such as those used to manage personnel and business data or other Personally Identifiable Information, will be subject to more stringent requirements. The control systems for the LSST Observatory will also require additional levels of security appropriate to SCADA (Supervisory Control and Data Acquisition) for physical systems.

2.7.7.2 Cyber Security Planning

ID: OSS-REQ-0109 **Last Modified: 10/7/2013**

Specification: The LSST project shall produce and maintain a cyber security plan and corresponding system architecture.

Discussion: The plan must comply with agency requirements (see OSS-REQ-0108). It should be based on established best practices appropriate to the sensitivity of the project and the data it maintains and produces. Within that context, it will reflect engineering tradeoffs based on an evaluation of the anticipated threats, capabilities of security systems, the role of personnel in maintaining a secure environment, and the cost of proposed mitigations.

3 Detailed Specifications

3.1 Science and Bulk Data

The composite requirements below concern the acquisition, processing, and management of science data, as well as certain other bulk data such as wavefront sensor images.

3.1.1 Scoping

ID: OSS-REQ-0188 **Last Modified: 10/7/2013**

Discussion: The scoping requirements control the amount of input data and catalog entries the Data Management system is expected to process, archive, distribute, and store, and the query and processing load design point for user support.

The processing load and resources associated with the derived data products are constrained by these requirements, and may be calculated from them, but do not appear here in the OSS.

Many data products are best defined with respect to content, quantity, or quality given certain reference conditions. These conditions are also grouped under this requirement.

3.1.1.1 Raw Exposures Per Night, Maximum

ID: OSS-REQ-0189 **Last Modified: 5/23/2011**

Specification: The LSST Observatory shall support the acquisition, processing, and archiving of a rate of at least **nRawExpNightMax** new science exposures per night, in isolated peaks, and an average rate of **nRawExpNightWinterAvg** for extended periods.

Discussion: These rates are derived from the estimate of **nightDurationMax** hours of science observing on the longest nights of the year, and from the **visitDuration** and **aveVisitInterval** parameters of the standard cadence. The peak requirement is derived by adding two hours of twilight observing and taking a worst-case scenario of short slews: it does not account for any time spent moving to a new field beyond the two-second readout period for the second exposure in a visit.

This requirement does not include calibration exposures, which are considered separately.

Description	Value	Unit	Name
Minimum number of raw science exposures required to be supported by the LSST Observatory in a single-night burst	2800	int	nRawExpNightMax
Minimum number of raw science exposures required to be supported by the LSST Observatory over a sustained period (as during the weeks around the winter solstice)	1960	int	nRawExpNightWinterAvg

3.1.1.2 Raw Exposures Per Year

ID: OSS-REQ-0190 **Last Modified: 10/7/2013**

Specification: The LSST Observatory shall support the acquisition, processing, and archiving of a rate of at least **nRawExpYear** new science exposures per year.

Discussion: This rate is derived from an estimate of an average of 10 hours of science observing per night, 300 nights per year that are available for observing (rounded up after taking **scheduledDownTime** and **cloudCoverFrac** into account), assuming **visitDuration** and **aveVisitInterval** parameters of the standard cadence, and adding a 10% margin.

Description	Value	Unit	Name
Minimum number of raw science exposures required to be supported by the LSST Observatory over the course of a single year	5.5E5	int	nRawExpYear

3.1.1.3 Galaxy Counts

ID: OSS-REQ-0191 **Last Modified: 10/7/2013**

Specification: The LSST Data Management system shall be sized to handle approximately **nGalaxyYr1**

identified galaxies by the end of the processing of the first year's data. It shall be designed to scale to **nGalaxySurvey** galaxies by the end of the planned survey.

Discussion: These numbers are based on peer reviewed estimates collected in the LSST Science Book, Section 3.7.2, and captured in the DM Sizing Model (LSE-81). They assume survey-depth coverage of 25,000 deg^2. Their values depend on the expected depth of single images and the survey. The scaling with time further depends on an assumed luminosity function.

Description	Value	Unit	Name
Minimum number of identified galaxies required to be supported by the end of the processing of the first year's data	8.0E9	int	nGalaxyYr1
Minimum number of identified galaxies required to be supported by the end of the processing of the data from the ten-year survey.	2.0E10	int	nGalaxySurvey

3.1.1.4 Star Counts

ID: OSS-REQ-0192 **Last Modified: 10/7/2013**

Specification: The LSST Data Management system shall be sized to handle approximately **nStarYr1** identified stars by the end of the processing of the first year's data. It shall be designed to scale to **nStarSurvey** stars by the end of the planned survey.

Discussion: These numbers are based on peer reviewed estimates collected in the LSST Science Book, Section 3.7, and captured in the DM Sizing Model (LSE-81). They assume survey-depth coverage of 25,000 deg^2. Their values depend on the expected depth of single images and the survey. The scaling with time further depends on an assumed luminosity function.

Description	Value	Unit	Name
Minimum number of identified stars required to be supported by the end of the processing of the first year's data	1.3E10	int	nStarYr1
Minimum number of identified stars required to be supported by the end of the processing of the data from the ten-year survey.	1.7E10	int	nStarSurvey

3.1.1.5 Alerts per Visit

ID: OSS-REQ-0193 **Last Modified: 10/7/2013**

Specification: The LSST Data Management system shall be sized to accommodate an average value of at least **nAlertVisitAvg** alerts generated per standard visit while meeting all its other requirements. Performance shall degrade gracefully beyond that limit.

Discussion: This is derived directly from the SRD specification for **transN.**

Description	Value	Unit	Name
Minimum number of alerts required to be accommodated from a single standard visit	10000	int	nAlertVisitAvg

3.1.1.6 Calibration Exposures Per Day

ID: OSS-REQ-0194 **Last Modified: 10/7/2013**

Specification: The LSST Observatory shall be capable of collecting at least **nCalibExpDay** calibration exposures per day, while meeting all other requirements for the use of day time for maintenance and other activities and at least **nCalExpMax** over a 24 hour period.

Discussion: These include bias frames, monochromatic flats, broadband flats, and twilight calibration exposures, as described in the Level 2 Photometric Calibration for the LSST Survey (LSE-180). It is understood that calibration data for guider sensors is a part of this data set. The specification for **nCalExpMax** is meant to accommodate a cloudy night that is dedicated to calibration.

Description	Value	Unit	Name
Minimum number of calibration exposures able to be acquired per day under normal operation shall be at least **nCalibExpDay**.	450	int	nCalibExpDay
The number of calibration exposures that can be acquired over a single 24 hour period (e.g. on a cloudy night) shall be at least **nCalibExpMax**.	750	int	nCalibExpMax

3.1.1.7 Calibration Exposures Per Year

ID: OSS-REQ-0323 **Last Modified: 10/7/2013**

Specification: The LSST Observatory shall support the acquisition, processing, and archiving of a rate of at least **nRawCalYear** new Calibration exposures per year.

Description	Value	Unit	Name
The total number of calibration exposures that the observatory must be capable of support over a 1 year period shall be at least **nCalExpYear**.	1.5E5	int	nCalExpYear

3.1.1.8 Bright, Isolated Point Source

ID: OSS-REQ-0337 **Last Modified: 9/22/2012**

Specification: The terms "bright, isolated point source" and "isolated point source" are used repeatedly in the data quality requirements. This is because many of the requirements are specified as an asymptotic value in the absence of contributions from photon statistics or overlapping objects/confusion. For the purposes of defining test cases for these requirements, "bright" shall be understood to mean having a magnitude in the "bright end" range as defined in sec. 3.3 of the SRD. "Isolated point source" shall be understood to mean a point source (typically a star) having no other detected source within a radius of **isolatedRadius** PSF FWHM.

Description	Value	Unit	Name
Radius containing no other detected sources	10	PSF FWHM	isolatedRadius

3.1.2 Science Image Handling Reliability

ID: OSS-REQ-0110 **Last Modified: 5/18/2011**

Discussion: The following requirements place constraints on the losses of and damage to science data

that has been archived and that are processed during each visit.

3.1.2.1 Science Image Archiving Reliability

ID: OSS-REQ-0111 **Last Modified: 9/21/2012**

Specification: No more than **sciImageLoss** % of science, wavefront, and guider images read out in the camera and specified to be acquired by Data Management shall be permanently lost or corrupted, integrated over all stages of data handling through archiving and availability of the image for access in the archive, or have its essential image acquisition metadata permanently lost or disassociated with the image.

Corruption of images shall mean changes of any image pixel values, with the exception of application of a compression algorithm. Any such compression algorithm must be shown to have no effect on any SRD requirement.

Discussion: The "specified to be acquired" language allows for the possibility that under some operating modes, such as diagnostics, images might be acquired by the camera and deliberately not archived.

Description	Value	Unit	Name
Maximum fraction of read-out raw images permitted to be permanently lost or corrupted downstream, including loss due to the loss or corruption of essential associated metadata.	1%	Percent	sciImageLoss

3.1.2.2 Science Visit Alert Generation Reliability

ID: OSS-REQ-0112 **Last Modified: 9/22/2012**

Specification: No more than **sciVisitAlertFailure** % of science visits read out in the camera [and specified to be analyzed by Data Management] shall fail to be subjected to alert generation and distribution, integrated over all stages of data handling from data acquisition through transmission of the alerts across the project boundary.

Specification: No more than **sciVisitAlertDelay** % of science visits read out in the camera [and specified to be analyzed by Data Management] shall have their alert generation and distribution completed later than the SRD specification for alert latency (**OTT1**).

Discussion: The "specified to be analyzed" language allows for the possibility that under some operating modes, such as diagnostics, images deliberately not be analyzed for alerts.

This requirement applies to *visits*, and not to individual alerts, because a specification that, e.g., "no more than 1% of alerts shall fail to be generated" gets tangled with questions of the scientific performance of the actual alert detection. This requirement is a performance specification on the DM system, taking the alert-detection algorithm as a given.

Note: Visits with alerts delayed beyond the latency specification will not have *all* of their alerts generated late. A substantial proportion of the alerts for those visits will still be delivered on time.

Description	Value	Unit	Name
Maximum fraction of science visits for which alerts are generated, but delivered later than the **OTT1** latency	1%	Percent	sciVisitAlertDelay

Description	Value	Unit	Name
specification			
Maximum fraction of visits for which alerts are not generated or distributed	0.1%	Percent	sciVisitAlertFailure

3.1.3 Data Acquisition

ID: OSS-REQ-0113 **Last Modified: 5/23/2011**

[This is a composite requirement in the SysML model, signifying simply the union of the requirements below it in the hierarchy.]

Discussion: These requirements deal primarily with the bulk science data.

3.1.3.1 Acquisition of Science Sensor data

ID: OSS-REQ-0114 **Last Modified: 5/18/2011**

Specification: The LSST data management system shall acquire science images from the camera, for archiving and for further processing.

3.1.3.2 Ancillary Image Data

ID: OSS-REQ-0315 **Last Modified: 5/18/2011**

Specification: The LSST shall provide for the acquisition of other ancillary image data (e.g. data from the auxiliary telescope) needed for the analysis of the science data.

3.1.3.3 Wavefront Sensor Data

ID: OSS-REQ-0316 **Last Modified: 5/18/2011**

Specification: The LSST shall provide for the acquisition of wavefront images used determine the alignment, surface control, and knowledge of the instrumental PSF over the FOV.

3.1.4 Data Processing

ID: OSS-REQ-0116 **Last Modified: 5/18/2011**

[This is a composite requirement in the SysML model, signifying simply the union of the requirements below it in the hierarchy.]

Discussion: These requirements enumerate the general principles that govern the processing of science data.

3.1.4.1 Automated Production

ID: OSS-REQ-0117 **Last Modified: 8/30/2010**

Specification: Level 1 Data Product production shall proceed without the need for routine human intervention in the course of a night's observing.

3.1.4.2 Consistency and Completeness

ID: OSS-REQ-0118 **Last Modified: 8/30/2010**

Specification: The LSST data management system shall ensure that internal processing tasks are carried out on self-consistent and complete inputs, and that means are provided for users to achieve this in their own processing tasks.

Discussion: it should not be possible to inadvertently mix data, calibrations, and code from different data releases. All available data shall be used, and no piece of input data shall be inadvertently double-counted.

Completeness

ID: OSS-REQ-0119 **Last Modified: 8/30/2010**

Specification: Completeness means that every appropriate piece of input data from the data sets intended to be processed, such as images or catalog entries, shall be included exactly once in the processing; i.e., that no data will be inadvertently skipped and that no single piece of data will be used, counted, etc. more than once.

Discussion:

Consistency

ID: OSS-REQ-0120 **Last Modified: 3/16/2010**

Specification: Consistency shall mean that all input data, such as raw images, facility data, catalogs, processed images, metadata, calibrations, camera configuration data, etc., match each other and arise from consistent previous stages of processing, and that all processing is carried out within a single major code release.

3.1.4.3 Open Source, Open Configuration

ID: OSS-REQ-0121 **Last Modified: 8/30/2010**

Specification: All LSST-written data processing software shall be released under an open-source license. All configuration information necessary for users to be able to apply the software to reproduce LSST's processing shall also be made publicly available.

Discussion: The LSST software is permitted to depend on other open-source software packages, and will establish a configuration control mechanism for determining which are acceptable for use in the project.

Discussion: This specification does not prohibit the LSST *production* system from using infrastructure with a proprietary component, if that is justified by a cost-benefit analysis. The software itself must be open-source, and must be able to be run in at least small-scale production on open platforms.

3.1.4.4 Provenance

ID: OSS-REQ-0122 **Last Modified: 9/21/2012**

Specification: The LSST Data Management system shall record provenance data on all its processing activities: all information necessary to reproduce computed data products from the associated raw data, and to understand the processing history of any data product.

This shall include at least: software version and build information, settings of all configurable parameters, history of processing steps, identification of all calibration constants used in processing, and hardware and operating system configurations used.

Discussion: The intent is for provenance information to be sufficient to support the Reproducibility requirement.

3.1.4.5 Reproducibility

ID: OSS-REQ-0123 **Last Modified: 11/18/2010**

Specification: The LSST data management system shall ensure that the results of processing of data are reproducible. Any data processing task, when re-run based on the provenance data from the previous run, on the same system, shall produce the same results (with the exception of provenance data or other execution records that depend on the wall-clock time or on variable system loads). Tasks re-run on different systems shall produce the same results to the extent computationally feasible.

Discussion: "Computationally feasible" refers to the fact that floating-point operations typically can return slightly different results on different hardware platforms. LSST code is required to use reasonable care in the implementation of floating-point computations to avoid the unnecessary accumulation of error, but is not required to adopt computationally costly defensive techniques to avoid differences altogether.

3.1.4.6 Software Development Standards

ID: OSS-REQ-0124 **Last Modified: 8/30/2010**

Specification: The LSST project shall define a set of software development standards that shall govern all code developed under project auspices, as well as open-source code contributed to and accepted by the project from outside. These standards shall take account of best practices in scientific software development and shall incorporate specifications of external programming language and operating system API standards where appropriate.

The software development standards shall be devised to meet applicable project requirements, and shall be under project configuration control.

Discussion: It is intended that these standards will include, for example, statements of which specific version of the C++ and POSIX standards the project will follow.

3.1.5 Data Products

ID: OSS-REQ-0125 **Last Modified: 11/23/2010**

Discussion: This composite requirement contains only the definitions for what data products are required to exist. It does not cover *how* they are produced nor where or how they are *archived* nor what means and level of *access* are to be provided.

3.1.5.1 Level 1 Data Products

ID: OSS-REQ-0126 **Last Modified: 10/7/2013**

Specification: Level 1 data products are intended to enable time-domain science use cases requiring timely alerting and follow-up. They are the result of processing of the stream of image data from the

Camera during normal observing.

Discussion: The baseline list of Level 1 data products is provided as the composite contents of this requirement.

Level 1 Data Product Availability

ID: OSS-REQ-0127 **Last Modified: 10/8/2013**

Specification: With the exception of alerts and Solar System Orbits, all Level 1 Data Products shall be made public within time **L1PublicT** of the acquisition of the data. Solar System Orbits shall be made available within **L1PublicT** of successful moving source linkage and orbit computation. Alerts shall be made available within time **OTT1**, from the conclusion of readout of the raw exposures used to generate each alert to the distribution of the alert to community distribution mechanisms.

Discussion: Level 1 Data Products will in general arise from either the nightly Alert Production or from the daily processing of each night's data, and will be released to the public promptly following the completion of processing. There is no high-level requirement in the SRD on the latency of delivery to external users of Level 1 data products other than transient alerts, but they should be distributed in a timely way.

Alerts

ID: OSS-REQ-0128 **Last Modified: 8/3/2010**

Specification: The Level 1 Data Products shall include the Alerts produced as part of the nightly Alert Production.

Exposures (Level 1)

ID: OSS-REQ-0129 **Last Modified: 10/7/2013**

Specification: The Level 1 Data Products shall include the following types of Exposures:

- Raw Exposures as obtained from the Camera and assembled/re-formatted for processing
- Processed Exposures (trimmed, de-biased, flattened, etc. - i.e., provisionally calibrated)
- Difference Exposures.

Discussion: All exposures, other than raw exposures, may be regenerated on demand from raw data, rather than be physically stored.

Catalogs (Level 1)

ID: OSS-REQ-0130 **Last Modified: 10/7/2013**

Specification: The Level 1 Data Products shall include the following catalogs:

- Exposure meta-data
- Difference Sources (DIASources, detected by comparing visits with reference images for the same field)
- Difference Objects (DIAObjects, inferred from positionally coincident DIASources)
- Difference Forced Sources (DIAForcedSources, obtained by performing photometry at the predicted location of previously detected DIAObjects)

- Solar System Objects (SSObjects, detected by associating sets of DIASources consistent with motion on Keplerian orbits around the Sun)

Discussion: These catalogs are all also recreated from scratch during the production of each Data Release. New Solar System Objects will be identified in daily post-processing.

Nightly Summary Products

ID: OSS-REQ-0131 **Last Modified: 8/3/2010**

Specification: The Level 1 Data Products shall include a variety of reports, generated every night, that summarize the scientific quality of the Level 1 data (SDQA metrics), and the associated Observatory performance and performance of the Data Management subsystem.

Engineering and Facility Database Archive

ID: OSS-REQ-0132 **Last Modified: 8/3/2010**

Specification: The Level 1 Data Products shall include a daily update of the Archive Center copy of the Engineering and Facilities Database (EFD), including all data from the Summit/Base copy of the EFD associated with other released Level 1 Data Products.

Level 1 Data Product Quality

ID: OSS-REQ-0147 **Last Modified: 10/7/2013**

Discussion: The requirements in this area specify the scientific performance required of the LSST Level 1 data products. These are driven by the needs of the science missions in the LSST SRD.

Level 1 Catalog Precision

ID: OSS-REQ-0149 **Last Modified: 10/7/2013**

Specification: Data processing shall contribute no more than a fraction **dmL1PhotoErr** to point source photometric errors in Level 1 data products. Data processing shall contribute no more than an RMS error of **dmL1AstroErr** to point source astrometric errors in Level 1 data products.

Discussion: This requirement will be tested with simulation, and in commissioning using repeated observations of one or more fields.

Description	Value	Unit	Name
Maximum contribution from DM to Level 1 point source astrometric errors	0.1	arcsec	dmL1AstroErr
Maximum contribution from DM to Level 1 point source photometric errors	6	mmag	dmL1PhotoErr

Level 1 Photometric Zero Point Error

ID: OSS-REQ-0152 **Last Modified: 10/7/2013**

Specification: The photometric zero point determined for each CCD in the Level 1 data products shall agree with the final zero point result from photometric calibration within **photoZeroPointOffset**.

Discussion: This is meant to be interpreted as a requirement on the accuracy of the Level 1 photometric zero-point determination algorithm compared to its Level 2 counterpart, and not a requirement on the weather (e.g., the presence or structure of clouds).

Description	Value	Unit	Name
Maximum photometric zero point offset between CCDs and final photometriccalibration	50	mili-Mag	photoZeroPointOffset

Alert Completeness and Purity

ID: OSS-REQ-0166 **Last Modified: 10/7/2013**

[This is a composite requirement in the SysML model, signifying simply the union of the requirements below it in the hierarchy.]

Difference Source Spurious Probability Metric

ID: OSS-REQ-0351 **Last Modified: 10/8/2013**

Specification: The Observatory shall develop a metric to characterize the probability of each reported difference source being spurious.

Discussion: This spuriousness metric will be “prior free” to the extent possible. For example, while it may make use of information from the source and image characterization (e.g., comparison of source to PSF morphology), as well as the information on the Telescope and Camera system (e.g., ghost maps, defect maps, etc.), it will not use any information about the astrophysical neighborhood of the source, whether it has been previously observed or not, etc. The intent is to avoid introducing a bias against unusual sources or sources discovered in unusual environments.

The performance of this metric will be assessed by simulations, by insertion and recovery of artificial sources, and comparisons to ground truth where known (i.e., asteroids, known variable stars, known variable quasars, etc).

Difference Source Sample Completeness

ID: OSS-REQ-0352 **Last Modified: 10/7/2013**

Specification: For each visit, the Observatory shall estimate the detected difference source sample completeness and purity as a function of spuriousness metric threshold cut.

Discussion: Assuming some spuriousness threshold T, a sample of sources with spuriousness $s > T$ will have some purity (defined as the ratio of the number real sources with $s > T$ and the number of all sources with $s > T$), and completeness (defined as the ratio of the number of real sources with $s > T$, and the total number of real sources). This information will aid the end users in selecting the spuriousness threshold appropriate for their particular science case.

Difference Source Spuriousness Threshold - Transients

ID: OSS-REQ-0353 **Last Modified: 10/8/2013**

Specification: There shall exist a spuriousness threshold T for which the completeness and purity of selected difference sources are higher than **transCompletenessMin** and **transPurityMin**, respectively, at the SNR detection threshold **transSampleSNR**. This requirement is to be interpreted as an average

over the entire survey.

Discussion: This specification captures representative completeness and purity rates supportive of time-domain science cases. Note that these are rates determined only using the spuriousness metric cut; it is likely the end-users will perform further classification steps to increase the purity of their samples, depending on their particular science case.

This specification will be tested using simulations, by insertion and recovery of artificial sources, and comparisons to ground truth where known (i.e., asteroids, known variable stars, known variable quasars, etc).

Description	Value	Unit	Name
Minimum average completeness for transient science	90	Percent	transCompletenessMin
Minimum average purity for transient science	95	Percent	transPurityMin
SNR threshold at which the above are evaluated	6	int	transSampleSNR

Difference Source Spuriousness Threshold - MOPS

ID: OSS-REQ-0354 **Last Modified: 10/8/2013**

Specification: There shall exist a spuriousness threshold *T* for which the completeness and purity of difference sources are higher than **mopsCompletenessMin** and **mopsPurityMin**, respectively, at the SNR detection threshold **orbitObservationThreshold**. This requirement is intended to be interpreted as an average for any one month of observing.

Discussion: This specification captures representative completeness and purity rates needed to enable successful identification and linking of observed Solar System objects. In particular, the need to have a Solar System object repeatedly detected **orbitObservation** times in **orbitObservationInterval** days strongly prefers high completeness, even at the expense of purity.

This specification will be tested using simulations, by insertion and recovery of artificial sources, and comparisons to ground truth where known (i.e., asteroids, known variable stars, known variable quasars, etc).

Description	Value	Unit	Name
Minimum average completeness for Solar System object discovery	99	Percent	mopsCompletenessMin
Minimum average purity for Solar System object discovery	50	Percent	mopsPurityMin

Level 1 Difference Source - Difference Object Association Quality

ID: OSS-REQ-0160 **Last Modified: 10/7/2013**

Specification: The fraction of isolated Difference Sources not flagged as likely artifacts that are associated with an incorrect Difference Object shall be less than **sourceMisassociation** for Difference Sources brighter than **sourceAssocThreshold** sigma in a single visit.

Discussion: Source association algorithms that take Difference Object characteristics, such as proper motions, positional error estimates, or shapes, may be needed to satisfy this requirement. The verification method will be by comparison with simulated inputs.

Description	Value	Unit	Name
Significance threshold for testing of Source-Object associations	5	Sigma	sourceAssocThreshold
Maximum fraction of significant Source detections that may be associated with the wrong Object	0.1	Percent	sourceMisassociation

Level 1 Moving Object Quality

ID: OSS-REQ-0159 **Last Modified: 10/7/2013**

Specification: Valid identification and orbits shall be determined for at least a fraction **orbitCompleteness** of Solar System objects which are detected **orbitObservations** times in **orbitObservationInterval** days at a level **orbitObservationThreshold** sigma or more above the single frame background.

Discussion: Valid identification means that detections of the same Solar System objects have been correctly associated as such. The verification method for this requirement will be comparison with simulated inputs.

Description	Value	Unit	Name
Minimum fraction of Solar System objects meeting reference criteria for which valid orbits shall be determined	95%	Percent	orbitCompleteness
Interval over which a reference test case Solar System object must be observed within a night	90	minutes	orbitNightlyObservationInterval
Interval over which a reference test case Solar System object must be observed	3	days	orbitObservationInterval
Number of detections within a single night required to define the reference test case for Solar System objects	2	int	orbitObservations
Significance threshold required for moving object detections to be included in the reference test case definition	5	Sigma	orbitObservationThreshold

3.1.5.2 Level 2 Data Products

ID: OSS-REQ-0133 **Last Modified: 9/21/2012**

Specification: Level 2 Data Products shall periodically be derived from a processing pass over the complete data set.

Discussion: The baseline list of Level 2 data products is provided as the composite contents of this requirement.

Level 2 Data Product Availability

ID: OSS-REQ-0134 **Last Modified: 9/21/2012**

Specification: All Level 2 Data Products shall be made public as part of a Data Release, with releases coming at least once every time **DRT1**, and as soon as possible following the completion of data release processing as is consistent with verifying the applicable data quality requirements.

Discussion: Data Release processing will be initiaed more frequently during the first year of the survey.

Uniformly calibrated and processed versions of Level 1 Data Products

ID: OSS-REQ-0135 **Last Modified: 5/18/2011**

Specification: In association with the production of the Level 2 Data Products, a data release shall also include uniformly processed and calibrated versions of all the Level 1 Data Products.

Co-added Exposures

ID: OSS-REQ-0136 **Last Modified: 10/7/2013**

Specification: The Level 2 Data Products shall include the following types of co-added Exposures, covering the full exposed area of the survey:

- Template co-adds for creating Difference Exposures, per filter band
- Detection co-adds for object detection, optimized for the faintest limiting magnitude; may be both multi-band and single-band
- Multi-band (RGB) co-adds for visualization and EPO

Catalogs (Level 2)

ID: OSS-REQ-0137 **Last Modified: 10/7/2013**

Specification: The Level 2 Data Products shall include the following catalogs, created anew, uniformly, during the production of each Data Release:

- Object
- Solar System Object
- Source
- Forced Source

In addition, the Exposure catalog shall be updated with the latest derived metadata, such as WCS and PSF.

Release Independence

ID: OSS-REQ-0138 **Last Modified: 11/18/2010**

Specification: Each Data Release shall consist of a complete reprocessing of the entire LSST data set on a uniform footing, and shall not require access to the data products of any previous Data Release to interpret.

Discussion: This does not prevent some results of one Data Release from being used as a seed for an iterative refinement of some calibration or reference catalog. It does require that any data so used, e.g., from Data Release N-1, be incorporated by value as part of the contents of Data Release N.

Level 2 Data Product Quality

ID: OSS-REQ-0338 **Last Modified: 10/7/2013**

Discussion: The requirements in this area specify the scientific performance required of the LSST Level 2 data products. These are driven by the needs of the science missions in the LSST SRD.

Level 2 Catalog Accuracy

ID: OSS-REQ-0162 **Last Modified: 10/7/2013**

Specification: DM processing shall result in products with photometric accuracy and precision consistent with OSS-REQ-0275. DM processing shall contribute no more than an RMS error of **dmL2AstroErr** to point source astrometric errors in Level 2 data products.

Discussion: The verification method for this requirement will be comparison with simulated inputs.

Description	Value	Unit	Name
Maximum contribution from DM to Level 2 point source astrometric errors	0.05	arcsec	dmL2AstroErr

World Coordinate System Accuracy

ID: OSS-REQ-0153 **Last Modified: 9/22/2012**

Specification: WCS inaccuracies, including any refinements due to astrometric calibration, in processed images shall contribute no more than **wcsAbsoluteError** to the PSF FWHM of template and deep detection coadds.

Description	Value	Unit	Name
Maximum contribution from WCS inaccuracy to the PSF FWHM in template and deep detection coadds	0.1	Pixels	wcsAbsoluteError

Level 2 Source-Object Association Quality

ID: OSS-REQ-0339 **Last Modified: 5/3/2012**

Specification: The Level 2 source-object association quality requirements are the same as at Level 1; see OSS-REQ-0160.

Coaddition for Deep Detection

ID: OSS-REQ-0157 **Last Modified: 10/7/2013**

Specification: False detections on the deep detection coadds caused by unremoved artifacts from moving objects, transient objects, and other instrumental artifacts (e.g. glints) shall be no more than **falseDeepDetect** fraction of all detections on those coadds. This specification will be tested using simulations under realistic survey conditions encountered in Commissioning.

Discussion: The scientific rationale for this requirement is that statistical studies of real objects (galaxies, stars) are not overwhelmed by false detections. 0.1% is a reasonable number that achieves this. This is also a reasonable upper limit based on experience with existing surveys.

Description	Value	Unit	Name
Fraction of all detections on deep detection coadds caused by unremoved artifacts	0.1%	percent	falseDeepDetect

Coaddition for Templates for Subtraction

ID: OSS-REQ-0158 **Last Modified: 10/7/2013**

Specification: Subtraction templates shall contribute no more than a fraction **templateNoiseLevelY1** to the noise of the difference images in year 1 of the survey and **templateNoiseLevelY2** to the noise in subsequent years of the survey. (The variance of the difference image shall be no more than 1 + **templateNoiseLevelY1** times the variance of the single visit image.)

Discussion: Note that this requirement imposes a constraint on the scheduler to obtain some minumum number of exposures of each part of the sky in order for it to be met. The time variation in this requirement reflects the fact that the first-year templates may not have as many epochs available as subsequent years.

Description	Value	Unit	Name
Maximum permissible fraction of the noise level in difference images contributed by the subtraction template in Year 1	40	Percent	templateNoiseLevelY1
Maximum permissible fraction of the noise level in difference images contributed by the subtraction template in Year 2 and following	20	Percent	templateNoiseLevelY2

Deep Detection and Measurement Quality

ID: OSS-REQ-0161 **Last Modified: 10/7/2013**

Specification: The deep detection and measurement shall meet the implied requirements from the SRD on coadded depth, assuming the nominal survey conditions.

For a galaxy with elliptical isophots and Sersic radial profile with radius **ellipTestRadius** and Sersic index **ellipTestSersicIndex**, the ellipse parameters shall be measured to an accuracy **ellipAccuracy1** for galaxies detected on the coadd at a signal-to-noise **ellipTestSNR1**, and **ellipAccuracy2** for galaxies detected on the coadd at a signal-to-noise **ellipTestSNR2**.

Discussion: While the detection will be performed on full-depth coadds, the measurement may use techniques such as multifit, that perform measurements using individual epoch data. The verification method for this requirement will be comparison with simulated inputs.

Description	Value	Unit	Name
Galaxy radius definition for the ellipse parameter accuracy test	5	Arcsec	ellipTestRadius
Galaxy Sersic index definition for the ellipse parameter accuracy test	1	float	ellipTestSersicIndex
Reference SNR #1 for ellipse parameter accuracy test	10	int	ellipTestSNR1
Reference SNR #2 for ellipse parameter accuracy test	1000	int	ellipTestSNR2
Maximum RMS error on ellipse parameters measured for a galaxy of magnitude **ellipTestSNR1**	1	Percent	ellipAccuracy1
Maximum RMS error on ellipse parameters measured for a galaxy of magnitude **ellipTestSNR2**	.01	Percent	ellipAccuracy2

Object Deblending

ID: OSS-REQ-0155 **Last Modified: 10/7/2013**

Specification: The Observatory shall be capable of measuring properties of overlapping (blended) objects. Any degradation of accuracy and precision in measurement of blended objects shall be bounded

by the need to satisfy LSR-REQ-0043 through LSR-REQ-0046.

Discussion: This requirement will give rise to a deblender software component, or an algorithm to perform simultaneous measurements of blended objects. While it is extremely difficult to write quantitative yet all-encompassing and actionable requirements on the deblender, it is understood that it is primarily an enabling component to perform measurements and statistical studies involving those measurements. Therefore, its performance will be evaluated by assessing the efficacy of measurements that employ it, and studies that depend on those measurements (e.g., in the context of weak lensing).

Level 2 Moving Object Quality

ID: OSS-REQ-0340 **Last Modified: 5/3/2012**

Specification: The Level 2 moving object quality requirements are the same as at Level 1; see OSS-REQ-0159.

Catalog Completeness and Reliability

ID: OSS-REQ-0164 **Last Modified: 5/3/2012**

Specification: The object catalog completeness and reliability shall be determined by the data management system for a variety of astrophysical objects to be specified by the LSST Science Council.

Discussion: Objects that will be evaluated for completeness in the catalogs will include at least stars of a range of colors, small galaxies on both the red- and blue-sequence at a range of redshifts, and supernovae at a range of redshifts, and will be reported as a function of magnitude.

Further, provisions will be made to determine completeness and reliability of more specialized object types through injection of synthetic objects into the DM pipelines during the Data Release processing (ie. not part of the live data stream).

3.1.5.3 Level 3 Data Products

ID: OSS-REQ-0139 **Last Modified: 10/7/2013**

Specification: The LSST Observatory shall support Level 3 Data Products that are the result of processing based on Level 1 and Level 2 Data Products, of a nature specified by users (by the provision of code and/or processing configuration data).

Discussion: This is flowed down from LSR-REQ-0041.

Production

ID: OSS-REQ-0140 **Last Modified: 8/3/2010**

Specification: It shall be possible to create Level 3 Data Products either using external or internal (Data Access Center) resources, provided they meet certain requirements. LSST shall provide a set of specifications and a software toolkit to facilitate this.

Level 3 Data Products may consist of new catalogs, additional data to be federated with existing catalogs, or image data.

Storage

ID: OSS-REQ-0141 **Last Modified: 8/3/2010**

Specification: The LSST Data Management system shall provide for the archiving of Level 3 Data Products that meet project-specified requirements.

Access

ID: OSS-REQ-0142 **Last Modified: 8/3/2010**

Specification: Archived Level 3 Data Products shall be capable of being federated with and analyzed in conjunction with Level 1, Level 2, and other Level 3 Data Products. The LSST project shall support access controls for Level 3 Data Products that allow them to be restricted to specific individuals or groups as well as released for public access.

Resource Allocation

ID: OSS-REQ-0143 **Last Modified: 8/3/2010**

Specification: The LSST project shall define a resource allocation policy and mechanism for arbitrating among the calls on Level 3 Data Product production, archiving, and analysis resources.

3.1.5.4 Internal Data Products

ID: OSS-REQ-0144 **Last Modified: 5/19/2011**

[This is a composite requirement in the SysML model, signifying simply the union of the requirements below it in the hierarchy.]

Science Data Quality Analysis

ID: OSS-REQ-0145 **Last Modified: 10/7/2013**

Specification: The facilities and software of LSST Observatory shall be designed and built so that Data Quality Analysis during operations is supported.

Discussion: For example, a DQA group should be able to monitor metrics and undertake data explorations of outliers. Automated searches and monitoring of known issues (example: known systematics) during pipeline processing could provide alerts to the operator and DQA group.

WCS Reporting

ID: OSS-REQ-0146 **Last Modified: 5/18/2011**

Specification: The LSST data management system shall make available to other Observatory systems a WCS solution for each exposure. The WCS is a computational map from pixel coordinates to sky (ra, dec) coordinates, and will have an RMS error of no more than **wcsReportingPrecision** within a time **wcsReportingLatency** of the completion of data readout for a standard visit.

Discussion: This is in addition to the archiving of the WCS solution as part of the metadata for each processed exposure. The purpose of this report is for the monitoring and potential recalculation of the accuracy of the mount model. The WCS reporting will be done with using the OCS publish/subscribe mechanism used for other observatory telemetry reporting.

Description	Value	Unit	Name
Maximum RMS uncertainty on the comparison of observed and reference star positions from the real-time WCS reporting	0.2	ArcsecRMS	wcsReportingPrecision
Maximum time for the reporting of telemetry data containing WCS solutions from the completion of the readout of the data for a standard visit	60	Seconds	wcsReportingLatency

3.1.6 Data Archiving

ID: OSS-REQ-0167 **Last Modified: 11/23/2010**

Specification: The LSST project shall create and manage an archive of all its public data products and the raw data necessary to reproduce them. In addition, the archive shall contain all necessary engineering and calibration data for the full understanding of the performance and operation of the Observatory.

3.1.6.1 Science Sensor Raw Data

ID: OSS-REQ-0168 **Last Modified: 8/27/2010**

Specification: The LSST project shall archive all raw data acquired from the science sensor array during operation of the Observatory.

3.1.6.2 Data Products

ID: OSS-REQ-0169 **Last Modified: 5/23/2011**

Specification: The LSST project shall archive each of its Level 1 and Level 2 data products, or the complete set of inputs and provenance necessary to reproduce it, for the lifetime of the survey.

Discussion: Some data products are archived, while others, such as calibrated exposures, are intended to be recreated on demand.

3.1.6.3 Calibration Data

ID: OSS-REQ-0170 **Last Modified: 8/27/2010**

Specification: The LSST project shall archive all raw data acquired from the calibration instrumentation and processes.

3.1.6.4 Engineering and Facilities Data

ID: OSS-REQ-0171 **Last Modified: 5/18/2011**

Specification: The LSST project shall archive all engineering and facility data required to (recreate the physical state of the observatory).

Discussion: This is not intended to be a live copy of the EFD, but rather a periodic transfer of a copy of the live database operating at the Base Facility.

3.1.6.5 Provenance Archiving

ID: OSS-REQ-0172 **Last Modified: 8/30/2010**

Specification: The LSST project shall archive all processing provenance associated with archived data products.

3.1.6.6 Wavefront Sensor Raw Data

ID: OSS-REQ-0173 **Last Modified: 10/7/2013**

Specification: The LSST project shall archive all raw data acquired from the wavefront sensing system during operation of the Observatory.

3.1.6.7 Data Archive Lifetime

ID: OSS-REQ-0174 **Last Modified: 5/23/2011**

Specification: The LSST data archive design shall facilitate the maintenance of the archive beyond the lifetime of the survey.

Discussion: The project recognizes that there will be great long-term interest in the availability of its data set.

Planning for long-term data curation should be guided by funding agency policies and requirements. This is an active area of research and policy development at present, which LSST should follow as the design and construction process continues.

This requirement does not commit the project to fund the operations costs of the archive beyond the lifetime of the survey. The intent here is to facilitate an orderly transition.

3.1.6.8 Redundant Backup of Archive

ID: OSS-REQ-0175 **Last Modified: 5/23/2011**

Specification: The LSST project shall ensure that a redundant and physically separate copy is maintained of the
1. raw science data;
2. raw calibration data;
3. the full engineering and facility data required to make use of the science and calibration raw data above; and
4. all science data products or the data necessary to reproduce them.

Discussion: This requirement goes beyond merely using the appropriate engineering required to meet the archive reliability requirements. It requires a backup that can be used for disaster recovery. The intent is that this redundant copy will be maintained at the Base Facility. It does not have to have the access performance required of the "live" copy.

3.1.7 Data Access

ID: OSS-REQ-0176 **Last Modified: 11/23/2010**

Specification: The LSST Data Management System shall provide open access to all LSST Level 1 and Level 2 Data Products, as defined in the LSST System Requirements and herein, in accordance with LSSTC Board approved policies. The LSST project shall make available open-source software for querying and processing the data products and for generating Level 3 Data Products, and limited

computing and storage resources for performing such analyses and productions.

3.1.7.1 Data Access Environment

ID: OSS-REQ-0177 **Last Modified: 5/18/2011**

Specification: The LSST shall provide an open-source environment for access to its public data products, including images and catalogs.

Discussion: It is expected that this software will be written to be compatible with common varieties of Linux, and perhaps other widely available Unix-like operating systems.

See also the "Software Development Standards" requirement elsewhere in this document.

It is a design goal of the LSST Data Management software that it be portable within the family of Unix-like operating systems. It is also a goal to separate, as much as possible, the parts of the code that implement substantive image processing and astronomical algorithms from the parts with platform dependencies.

3.1.7.2 Data Distribution

ID: OSS-REQ-0178 **Last Modified: 8/29/2010**

Specification: The LSST project shall facilitate the distribution of its data products in bulk to other sites and institutions willing to host it, in accordance with LSSTC Board approved policies for data release.

Discussion: This does not require the LSST project to absorb the marginal costs of the actual distribution, e.g., the provision of increased network bandwidth between the Archive Center and the external consumer.

3.1.7.3 Data Products Processing Infrastructure

ID: OSS-REQ-0179 **Last Modified: 11/18/2010**

Specification: The Data Management System shall provide at least a fraction **userComputingFraction** of its total capability for user-dedicated processing and user-dedicated storage, including for the generation of Level 3 data products.

Discussion: This allocation does not include the resources needed to support the expected load of queries against the catalog database.

3.1.7.4 Data Products Query and Download Availability

ID: OSS-REQ-0180 **Last Modified: 5/23/2011**

Specification: The data product query and download system at each Data Access Center shall be available to end users a fraction **dpAvailabilityFraction** of the time, averaged over a year. Individual outages shall be no longer than **dpAvailabilityOutage** working days.

These include both scheduled and unscheduled downtime.

Description	Value	Unit	Name

Description	Value	Unit	Name
Minimum fraction of the time that data products are available for query and/or download, including scheduled and unscheduled downtime.	98	Percent	dpAvailabilityFraction
Maximum duration of a single outage of data product access, in working days.	3	Days	dpAvailabilityOutage

3.1.7.5 Data Products Query and Download Infrastructure

ID: OSS-REQ-0181 **Last Modified: 8/29/2010**

Specification: The LSST project shall provide processing, storage, and network resources for general community query and download access to LSST data products.

Discussion: The resources to be provided will be based on a sizing model using representative queries derived from the key science goals of LSST.

3.1.7.6 Transient Alerts

ID: OSS-REQ-0183 **Last Modified: 11/17/2010**

[This is a composite requirement in the SysML model, signifying simply the union of the requirements below it in the hierarchy.]

Transient Alert Publication

ID: OSS-REQ-0184 **Last Modified: 11/17/2010**

Specification: Transient alerts shall be published to community alert distribution networks using community-standard protocols, to be determined during the LSST construction phase as community standards evolve.

Discussion: The intent is to use a community standard like VOEvent, assuming that the standard as of the time of LSST construction meets the project's requirements.

Transient Alert Query

ID: OSS-REQ-0185 **Last Modified: 11/17/2010**

Specification: All published transient alerts, as well as all reprocessed historical alerts generated as part of a Data Release, shall be available for query.

Discussion: This allows users to perform statistical analyses on alerts, which are of interest both for actually published, real-time alerts, e.g., for assessment of the quality of the real-time alert analysis, and for uniformly reprocessed alerts in Data Releases, e.g., for optimally calibrated studies of the statistics of actual astrophysical transients.

3.1.7.7 Access to Previous Data Releases

ID: OSS-REQ-0186 **Last Modified: 10/7/2013**

Specification: The LSST project shall maintain user access to the contents of Data Releases prior to the current one. However, this facility may be provided with substantially reduced performance and capability

compared to the access provided to the most recent Data Release.

Discussion: Data Releases other than the two most recent ones are planned to be archived on tape (e.g., as database table dumps) and be accessible as bulk downloads only. End-users interested in these products are expected to use their own hardware and set up any the necessary software infrastructure (e.g., databases).

3.1.7.8 Information Security

ID: OSS-REQ-0187 **Last Modified: 5/18/2011**

Specification: The LSST project shall ensure that Personally Identifiable Information (PII) and other sensitive data relating to individuals or business relationships are protected from unauthorized disclosure, as required by law and applicable standards.

Discussion: Data of this nature is not expected to be part of the science data set, but could arise in the engineering and facilities data collected as part of Observatory operations (e.g., information associated with the operations personnel). PII may also be associated with the resource management in Data Access Centers (e.g. names, addresses, etc. for researchers producing Level 3 data products).

3.2 Optical System

The LSST shall be design and constructed using the following specifications for:

1. Optical design Prescription
2. Optical Alignment and Compensation
3. Ghost Image Control
4. Stray and Scattered Light Control

3.2.1 Optical Design Specification

ID: OSS-REQ-0200 **Last Modified: 11/23/2010**

Specification: The LSST optical system shall be a Mersene-Schmidt design consisting of a 3-mirror modified Paul-Baker telescope and a 4-element (3 lenses + filter) refractive corrector.

Discussion: The reference optical prescription is given below with details and performance discussed in document LSE-11. The prescription contains parameters to define each surface, their separations, and clear apertures.

All parameters follow the sign conventions used by the Zemax raytracing software.
https://www.lsstcorp.org/docushare/dsweb/Get/LCR-14
https://www.lsstcorp.org/docushare/dsweb/Get/LSE-11

3.2.1.1 M1 Prescription

ID: OSS-REQ-0201 **Last Modified: 7/19/2010**

Specification: The surface prescription of the primary mirror (M1) shall be defined by the table of parameters **m1Prescription:**

Description	Value	Unit	Name

Description	Value	Unit	Name
The primary mirror outer clear aperture radius shall be at least **m1OuterCa.**	4180.0	mm	m1OuterCa
The primary mirror inner clear aperture radius shall be no more than **m1InnerCa.**	2558.0	mm	m1InnerCa
The primary mirror radius of curvature shall be **m1Radius**	-19835.0	mm	m1Radius
The primary mirror surface conic constant shall be **m1ConicConstant.**	-1.2150		m1ConicConstant
The primary mirror surface 6th order aspheric coefficient shall be **m1_6thAsphere**	1.381e-24	mm^-5	m1_6thAsphere

3.2.1.2 M2 Prescription

ID: OSS-REQ-0202 **Last Modified: 7/19/2010**

Specification: The surface prescription of the secondary mirror (M2) shall be defined by the table of parameters **m2Prescription:**

Description	Value	Unit	Name
The secondary mirror (m2) outer clear aperture radius shall be **m2OuterCa.**	1710.0	mm	m2OuterCa
The secondary mirror (m2) inner clear aperture radius shall be **m2InnerCa**	900.0	mm	m2InnerCa
The secondary mirror surface radius of curvature shall be **m2Radius.**	-6788.0	mm	m2Radius
The secondary mirror surface conic constant shall be **m2Conic.**	-0.2220		m2Conic
The secondary mirror surface 6th order aspheric coefficient shall be **m2_6thAsphere.**	-1.274e-20	mm^-5	m2_6thAsphere
The secondary mirror surface 8th order aspheric coefficient shall be **m2_8thAsphere.**	-9.680e-28	mm^-7	m2_8thAsphere

3.2.1.3 M3 Prescription

ID: OSS-REQ-0203 **Last Modified: 7/19/2010**

Specification: The surface prescription of the tertiary mirror (M3) shall be defined by the table of parameters **m3Prescription:**

Description	Value	Unit	Name
The tertiary mirror outer clear aperture radius shall be at least **m3OuterCa.**	2508.0	mm	m3OuterCa
The tertiary mirror inner clear aperture radius shall be at least **m3InnerCa.**	550.0	mm	m3InnerCa
The tertiary mirror surface radius of curvature shall be **m3Radius.**	-8344.5	mm	m3Radius
The tertiary mirror surface conic constant shall be **m3Conic.**	0.1550		m3Connic
The tertiary mirror surface 6th order aspheric coefficient shall be **m3_6thAsphere.**	-4.500e-22	mm^-5	m3_6thAsphere
The tertiary mirror surface 8th order aspheric coefficient shall	-8.150e-	mm^-7	m3_8thAsphere

Description	Value	Unit	Name
be **m3_8thAsphere.**	30		

3.2.1.4 Mirror Spacings

ID: OSS-REQ-0204 **Last Modified: 7/19/2010**

The prescription for the separation of the successive mirror surfaces and the next optical element in the system shall be defined by the parameters in table **mirrorSpacings**

Description	Value	Unit	Name
The distance from the vertex of M1 to the vertex of M2 shall be **m1m2Spacing**	-6156.2006	mm	m1m2Spacing
The distance from the vertex of M2 to the vertex of M3 shall be **m2m3Spacing**	6390.0006	mm	m2m3Spacing
The distance from the vertex of M3 to the vertex of the first surface of L1 in the r-band shall be **m2l1Spacing**	-3631.273	mm	m3l1Spacing

3.2.1.5 L1 Prescription

ID: OSS-REQ-0205 **Last Modified: 7/19/2010**

Specification: The prescription of the first lens (L1) shall be defined by the table of parameters **l1Prescription:**

Description	Value	Unit	Name
The first lens (L1) shall be fabricated from **l1GlassType**	Fused Silica		l1GlassType
The clear aperture radius of the first lens (L1) shall be **l1OuterCa**	775	mm	l1OuterCa
The radius of the first surface (s1) of the first lens (l1) shall be **l1_s1Radius**	-2824.0	mm	l1_s1Radius
The center thickness of the first lens (L1) shall be **l1CenThic**	82.23	mm	l1CenThick
The radius of the second surface (s2) of the first lens (l1) shall be **l1_s2Radius**	-5021.00	mm	l1_s2Radius

3.2.1.6 L2 Presciption

ID: OSS-REQ-0206 **Last Modified: 7/19/2010**

Specification: The prisciption of the second lens (L2) shall be defined by the table of parameters **l2Prescription:**

Description	Value	Unit	Name
The second lens (L2) shall be fabricated from **l2GlassType**	Fused Silica		l2GlassType
The clear aperture radius of the second lens (L2) shall be **l2OuterCa**	551.0	mm	l2OuterCa
The radius of the first surface (s1) of the second lens (l2)	Infinite		l2_s1Radius

Description	Value	Unit	Name
shall be **l2_s1Radius**			
The center thickness of the second lens (L2) shall be **l2CenThic**	30.00	mm	l2CenThick
The radius of the second surface (s2) of the second lens (l2) shall be **l2_s2Radius**	-2529.0	mm	l2_s2Radius
The second surface (s2) conic constant on the second lens (L2) shall be **l2_s2Conic**.	-1.5700		l2_s2Conic
The second surface 6th order aspheric coefficient on the second lens shall be **l2_s2_6thAsphere.**	1.656e-18	mm^-5	l2_s2_6thAsphere

3.2.1.7 Filter Prescription

ID: OSS-REQ-0207 **Last Modified: 7/19/2010**

Specification: The prisciption of the filter substrates shall be defined by the table of parameters **filterPrescription:**

Description	Value	Unit	Name
The third lens (L3) shall be fabricated from **l3GlassType**	Fused Silica		filterGlassType
The clear aperture radius of the filter substrates shall be **filterOuterCa**	378.0	mm	filterOuterCa
The radius of the first surface (s1) of the filter substrates shall be **filter_s1Radius**	-5632.0	mm	filter_s1Radius
The thicknes of the u-band filter substrate shall be **filterThick_u**	26.60	mm	filterThick_u
The thicknes of the g-band filter substrate shall be **filterThick_g**	21.50	mm	filterThick_g
The thicknes of the r-band filter substrate shall be **filterThick_r**	17.90	mm	filterThick_r
The thicknes of the i-band filter substrate shall be **filterThick_i**	15.70	mm	filterThick_i
The thicknes of the z-band filter substrate shall be **filterThick_z**	14.4	mm	filterThick_z
The thicknes of the y-band filter substrate shall be **filterThick_y**	13.60	mm	filterThick_y
The radius of the second surface (s2) of the u-band filter substrate shall be **filter_s2Radius_u**	-5530.0	mm	filter_s2Radius_u
The radius of the second surface (s2) of the g-band filter substrate shall be **filter_s2Radius_g**	-5576.0	mm	filter_s2Radius_g
The radius of the second surface (s2) of the r-band filter substrate shall be **filter_s2Radius_r**	-5606.0	mm	filter_s2Radius_r
The radius of the second surface (s2) of the i-band filter substrate shall be **filter_s2Radius_i**	-5623.0	mm	filter_s2Radius_i
The radius of the second surface (s2) of the z-band filter substrate shall be **filter_s2Radius_z**	-5632.0	mm	filter_s2Radius_z
The radius of the second surface (s2) of the y-band filter substrate shall be **filter_s2Radius_y**	-5640.0	mm	filter_s2Radius_y

3.2.1.8 L3 Prescription

ID: OSS-REQ-0208 **Last Modified: 7/19/2010**

Specification: The prescription of the third lens (L3) shall be defined by the table of parameters **l3Prescription:**

Description	Value	Unit	Name
The third lens (L3) shall be fabricated from **l3GlassType**	Fused Silica		l3GlassType
The clear aperture radius of the third lens (L3) shall be **l3OuterCa**	361.0	mm	l3OuterCa
The radius of the first surface (s1) of the third lens (L3) shall be **l3_s1Radius**	-3169.0	mm	l3_s1Radius
The first surface (s1) conic constant on the third lens (L3) shall be **l3_s1Conic**.	-0.9620		l3_s1Conic
The center thickness of the third lens (L3) shall be **l3CenThic**	60.00	mm	l3CenThick
The radius of the second surface (s2) of the third lens (L3) shall be **l3_s2Radius**	13360.0	mm	l3_s2Radius

3.2.1.9 Lens Spacings

ID: OSS-REQ-0209 **Last Modified: 7/19/2010**

The prescription for the separation of the successive lenses in the system shall be defined by the parameters in table **lensSpacings**

Description	Value	Unit	Name
The distance from the vertex of the second surface of L1 to the vertex of the first surface of L2 shall be **l1_l2Spacing.**	-412.642	mm	l1_l2Spacing
The distance from the vertex of the second surface of L2 to the vertex of the first surface of the filter substrate shall be **L2_filterSpacing.**	-349.58	mm	l2_filterSpacing
The distance from the vertex of the second surface of the u-band filter substrate to the vertex of the first surface of L3 shall be **L3_filterSpacing_u.**	-42.40	mm	L3_filterSpacing_u
The distance from the vertex of the second surface of the g-band filter substrate to the vertex of the first surface of L3 shall be **L3_filterSpacing_g.**	-47.50	mm	L3_filterSpacing_g
The distance from the vertex of the second surface of the r-band filter substrate to the vertex of the first surface of L3 shall be **L3_filterSpacing_r.**	-51.10	mm	L3_filterSpacing_r
The distance from the vertex of the second surface of the i-band filter substrate to the vertex of the first surface of L3 shall be **L3_filterSpacing_i.**	-53.30	mm	L3_filterSpacing_i
The distance from the vertex of the second surface of the z-band filter substrate to the vertex of the first surface of L3 shall be **L3_filterSpacing_z.**	-54.60	mm	L3_filterSpacing_z
The distance from the vertex of the second surface of the y-band filter substrate to the vertex of the first surface of L3 shall be **L3_filterSpacing_y.**	-55.40	mm	L3_filterSpacing_y

Description	Value	Unit	Name
The distance from the vertex of the second surface of L3 to the focal plane array (FPA) shall be **l3_fpaSpacing.**	-28.50	mm	l3_fpaSpacing

3.2.2 Optical Alignment and Compensation

ID: OSS-REQ-0210 **Last Modified: 11/23/2010**

Discussion: The LSST optical design has been analyzed for its ability to compensate for errors in alignment and optical fabrication. There are two "one time" compensators in the lens positions that correct for fabrication errors in radii and conic constants of the mirrors. Additionally there are 10 degrees of freedom between the secondary mirror and the camera optics for alignment. The specifications below constrain the minimum range of adjustment for each compensator.

3.2.2.1 Dynamic Alignment and Figure Compensation

ID: OSS-REQ-0211 **Last Modified: 7/21/2010**

Specification: The LSST optical shall dynamically compensate for deflections and deformation caused by gravity and thermal gradients.

Secondary (M2) Adjustement

ID: OSS-REQ-0212 **Last Modified: 8/30/2010**

Specification: The rigid body position of the secondary mirror shall be adjustable in 5 degrees of freedom (decenter x-y, piston along the optical axis, tilt x-y) over a range specified in the table below.

Description	Value	Unit	Name
The range of motion of the secondary on either side of its nominal design position in the x-direction.	10	mm	x-decenterRangeM2
The range of motion of the secondary on either side of its nominal design position in the y-direction.	10	mm	y-decenterRangeM2
The range of motion of the secondary on either side of its nominal design position in the z-direction.	10	mm	z-positionRangeM2
The range of tilt of the secondary on either side of its nominal design position about the x-axis.	0.1	Degrees	x-tiltRangeM2
The range of tilt of the secondary on either side of its nominal design position about the y-axis.	0.1	Degrees	y-tiltRangeM2

Camera Adjustment

ID: OSS-REQ-0213 **Last Modified: 5/16/2011**

Specification: The rigid body position of the camera optical system (3 lenses, filter and focal plane) shall adjustable in 5 degrees of freedom over a range specified in the table below.

Description	Value	Unit	Name
The range of motion of the camera on either side of its nominal design position in the x-direction.	10	mm	x-decenterRangeCam
The range of motion of the camera on either side of its	10	mm	y-

Description	Value	Unit	Name
nominal design position in the y-direction.			decenterRangeCam
The range of motion of the camera on either side of its nominal design position in the z-direction.	10	mm	z-positionRangCcam
The range of tilt of the camera on either side of its nominal design position about the x-axis.	0.1	Degrees	x-tiltRangeCam
The range of tilt of the camera on either side of its nominal design position about the y-axis.	0.1	Degrees	y-tiltRangeCam

3.2.2.2 One-time Static Compensation

ID: OSS-REQ-0214 **Last Modified: 5/16/2011**

Specification: The LSST optical system shall provide for one time compensation for the as-built prescriptions (radii and conic constant) on the three mirror surfaces.

L3+FPA to L2 Spacing

ID: OSS-REQ-0215 **Last Modified: 11/18/2010**

Specification: The spacing of the FPA+L3 (+ optionally the filter) to L2 shall be adjustable one time over a range of **l3L2Comp** about its nominal design spacing.

Discussion: Sensitivity analysis show that the filter can be optionally allowed to move with the FPA+L3 group when making this adjustment within system performance.

Description	Value	Unit	Name
The minimum adjustment range of the L3-L2 spacing about either side of the nominal design spacing as a one-time compensator.	5	mm	l3L2Comp

L3-FPA Spacing

ID: OSS-REQ-0216 **Last Modified: 7/21/2010**

Specification: The spacing between L3 and the FPA shall be adjustable one time within the range of **fpaL3Comp** about the nominal design spacing.

Description	Value	Unit	Name
The minimum adjustment range of the FPA+L3 spacing about either side of the nominal design spacing as a one-time compensator.	3.5	mm	fpaL3Comp

3.2.2.3 Wavefront Sensing Functions

ID: OSS-REQ-0217 **Last Modified: 8/5/2010**

Specification: The LSST optical system shall be able to determine the self induced wavefront aberrations caused by misalignment of the secondary mirror and camera along with figure distortions on the surfaces of the 3 telescope mirrors.

Wavefront Estimation Range

ID: OSS-REQ-0218 **Last Modified: 7/21/2010**

Specification: Each wavefront sensor shall provide sufficient information to be able to reconstruct the equivalent of up to the first 22 Zernike modes of wavefront error at the telescope pupil.

Wavefront Sensing on Sky Efficiency

ID: OSS-REQ-0219 **Last Modified: 5/16/2011**

Specification: The wavefront sensors shall supply data for the estimation of the wavefront over at least **wfsSkyEfficiency** of all visits regardless of visit filter.

Discussion: The fraction of sky coverage is based on the ability to recover the coefficients for Zernikie polynomials (or equivalent) Z4 - Z22 using the standard Noll notation.

Description	Value	Unit	Name
The minimum fraction of visits where valid wavefront sensing data can be obtained.	95	Percent	wfsSkyEfficiency

Wavefront Sensor FPA Geometry

ID: OSS-REQ-0220 **Last Modified: 5/26/2011**

Specification: For the purpose of determining the optical alignment and mirror surface errors the LSST optical system shall use 4 wavefront sensors located near the corners of the inscribed square to the 3.5 degree FOV.

WFS Data Archiving and Buffering

ID: OSS-REQ-0221 **Last Modified: 7/21/2010**

Specification: For the purposes of archiving and buffering the wavefront sensor imaging data shall be treated the same as science image data.

3.2.3 Stray and Scattered Light Control

ID: OSS-REQ-0224 **Last Modified: 11/23/2010**

Specification: All sources of stray and scattered light shall be minimized by design to the extent that it is feasible using standard practices and surface treatments.

3.2.3.1 Ghost Image Control

ID: OSS-REQ-0222 **Last Modified: 5/18/2011**

Specification: The effects of image ghosts in single visits shall not increase the errors in photometric repeatability of non-varying sources by more than **ghostPhotErr** above the limit set by the calculated noise (photon statistics and other measured noise sources).

Specification: No more than **ghostGradientArea** % of image area in a single visit shall be affected by ghosts with surface brightness gradients on 1 arcsec scale exceeding 1/3 of the sky noise.

Discussion: These requirements limit the impact of ghosting. The first requirement effectively places an upper limit on the precision of sky brightness determination (~1 % for design specification), which may be affected by ghosts. The second requirement is derived from the effects of ghosting on shape systematics on the scale of faint galaxies.

Description	Value	Unit	Name
The increase in photometric error over repeated measurements caused by the effects of image ghosts shall not exceed **ghostPhotErr**.	10.0	Percent	ghostPhotErr
The maximum scientific image area that can be affected by 1 arcsec scale ghost gradients exceeding 1/3 of the sky noise shall be no more than **ghostGradientArea.**	1.0	Percent	ghostGradientArea

Lens Anti-Reflection Coating

ID: OSS-REQ-0223 **Last Modified: 9/17/2010**

Specification: The reflection off the any transmissive optical surface shall be less than **lensReflection** over the entire operating wavelength rage of the LSST system.

Discussion: These specifications constrain the intensity of the 2-reflection ghost images.

Description	Value	Unit	Name
The maximum allowable reflection fraction from any lens surface after AR coating.	2	Percent	lensReflection

3.2.3.2 Lunar Stray Light

ID: OSS-REQ-0225 **Last Modified: 11/18/2010**

Specification: All sources of stray light that contribute more than **strayThreshold** relative to the natural sky background within **lunarAngle** shall be identified and treated to minimize their impact on diffuse stray light.

Description	Value	Unit	Name
The threshold above which surfaces need to be identified and treated for minimization of stray light.	10	Percent	strayThreshold
The limiting angle from the moon with respect to the optical axis where surface contributions to stray light need to be identified.	45	Degrees	lunarAngle

3.2.3.3 Optical Baffing

ID: OSS-REQ-0226 **Last Modified: 11/18/2010**

Specification: The optical system shall be baffled such that there are no direct specular paths to the focal plane outside the nominal field of view from celestial sources.

3.2.4 Image Quality

ID: OSS-REQ-0227 **Last Modified: 5/16/2011**

The delivered PSF image quality specifications flow directly from the SRD/LSR.

3.2.4.1 System Image Quality

ID: OSS-REQ-0228 **Last Modified: 7/16/2011**

Specification: The delivered image quality of isolated bright unresolved point sources in images from a single visit shall have the properties specified in the table **imageQuality**.

Discussion: The design point specified here deviates from the SRD design specification due to the conflict between image quality and charge spreading in thick detectors, needed to achieve the desired z-band and y-band sensitivities. The adopted base system image quality of 0.4 arcsec FWHM is within the allowed value set by the SRD minimum specification.

Description	Value	Unit	Name
The maximum RSS contribution from the LSST system to the atmospheric seeing referenced at zenith or airmass (sec(zd)) = 1.	0.40	ArcsecFWHM	SysIm_0
The maximum RSS contribution from the LSST system to the atmospheric seeing referenced at zenith distance of 45 degrees or airmass (sec(zd)) = 1.4.	0.49	ArcsecFWHM	SysIm_45
The maximum RSS contribution from the LSST system to the atmospheric seeing referenced at zenith distance of 60 degrees or airmass (sec(zd)) = 2.0.	0.60	ArcsecFWHM	SysIm_60
Delivered image quality increase factor allowed over **SF1** fraction of the field of view.	1.1	float	SX
The maximum fraction of the field of view that can exceed the delivered image size by a factor of **SX**.	10	Percent	SF1
The minimum number of pixels across the FWHM of the delivered PSF under median atmospheric conditions (0.6 arcsec FWHM) shall be	3	Pixels	PSFSample
The system image budget is allowed to degrade through the three reference zenith distances (zd) as sec(zd)^ **ImFunc**.	0.6		ImFunc
The maximum radius of the PSF spatial profile for a fiducial delivered image quality of 0.69 arcsec FWHM containing 80 percent encircled energy shall be no more than **SR1**.	0.76	Arcsec	SR1
The maximum radius of the PSF spatial profile for a fiducial delivered image quality of 0.69 arcsec FWHM containing 90 percent encircled energy shall be no more than **SR2**.	1.17	Arcsec	SR2
The maximum radius of the PSF spatial profile for a fiducial delivered image quality of 0.69 arcsec FWHM containing 95 percent encircled energy shall be no more than **SR3**.	1.62	Arcsec	SR3

3.2.4.2 Image Quality Subsystem Allocations

ID: OSS-REQ-0229 **Last Modified: 7/17/2011**

Specification: The telescope and camera subsystems shall use the RSS budget allocations defined by **imgBudgetTel** and **imgBudgetCam** in the table below.

Description	Value	Unit	Name
The portion of the system image budget allocated to the Telescope is **imgBudgetTel.**	0.25	ArcsecFWHM	imgBugetTel
The portion of the system image budget allocated to the Camera is **imgBudgetCam.**	0.30	ArcsecFWHM	imgBugetTCam

3.2.4.3 Off Zenith Image Degradation

ID: OSS-REQ-0230 **Last Modified: 11/17/2010**

Specification: The system image quality is allowed to degrade as a function of Zenith Distance (angle) at the same rate as the atmospheric turbulent seeing. The canonical dependence on zenith distance is given as $\sec(ZD)^{0.6}$.

Discussion: The design specification for the image quality requires that, for the median atmospheric seeing, the system contribution to the delivered image quality never exceeds 15%. This requirement should be fulfilled irrespective of the airmass, which limits the seeing degradation due to hardware away from the zenith (e.g. due to gravity load). Assuming that the atmospheric seeing increases with airmass, X, as X^0.6 , the design specification for the allowed error budget due to system is 0.52 arcsec at airmass of 2 and for the median seeing conditions (0.42 arcsec for X=1.4).

3.2.4.4 Image Pixel Sampling

ID: OSS-REQ-0231 **Last Modified: 5/16/2011**

Specification: The image sampling shall be pixelSize.

Description	Value	Unit	Name
The maximum physical pixel size needed to achieve critical PSF sampling in the reference median seeing conditions.	10.0	Microns	pixelSize

3.2.5 Image Ellipticity

ID: OSS-REQ-0232 **Last Modified: 5/16/2011**

Discussion: The image ellipticity performance parameters specified here flow directly from the SRD/LSR without any further derivation. Monte Carlo analysis of the optical system using the component tolerances derived from the image quality budget shows that these ellipticity specifications are met (see Document-1361).

Thus, the ellipticity specifications detailed here are held at the System Level and do not flow down to either the camera or telescope subsystems.
https://www.lsstcorp.org/docushare/dsweb/Get/Document-1361

3.2.5.1 Single Image PSF Ellipticity

ID: OSS-REQ-0233 **Last Modified: 5/16/2011**

Specification: The Point spread function ellipticity of bright isolated unresolved sources in images from a single r-band or i-band visit shall have the properties specified in the table **imageEllipticity** below.

Discussion: These specifications apply to single isolated unresolved sources as delivered to and

recorded by the LSST imaging system.

Description	Value	Unit	Name
The maximum median raw PSF ellipticity over the full field of view in a single 15 second exposure for bright isolated non-saturated stars.	0.04	Ellipticity	SE1
The maximum PSF raw ellipticity limit.	0.07	Ellipticity	SE2
The fraction of PSF ellipticity measurements allowed to exceed the ellipticity outlier limit for bright isolated non-saturated stars.	5	Percent	EF1
The maximum residual ellipticity correlation amplitude over 1 arcmin scales.	2.0e-4		SE3
The maximum residual ellipticity correlation amplitude over 5 arcmin scales.	5.0e-7		SE4
The maximum median residual ellipticity amplitude outlier limit on scales less than or equal to 1 arcmin.	4.0e-4		SE5
The maximum median residual ellipticity amplitude outlier limit on scales between 1 and 5 arcmin.	1.0e-6		SE6
Fraction of allowed PSF measurements of isolated bright stars to exceed the ellipticity residual correlation amplitude outlier limit.	10	Percent	EF2

3.2.5.2 10-year Ellipticity Residuals

ID: OSS-REQ-0234 **Last Modified: 5/16/2011**

Specification: Over the total number of visits in the full set of survey data (or 10 year equivalent stack), the residual ellipticity correlations of bright isolated point sources in the r-band or i-band, after correction, shall have the properties defined in the **overallEllipticity** table below.

Description	Value	Unit	Name
Median residual PSF ellipticity correlations averaged over an arbitrary field of view for separations less than 1 arcmin shall be no greater than **TE1.**	2.0e-5		TE1
Median residual PSF ellipticity correlations averaged over an arbitrary field of view for separations less than 5 arcmin shall be no greater than **TE2.**	1.0e-7		TE2
The outlier limit on the PSF ellipticity correlation residuals on 1 arcminute scales shall be no more than **TE3.**	4.0e-5		TE3
The outlier limit on the PSF ellipticity correlation residuals on 5 arcminute scales shall be no more than **TE4.**	2.0e-7		TE4
The fraction of PSF ellipticity correlation residuals that can	15	Percent	TF1

Description	Value	Unit	Name
exceed the outlier limits on 1 and 5 arcminutes scales over an arbitrary field of view shall be no more than **TF1**.			

3.3 System Throughput

The LSST system throughput shall allow efficient collection of the science data over a wide range of wavelengths, from near the atmospheric cutoff in the blue to the band gap of silicon in the red.

3.3.1 Filter Response

ID: OSS-REQ-0235 **Last Modified: 5/25/2011**

Specification: The response function of each filter integrated over the incident beam in the center 100mm circle shall lie within the defined upper and lower response envelope defined below.

Discussion: The LSST filter band passes are defined below by three sets of wavelengths specifying the nominal trapezoidal shape for the nominal bandpass, the upper envelope, and lower envelope.

Note: The response functions for the baseline ideal filters are contained in Collection-1777 in the LSST document archive (see collection link below)
https://www.lsstcorp.org/docushare/dsweb/View/Collection-1777

3.3.1.1 Filter Out of Band Constraints

ID: OSS-REQ-0237 **Last Modified: 11/3/2010**

Specification: Each of the 6 defined filters must block its out of band transmission according to the specifications in the table below.

Discussion: For leakage that occurs in the wavelength region beyond 1050 the response of 200 micron thick silicon at -100 C can be multiplied against the filter response in the total integrated leak evaluation.

Description	Value	Unit	Name
The average leakage in any 10nm segment between 300-1200nm outside the wavelength span one FWHM from the cetral wavelength shall be no more than **fLeak_10nm**.	0.01	Percent	fLeak_10nm
The integrated over all wavelengths between 300-1200nm outside the wavelength span between the first time the filter response goes below 0.1% of the peak the total leakage shall not exceeded **fleakTotal.**	0.05	Percent	fLeakTotal

3.3.1.2 Filter Response Uniformity

ID: OSS-REQ-0238 **Last Modified: 5/16/2011**

Specification: The filter response function as measured in any 100mm circle shall vary smoothly as a function of radius by no more than filtUniformity from the measured response in the central 100mm circle.

Description	Value	Unit	Name
The maximum filter response uniformity variation.	2.5%	Percent	filtUniformity

3.3.1.3 In-band Ripple

ID: OSS-REQ-0239 **Last Modified: 5/25/2011**

Specification: The in-band filter response function shall have a semi-amplitude peak-to-valley ripple of no more than **maxFiltRipple** about the in-band mean response.

Discussion: The in-band region for measuring ripple is defined as the wavelength segment between the red and blue upper envelope at the 100% relative response wavelengths and the red and blue lower envelope at the 100% relative response wavelengths for positive and negative going excursions respectively.

Description	Value	Unit	Name
The maximum semi-amplitude peak-to-valley ripple.	3	Percent	maxFiltRipple

3.3.1.4 u-band Response

ID: OSS-REQ-0240 **Last Modified: 11/3/2010**

Specification: The response relative to the in-band average (as measured between **uLowerBlue_100** and **uLowerRed_100**) of the u-band filter shall lie between the upper and lower envelopes defined in the tables below.

Discussion: The target relative u-band response is defined by the nominal parameters below.

Description	Value	Unit	Name
The nominal u-band zero relative response wavelength on the blue side.	309	nm	uNomBlue_0
The nominal u-band 50% relative response wavelength on the blue side..	321	nm	uNomBlue_50
The nominal u-band 100% relative response wavelength on the blue side.	334	nm	uNomBlue_100
The nominal u-band 100% relative response wavelength on the red side.	379	nm	uNomRed_100
The nominal u-band 50% relative response wavelength on the red side.	391	nm	uNomRed_50
The nominal u-band zero relative response wavelength on the red side.	404	nm	uNomRed_0

Description	Value	Unit	Name
The lower envelope u-band zero relative response wavelength on the blue side.	311	nm	uLowerBlue_0
The lower envelope u-band 50% relative response wavelength on the blue side.	323	nm	uLowerBlue_50
The lower envelope u-band 100% relative response wavelength on the blue side.	336	nm	uLowerBlue_100
The lower envelope u-band 100% relative response wavelength on the red side.	377	nm	uLowerRed_100
The lower envelope u-band 50% relative response wavelength on the red side.	389	nm	uLowerRed_50

Description	Value	Unit	Name
The lower envelope u-band zero relative response wavelength on the red side.	402	nm	uLowerRed_0
The upper envelope u-band zero relative response wavelength on the blue side.	306	nm	uUpperBlue_0
The upper envelope u-band 50%relative response wavelength on the blue side.	318	nm	uUpperBlue_50
The upper envelope u-band 100% relative response wavelength on the blue side.	331	nm	uUpperBlue_100
The upper envelope u-band 100% relative response wavelength on the red side.	382	nm	uUpperRed_100
The upper envelope u-band 50% relative response wavelength on the red side.	394	nm	uUpperRed_50
The upper envelope u-band zero relative response wavelength on the red side.	407	nm	uUpperRed_0

3.3.1.5 g-band Response

ID: OSS-REQ-0241 **Last Modified: 11/3/2010**

Specification: The response relative to the in-band average (as measured between **gLowerBlue_100** and **gLowerRed_100**) of the g-band filter shall lie between the upper and lower envelopes defined in the tables below.

Discussion: The target relative g-band response is defined by the nominal parameters below.

Description	Value	Unit	Name
The nominal g-band zero relative response wavelength on the blue side.	390	nm	gNomBlue_0
The nominal g-band 50% relative response wavelength on the blue side.	402	nm	gNomBlue_50
The nominal g-band 100% relative response wavelength on the blue side.	415	nm	gNomBlue_100
The nominal g-band 100% relative response wavelength on the red side.	540	nm	gNomRed_100
The nominal g-band 50% relative response wavelength on the red side.	552	nm	gNomRed_50
The nominal g-band zero relative response wavelength on the red side.	565	nm	gNomRed_0

Description	Value	Unit	Name
The lower envelope g-band zero relative response wavelength on the blue side.	392	nm	gLowerBlue_0
The lower envelope g-band 50% relative response wavelength on the blue side.	404	nm	gLowerBlue_50
The lower envelope g-band 100% relative response wavelength on the blue side.	417	nm	gLowerBlue_100
The lower envelope g-band 100% relative response wavelength on the red side.	537	nm	gLowerRed_100
The lower envelope g-band 50% relative response	550	nm	gLowerRed_50

Description	Value	Unit	Name
wavelength on the red side.			
The lower envelope g-band zero relative response wavelength on the red side.	562	nm	gLowerRed_0
The upper envelope g-band zero relative response wavelength on the blue side.	387	nm	gUpperBlue_0
The upper envelope g-band 50% relative response wavelength on the blue side.	399	nm	gUpperBlue_50
The upper envelope g-band 100% relative response wavelength on the blue side.	412	nm	gUpperBlue_100
The upper envelope g-band 100% relative response wavelength on the red side.	542	nm	gUpperRed_100
The upper envelope g-band 50% relative response wavelength on the red side.	555	nm	gUpperRed_50
The upper envelope g-band zero relative response wavelength on the red side.	567	nm	gUpperRed_0

3.3.1.6 r-band Response

ID: OSS-REQ-0242 **Last Modified: 11/3/2010**

Specification: The response relative to the in-band average (as measured between **rLowerBlue_100** and **rLowerRed_100**) of the r-band filter shall lie between the upper and lower envelopes defined in the tables below.

Discussion: The target relative r-band response is defined by the nominal parameters below.

Description	Value	Unit	Name
The nominal r-band zero relative response wavelength on the blue side.	540	nm	rNomBlue_0
The nominal r-band 50% relative response wavelength on the blue side.	552	nm	rNomBlue_50
The nominal r-band 100% relative response wavelength on the blue side.	565	nm	rNomBlue_100
The nominal r-band 100% relative response wavelength on the red side.	679	nm	rNomRed_100
The nominal r-band 50% relative response wavelength on the red side.	691	nm	rNomRed_50
The nominal r-band zero relative response wavelength on the red side.	704	nm	rNomRed_0

Description	Value	Unit	Name
The lower envelope r-band zero relative response wavelength on the blue side.	542	nm	rLowerBlue_0
The lower envelope r-band 50% relative response wavelength on the blue side.	555	nm	rLowerBlue_50
The lower envelope r-band 100% relative response wavelength on the blue side.	567	nm	rLowerBlue_100
The lower envelope r-band 100% relative response wavelength on the red side.	676	nm	rLowerRed_100

Description	Value	Unit	Name
The lower envelope r-band 50% relative response wavelength on the red side.	689	nm	rLowerRed_50
The lower envelope r-band zero relative response wavelength on the red side.	701	nm	rLowerRed_0
The upper envelope r-band zero relative response wavelength on the blue side.	537	nm	rUpperBlue_0
The upper envelope r-band 50% relative response wavelength on the blue side.	550	nm	rUpperBlue_50
The upper envelope r-band 100% relative response wavelength on the blue side.	562	nm	rUpperBlue_100
The upper envelope r-band 100% relative response wavelength on the red side.	681	nm	rUpperRed_100
The upper envelope r-band 50% relative response wavelength on the red side.	694	nm	rUpperRed_50
The upper envelope r-band zero relative response wavelength on the red side.	706	nm	rUpperRed_0

3.3.1.7 i-band Response

ID: OSS-REQ-0243 **Last Modified: 11/3/2010**

Specification: The response relative to the in-band average (as measured between **rLowerBlue_100** and **rLowerRed_100**) of the r-band filter shall lie between the upper and lower envelopes defined in the tables below.

Discussion: The target relative i-band response is defined by the nominal parameters below.

Description	Value	Unit	Name
The nominal i-band zero relative response wavelength on the blue side.	679	nm	iNomBlue_0
The nominal i-band 50% relative response wavelength on the blue side.	691	nm	iNomBlue_50
The nominal i-band 100% relative response wavelength on the blue side.	704	nm	iNomBlue_100
The nominal i-band 100% relative response wavelength on the red side.	806	nm	iNomRed_100
The nominal i-band 50% relative response wavelength on the red side.	818	nm	iNomRed_50
The nominal i-band zero relative response wavelength on the red side.	831	nm	iNomRed_0

Description	Value	Unit	Name
The lower envelope i-band zero relative response wavelength on the blue side.	681	nm	iLowerBlue_0
The lower envelope i-band 50% relative response wavelength on the blue side.	694	nm	iLowerBlue_50
The lower envelope i-band 100% relative response wavelength on the blue side.	706	nm	iLowerBlue_100
The lower envelope i-band 100% relative response	803	nm	iLowerRed_100

Description	Value	Unit	Name
wavelength on the red side.			
The lower envelope i-band 50% relative response wavelength on the red side.	816	nm	iLowerRed_50
The lower envelope i-band zero relative response wavelength on the red side.	828	nm	iLowerRed_0
The upper envelope i-band zero relative response wavelength on the blue side.	676	nm	iUpperBlue_0
The upper envelope i-band 50% relative response wavelength on the blue side.	689	nm	iUpperBlue_50
The upper envelope i-band 100% relative response wavelength on the blue side.	701	nm	iUpperBlue_100
The upper envelope i-band 100% relative response wavelength on the red side.	808	nm	iUpperRed_100
The upper envelope i-band 50% relative response wavelength on the red side.	821	nm	iUpperRed_50
The upper envelope i-band zero relative response wavelength on the red side.	833	nm	iUpperRed_0

3.3.1.8 z-band Response

ID: OSS-REQ-0244 **Last Modified: 11/3/2010**

Specification: The response relative to the in-band average (as measured between **zLowerBlue_100** and **zLowerRed_100**) of the z-band filter shall lie between the upper and lower envelopes defined in the tables below.

Discussion: The target relative z-band response is defined by the nominal parameters below.

Description	Value	Unit	Name
The nominal z-band zero relative response wavelength on the blue side.	806	nm	zNomBlue_0
The nominal z-band 50% relative response wavelength on the blue side.	818	nm	zNomBlue_50
The nominal z-band 100% relative response wavelength on the blue side.	831	nm	zNomBlue_100
The nominal z-band 100% relative response wavelength on the red side.	910	nm	zNomRed_100
The nominal z-band 50% relative response wavelength on the red side.	922	nm	zNomRed_50
The nominal z-band zero relative response wavelength on the red side.	935	nm	zNomRed_0

Description	Value	Unit	Name
The lower envelope z-band zero relative response wavelength on the blue side.	808	nm	zLowerBlue_0
The lower envelope z-band 50% relative response wavelength on the blue side.	821	nm	zLowerBlue_50
The lower envelope z-band 100% relative response wavelength on the blue side.	833	nm	zLowerBlue_100

Description	Value	Unit	Name
The lower envelope z-band 100% relative response wavelength on the red side.	909	nm	zLowerRed_100
The lower envelope z-band 50% relative response wavelength on the red side.	921	nm	zLowerRed_50
The lower envelope z-band zero relative response wavelength on the red side.	934	nm	zLowerRed_0
The upper envelope z-band zero relative response wavelength on the blue side.	803	nm	zUpperBlue_0
The upper envelope z-band 50% relative response wavelength on the blue side.	816	nm	zUpperBlue_50
The upper envelope z-band 100% relative response wavelength on the blue side.	828	nm	zUpperBlue_100
The upper envelope z-band 100% relative response wavelength on the red side.	914	nm	zUpperRed_100
The upper envelope z-band 50% relative response wavelength on the red side.	926	nm	zUpperRed_50
The upper envelope z-band zero relative response wavelength on the red side.	939	nm	zUpperRed_0

3.3.1.9 y-band Response

ID: OSS-REQ-0245 **Last Modified: 11/3/2010**

Specification: The response relative to the in-band average (as measured between **yLowerBlue_100** and **yLowerRed_100**) of the y-band filter shall lie between the upper and lower envelopes defined in the tables below.

Discussion: The target relative y-band response is defined by the nominal parameters below.

Description	Value	Unit	Name
The nominal y-band zero relative response wavelength on the blue side.	918	nm	yNomBlue_0
The nominal y-band 50%relative response wavelength on the blue side.	930	nm	yNomBlue_50
The nominal y-band 100%relative response wavelength on the blue side.	943	nm	yNomBlue_100
The nominal y-band 100%relative response wavelength on the blue side.	INDEF	nm	yNomRed_100
The nominal y-band 50%relative response wavelength on the blue side.	N/A	nm	yNomRed_50
The nominal y-band zero relative response wavelength on the blue side.	N/A	nm	yNomRed_0

Description	Value	Unit	Name
The lower envelope y-band zero relative response wavelength on the blue side.	919	nm	yLowerBlue_0
The lower envelope y-band 50%relative response wavelength on the blue side.	931	nm	yLowerBlue_50
The lower envelope y-band 100%relative response	944	nm	yLowerBlue_100

Description	Value	Unit	Name
wavelength on the blue side.			
The lower envelope y-band 100%relative response wavelength on the red side.	1057	nm	yLowerRed_100
The lower envelope y-band 50% relative response wavelength on the red side.	1069	nm	yLowerRed_50
The lower envelope y-band zero relative response wavelength on the red side.	1082	nm	yLowerRed_0
The upper envelope y-band zero relative response wavelength on the blue side.	914	nm	yUpperBlue_0
The upper envelope y-band 50% relative response wavelength on the blue side.	926	nm	yUpperBlue_50
The upper envelope y-band 100% relative response wavelength on the blue side.	939	nm	yUpperBlue_100
The upper envelope y-band 100% relative response wavelength on the red side.	INDEF	nm	yUpperRed_100
The upper envelope y-band 50% relative response wavelength on the red side.	N/A	nm	yUpperRed_50
The upper envelope y-band zero relative response wavelength on the red side.	N/A	nm	yUpperRed_0

3.3.2 Optical Throughput

ID: OSS-REQ-0246 **Last Modified: 5/25/2011**

Discussion: The instantaneous throughput requirements specified here define sensitivity performance of the overall system components required to meet the limiting magnitude specified in the LSST System Requirements. These requirements include the response definitions of the six LSST filters, and the total system throughput integrals for each filter.

The total system throughput integrals are allocated to the camera and telescope subsystems as a percentage throughput specified at three critical wavelengths for each filter.

TBR Throughput requirements are being reviewed (see Document-11267) and will be made consistent with the filter definitions above.

3.3.2.1 Total Optical Throughput

ID: OSS-REQ-0247 **Last Modified: 5/20/2011**

Specification: Averaged over the 10-year survey period, the total system response integral over a given filter bandpass shall meet or exceed the following specified parameters for each of the LSST's six filters defined previously.

Discussion: The system response includes the efficiency of photon detection, lens and mirror coating performances, and the transmission of the atmosphere referenced at zenith under nominal conditions found at the Cerro Pachon site.
https://www.lsstcorp.org/docushare/dsweb/Get/Document-8857

u-Band Throughput

ID: OSS-REQ-0248 **Last Modified: 8/2/2010**

Description	Value	Unit	Name
The lower wavelength limit (5% filter response) for the system u-band response shall be	318.5	nm	uLambdaLower
The reference (equivalent to the effective response weighted mean) u-band response shall be	365.5	nm	uLambdaRef
The upper wavelength limit (5% percent filter response) for the system u-band response shall be	405.2	nm	uLambdaUpper
The system response efficiency, less filter, at the u-band lower limit wavelength, **uLambdaLower**, shall be at least	8.8	Percent	uThroughputLower
The system response efficiency, less filter, at the u-band reference wavelength, **uLambdaRef**, shall be at least	21.7	Percent	uThroughputRef
The system response efficiency, less filter, at the u-band upper limit wavelength, **uLambdaUpper**, shall be at least	30.5	Percent	uThroughputUpper
The integrated u-band throughput, not including the atmosphere response, over all wavelengths (300-1200nm) shall be at least	0.0411	-	uSysIntegral

g-band Throughput

ID: OSS-REQ-0249 **Last Modified: 8/2/2010**

Description	Value	Unit	Name
The lower wavelength limit (5% filter response) for the system g-band response shall be	387.5	nm	gLambdaLower
The reference (equivalent to the effective response weighted mean) g-band response shall be	480.4	nm	gLambdaRef
The upper wavelength limit (5% percent filter response) for the system g-band response shall be	559.2	nm	gLambdaUpper
The system response efficiency, less filter, at the g-band lower limit wavelength, **gLambdaLower**, shall be at least	44.0	Percent	gThroughputLower
The system response efficiency, less filter, at the g-band reference wavelength, **gLambdaRef**, shall be at least	44.0	Percent	gThroughputRef
The system response efficiency, less filter, at the g-band upper limit wavelength, **gLambdaUpper**, shall be at least	44.0	Percent	gThroughputUpper
The integrated g-band throughput, not including the atmosphere response, over all wavelengths (300-1200nm) shall be at least	0.1387	-	gSysIntegral

r-band Throughput

ID: OSS-REQ-0250 **Last Modified: 5/16/2011**

Discussion: The r-band specifications for the system integral and average throughput at each of the reference wavelengths deviate from those required to meet the SRD. This is because when losses are accounted for on all optical surface it is not feasible to meet the SRD design requirement.

The system requirement specified here meets the SRD minimum r-band limiting magnitude requirements, but fall short of the design requirement by 0.25mag.

Description	Value	Unit	Name
The lower wavelength limit (5% filter response) for the system r-band response shall be	534.2	nm	rLambdaLower
The reference (equivalent to the effective response weighted mean) r-band response shall be	622.4	nm	rLambdaRef
The upper wavelength limit (5% filter response) for the system r-band response shall be	701.0	nm	rLambdaUpper
The system response efficiency, less filter, at the r-band lower limit wavelength, **rLambdaLower**, shall be at least	50.0	Percent	rThroughputLower
The system response efficiency, less filter, at the r-band reference wavelength, **rLambdaRef**, shall be at least	50.0	Percent	rThroughputRef
The system response efficiency, less filter, at the r-band upper limit wavelength, **rLambdaUpper**, shall be at least	50.0	Percent	rThroughputUpper
The integrated r-band throughput, not including the atmosphere response, over all wavelengths (300-1200nm) shall be at least	0.1134	-	rSysIntegral

i-band Throughput

ID: OSS-REQ-0251 **Last Modified: 8/2/2010**

Description	Value	Unit	Name
The lower wavelength limit (5% filter response) for the system i-band response shall be	670.1	nm	iLambdaLower
The reference (equivalent to the effective response weighted mean) i-band response shall be	754.1	nm	iLambdaRef
The upper wavelength limit (5% filter response) for the system i-band response shall be	837.0	nm	iLambdaUpper
The system response efficiency, less filter, at the i-band lower limit wavelength, **iLambdaLower**, shall be at least	39.2	Percent	iThroughputLower
The system response efficiency, less filter, at the i-band reference wavelength, **iLambdaRef**, shall be at least	39.2	Percent	iThroughputRef
The system response efficiency, less filter, at the i-band upper limit wavelength, **iLambdaUpper**, shall be at least	39.2	Percent	iThroughputUpper
The integrated i-band throughput, not including the atmosphere response, over all wavelengths (300-1200nm) shall be at least	0.0674	-	iSysIntegral

z-band Throughput

ID: OSS-REQ-0252 **Last Modified: 8/2/2010**

Description	Value	Unit	Name
The lower wavelength limit (5% filter response) for the system z-band response shall be	798.9	nm	zLambdaLower
The reference (equivalent to the effective response weighted mean) z-band response shall be	868.1	nm	zLambdaRef

The upper wavelength limit (5% filter response) for the system z-band response shall be	948.3	nm	zLambdaUpper
The system response efficiency, less filter, at the z-band lower limit wavelength, **zLambdaLower**, shall be at least	30.8	Percent	zThroughputLower
The system response efficiency, less filter, at the z-band reference wavelength, **zLambdaRef**, shall be at least	30.8	Percent	zThroughputRef
The system response efficiency, less filter, at the z-band upper limit wavelength, **zLambdaUpper**, shall be at least	30.8	Percent	zThroughputUpper
The integrated z-band throughput, not including the atmosphere response, over all wavelengths (300-1200nm) shall be at least	0.0376	-	zSysIntegral

y-band Throughput

ID: OSS-REQ-0253 **Last Modified: 5/25/2011**

Note: The current project y-band baseline is "y4".

Description	Value	Unit	Name
The lower wavelength limit (5% filter response) for the system y-band response shall be	955.3	nm	yLambdaLower
The reference (equivalent to the effective response weighted mean) y-band response shall be	1005.0	nm	yLambdaRef
The upper wavelength limit (5% filter response) for the system y-band response shall be	1100.0	nm	yLambdaUpper
The system response efficiency, less filter, at the y-band lower limit wavelength, **yLambdaLower**, shall be at least	15.4	Percent	yThroughputLower
The system response efficiency, less filter, at the y-band reference wavelength, **yLambdaRef**, shall be at least	6.4	Percent	yThroughputRef
The system response efficiency, less filter, at the y-band upper limit wavelength, **yLambdaUpper**, shall be at least	0.0	Percent	yThroughputUpper
The integrated y-band throughput, not including the atmosphere response, over all wavelengths (300-1200nm) shall be at least	0.0110	-	ySysIntegral

3.3.2.2 Telescope Throughput Allocation

ID: OSS-REQ-0254 **Last Modified: 5/20/2011**

Specification: The 10-year mean throughput response of the telescope (3-mirror) system averaged over each of the 6 filter passbands between their 90% response points defined above shall be meet the specifications in the table of attributes below.

Discussion: Based on the performance of aged protected aluminum coatings.

Description	Value	Unit	Name
When averaged over the u-band filter the telescope throughput shall be at least	67.6	Percent	telAveThroughput_u

Description	Value	Unit	Name
When averaged over the g-band filter the telescope throughput shall be at least	68.3	Percent	telAveThroughput_g
When averaged over the r-band filter the telescope throughput shall be at least	65.9	Percent	telAveThroughput_r
When averaged over the i-band filter the telescope throughput shall be at least	59.2	Percent	telAveThroughput_i
When averaged over the z-band filter the telescope throughput shall be at least	59.0	Percent	telAveThroughput_z
When averaged over the y4-band filter the telescope throughput shall be at least	68.6	Percent	telAveThroughput_y4

3.3.2.3 Camera Throughput Allocation

ID: OSS-REQ-0255 **Last Modified: 10/8/2013**

Specification: The 10-year mean throughput response of the camera system, including the lenses, filters, and sensors, averaged over each of the 6 filter passbands between their 90% response points defined above shall be specified by the table of attributes below.

Discussion: The total camera throughput specifications must include the constraints imposed by the specifications for the filter bandpasses and anti-reflection coating performance.

Description	Value	Unit	Name
When averaged over the u-band filter the camera throughput shall be at least	30.3	Percent	camAveThroughput_u
When averaged over the g-band filter the camera throughput shall be at least	59.5	Percent	camAveThroughput_g
When averaged over the r-band filter the camera throughput shall be at least	63.9	Percent	camAveThroughput_r
When averaged over the i-band filter the camera throughput shall be at least	61.0	Percent	camAveThroughput_i
When averaged over the z-band filter the camera throughput shall be at least	48.5	Percent	camAveThroughput_z
When averaged over the y4-band filter the camera throughput shall be at least	10.1	Percent	camAveThroughput_y4

3.3.2.4 Throughput variation

ID: OSS-REQ-0256 **Last Modified: 5/20/2011**

Specification: The variation of system throughput, defined as the RMS/Mean, over all science pixels within the 3.5 degree FOV shall meet the performance defined in the table **maxThroughputVariation** below for each filter band.

Discussion: The performance values defined here are set to meet the allowed variation in limiting magnitude (LSR-0109). These values assume a Gaussian distribution convolved with the field dependent effective aperture caused by vignetting.

These specifications are TBR.

Description	Value	Unit	Name
The throughput variation in the u-band shall be no more than **uThroughputVar**.	0.176		uThroughputVar
The throughput variation in the g-band shall be no more than g**ThroughputVar**.	0.235		gThroughputVar
The throughput variation in the r-band shall be no more than r**ThroughputVar**.	0.260		rThroughputVar
The throughput variation in the i-band shall be no more than i**ThroughputVar**.	0.259		iThroughputVar
The throughput variation in the z-band shall be no more than z**ThroughputVar**.	0.262		zThroughputVar
The throughput variation in the y-band shall be no more than y**ThroughputVar**.	0.260		yThroughputVar

3.3.3 10-year Integrated Throughput

ID: OSS-REQ-0258 **Last Modified: 11/23/2010**

Specification: Integrated performance of the system to meet the 10 year survey requirements.

Discussion: These requirements deal mostly with fill factor and other losses to the focal plane coverage that impact the integrated 10-year depth performance. Other terms, like down time, are allocated in the system availability requirements.

3.3.3.1 Focal Plane Coverage

ID: OSS-REQ-0259 **Last Modified: 9/13/2010**

Specification: The base design coverage of the imaging area shall comply with the specifications detailed in the table below.

Description	Value	Unit	Name
The nominal geometric area of the focal plane covered by science grade imaging devices with **sciFillFactor** coverage shall be at least equivalent to a 3.5 degree circle (TBR).	9.6	SquareDegrees	fpaScienceArea
The area covered by science grade imaging devices within the nominal 3.5 degree circular FOV shall be at least	85.0	Percent	fpaFillFactor
The fill factor of active pixels in the area covered by science grade imaging devices shall be at least	90.0	Percent	sciFillFactor

3.3.3.2 Focal Plane Losses

ID: OSS-REQ-0260 **Last Modified: 5/18/2011**

Specification: The total losses due to "dead" or "bad" pixels within the 3.5 degree FOV averaged over the 10-year survey shall be no more than **fpaLosses.**

Discussion: The allocation for **fpaLosses** is determined by the estimated debits against the difference between the predicted number of visits over 18000 sq. deg. and the required number of visits.

Description	Value	Unit	Name

Description	Value	Unit	Name
The fraction of unusable pixels (those that can not be calibrated to meet SRD/LSR specifications) at the time of instrument deliver shall be no more than **deliveredPixelLoss.**	2	Percent	deliveredPixelLoss
The additional pixel loss over and above the **deliveredPixelLoss** when averaged over the 10-year survey lifetime shall be no more than **agedPixelLoss.**	2	Percent	agedPixelLoss

3.4 Camera System

The imaging system shall convert the incident optical beam to an electronic signal that is in computer readable form.

3.4.1 Image Delivery

ID: OSS-REQ-0261 **Last Modified: 5/18/2011**

[This is a composite requirement in the SysML model, signifying simply the union of the requirements below it in the hierarchy.]

3.4.1.1 Science Image Delivery

ID: OSS-REQ-0262 **Last Modified: 5/18/2011**

Specification: The imaging system shall deliver the science data with a unique identifier per device per exposure.

3.4.1.2 Raw Science Image Data

ID: OSS-REQ-0263 **Last Modified: 9/24/2012**

Specification: The LSST imaging system (e.g. Camera) shall provide raw pixel data from the science imager, in response to a request for one or more specific images.

3.4.1.3 Crosstalk-corrected Science Image Data

ID: OSS-REQ-0264 **Last Modified: 10/4/2012**

Specification: The LSST imaging system (e.g. the Camera) shall provide crosstalk-corrected pixel data from the science imager to client subscribers.

3.4.2 Image Acquisition

ID: OSS-REQ-0265 **Last Modified: 5/26/2011**

[This is a composite requirement in the SysML model, signifying simply the union of the requirements below it in the hierarchy.]

3.4.2.1 Science Data Crosstalk

ID: OSS-REQ-0346 **Last Modified: 10/4/2012**

[This is a composite requirement in the SysML model, signifying simply the union of the requirements below it in the hierarchy.]

Discussion: The camera design synchronizes the charge transfer and digitization across all amplifiers in the focal plane. We assume that for the purposes of crosstalk correction it is only necessary to consider pixels sampled at the same time. Because of the synchronization these have a fixed geometrical relationship across the focal plane.

These requirements are based on an underlying assumption of linearity of the actual crosstalk, as well as of a linear correction algorithm.

Crosstalk Magnitude Limits

ID: OSS-REQ-0327 **Last Modified: 10/5/2012**

Specification: The LSST Imaging system (i.e., the Camera) shall provide raw pixel data with crosstalk performance allocations listed in the table **xtalkPerfAlloc**. In particular, before correction, crosstalk between any two electronic channels within a single focal plane unit (i.e., one raft) shall not exceed **maxXtalkIntraRaft**; and crosstalk between focal plane units (i.e., raft-to-raft) shall not exceed **maxXtalkInterRaft**, with a goal of **goalXtalkInterRaft**.

Discussion: The "Aggressor Limits" requirement, OSS-REQ-0328, in this section limits raft-to-raft crosstalk above the data release production threshold relevant to the science to a limited number of amplifiers (presumably nearby neighbors), to limit the data-transfer scope of the downstream corrections Data Management must perform. If the above "goal" is met, then all inter-raft crosstalk will be below the (less stringent) threshold for alert production, consistent with the current design for crosstalk correction by the Camera for the purposes of alert production. If not, then some mitigation will be required.

Description	Value	Unit	Name
Maximum crosstalk between any two electronic channels within a single Science Raft	0.002	float	maxXtalkIntraRaft
Maximum crosstalk between rafts	0.0001	float	maxXtalkInterRaft
Non-normative goal for inter-raft crosstalk	2.5e-5	float	goalXtalkInterRaft

Crosstalk Aggressor Limits

ID: OSS-REQ-0328 **Last Modified: 10/5/2012**

Specification: The LSST system shall be capable of applying pixel crosstalk correction subject to the constraints given in the table **xtalkAggressorLimits**. In particular: for all the pixels on a given Science Raft, the Camera shall have no more than **maxXtalkAggressor** amplifiers on other rafts that contribute crosstalk greater than **xtalkAggressorThresh**, per aggressor.

Discussion: The crosstalk is defined in terms of aggressors and victims. A set of pixels is read out simultaneously by the camera (one per amplifier). For any specific pixel (the victim), all the other pixels in the set are the potential aggressors. The threshold **xtalkAggressorThresh** is deliberately set to the same value as **xtalkSciAccuracy** below, and together they represent the idea that for data release purposes it is acceptable either for the raw crosstalk to be below this value, or for it to be correctable to this level.

Description	Value	Unit	Name

Description	Value	Unit	Name
Maximum number of amplifiers from other rafts that may contribute above-threshold crosstalk to the pixels on a single raft	256	int	maxXtalkAggressor
Threshold above which off-raft crosstalk aggressor limit applies	1e-6 (TBR)	int	xtalkAggressorThresh

Crosstalk Accuracy

ID: OSS-REQ-0329 **Last Modified: 10/7/2013**

Specification: The accuracy to which crosstalk is determined and corrected shall meet the requirements in the table **xtalkAccuracyAlloc**. In particular:

- The product of any given crosstalk coefficient to be used in the data release production crosstalk correction process and the relative accuracy with which it is known shall not exceed **xtalkSciAccuracy**;
- The product of any given crosstalk coefficient to be used in the alert production crosstalk correction process and the relative accuracy with which it is known shall not exceed **xtalkAlertAccuracy**.
- The crosstalk from any full-scale pixel to any other pixel shall be stable to **xtalkSciAccuracy** (and thus **xtalkAlertAccuracy**) over a period of at least **xtalkStability,** or the crosstalk correction algorithms shall be capable of using available metadata to correct any variations to the required precision.

Discussion:The references to production "processes" above incorporates all steps in the data chain, whether crosstalk correction is actually performed in the Camera or in Data Management.By way of example, if the crosstalk proves to be temperature dependent in a predictable way, camera temperature telemetry could be used to improve the crosstalk correction.

Description	Value	Unit	Name
The product of any given crosstalk coefficient used in the data release production process and the relative accuracy with which it is known	1e-5	float	xtalkSciAccuracy
The product of any given cross-talk coefficient used in the alert production process and the relative accuracy with which it is known	2.5e-5	float	xtalkAlertAccuracy
Crosstalk stability period	14	Days	xtalkStability

Crosstalk Measureability

ID: OSS-REQ-0330 **Last Modified: 10/4/2012**

Specification: The crosstalk coefficients used by the data release production process, and those used by the alert production process, shall be measurable at least at intervals of **xtalkStability** (see the "Crosstalk Accuracy" requirement OSS-REQ-0329 above).

Discussion: The two sets of coefficients that apply for any given moment's data need not be the same. The coefficients for data release production are not needed, typically, until months after the collection of the science images. Sets of these coefficients may be computed for periods of time chosen after the fact, and can be determined, for each period, from the data from that period.

For alert production, coefficients must be available at the time the images are acquired, and therefore the set of coefficients for a given time can only be determined from data previously taken. This means, that,

say, for fixed two-week blocks of data, DRP coefficients may be taken from the mid-point of the interval, while AP coefficients will be applied to data at or after the end of the interval and therefore may be more out of date. However, since the stability requirement for AP coefficients is less stringent, this is likely to be OK.

This requirement is intended to apply whether in practice crosstalk coefficients are measured on the sky using only the normal science data, or whether they are measured with a dome-based calibration system, potentially in competition with other needs for calibration data. The intent is that, either way, two weeks is enough time to collect the required data.

Crosstalk Correction Capability

ID: OSS-REQ-0347 **Last Modified: 10/5/2012**

[This is a composite requirement in the SysML model, signifying simply the union of the requirements below it in the hierarchy.]

Discussion: The capabilities described are meant to be interpreted as capabilities of the end-to-end processing of the Observatory, able to be allocated to subsystems (i.e., Camera or Data Management) as an engineering judgment.

In fact we do plan to allocate the crosstalk correction for alert production to the Camera, as indicated elsewhere in this section.

These requirements do not specify the algorithms to be used (although a baseline of a linear "matrix multiplication" type of correction is implicit in the design) and in particular they do not require the data release and alert production corrections to use the same algorithm or the same coefficients. The DRP corrections might well be more sophisticated in form, as well as just considering additional, off-raft, amplifiers as aggressors.

Alert Production Crosstalk Correction

ID: OSS-REQ-0348 **Last Modified: 10/5/2012**

Specification: For each science raft, the alert production process shall be capable of applying crosstalk corrections across all the amplifiers within that raft.

Discussion: This is sufficient to meet the **xtalkAlertAccuracy** requirement above if the Camera achieves the goal raft-to-raft crosstalk requirement **goalXtalkInterRaft** in OSS-REQ-0327.

Data Release Production Crosstalk Correction

ID: OSS-REQ-0349 **Last Modified: 10/5/2012**

Specification: The data release production process shall be capable of applying crosstalk corrections for a given raft based on the data from that raft and at least **dataRelXtalkMaxAmp** amplifiers from other rafts.

Discussion: This capability is matched to the need for such corrections being limited (OSS-REQ-0328) to using no more than this many off-raft amplifiers, i.e., the capability is mandated to meet or exceed the need.

Note that this requirement significantly exceeds the number of nearest-neighbor amplifiers for a raft,

which is 2*3*8 (short edges) + 2*3*2 (long edges) + 4 (corners) = 64. 256 is the number of amplifiers on nearest-neighbor *CCDs*, 4*3 (sides) + 4 (corners), 16 amplifiers each. It is believed that proximity of amplifier segments and their leads is likely to be the most relevant factor in producing inter-raft crosstalk.

Description	Value	Unit	Name
Minimum capability for the number of amplifiers on other rafts which can be considered in corrections for a full raft	256	int	dataRelXtalkMaxAmp

3.4.2.2 Science Data Bit Depth

ID: OSS-REQ-0266 **Last Modified: 5/18/2011**

Specification: The imaging system shall acquire science data with a bit depth of least **pixelBitDepth.**

Description	Value	Unit	Name
The number of bit per pixel in the digitally recorded image data	16	int	pixelBitDepth

3.4.2.3 Science Data Pixel Noise

ID: OSS-REQ-0267 **Last Modified: 2/15/2013**

Specification: The electronic noise from the LSST Camera system shall contribute no more than **camSysNoise** to each pixel per visit in the data from the science sensor array.

Discussion: This top level noise budget includes all sources internal to the camera system that contribute to the base noise in each pixel, including readout noise, residual noise from dark current, additional noise in the electronics, etc...

Specified pixel noise per visit implied 9.0e- per 15 sec exposure.

Description	Value	Unit	Name
The camera system noise contributed to each pixel per visit in the science data.	12.7	electrons	camSysNoise

3.4.2.4 Dynamic Range

ID: OSS-REQ-0268 **Last Modified: 5/18/2011**

Specification: The LSST Camera system shall have a single exposure unsaturated dynamic range of at least **camDynamicRange** above the 5-sigma point source r-band limiting magnitude in a standard 15 second exposure.

Discussion; This requirement is referenced to the fiducial conditions used to define the limiting magnitude requirements.

Description	Value	Unit	Name
The camera minimum dynamic range in a single 15 sec. exposure.	8	ABmag	camDynamicRange

3.4.2.5 Filter Change

ID: OSS-REQ-0269 **Last Modified: 5/18/2011**

Specification: The camera system shall accept an external command to select and change any one of the five internal filters into the optical beam per the optical design specifications.

3.4.2.6 Filter Swap

ID: OSS-REQ-0270 **Last Modified: 10/4/2012**

Specification: The internal filter complement of the Camera shall be re-configurable by swapping any one of the internal filters with one stored externally without requiring the removal of the Camera from the telescope.

3.4.2.7 Supported Image Types

ID: OSS-REQ-0271 **Last Modified: 10/4/2012**

Specification: The LSST camera system shall support the acquisition of the following image types:

- standard exposures image
- bias image (zero integration readout of the FPA)
- dark image (finite duration integration with a closed shutter)

3.4.3 Imaging Control

ID: OSS-REQ-0272 **Last Modified: 11/23/2010**

Specification: The LSST Camera system shall acquire images in the current filter on command from the OCS by specifying exposure time and number of exposures.

Discussion: Filter change is a separate function requiring coordination between both the Telescope and Camera

3.5 Photometric Calibration

The highest-level performance requirements for calibration of LSST data are specified in the LSST Science Requirements Document (SRD) and LSST System Requirements (LSR). The photometric calibration process will be divided into three main elements that contribute to calibration of LSST data:

1. An Instrument Calibration System that is tasked with calibrating the overall LSST system instrumental response to photons that are within the field of view of the telescope and camera;
2. An Auxiliary Telescope and thermal IR Cloud Camera that are tasked with characterizing the extinction of light as it travels from the top of the atmosphere to the entrance pupil of the telescope; and
3. The processing of Reference and Standard stars in LSST science images by algorithms in the DM pipelines.

The flow-down of functional specifications from the highest level SRD requirements to these three elements of the calibration system is described in Document-7658, "LSST Calibration Functional Requirements", in the LSST archive.

The first column of Table 1 in Document-7658 gives specifications on the temporal variation of calibration errors. The values in the second column are specifications on the spatial variation of calibration errors. The values in the final column are specifications on chromatic errors. The table lists specifications for the

LSST *griz* optical bands; specifications for the *u* and *y* bands are 50% larger. This document addresses the functional performance requirements for each of these dimensions for each of the three elements involved in calibration of LSST data.

Bright isolated point sources are functionally stars that are not merged with other sources and are bright enough (17<*r*<20) to provide single measurements with S/N > 100.

3.5.1 Calibration of the Instrumental Transmission

ID: OSS-REQ-0282 **Last Modified: 9/24/2012**

Specification: The LSST System shall calibrate the wavelength-dependent instrumental transmission function such that it contributes no more than the allocations in the table **instCalAlloc** for repeatability, uniformity, and relative accuracy.

Discussion: The instrumental transmission function includes the effect of the three telescope mirrors, three camera refractive elements, filters, and the sensors making up the FPA.

Sub-allocations for specific effects are given in the requirements that follow. These allocations include further distinction between the maximum uncorrected effect and the minimum required attenuation from either measurement and/or software algorithms.

Description	Value	Unit	Name
The maximum allowed RSS contribution to the overall photometric repeatability in "g", "r", "i", or "z" filters of bright isolated point sources caused by errors in estimating the wavelength-dependent instrumental transmission function shall not exceed **instCalRep_griz**.	1.9	mili-mag	instCalRep_griz
The maximum allowed RSS contribution to the overall photometric repeatability in "z" and "y" filters of bright isolated point sources caused by errors in estimating the wavelength-dependent instrumental transmission function shall not exceed **instCalRep_zy**.	5.3	mili-mag	instCalRep_zy
The maximum allowed RSS contribution to the overall uniformity across the sky of the photometric zero-point of bright isolated point sources caused by errors in estimating the wavelength-dependent instrumental transmission function.	2.0	mili-mag	instCalUniformity
The maximum allowed RSS contribution to the overall accuracy of the color zero points of bright isolated point sources caused by errors in estimating the wavelength-dependent instrumental transmission function.	3.0	mili-mag	instColorZP

3.5.1.1 Filter Variation Allocations

ID: OSS-REQ-0331 **Last Modified: 9/21/2012**

Specification: Photometric errors caused by uncertainties in filter placement and/or variations over the FOV shall result in an RSS contribution of not more than **photFiltVarErr** to the repeatability of magnitudes for bright isolated point sources with allocations to maximum uncorrected effect and minimum attenuation give in table **photFiltVarAlloc.**

Description	Value	Unit	Name
The maximum post correction RSS contribution to the photometric repeatability budget from positioning errors and or variations over the FOV shall be no more than **photFiltVarErr.**	0.5	mili-mag	photFilterVarErr
The maximum un-modeled RSS contribution to the photometric repeatability budget from filter placements errors and/or response variations over the FOV shall be no more than **maxFiltVarEffect.**	0.5	mili-mag	maxFiltVarEffect
Attenuation of the raw un-modeled filter placement errors and/or response variation over the FOV (**maxFiltVarEffect**) either by direct measurement or through software algorithms shall be at least **minFiltVarAttenuation.**	1.0	int	minFiltVarAttenuation

3.5.1.2 FPA Gain Allocations

ID: OSS-REQ-0332 **Last Modified: 9/21/2012**

Specification: FPA sensor gain variation errors shall result in an RSS contribution of not more than **photFPAGainErr** to the repeatability of magnitudes for bright isolated point sources with allocations to maximum uncorrected effect and minimum attenuation give in table **photFPAGainAlloc.**

Description	Value	Unit	Name
The maximum post correction RSS contribution to the photometric repeatability budget from FPA gain variation errors shall be no more than **photFPAGainErr.**	1.4	mili-mag	photFPAGainErr
The maximum error in photometric repeatability from uncorrected gain variations over spatial scales equal to or exceeding a single imaging device (e.g. CCD) over a 12 hour observing period shall not exceed **maxLSGainEffect.**	10	mili-mag	maxLSGainEffect
Attenuation of the raw large scale gain variation errors (**maxLSGainEffect**) either by direct measurement or through software algorithms shall be at least **minLSGainAttenuation.**	100	int	minLSGainAttenuation
The maximum error in photometric repeatability from uncorrected gain variations over spatial scales equal a single output amplifier and over a 12 hour observing period shall not exceed **maxSSGainEffect(>1hr).**	10	mili-mag	maxSSGainEffect (>1hr)
Attenuation of the raw amplifier scale gain variation errors over periods greater than 1 hour (**maxSSGainEffect(>1hr)**) either by direct measurement or through software algorithms shall be at least **minSSGainAttenuation(>1hr).**	10	int	minSSGainAttenuation(>1hr)
The gain offset for an area with a spatial scale equal to a single amplifier relative to the gain of the imaging device (e.g. CCD) on which that area resides shall vary by no more than **maxSSGainEffect(<1hr)** for periods less than 1 hour.	1.0	mili-mag	maxSSGainEffect (<1hr)
Attenuation of the raw small scale short term gain variation errors (**maxSSGainEffect(<1hr)**) either by direct measurement or through software algorithms shall be at least **minSSGainAttenuation(<1hr).**	1.0	int	minSSGainAttenuation(<1hr)

3.5.1.3 FPA Temperature Allocations

ID: OSS-REQ-0333 **Last Modified: 10/2/2012**

Specification: FPA temperature variation errors shall result in an RSS contribution of not more than **photFPATempErr** to the repeatability of magnitudes for bright isolated point sources with allocations to maximum uncorrected effect and minimum attenuation give in table **photFPATempAlloc.**

Discussion: This requirement only applies to y-band photometric repeatability due to the temperature sensitivity of the extreme red (~1 micron) QE response of silicon.

Description	Value	Unit	Name
The maximum post correction RSS contribution to the photometric repeatability budget from FPA temperature variation errors shall be no more than **photFPATempErr.**	5.0	mili-mag	photFPATempErr
The maximum un-modeled RSS contribution to the y-band photometric repeatability budget from un-modeled FPA temperature variation errors shall be no more than **photFPAGainErr.**	5.0	mili-mag	maxFPATempEffect
Attenuation of the raw un-modeled temperature variation errors (**maxFPATempEffect**) either by direct measurement or through software algorithms shall be at least **minFPATempAttenuation.**	1.0	int	minFPATempAttenuation

3.5.1.4 Flat Fielding Allocations

ID: OSS-REQ-0334 **Last Modified: 9/21/2012**

Specification: Flat fielding errors shall result in an RSS contribution of not more than **photFlatFieldErr** to the repeatability of magnitudes for bright isolated point sources with allocations to the maximum uncorrected effect and minimum attenuation given in table **photFlatFieldAlloc.**

Description	Value	Unit	Name
The maximum post correction RSS contribution to the photometric repeatability budget from flat fielding errors shall be no more than **photFlatFieldErr.**	0.6	mili-mag	photFlatFieldErr
The maximum error in photometric repeatability from uncorrected flat fielding errors shall not exceed **maxFlatFieldEffect.**	250	mili-mag	maxFlatFieldEffect
Attenuation of the raw flat fielding errors (**maxFlatFieldEffect**) either by direct measurement or through software algorithms shall be at least **minFlatFieldAttenuation.**	400	int	minFlatFieldAttenuation

3.5.1.5 Shutter Timing Allocations

ID: OSS-REQ-0335 **Last Modified: 9/21/2012**

Specification: Shutter timing errors shall result in an RSS contribution of not more than **photShutterErr** to the repeatability of magnitudes for bright isolated point sources with allocations to the maximum uncorrected effect and minimum attenuation given in table **photShutterAlloc.**

Description	Value	Unit	Name
The maximum post correction RSS contribution to the photometric repeatability budget from shutter timing errs shall be no more than **photShutterErr.**	0.4	mili-mag	photShutterErr
The maximum error in photometric repeatability from uncorrected shutter timing errors shall not exceed **maxShutterEffect.**	20.0	mili-mag	maxShutterEffect
Attenuation of the raw shutter timing errors (**maxShutterEffect**) either by direct measurement or through software algorithms shall be at least **minShutterAttenuation.**	50	int	minShutterAttenuation

3.5.1.6 Calibration Meta Data

ID: OSS-REQ-0317 **Last Modified: 5/18/2011**

Specification: As required by OSS-REQ-0063, the Telescope and Site and the Camera systems shall provide all real-time metadata needed to maintain the required photometric precision and accuracy during operations between daily and periodic acquisition of dedicated calibration data.

3.5.2 Calibration of the Atmospheric Transmission

ID: OSS-REQ-0276 **Last Modified: 9/24/2012**

Specification: The LSST System shall calibrate the wavelength-dependent transmission of the atmosphere above the Summit Site such that it contributes no more than the allocations in the table **atmCalAlloc** for repeatability (parameter **atmCalRep**), uniformity (**atmCalUniformity**), and relative accuracy (**atmCalColorZP**).

Sub-allocations for specific effects are given in the requirements that follow. These allocations include further distinction between the maximum uncorrected effect and the minimum required attenuation from either measurement and/or software algorithms.

Description	Value	Unit	Name
The maximum allowed RSS contribution to the overall photometric repeatability of bright isolated point sources in the "u", "g", "r", and "i" filters caused by errors in estimating the wavelength-dependent atmospheric transmission function shall not exceed **photAtmColorErr_ugri**.	1.0	mili-mag	photAtmColorErr_ugri
The maximum error in photometric repeatability from uncorrected wavelength dependent atmospheric transmission errors shall not exceed **maxAtmColorEffect_ugri** in the "u", "g", "r" and "i" filters**.**	50	mili-mag	photAtmColorEffect_ugri
The maximum allowed RSS contribution to the overall photometric repeatability of bright isolated point sources in the " "z", and "y" filters caused by errors in estimating the wavelength-dependent atmospheric transmission function shall not exceed **photAtmColorErr_zy**.	2.0	mili-mag	photAtmColorErr_zy
Attenuation of the raw wavelength dependent atmospheric transmission errors (**maxAtmColorEffect**) either by direct measurement or through software algorithms shall be at least **minFAtmColorAttenuation.**	50	mili-mag	photAtnColorAttenuation

Description	Value	Unit	Name
The maximum error in photometric repeatability from uncorrected wavelength dependent atmospheric transmission errors shall not exceed **maxAtmColorEffect_zy** in the "z" and "y" filters**.**	100	mili-mag	photAtmColorEffect_zy

3.5.2.1 ATM Color Allocations

ID: OSS-REQ-0277 **Last Modified: 9/24/2012**

Specification: Photometric errors caused by uncertainties in the measurement of the wavelength dependent (color) atmospheric transmission shall result in an RSS contribution of not more than **photAtmColorErr** to the repeatability of magnitudes for bright isolated point sources with allocations to maximum uncorrected effect and minimum attenuation give in table **photAtmColorAlloc.**

Description	Value	Unit	Name
The maximum allowed RSS contribution to the overall photometric repeatability of bright isolated point sources caused by errors in estimating the wavelength-independent atmospheric transmission function shall not exceed **photAtmGrayrErr**.	2.0	mili-mag	photAtmGrayErr
The maximum allowed RSS contribution to the overall uniformity across the sky of the photometric zero-point of bright isolated point sources caused by errors in estimating the wavelength-dependent atmospheric transmission function.	4.0	mili-mag	atmCalUniformity
The maximum allowed RSS contribution to the overall accuracy of the color zero points of bright isolated point sources caused by errors in estimating the wavelength-dependent atmospheric transmission function.	3.0	mili-mag	atmCalColorZP
The maximum allowed RSS contribution to the overall photometric repeatability across the sky of the photometric zero-point in the "u", "g", "r", and "i" filters of bright isolated point sources caused by errors in estimating the atmospheric transmission function shall not exceed **atmCalRep_ugri**.	3.2	mili-mag	atmCalRep_ugri
The maximum allowed RSS contribution to the overall photometric repeatability across the sky of the photometric zero-point in the "z" and "y" filters of bright isolated point sources caused by errors in estimating the atmospheric transmission function shall not exceed **atmCalRep_zy**.	3.6	mili-mag	atmCalRep_zy

ATM Color Spectral Range

ID: OSS-REQ-0279 **Last Modified: 9/24/2012**

Specification: The atmospheric transmission function shall be estimated over a range of wavelengths with resolution defined in the table **atmTranSpec.**

Description	Value	Unit	Name
The maximum wavelength of the spectral range over which the atmospheric transmission function is estimated.	1125	nm	atmLambdaMax

Description	Value	Unit	Name
The minimum wavelength of the spectral range over which the atmospheric transmission function is estimated.	315	nm	atmLambdaMin
The maximum resolution of the estimated atmospheric transmission function at 500nm.	1.5	nm	atmLambdaRes

Atmospheric Transmission Sky Coverage

ID: OSS-REQ-0278 **Last Modified: 9/24/2012**

Specification: The atmospheric transmission function shall be mapped over the nightly survey operating area.

Spatial and temporal proximity with respect to the LSST pointings is TBD (will be resolved as the Photometric calibration plan is fully detailed).

Atmospheric Transmission Temporal Sampling

ID: OSS-REQ-0280 **Last Modified: 9/24/2012**

Specification: The atmospheric transmission function shall be determined with a period no longer than **atmTempSamp** between measurements.

Description	Value	Unit	Name
The maximum time between measurements of the atmospheric transmission function for a single point on the sky.	5	Minute	atmTempSamp

3.5.2.2 ATM Gray Allocations

ID: OSS-REQ-0336 **Last Modified: 9/24/2012**

Specification: Photometric errors caused by uncertainties in the measurement of the wavelength independent (gray) atmospheric transmission shall result in an RSS contribution of not more than **photAtmGrayErr** to the repeatability of magnitudes for bright isolated point sources with allocations to maximum uncorrected effect and minimum attenuation give in table **photAtmGrayAlloc.**

Description	Value	Unit	Name
The maximum allowed RSS contribution to the overall photometric repeatability of bright isolated point sources caused by errors in estimating the gray atmospheric transmission function shall not exceed **photAtmGrayErr.**	3.0	mili-mag	photAStmGrayErr
The maximum error in photometric repeatability from uncorrected gray atmospheric transmission errors shall not exceed **maxAtmGrayEffect.**	250	mili-mag	maxAtmGrayEffect
Attenuation of the raw gray atmospheric transmission errors (**maxAtmGrayEffect**) either by direct measurement or through software algorithms shall be at least **minFAtmGrayAttenuation.**	83	mili-mag	minAtmGrayAttenuation

Cloud Map (TBR)

ID: OSS-REQ-0281 **Last Modified: 9/24/2012**

Specification: A cloud map, meeting **cloudMapPerf** specifications, showing relative cloud densities (grey extinction) across the LSST's field-of-view (3.5 deree) will be provided for each survey science image.

Discussion: The intent of the cloud map described here is to provide additional information on how to interpolate the grey extinction variation occurring between reference stars used to anchor the internal LSST photometric system.

Description	Value	Unit	Name
The resolution (rms) for the map showing the relative grey extinction (clouds) across the LSST FOV for each survey science image.	60	Arcsec	cloudMapRes
The sensitivity to variations in grey extinction (clouds) within a resolution element.	0.005	ABmag	cloudMaprelSens

3.5.3 Calibration Data Processing

ID: OSS-REQ-0273 **Last Modified: 5/18/2011**

[This is a composite requirement in the SysML model, signifying simply the union of the requirements below it in the hierarchy.]

3.5.3.1 Calibration Processing Performance Allocations

ID: OSS-REQ-0275 **Last Modified: 10/7/2013**

Specification: The LSST System shall photometrically calibrate raw image data such that the data processing contributes no more than the allocations in the table **procCalAlloc** for repeatability (parameter **procCalRep**), uniformity (**procCalUniformity**), and relative accuracy (**procCalZP**).

Discussion: These allocations include effects from calibration algorithms, errors and noise in producing the necessary calibration data products, as well as errors and uncertainties in any reference catalogs used in the calibration process.

Description	Value	Unit	Name
The maximum allowed RSS contribution to the overall photometric repeatability of bright isolated point sources caused by errors introduced in the data processing pipelines.	0.003	ABmag	procCalRep
The maximum allowed RSS contribution to the overall uniformity across the sky of the photometric zero-point of bright isolated point sources introduced in the data processing pipelines.	0.007	ABmag	procCalUniformity
The maximum allowed RSS contribution to the overall accuracy of the color zero points of bright isolated point sources introduced by the data processing pipelines.	0.003	ABmag	procColorZP

3.5.3.2 Extrapolation of Calibration from Reference

ID: OSS-REQ-0318 **Last Modified: 10/7/2013**

Specification: The LSST data processing system shall be able to extrapolate calibration performance established with bright isolated stars to faint resolved source with a degradation that is no worse that the growth of errors from Poisson noise.

3.5.4 Data Products for Photometric Calibration

ID: OSS-REQ-0284 **Last Modified: 11/23/2010**

Specification: The LSST Data Management system output shall include the calibration data products required to support the photometric calibration requirements within this document. The Data Management system shall archive all Calibration Data Products.

3.5.4.1 Reference Star Catalog

ID: OSS-REQ-0285 **Last Modified: 5/26/2011**

Calibration of LSST data will require a catalog of non-variable main-sequence reference stars with magnitudes 17 < r < 20. This catalog shall contain 10000 stars in each LSST 9.8sq deg survey field.

3.5.4.2 White Dwarf Flux Standards

ID: OSS-REQ-0286 **Last Modified: 7/29/2010**

Determination of transformations between LSST filter bands will require a catalog of hydrogen (DA) and helium (DB) white dwarf stars with magnitudes within the range of the LSST main telescope. This catalog must contain at least one DA or DB WD in each LSST 9.8sq deg survey field.

3.6 System Timing and Dynamics

3.6.1 Cadence and Visit Timing

ID: OSS-REQ-0287 **Last Modified: 5/19/2011**

[This is a composite requirement in the SysML model, signifying simply the union of the requirements below it in the hierarchy.]

3.6.1.1 Standard Visit Duration

ID: OSS-REQ-0288 **Last Modified: 5/19/2011**

Specification: The total elapsed time for a standard visit (2 x 15 sec exposures), from the command to begin the first exposure to the end of the second exposure when the shutter is fully closed, shall be no more than **visitDuration.**

Discussion: The end point of the second exposure is defined when the shutter is fully closed and does not include the readout time. This is because the readout of the second exposure is done while the system is being re-pointed to the next field location.

The baseline sequence for a standard visit is 1 sec open shutter; 14 sec integration; 1 sec close shutter; 2 sec pixel readout 1 sec shutter open; 14 sec integration; 1 sec shutter close.

Description	Value	Unit	Name

Description	Value	Unit	Name
The maximum duration of a visit is **visitDuration**.	34	Seconds	visitDuration

3.6.1.2 Time Interval Between Visits

ID: OSS-REQ-0289 **Last Modified: 12/3/2010**

Specification: The *median* time between successive visits shall be less than **medianVisitInterval** over the full set of survey observations.

Specification: The *average* time between successive visits shall be less than **aveVisitInterval** over the full set of survey observations.

Discussion: This requirement is derived from the total number of visits per field and the total number of fields needed to cover the defined survey area. The interval between successive visits starts when the shutter of the second exposure of the visit is fully closed, and ends when the shutter of the first exposure of the next visit opens.

The minimum interval between visits is limited by the FPA readout time when there is not a repositioning of the telescope. Operating for an entire night at that cadence is the extreme limit of what might be required in deep-drilling operations. That specification does not require that this mode of operation be able to be sustained indefinitely.

Description	Value	Unit	Name
The median interval as defined above over all successive visit pairs over the 10 year survey.	5	Seconds	medianVisitInterval
The average interval as defined above over all successive visit pairs over the 10 year survey	10	Seconds	aveVisitInterval

3.6.1.3 Continuous Exposures

ID: OSS-REQ-0319 **Last Modified: 5/19/2011**

Specification: The Observatory shall be capable of continuous operation throughout a night with the interval between successive visits equal to the FPA readout time.

Discussion: This mode of observing is needed to support observations when the telescope is not being re-pointed. For example observing "deep drilling" fields, where successive exposures are obtained through one or more filters over an extended period, and obtaining calibration images adjuring a cloudy night..

3.6.1.4 Minimum Exposure Time

ID: OSS-REQ-0291 **Last Modified: 5/19/2011**

Specification: The camera shall be able to obtain a single exposure with an effective minimum exposure time of no more than **minExpTime**.

Discussion: The camera thermal stability may be affected if the duty cycle differs from the standard 15

second exposure. If the exposure is shortened from the 15 second nominal, the spacing between successive exposures should be extended to maintain the average readout rate consistent with a 15 second exposure. If the exposure is lengthened from the 15 second nominal, the thermal stability may be affected, which may affect photometric accuracy.

Description	Value	Unit	Name
The maximum shortest exposure time of a single exposure is **minExpTime**.	5	Seconds	minExpTime

3.6.2 Filter Swaps & Changes

ID: OSS-REQ-0292 **Last Modified: 5/18/2011**

Specification: The system shall be designed such that the following performance specifications are met:

1. maximum time to change the operational filter
2. maximum time to swap a single filter from the internal complement

3.6.2.1 Maximum time for operational filter change

ID: OSS-REQ-0293 **Last Modified: 5/26/2011**

Specification: The camera system shall provide the capability of changing the operational filter with any other internal filter in a time less than **tFilterChange**.

Discussion: This time allocation includes any overhead required to position the camera into a specific orientation required to execute the filter change.

This requirement allocates 30 seconds to the telescope (reorient the camera to its nominal zero angle position on the rotator) and 90 seconds to the camera subsystem (for executing the change).

Total time allowed for moving any one of the internal filters in the camera into its operating position. This includes any overhead required to place the camera in a specific orientation prior to the change.

Description	Value	Unit	Name
Total time allowed for moving any one of the internal filters in the camera from a stowed position into its operating position. This includes any overhead required to place the camera in a specific orientation prior to the change.	120	Seconds	tFilterChange

3.6.2.2 Maximum time to swap internal filter

ID: OSS-REQ-0294 **Last Modified: 5/18/2011**

Specification: The filter complement internal to the camera shall be reconfigured by swapping one of the internal filters with one stored externally in a time less than **tFilterSwapOut**.

Discussion: This time is allocated between two activities involving the telescope and camera, operational needs. Nominal allocation is 1.5 hours to each subsystem.

This requirement does *not* include the time required to obtain the necessary calibration data needed when the filter complement is changed.

Description	Value	Unit	Name
Maximum time required to swap a single filter in the complement of 5 internal filters to the camera with one that has been externally stored.	3	Hours	tFilterSwapOut

3.6.2.3 Filter Change Count

ID: OSS-REQ-0295 **Last Modified: 5/19/2011**

Specification: For design purposes the number of daily and nightly operational filter changes shall be **dailyFiltChanges** and **nightlyFiltChanges** given in the table below.

Discussion: Based on calibration baseline of taking dome flats twice per day (beginning / end of night). These value need to be check against the most recent OpsIm output

Description	Value	Unit	Name
The expected minimum number of daily filter changed shall be **dayFiltChnages**. (TBR)	8	int	dailyFiltChanges
The expected minimum number of nightly filter change shall be **dayFiltChnages**. (TBR)	4	int	nightlyFiltChanges

3.6.2.4 Filter Swap Count

ID: OSS-REQ-0320 **Last Modified: 5/19/2011**

Specification: For design purposes the number of monthly filter complement swaps shall be at least **monthlyFiltSwaps** given in the table below.

Discussion: The number of swaps supports replace one of the red filters with the u-band filter during the dark time around new moon.

Description	Value	Unit	Name
The minimum number of filter swaps per month shal be taken as **monthlyFiltSwaps.**	2	int	monthlyFiltSwaps

3.6.3 Observatory Pointing and Tracking

ID: OSS-REQ-0297 **Last Modified: 11/23/2010**

[This is a composite requirement in the SysML model, signifying simply the union of the requirements below it in the hierarchy.]

3.6.3.1 Absolute Pointing

ID: OSS-REQ-0298 **Last Modified: 5/19/2011**

Specification: The LSST shall point to a defined set of sky coordinates with an RMS accuracy of **absPointErr.**

Discussion: It is understood that pointing does not require direct access to any sky references (e.g. guide stars).

Description	Value	Unit	Name
The minimum RMS point error of the full range of operational sky coverage.	2	Arcsec	absPointErr

3.6.3.2 Field de-rotation

ID: OSS-REQ-0299 **Last Modified: 8/5/2010**

Specification: The LSST shall provide the ability to track the apparent field rotation caused by tracking the sky in altitude and azimuth.

Discussion: It is understood that the telescope mount configuration will be that of an altitude over azimuth design.

Rotator Range

ID: OSS-REQ-0300 **Last Modified: 11/18/2010**

Specification: The LSST shall be capable of maintaining rotation tracking the duration of a standard visit over a range of angles **rotTrackRange** on either side of a nominal reference with respect to the optical bore sight.

Discussion: This requirements is designed to allow analysis of PSF shape systematics generated by the optical system to meet the full survey ellipticity performance requirements.

Description	Value	Unit	Name
The half range of the rotator motion.	90	Degrees	rotTrackRange

Rotator tracking Time

ID: OSS-REQ-0301 **Last Modified: 8/5/2010**

Specification: The LSST shall be able to maintain field rotation tracking over a period of at least **rotTrackTime** without the need to reset (e.g. unwind cable wraps).

Discussion: This requirements is driven by the need to conduct extended "deep drilling" observations on a single field.

Description	Value	Unit	Name
Minimum time required for continuous rotation tracking	1	Hour	rotTrackTime

3.6.3.3 Offset Pointing

ID: OSS-REQ-0302 **Last Modified: 9/8/2010**

Specification: The LSST shall be capable of offset pointing within a single field-of-view with a precision of no more than **offsetPointingErr.**

Description	Value	Unit	Name
The RMS error for offset pointing within the FOV.	0.2	Arcsec	offsetPointingErr

3.6.3.4 Open Loop Tracking

ID: OSS-REQ-0303 **Last Modified: 8/5/2010**

Specification: The LSST shall be capable of open loop tracking without the assistance of real time optical feedback to an accuracy of **openTrackErr** over any 10 minute duration during normal night time operations.

Discussion: This requirement is somewhat soft and is driven primarily by ease of operation while acquiring guide stars for optical tracking feed back. It also partially driven by the need to be able to track well enough without guiding to assess optical performance during the early commissioning phase of the project.

Description	Value	Unit	Name
Allowed open loop tracking error in 10 minutes.	1.0	Arcsec	openTrackErr

3.6.3.5 Tracking Range

ID: OSS-REQ-0304 **Last Modified: 5/19/2011**

Specification: The LSST telescope shall maintain tracking over all elevation angles over a range given by **trackRange** below.

Description	Value	Unit	Name
Minimum high elevation limit where tracking is to be maintained.	86.5	Degrees	maxTrackEl
Minimum low elevation limit where tracking is to be maintained.	15.0	Degrees	minTrackEl

3.6.3.6 Guiding

ID: OSS-REQ-0305 **Last Modified: 11/18/2010**

Specification: The LSST system shall improve the tracking of the optical system to the sky by means of active guiding over the whole accessible sky.

The history of the feedback signal involved shall be archived in the telemetry database.

Discussion: Guiding includes providing feedback of the tracking errors of the mount in both axes as well as the field de-rotation.

The required performance for closed loop tracking with guiding is derived from the image quality allocation to the telescope.

Guide Signal Source

ID: OSS-REQ-0306 **Last Modified: 11/18/2010**

Specification: It is the responsibility of the LSST instrument (i..e. Camera) to provide a suitable signal to the mount control system to enact guide error feedback.

3.7 Education and Public Outreach

3.7.1 EPO - National Priorities

ID: OSS-REQ-0355 **Last Modified: 10/4/2013**

Specification: LSST EPO shall contribute directly or indirectly to four of the top five priority STEM investment areas as described in the "Federal STEM Education 5-Year Strategic Plan":

- Improve STEM instruction
- Increase and Sustain Youth and Public Engagement in STEM
- Enhance STEM experience of Undergraduate Students
- Better Serve Groups Historically Underrepresented in STEM fields

Discussion: The “Federal STEM Education 5-Year Strategic Plan” can be accessed at: http://www.whitehouse.gov/sites/default/files/microsites/ostp/stem_stratplan_2013.pdf

3.7.1.1 EPO - Emphasize Diversity

ID: OSS-REQ-0356 **Last Modified: 10/4/2013**

Specification: LSST EPO shall actively partner with minority-serving institutions and organizations to engage traditionally under-represented groups in LSST activities.

Discussion: In order to maximize our reach into this targeted audience, we will coordinate with existing programs and leverage their efforts.

3.7.1.2 EPO - Audience Definition

ID: OSS-REQ-0357 **Last Modified: 10/4/2013**

Specification: The LSST EPO subsystem shall serve four main categories of users: the General Public, Citizen Scientists, Content Developers at Science Museums and Planetariums, and Instructors and Students in research experiences.

Discussion: Each audience will be served through an individualized interface to data products.

3.7.1.3 EPO - Direct and Indirect Users

ID: OSS-REQ-0358 **Last Modified: 10/4/2013**

Specification: EPO data products, interfaces, materials, and support shall be provided to direct users of LSST EPO as well as to content developers at partner organizations for their use and deployment.

Discussion: LSST cannot be everything to everyone; some audiences will be served indirectly through content providers. For example, LSST will provide modules to content creators in science centers who will incorporate those products into their productions (kiosks, video, digital planetarium shows, etc.)

3.7.1.4 EPO - System Deliverables

ID: OSS-REQ-0359 **Last Modified: 10/4/2013**

Specification: The EPO system will provide data products, user interfaces, data access and analysis tools, educational materials, support facilities, performance metrics, links to external datasets, and a

collaborative framework to support its users.

Discussion: These deliverables will be available from the EPO center.

3.7.1.5 EPO - Evaluation

ID: OSS-REQ-0360 **Last Modified: 10/4/2013**

Specification: LSST EPO shall conduct regular internal and external evaluations of EPO products and share assessment results with the science education community.

Discussion: Outcomes and metrics will be tracked for all registered users and directly-supplied learning experiences

3.7.1.6 EPO - Sustainable Partnerships

ID: OSS-REQ-0361 **Last Modified: 10/4/2013**

Specification: LSST EPO shall build partnerships with local, regional and national organizations, institutions, agencies, museums, schools, and interested groups to facilitate education and outreach programs for diverse audiences.

Discussion: "If you want to go fast, go alone. If you want to go far, go with others." LSST EPO wants to go far and remain useful through operations and beyond. This is best accomplished in partnership with other organizations with similar goals.

3.7.1.7 EPO - Flexible Interface Design

ID: OSS-REQ-0362 **Last Modified: 10/4/2013**

Specification: The EPO User Interface design shall be agile and capable of evolving in response to user experience and demand.

Discussion: The EPO interface is certain to change with time as new user needs are identified, new technology capabilities come on line, and opportunities arise due to partnerships, new funding, or social trends. LSST EPO must be able to identify these changes and adapt to them.

3.7.1.8 EPO - Cloud Capable

ID: OSS-REQ-0363 **Last Modified: 10/4/2013**

Specification: LSST EPO shall be designed such that it is capable of using the cloud for data storage and distribution.

Discussion: The EPO user load is much less predictable and is more volatile than the science user load. Compatibility with the use of elastic cloud technologies ensures that EPO can handle the potential load volatility.

3.7.1.9 EPO - System Responsiveness

ID: OSS-REQ-0364 **Last Modified: 10/4/2013**

Specification: LSST EPO shall serve each user in a acceptable response time.

Discussion: Acceptable response times have been established for each user action and must be achieved to meet the audience need. See EPO-REQ-0092 for further derivation of this requirement.

3.7.1.10 EPO - Conform to Software Standards

ID: OSS-REQ-0365 **Last Modified: 10/4/2013**

Specification: LSST EPO shall conform to project-wide software standards and practices.

Discussion: In order to maximize the cost-savings and expertise-sharing, EPO software will follow the project-wide standards and practices.