Large Synoptic Survey Telescope (LSST)
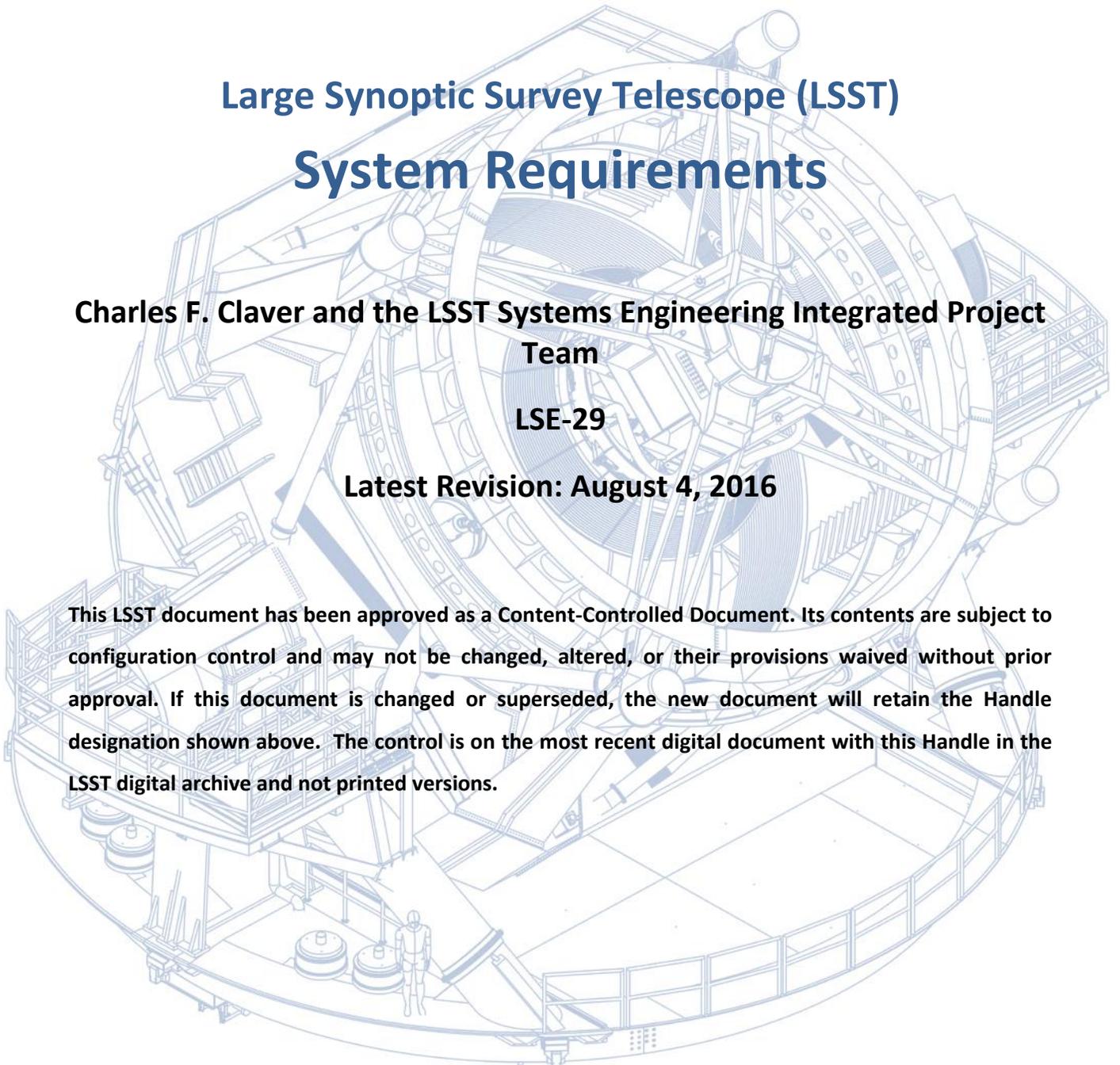
System Requirements

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

LSE-29

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Change Record

Version	Date	Description	Owner name
1	5/18/2010	Initial Version	Charles F. Claver and the LSST Systems Engineering Group
1.4	3/23/2011	Initial version placed under change control by CCB. This is baselined as version 1.4 in the SysArch model	Charles F. Claver and the LSST Systems Engineering Group
2.0	10/08/2013	Incorporates LCR-148, LCR-153 (amended by the 10/08/2013 CCB meeting minutes), and LCR-144 (amended by the 10/02/2013 meeting minutes)	Brian Selvy and the LSST Systems Engineering Integrated Product Team
3	3/11/2015	Incorporates LCRs 141, 182, and 253. LCR-141 flows down SRD text edit to clarify the intent of photometry requirements. LCR-182 adds a minimum exposure time specification. Changes related to LCR-253 provide consistency throughout throughput flowdown chain.	C. Claver and the LSST Systems Engineering Integrated Product Team
3.1	8/4/2016	Implementation of LCR-584. Add requirements that provide the flow down logic for advanced publication of the expected scheduler.	C. Claver (LCR), B. Selvy (SysML), Robert McKercher (DocuShare)

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The LSST System Requirements

Project Background

The LSST is a large-aperture, wide-field, ground-based telescope that will survey the visible sky every few nights in six photometric bands. The 10-year survey will produce a database suitable for answering a wide range of pressing questions in astrophysics, cosmology, and fundamental physics. LSST is designed to be a public facility. The images, alerts, and resulting catalogs will be made available to a broad community with no proprietary period. A sophisticated data management system will provide easy access to these data, enabling simple queries from individual users (both professionals and laypersons), as well as computationally intensive scientific investigations that utilize the entire dataset.

Document Scope

This LSST System Requirements (LSR) document provides a comprehensive definition of the highest level of LSST Observatory system requirements. Contents of the document are generated out of the SysML based LSST System Architecture model (see Claver et al, 2010). It is derived from the LSST Science Requirements Document [LSST LPM-17] that describes the scientific motivations for the project, the survey capabilities and the reference science missions used to develop detailed scientific specifications for the LSST survey. This document builds on those to fully describe the specific nature of the LSST survey, final data products, and derived system functions and specifications that must be met in the execution of the LSST project.

These requirements cover the following areas:

- Adopted survey performance parameters from the SRD table and Technical requirements extracted from the SRD text,
- Required system capabilities for
    1) Optical configuration
    2) Data collection functions and performance
    3) Data processing functions and performance
    4) Archiving and services functions and performance
- Survey operation and administration functions

Acronyms and Definitions of Terms

In this document a **_requirement_** refers to a declaration of a specified function or quantitative performance that the delivered system or subsystem must meet. It is a statement that identifies a necessary attribute, capability, characteristic, or quality of a system in order for the delivered system or subsystem to meet a derived or higher requirement, constraint, or function.

This document uses the term **_specification(s)_** to mean one or more performance parameter(s) being

established by a requirement that the delivered system or subsystem must meet.

An *attribute* specifies a quantitative performance *parameter* in the context of the SysML based SysArch model used to generate this document.

A *constraint* is used to refer to a external limitation imposed on a delivered item under which it must meet its requirements (e.g., the survey performance must be met under the constraint of the historical weather pattern of the chose site). A constraint in not a characteristic of the system or subsystem itself possesses.

Glossary of Abbreviations (Document-11921)

Glossary of Definitions (Document-14412)

Reference Documents

Science Requirements Document (v5.1.3), (SRD) (LPM-17)

Observatory System Specifications, (OSS) (LSE-30)

The LSST System Requirements

1 Survey Design Specifications

ID: LSR-REQ-0080   **Last Modified: 8/3/2016**

Requirement: The LSST system shall be designed such that the system achieves a survey with the following scientific and performance requirements.

Discussion: The LSST SRD specifies a suite of requirements for the scientific performance of the survey with minimum, design, and stretch goals. For the purpose of establishing the system design and flow down to lower level requirements a single value for each parameter for these requirements is defined here. The requirements that follow establish which specific value for each of the SRD performance parameters has been adopted, from within the SRD-defined ranges for the system design.

Further additional requirements and parameters have been pulled out of the body text in the SRD as identified requirements.

In nearly all cases the SRD design specification has been adopted for each parameter. It is explicitly noted where the design specification has not been adopted.

1.1   Filter Set Characteristics

ID: LSR-REQ-0081   **Last Modified: 8/3/2016**

Requirement: The LSST survey shall provide imaging in 6 spectral bandpasses that are defined in the following requirements for the **Filter Complement** and the **Filter Bandpass Performance**.

1.1.1 Filter Complement

ID: LSR-REQ-0082   **Last Modified: 8/3/2016**

Requirement: The filter set to be used during the lifetime of the survey shall comprise a complement of least 6 filters, **FC**, providing uniform sampling across the optical spectrum. The active complement shall be changeable within **TDFMax** hours.

Description	Value	Unit	Name
The ugrizy filter set is based on the filters from the SDSS with the addition of the y-band. These provide roughly uniform sampling of the optical spectrum from 320-1000nm.	ugrizy		FC

1.1.2 Filter Complement Swap Time

ID: LSR-REQ-0103   **Last Modified: 8/3/2016**

Requirement: The active complement shall be changeable within **TDFMax** hours.

Description	Value	Unit	Name
This is the time allowed for swapping out any filter in the internal complement of **nFilters** filters (those available on a nightly basis) for another filter from the full complement **FC**.	8	Hour	TDFmax

1.1.3 Night Filter Availability

ID: LSR-REQ-0083   **Last Modified: 8/3/2016**

Requirement: The number of filters available for use in the course of a night shall be at least **NFilters**, with no more than **TFMax** seconds required to change the active filter.

Description	Value	Unit	Name
The number of filters available on a nightly basis within the required change time.	5	int	NFilters
The total time allowed to change the selected internal filter. This time includes any time needed to configure the LSST hardware to execute the change and then return to normal operations.	120	Seconds	TFMax

1.1.4 Filter Bandpass Performance

ID: LSR-REQ-0084   **Last Modified: 8/3/2016**

Requirement: The filter bandpasses shall have a maximum out of band leakage in an any 10nm interval of no more than FLeak relative to the peak filter response more than one FWHM from the filter center wavelength, with the total integrated leak outside the first 0.1% response points no more than FLeakTot relative to the total transmission.

Discussion: The rationale is that this form of a requirement moves the max out of band leakage out to beyond the foot of the filter response, and avoids the computational problem with the original spec. Furthermore this form does not leave a gap between the 0.1% response and the FWHM point since the integrated out-of-band is maintained to the first 0.1%, which controls the overall foot.

Issue: This requirement deviates from what is in the SRD. It is not possible to meet the requirement as stated in the SRD. A change request to the SRD is pending to rectify the differences here.

Description	Value	Unit	Name
The maximum out of band leakage in any 10nm interval relative to the peak filter response outside first instance of reaching 0.1% relative response..	0.01	Percent	FLeak
The integrated leak is measured from 300-1200nm.	0.05	Percent	FLeakTot

1.1.5 Filter Temporal Stability

ID: LSR-REQ-0085   **Last Modified: 8/3/2016**

Requirement: The temporal stability of the filter bandpasses shall be sufficiently small such that the required photometric calibration repeatability requirements can be met.

1.2   Single Image Performance

ID: LSR-REQ-0086   **Last Modified: 8/3/2016**

Requirement: The LSST shall meet the following requirements for a **single standard visit** (defined by LSR-REQ-0016) performance:

1. Delivered Image Quality
2. Photometric Performance
3. Astrometric Performance
4. Image Depth

Discussion: The SRD defines a "single image" as the coaddition of the two exposures in a standard visit (see SRD sections 3.2 and 3.3.2).

1.2.1   Delivered Image Quality

ID: LSR-REQ-0007   **Last Modified: 8/3/2016**

Requirement: The design requirement for the image quality requires that, for the median atmospheric seeing, the system contribution to the delivered image quality never exceeds 15% and have the properties specified in the table **imageQuality**.

Discussion: The design point specified here deviates from the SRD design requirement due to the conflict between image quality and charge spreading in the thick detectors, needed to achieve the desired z-band and y-band sensitivities. Nevertheless, the adopted base system image quality of 0.4 arcsec FWHM remains within the allowed value set by the SRD minimum specifications. Similarly the minimum specifications for encircled energy have also been adopted.

Description	Value	Unit	Name
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
Median system delivered image quality in atmospheric seeing of 0.44 arcseconds in the r and i filters.	0.59	ArcsecFWHM	S1_0.44
Median system delivered image quality in atmospheric seeing of 0.60 arcsec in the r and i filters.	0.72	ArcsecFWHM	S1_0.60
Median system delivered image quality in atmospheric seeing of 0.80 arcseconds in the r and i filters.	0.89	ArcsecFWHM	S1_0.80
The maximum fraction of the images that can exceed the delivered image size by a factor of **SX**.	10	Percent	SF1
The maximum radius of the PSF spatial profile containing 80 percent encircled energy.	0.80	Arcsec	SR1
The maximum radius of the PSF spatial profile containing 90 percent encircled energy.	1.31	Arcsec	SR2
The maximum radius of the PSF spatial profile containing 95 percent encircled energy.	1.81	Arcsec	SR3

Description	Value	Unit	Name
Delivered image quality increase factor allowed over **SF1** fraction of images.	1.1	float	SX
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

1.2.1.1 Variation Over FOV

ID: LSR-REQ-0008   **Last Modified: 3/29/2011**

Requirement: The image degradation due to all system components (not including the atmosphere) over the field of view shall be smooth and small compared to the atmospheric seeing such that no more than 10 percent of the field of view shall be allowed to exceed a total RSS system image blur budget of

10%outlierBudget_0.44 in first quartile atmospheric seeing
10%outlierBudget_0.60 in median atmospheric seeing
10%outlierBudget_0.80 in third quartile atmospheric seeing

Discussion: The specified budget allocations are consistent with the base system budget, **medianRMSBudget,** being invariant with atmospheric conditions.

Description	Value	Unit	Name
The limiting RSS image blur that can be exceeded by 10% of the field of view in the first quartile (0.44 arcsec FWHM) atmospheric seeing conditions.	0.43	ArcsecFWHM	10%outlierBudget_0.44
The limiting RSS image blur that can be exceeded by 10% of the field of view in the median (0.60 arcsec FWHM) atmospheric seeing conditions.	0.46	ArcsecFWHM	10%outlierBudget_0.60
The limiting RSS image blur that can be exceeded by 10% of the field of view in the third quartile (0.80 arcsec FWHM) atmospheric seeing conditions.	0.52	ArcsecFWHM	10%outlierBudget_0.80

1.2.1.2 Off Zenith Degradation

ID: LSR-REQ-0087   **Last Modified: 3/16/2011**

Requirement: 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)$^{\textbf{ImFunc}}$.

Discussion: 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 $X^{\textbf{ImFunc}}$, the design specification for the allowed image quality budget due to the system is 0.60 arcsec at airmass of 2 and for the median seeing conditions (0.49 arcsec for X=1.4) as defined by the attributes **SysIm_60** (equivalent to **SXE** in SRD) and **SysIm_45** respectively.

Description	Value	Unit	Name

Description	Value	Unit	Name
The system image budget is allowed to degrade through the three reference zenith distances (ZD) as sec(ZD)^{ImFunc}.	0.6		ImFunc
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	ArcsecFW HM	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	ArcsecFW HM	SysIm_60

1.2.2 Delivered Image Ellipticity

ID: LSR-REQ-0092   **Last Modified: 3/29/2011**

Requirement: The Point spread function ellipticity for bright isolated unresolved sources in images from a single visit shall have the properties specified in the table **imageEllipticity** below.

Description	Value	Unit	Name
The fraction of PSF ellipticity measurements allowed to exceed the ellipticity outlier limit for bright isolated non-saturated stars.	5	Percent	EF1
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 outlier limit.	0.07	Ellipticity	SE2

1.2.3 Filter Depths

ID: LSR-REQ-0090   **Last Modified: 8/3/2016**

Requirement: The single visit depth for unresolved point sources in each of the 6 LSST filters shall meet the specifications in the following table, assuming the reference conditions specified in LSR-REQ-0089 scaled appropriately for each filter.

Discussion: A detailed description of the assumed inputs and methods used to calculate the 5-sigma limiting magnitudes are given in Document-8857.
https://www.lsstcorp.org/docushare/dsweb/Get/Document-8857

Description	Value	Unit	Name
g-band point source 5-sigma detection depth median	24.8	ABmag	DB1g
i-band point source 5-sigma detection depth median	23.9	ABmag	DB1i
r-band point source 5-sigma detection depth median	24.4	ABmag	DB1r
u-band point source 5-sigma detection depth median	23.5	ABmag	DB1u
y-band point source 5-sigma detection depth median	22.1	ABmag	DB1y
z-band point source 5-sigma detection depth median	23.3	ABmag	DB1z

1.2.3.1 r-band Reference Depth

ID: LSR-REQ-0089   **Last Modified: 1/27/2015**

Requirement: The single visit median depth in the r-band for unresolved point sources shall meet the specifications in the following table, assuming the reference conditions specified therein.

Discussion: The SNR v1.2 (Document-8857) calculation assumes optimal extraction even for sources near the noise limit. Optimal extraction is applicable to time series photometry, and this is extrapolated to the background limited extreme in all bands but u.
https://www.lsstcorp.org/docushare/dsweb/Get/Document-8857

Description	Value	Unit	Name
Given the median detection depth for a visit as MVD(i), the distribution of MVD(i) shall have a median r-band 5-sigma limiting magnitude no brighter than **D1** for unresolved point sources.	24.7	ABmag	D1
The fraction of the images with a median 5-sigma point source detection depth (MVD(i)) brighter than the depth outlier limit (**Z1**) shall be no more than **DF1.**	10	Percent	DF1
The reference airmass under which the depth specifications shall be met is **refAirmass.**	1.0	Airmass	refAirmass
The reference exposure time for which the single image depth specifications shall be met is **refExposureTime.**	30	Seconds	refExposureTime
The reference atmospheric seeing for which the depth specifications shall be met is **refSeeing** as measured in the r-band.	0.7	ArcsecFWHM	refSeeing
The reference sky surface brightness for which the depth specifications shall be met is **refSkyBrightness** as measured in the r-band.	21	mag/SqArcsec	refSkyBrightness
The outlier limit for 5-sigma point source detection depth is **Z1**.	24.4	ABmag	Z1

1.2.3.2 Depth Variation Over FOV

ID: LSR-REQ-0109   **Last Modified: 3/11/2015**

Requirement: An image meeting the median depth defined by the requirement *Filter Depths* (LSR-REQ-0090) shall meet the specification for depth distribution given in **depthVarFOV** below.

Discussion: The variations in depth allowed for in this requirement are less stringent than those implied by the variation in image quality. This requirement is meant to allow for variations in sensor sensitivity and effects of vignetting. The intent of this requirement is to restrict using low QE sensors in the focal plane array is met by requiring the camera detectors meet their minimum QE specifications (see OSS-REQ-0256 in the flow down).

Description	Value	Unit	Name
The maximum area over the 3.5 degree field-of-view with a 5-sigma point source detection brighter than **Z2** above the	15%	Percent	DF2

Description	Value	Unit	Name
median limiting magnitude for that visit shall be no greater than **DF2**.			
The allowed 5-sigma detection outlier limit is Z2..	0.2	ABmag	Z2

1.2.4 Photometric Performance

ID: LSR-REQ-0093   **Last Modified: 8/3/2016**

Requirement: The photometric quality of images from a single visit shall meet the specifications listed in the table **photometricPerformance** below.

Discussion: The specifications for photometric repeatability, PA1, PA2 and PF1, applies to the cataloged LSST magnitudes, m^{std}(catalog) (see SRD eq. 8), for appropriately chosen main sequence stars (e.g. non-variable stars color-selected from the main stellar locus).

Description	Value	Unit	Name
Percentage of image area that can have ghosts with surface brightness gradient amplitude of more than 1/3 of the sky noise over 1 arcsec.	1	Percent	GhostAF
The RMS photometric repeatability of bright non-saturated unresolved point sources in the **g**, **r,** and **i** filters.	5	mili-Mag	PA1gri
The RMS photometric repeatability of bright non-saturated unresolved point sources in the **u**, **z**, and **y** filters.	7.5	mili-Mag	PA1uzy
Repeatability outlier limit for isolated bright non-saturated point sources in the **g**, **r**, and **i** filters.	15	mili-Mag	PA2gri
Repeatability outlier limit for isolated bright non-saturated point sources in the **u**, **z**, and **y** filters.	22.5	mili-Mag	PA2uzy
RMS width of internal photometric zero-point (precision of system uniformity across the sky) for all bands except u-band.	10	mili-Mag	PA3
RMS width of internal photometric zero-point (precision of system uniformity across the sky) in the u-band.	20	mili-Mag	PA3u
Accuracy of absolute band-to-band color zero-point for all colors constructed from any filter pair, excluding the u-band.	5	mili-Mag	PA5
Accuracy of absolute band-to-band color zero-point for colors constructed using the u-band.	10	mili-Mag	PA5u
Accuracy of the transformation of the internal LSST photometry to a physical scale (e.g. AB magnitudes).	10	mili-Mag	PA6
The maximum fraction of isolated non-saturated point source measurements exceeding the outlier limit.	10	Percent	PF1
Fraction of zeropoint errors that can exceed the zero point error outlier limit.	10	Percent	PF2
The zero point error outlier limit.	15	mili-Mag	PF4
The maximum fraction of pixels scientifically unusable per sensor out of the total allowable fraction of sensors meeting this performance.	1	Percent	PixFrac
Maximum RMS of the ratio of the error in integrated flux measurement between bright, isolated, resolved sources less than 10 arcsec in diameter and bright, isolated unresolved	2		ResSource

Description	Value	Unit	Name
point sources.			
The maximum error in the precision of the sky brightness determination.	1	Percent	SBPrec
The maximum allowable fraction of sensors with **PixFrac** scientifically unusable pixels.	15	Percent	SensorFraction
The maximum local significance integrated over the PSF of imperfect crosstalk corrections.	3	Sigma	Xtalk

1.2.5 Astrometric Performance

ID: LSR-REQ-0094   **Last Modified: 8/3/2016**

Requirement: The astrometric quality of images from a single visit shall meet the specifications listed in the table **astrometricPerformance** below.

Description	Value	Unit	Name
Median error in absolute position for each axis, RA & DEC, shall be less than **AA1**.	50	mili-Arcsec	AA1
RMS difference between separations measured in the r-band and those measured in any other filter.	10	mili-Arcsec	AB1
The color difference outlier limit for separations measured relative the r-band filter in any other filter.	20	mili-Arcsec	AB2
Fraction of separations measured relative to the r-band that can exceed the color difference outlier limit.	10	Percent	ABF1
5 arcminute outlier limit.	20	mili-Arcsec	AD1
20 arcminute outlier limit.	20	mili-Arcsec	AD2
200 arcminute outlier limit.	30	mili-Arcsec	AD3
The maximum fraction of relative astrometric measurements on 5 arcminute scales to exceed 5 arcminute outlier limit.	10	Percent	AF1
The maximum fraction of relative astrometric measurements on 20 arcminute scales to exceed 20 arcminute outlier limit.	10	Percent	AF2
Fraction of relative astrometric measurements on 200 arcminute scales to exceed 200 arcminute outlier limit.	10	Percent	AF3
Median relative astrometric measurement error on 5 arcminute scales shall be less than **AM1**.	10	mili-Arcsec	AM1
Median relative astrometric measurement error on 20 arcminute scales.	10	mili-Arcsec	AM2
Median relative astrometric measurement error on 200 arcminute scales.	15	mili-Arcsec	AM3

1.2.6 Bright Sources

ID: LSR-REQ-0095   **Last Modified: 8/3/2016**

Requirement: The LSST shall be capable of unsaturated measurements of sources brighter than the nominal 15-second saturation limit by at least **brightSource.**

Discussion: This is not a requirement on the ability to measure saturated sources in standard visits. It is largely a requirement on the capability of the system to acquire and process visits of such duration that an object **brightSource** brighter than the nominal saturation limit would not be saturated (e.g., to support overlaps with brighter external catalogs).

Description	Value	Unit	Name
The LSST shall be capable of unsaturated measurements of sources brighter than the nominal 15-second saturation limit by at least **brightSource.**	1.0	ABmag	brightSource

1.3   Full Survey Performance

ID: LSR-REQ-0096   **Last Modified: 8/3/2016**

Requirement: Integrated over all survey observations made over a 10 year period the LSST shall meet all specifications for **skyCoverage** and **overallEllipticityCorrelations**.

1.3.1   Ellipticity Correlations

ID: LSR-REQ-0097   **Last Modified: 10/3/2013**

Requirement: Using the full survey data, the E1 and E2 (see SRD for definitions) distributions averaged over an arbitrary FOV shall have medians less than **TE1** for theta ~ 1 arcmin, and less than **TE3** for theta < 5 arcmin. No more than **TEF** % of images shall have these medians for E1 and E2 larger than **TE2** for theta ~ 1 arcmin, or larger than **TE4** for theta < 5 arcmin.

Discussion: The requirements specified here require the full survey data set to exist before they can be met. Thus these are intended to ensure that the LSST system design enables that these requirements can be met after the 10-year survey. Prior to survey start, they will be verified to the extent possible using simulations incorporating the as-built telescope and camera performance characteristics.

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	2.0e-5		TE1
Median residual PSF ellipticity correlations averaged over an arbitrary field of view for separations between 1 and 5 arcmin shall be no greater than	1.0e-7		TE2
The outlier limit on the PSF ellipticity correlation residuals on 1 arcminute scales shall be no more than	4.0e-5		TE3
The outlier limit on the PSF ellipticity correlation residuals on 5 arcminute scales shall be no more than	2.0e-7		TE4
The fraction of PSF ellipticity correlation residuals that can exceed the outlier limits on 1 and 5 arcminutes scales, over an arbitrary field, of view shall be no more than	15	Percent	TEF

1.3.2   Sky Coverage

ID: LSR-REQ-0098   **Last Modified: 3/16/2011**

Requirement: Integrated over all survey observations made over a 10 year period the LSST shall meet all specifications for **skyCoverage.**

Description	Value	Unit	Name
The total area of sky covered by the median number of visits shall be no less than	18000	SquareDegrees	Asky
Upper limit of time intervals for the required "fast revisit" range, for the fraction of sky specified by **RVA1**.	1800	Seconds	fastRevisitMax
Lower limit of time intervals for the required "fast revisit" range, for the fraction of sky specified by **RVA1**.	40	Seconds	fastRevisitMin
The median number of visits for each place of the sky within the main survey area shall be at least	825	Visits	Nv1Sum
The minimum area of sky covered at nearly uniformly sampled revisit time scales between **fastRevisitMin** and **fastRevisitMax**.	2000	SquareDegrees	RVA1

1.3.3 Integrated Astrometric Performance

ID: LSR-REQ-0099   **Last Modified: 3/16/2011**

Requirement: For all observations of unresolved point sources having r<24, after 10 years the astrometric performance shall meet the specifications in the table **astrometricPerf** below.

Discussion: These requirements constrain the distribution in time over 10 years such that the parallax factor is even sampled and that the time baseline is sufficient to meet the proper motion performance specification.

Description	Value	Unit	Name
The median parallax uncertainty (sigma) for sources with r=24 or brighter shall be no more than **SiGpar**.	3.0	mili-Arcsec	SIGpar
The median parallax uncertainty (sigma) in the y-band shall be no more than **SiGparRed**.	6.0	mili-Arcsec	SIGparRed
The median proper motion accuracy per coordinate across the main survey area for sources brighter than r=24 must be at least SIGpm.	1.0	mili-Arcsec	SIGpm

1.4 Data Processing and Management

1.4.1 Data Processing for Single Visits and Transients

ID: LSR-REQ-0101   **Last Modified: 3/16/2011**

Requirement: The LSST shall meet the following specification for reporting of data on optical transients detected in single-visit data: **OTT1**, **transN**, and **transSNR**.

Discussion: It is unclear whether the SRD specification of **transN** refers to the number of alerts that can be generated for a single visit (i.e. an instantaneous limit), or the number per visit averaged over time.

Description	Value	Unit	Name
The latency of reporting optical transients following the completion of readout of the last image of a visit	1	Minute	OTT1
The minimum number of optical transients for which data can be reported per visit	1.0e4	int	transN
The signal-to-noise ratio in single-visit difference images above which all optical transients are to be reported.	5	float	transSNR

1.4.2 Data Release Processing

ID: LSR-REQ-0102   **Last Modified: 3/16/2011**

Requirement: Specific, fixed "snapshots" of the data (*data releases*) of the data shall be released to the public periodically, at least every **DRT1** years.

Discussion: The project is planning on at least two Data Releases in the first year of opperations.

Description	Value	Unit	Name
The minimum interval between standard Data Releases	1	Years	DRT1

2 System Capabilities

ID: LSR-REQ-0001   **Last Modified: 8/3/2016**

Requirement: In order to perform a survey as defined above and present the data in a scientifically useful manner the LSST Observatory shall be a complete system that:

1. obtains survey data in the form of digital images,
2. processes, calibrates, and archives the images,
3. generates source and object catalogs, and
4. makes all data and data products available to a wide range of users.

Discussion: The requirements that define the system capabilities have been organized into 4 groupings that characterize the high level performance and functional requirements that must be met. The 4 groupings include:

1.   **The Optical Configuration:** These requirements specify the type of optical design, field of view, effective aperture, and overall system throughput that are derived from the SRD.
2.   **Observatory Control Capabilities:** These requirements specify the overall control and administration functions needed to conduct the survey and ensure that the LSST is responsive to the scientific community of its lifetime.
3.   **Data Collection:** These requirements specify in broad terms the data collection functions the LSST system must have in order to conduct the specified survey, optimize its operation, and record knowledge of its physical state during routine operation.
4.   **Data Products & Processing:** These requirements specify the high-level definition of the LSST data and data quality products to be delivered to the user community and what process must occur to create these products.
5.   **Data Archiving and Services:** These requirements define the high-level archiving and data delivery functions that are needed to deliver the LSST data and Data Products to its intended user base.

Also included are the definitions of other data processing services that will be provided by the LSST system.

2.1   Optical Configuration

ID: LSR-REQ-0002   **Last Modified: 3/16/2011**

Requirement: The LSST optical configuration shall be from the anastigmatic class of optical designs meeting the specification given below.

Discussion: The anastigmatic design class eliminates 3rd order astigmatism across the field of view.

2.1.1 Effective Aperture

ID: LSR-REQ-0003   **Last Modified: 3/16/2011**

Requirement: The on-axis effective light collecting area of the LSST shall be equivalent to a clear unobstructed circular aperture of at least **effAperture**.

Description	Value	Unit	Name
The on-axis effective aperture diameter - equivalent to 33.2 square meters of collecting area.	6.5	Meters	effAperture

2.1.2 Field Of View

ID: LSR-REQ-0004   **Last Modified: 3/16/2011**

Requirement: The field of view of the LSST optical system shall be at least an angle **fieldOfView** in diameter.

Discussion: The FOV defined here is not meant to be the final effective FOV recorded by the LSST camera. This is meant to be a nominal optical configuration requirement from which the optical design is derived.

Description	Value	Unit	Name
The diameter of the field of view - equivalent to 9.6 square degrees of sky coverage.	3.5	Degrees	fieldOfView

2.1.3 Effective Etendue

ID: LSR-REQ-0005   **Last Modified: 3/16/2011**

Requirement: The LSST optical system shall have an effective etendue (effective collecting **x** area of sky recorded in each image integrated over the **fieldOfView**) of at least **etendueRec**.

Discussion: The specified value is less than the product of **effAperture** and **fieldOfView** because of vignetting and focal plane fill factor.

Description	Value	Unit	Name
The effective collecting area integrated over the field of view * field of view area recorded in each image.	280	Etendue	etendueRec

2.1.4 Atmospheric Dispersion Correction

ID: LSR-REQ-0006   **Last Modified: 3/16/2011**

Requirement: An atmospheric dispersion corrector (ADC) is not required in the LSST system design.

Discussion: The project undertook a detailed trade study during the early conceptual phase of the project to determine if an ADC is needed and if it was even feasible to design and build an ADC large enough to accommodate the LSST field of view. This trade study concluded that an ADC was feasible but was not necessary provided that the survey observations were kept below 1.4 airmasses for that science needing the most control of the PSF shape. The minimum survey area is achievable while staying below 1.4 airmasses. (Documentation relating to this study is contained in Collection-894 on the LSST Document Archive).
https://www.lsstcorp.org/docushare/dsweb/View/Collection-894

2.1.5 Stray and Scattered Light

ID: LSR-REQ-0009   **Last Modified: 3/16/2011**

Requirement: The LSST design shall control the effects of stray and scattered light to the extent necessary to meet the performance in the Survey Specifications.

Discussion: Stray and scattered light is defined as any light that is not part of the ideal image and includes:
- diffuse scattered light,
- secondary ghost images,
- diffraction, and
- structured glints.

2.1.5.1 Baffling

ID: LSR-REQ-0011   **Last Modified: 3/16/2011**

Requirement: The LSST optical system shall be baffled as required to ensure that no unwanted specular path can put light onto the LSST focal plane.

2.1.6 Science Instrument

ID: LSR-REQ-0012   **Last Modified: 3/16/2011**

Requirement: The LSST system shall contain a single science instrument - the Camera.

Discussion: By the very nature of conducting a consistent well calibrated survey the LSST will not need to support the multiple instruments often found on classical telescope systems.

2.2   Observatory Control Capabilities

ID: LSR-REQ-0067   **Last Modified: 3/16/2011**

Requirement: The observatory shall be developed with the necessary control centers to achieve the LSST objectives. This shall include, as a minimum, the capabilities defined here.

2.2.1   Central Administration

ID: LSR-REQ-0068   **Last Modified: 3/16/2011**

Requirement: A central location shall serve as Project Headquarters for operational coordination and project interfaces to supporting agencies.

Discussion: The LSST Observatory will be a distributed set of assets functioning for the specific objectives of executing the survey and serving the raw data and its data products to the public.

2.2.2   Autonomous Operation

ID: LSR-REQ-0072   **Last Modified: 3/16/2011**

Requirement: The LSST system shall operate in a locally supervised autonomous mode during routine survey data collection and processing, with little human intervention required.

Discussion: It is not practical to expect human driven observations to keep pace with the observing cadence dictated by the LSST survey requirements.

2.2.3   Survey Scheduling

ID: LSR-REQ-0062   **Last Modified: 8/3/2016**

Requirement: The Observatory shall include a dynamic scheduler sufficient to achieve the survey requirements in the presence of changing observing conditions, nightly technical performance, and previous survey performance.

2.2.4   External Observatory Co-Observing Capability
ID: LSR-REQ-0119   **Last Modified: 8/3/2016**

Specification: LSST Observatory shall enable "co-observing", where an external observatory can anticipate where future observations will be made with reasonable likelihood.

2.2.5   Scientific Oversight During Data Collection

ID: LSR-REQ-0071   **Last Modified: 3/16/2011**

Requirement: The LSST Observatory shall be developed to allow an observing scientist to have oversight of the Data Collection process. This interaction shall be enabled either locally on the summit or

at remote locations. The data provided shall include all observing condition data, telemetry data to assess telescope conditions, and science data quality metrics for evaluation of the data collection process.

Discussion: The objective this requirement is to enable the observing scientist to be directly involved in the observing process. Under normal circumstances the observing scientist will not intervene with the autonomous operations (LSR-REQ-0072), but should be allowed to override if anomalous behavior occurs.

2.2.6 Process Command and Control

ID: LSR-REQ-0069   **Last Modified: 3/16/2011**

Requirement: In addition to the connectivity required for the science data, the observatory shall include the necessary capability to command and control the process from multiple centers and to adjust for changing environmental, technical, and scientific conditions.

2.3   Data Collection

ID: LSR-REQ-0013   **Last Modified: 3/16/2011**

Requirement: The LSST shall provide a Data Collection system that is capable of providing all necessary data to meet the SRD survey specifications including science image data and all ancillary data needed to calibrate the survey and to optimize operations.

2.3.1 Science Data

ID: LSR-REQ-0014   **Last Modified: 3/16/2011**

Requirement: The observatory shall collect science images as a series of "visits", sequenced by an automated system that optimizes the scientific return of the survey according to established priorities, taking into account environmental and sky conditions in the course of each night.

2.3.1.1 Standard Visit

ID: LSR-REQ-0016   **Last Modified: 3/16/2011**

Requirement: The bulk of the survey shall be performed as a sequences of "standard Visits", defined as **nVisitexp** back to back exposures in one of the system spectral bands, each having an exposure time of **visitExpTime**.

Description	Value	Unit	Name
The number of exposures, **nVisitExp**, in a standard visit shall be	2	int	nVisitExp
The exposure time, **visitExpTime**, for single images in a standard visit shall be	15	Seconds	visitExpTime

2.3.1.2 Non-Standard Visit

ID: LSR-REQ-0111   **Last Modified: 3/11/2015**

Requirement: The LSST shall be capable of obtaining and processing exposure not taken in a standard visit mode including those with minimum exposure time of **minExpTime**.

Discussion: Non-standard visits are defined as having a number of exposures per vist and vist exposure time different from the values of **nVisitExp** and **visitExpTime** respectively, speficied in **LSR-REQ-0016**. Non-standard visit exposures may possibly be degraded in some aspects of performance (e.g. cosmic ray rejection on visits consisting of a single exposure).

Description	Value	Unit	Name
The maximum shortest exposure time of a single exposure is **minExpTime**.	1	Seconds	minExpTime
The goal for the shortest exposure time of a single exposure is **minExpTimeGoal**.	0.1	Seconds	minExpTimeGoal

2.3.1.3 Data Format

ID: LSR-REQ-0015   **Last Modified: 3/16/2011**

Requirement: The LSST survey data shall be collected in the form of pixel addressable digital images that preserve the full information content of the LSST instrument.

2.3.2 Photometric Calibration Data

ID: LSR-REQ-0017   **Last Modified: 3/23/2011**

Requirement: The LSST shall measure and record data relating to instrumental and atmospheric transmission as necessary to photometrically calibrate the science data, referenced to the top of the Earth's atmosphere.

2.3.3 Engineering Data

ID: LSR-REQ-0018   **Last Modified: 3/16/2011**

Requirement: The LSST data collection system shall collect engineering and environmental data necessary to capture the physical state of the observatory, its components, and surrounding environment, during all modes of operation.

2.3.4 Ancillary Data

ID: LSR-REQ-0019   **Last Modified: 3/16/2011**

Requirement: The LSST system shall measure and record the data required as input to the optimization of the acquisition of survey data as well as record the environmental conditions that existed during each exposure. These data shall include but are not limited to:

1.   atmospheric seeing;

2. cloud cover; and
3. meteorological information (temperatures, wind, humidity etc..)

2.4   Data Products and Processing

ID: LSR-REQ-0020   **Last Modified: 3/16/2011**

Requirement: The system shall process the raw image data from the camera to produce calibrated images, analyze them to generate source and object catalogs, detect and generate alerts for transient phenomena, and record the quality of the data collected and its processing provenance.

Discussion: The Observatory is expected to process and calibrate the data from the entire focal plane. While the SRD requirements on image quality and depth are specified as applying only within the nominal 3.5-degree field of view, the data processing is nevertheless expected to strive to maximize the scientific usability of the data outside the nominal field.

2.4.1   Calibrated Image Production

ID: LSR-REQ-0021   **Last Modified: 10/3/2013**

Requirement: The LSST data processing system shall process raw image data to produce photometrically and astrometrically calibrated images, both from single visits and from deep coadds.

Discussion: The single-visit and deep-coadd image-level calibrations are a subset of the final catalog-level calibrations, which will be done in later stages of the processing flow (LSR-REQ-0029).

2.4.2   Catalog Production

ID: LSR-REQ-0029   **Last Modified: 10/3/2013**

Requirement: The data processing system shall process calibrated image data to produce catalogs with photometrically and astrometrically calibrated sources and objects.

Discussion: "Sources" refer to measured properties from an astrophysical event or object in a single individual visit, where as "Objects" refer to the inferred properties of the underlying astrophysical phenomenon, given information collected from all visits to date.

2.4.3   Calibration Data Products

ID: LSR-REQ-0030   **Last Modified: 3/16/2011**

Requirement: The data processing system shall, from time to time, generate Calibration Data Products, including bias frames and flat fields, as required by the other processing functions.

Discussion: These will typically appear at time scales intermediate to those of the Level 1 and Level 2 Data Products as described below. The Alert Production will require calibration data products of sufficient timeliness and quality to permit instrument signature removal prior to transient detection. These must be updated as often as necessary to meet this need. Data Release Production will require higher-quality

calibrations, but the production of these may be done as part of the preparations for each new Data Release, i.e., annually.

2.4.4 Optical Transient Alert Production

ID: LSR-REQ-0022   **Last Modified: 3/16/2011**

Requirement: The LSST data processing system shall process raw image data to detect optical transients and generate alerts to the astronomical community based on these detections.

2.4.4.1 Optical Transient Event Detection

ID: LSR-REQ-0023   **Last Modified: 3/16/2011**

Requirement: Transient events above one or more thresholds shall be detected in acquired raw images, and their detection and associated parameters shall be archived and made available for future transient classification.

Discussion: SRD flow down for transient detection is described in LSR-REQ-101.

2.4.4.2 Optical Transient Event Classification

ID: LSR-REQ-0024   **Last Modified: 8/3/2016**

Requirement: The data processing for Optical Transient Alert production shall differentiate between moving objects and other types of optical transients and shall reject cosmic rays and other non-astrophysical sources of transients, to the extent practicable. Cosmic-ray rejection will primarily be based on the use of exposure pairs. If a detected transient can be associated with a previously observed object, the processing shall include a calculation of the probability that the object is variable, based on prior observations.

Discussion: It is not possible to differentiate between moving objects and other types of optical transients in all cases. For slowly moving objects, we can do so only to the extent that the catalog of moving objects is complete, and this will never be 100%. At the beginning of the survey, it will be very incomplete, unless we are able to initialize it based on a precursor survey.

2.4.4.3 Optical Transient Alert Generation

ID: LSR-REQ-0027   **Last Modified: 8/3/2016**

Requirement: Transient alerts shall be generated based on detected transients, and made available to external consumers. Alerts shall include measurements of position, flux, size and shape, using appropriate weighting functions, as well as prior variability information and data from the same night, if available. Prior variability information shall include, at minimum, low-order light- curve moments and the above assessment of the probability that the object is variable.

Discussion: Alerts should ideally include the full light curves in all available bands as well.

> *Transient Filtering*

ID: LSR-REQ-0025   **Last Modified: 3/16/2011**

Requirement: Given an alert-detection algorithm chosen to meet LSR-REQ-0027, the algorithm shall be applied and the alert transmitted within the specified latency for at least a fraction **OTR1** of instances where the image data contains a transient detectable by the algorithm. The remaining transients so detectable must still be identified and recorded at the next processing opportunity.

Discussion: This requirement is on the production system given a particular algorithm and covers both detection and latency. This requirement constrains the reliability and timeliness of application of the algorithm and the alert publication. It does not constrain either the completeness or purity of the transient identifications themselves. It is unspecified whether the "next processing opportunity" is a fault-tolerance fallback or the daily reprocessing at the Archive.

Description	Value	Unit	Name
Fraction of detectable alerts for which an alert is actually transmitted within latency **OTT1** (see LSR-REQ-0101).	98	Percent	OTR1

Predefined Transient Filters

ID: LSR-REQ-0026   **Last Modified: 3/16/2011**

Requirement: Pre-defined filters optimized for traditionally popular transients shall be made available. It shall be possible for the project to add new pre-defined filters as the survey progresses.

Discussion: The list of pre-defined filters, by way of example, should include ones for supernovae and microlensed sources.

2.4.5 Science Data Products

ID: LSR-REQ-0031   **Last Modified: 3/15/2011**

Discussion: The requirements that follow govern the content and organization of the data products to be delivered by the LSST Observatory and the need to support the 4 primary science missions of the LSST.

2.4.5.1 Organization of Data Products

ID: LSR-REQ-0032   **Last Modified: 3/16/2011**

Requirement: The LSST data processing system shall provide the means for organizing the production of three classes of science data products: Level 1 (nightly cadence), Level 2 (data release cadence), and Level 3 (user-specified).

Level 1 Data Products

ID: LSR-REQ-0033   **Last Modified: 10/3/2013**

Requirement: The LSST Observatory shall produce Level 1 Data Products as the result of processing of the stream of image data from the Data Collection system during the course of normal observing.

Discussion: Level 1 data products are intended to enable time-domain science use cases requiring timely alerting and follow-up.

Level 1 Scientific Content

ID: LSR-REQ-0110   **Last Modified: 8/3/2016**

Requirement: The Level 1 data products shall include:

- Raw Science Images
- Calibrated Science Images (trimmed, de-biased, flattened, etc.)
- Difference Images
- Image Metadata/Catalog
- DIA Source Catalog
- DIA Forced Source Catalog
- DIA Object Catalog
- Solar System Orbit Catalog
- Transient Alerts
- Nightly Data Quality Summary Report
- Nightly Data Management System Performance Report

Discussion: Level 1 products are generated by pipeline processing the stream of data from the camera system during normal observing. Level 1 data products are therefore continuously generated and / or updated every observing night. This process is of necessity highly automated, and must proceed with absolutely minimal human interaction. In addition to science data products, a number of Level 1 SDQA data products are generated to assess quality and to provide feedback to the Observatory Control System. The abbreviation "DIA" stands for "Difference Imaging Analysis".

Level 1 Data Product Availability

ID: LSR-REQ-0104   **Last Modified: 8/3/2016**

Requirement: All Level 1 Data Products except Transient Alerts & Solar System Objects shall be produced and made publicly available within time **L1PublicT** of the acquisition of the corresponding raw images.

Discussion: The exceptions for Transient Alerts and Solar System Objects are defined in requirements LSR-REQ-0117 and LSR-REQ-0118, respectively.

Description	Value	Unit	Name
Maximum time from the acquisition of science data to the public release of associated Level 1 Data Products (except alerts)	24	Hour	L1PublicT

Level 1 Data Product Availability for Solar System Objects

ID: LSR-REQ-0118   **Last Modified: 10/8/2013**

Requirement: Solar System Objects shall be made publicly available within **L1PublicT** of successful moving source linkage and orbit computation.

Discussion: It takes multiple visits to the same Solar System Object in order to successfully link moving sources and compute their orbital parameters. As such, the time in which Solar System Objects can be made publicly available is dependent upon the time it takes to obtain these multiple visit images.

Level 1 Data Product Availability for Transient Alerts

ID: LSR-REQ-0117   **Last Modified: 10/4/2013**

Requirement: Transient Alerts shall be produced and made publicly available within time **OTT1** of the acquisition of the corresponding raw images.

Discussion: OTT1 is the SRD (LPM-17) latency requirement and is defined in SRD section 3.4. LSR requirement LSR-REQ-0101 defines the design value to be used for design purposes.

Calibration, Engineering, Ancillary, and Provenance Data

ID: LSR-REQ-0034   **Last Modified: 3/16/2011**

Requirement: The Level 1 Data Products shall include all collected calibration, engineering, and ancillary data, and all processing history and provenance, required to make sense of the science data.

Science Data Quality Monitoring

ID: LSR-REQ-0035   **Last Modified: 3/16/2011**

Requirement: Level 1 Data Product production shall include the production of sufficient Science Data Quality Assessment (SDQA) data, in a manner which supports feedback of observatory and observing conditions to the Observatory Control System, and alerts to observatory operators when poor quality data are detected.

Science Data Quality Archiving

ID: LSR-REQ-0105   **Last Modified: 3/16/2011**

Requirement: SDQA data produced shall be archived in association with the corresponding raw image data.

Level 2 Data Products

ID: LSR-REQ-0036   **Last Modified: 3/16/2011**

Requirement: The LSST shall produce a set of Level 2 Data Products as the result of periodic processing of the entire archive of raw image data from the Data Collection system.

Level 2 Scientific Content

ID: LSR-REQ-0037   **Last Modified: 10/4/2013**

Requirement: The Level 2 Data Products in a Data Release shall include:
- images, corrected for instrumental artifacts and photometrically and astrometrically calibrated,
- measurements of the properties (positions, fluxes, shapes, motions) of all detected objects, including those below single visit sensitivity limit;
- astrometric and photometric calibration of the object catalog,
- photometrically calibrated light curves for all detected objects,
- orbital parameters for Solar System Objects (see discussion in LSR-REQ-0024),
- limited classification of objects based on their static properties and time-domain behavior, and
- deep co-added images of the full survey area on the sky.

Discussion: The determination of motions for objects below the single-visit sensitivity limit will be constrained by the data and by computational limits, and may have limited precision or be possible only in a limited part of parameter space. The intent is to provide sufficient capability to support the planned TNO/KBO science.

Note that the requirement to provide light curves for "all" detected objects implies the provision of forced photometry, for the evaluation of light curves below the single-visit sensitivity limit.

Examples of limited classification include star-galaxy separation, or assessment whether an object is variable or not (see section 3.5 of the SRD).

Production in Data Releases

ID: LSR-REQ-0038   **Last Modified: 3/16/2011**

Requirement: All Level 2 Data Products shall be produced in the context of Data Releases. These Data Releases shall be produced at intervals no less than the Survey Specification for standardized data release interval - **DRT1** (see LSR-REQ-0102).

Discussion: Data Releases will be performed more frequently during the first year of the survey.

Calibration, Engineering, Ancillary, and Provenance Data

ID: LSR-REQ-0039   **Last Modified: 10/4/2013**

Requirement: A release of Level 2 Data Products shall include a consistent set of all necessary calibration, engineering, and ancillary data, and all processing history and provenance, required to understand how Level 2 data products were generated, and allow their reproduction from the raw input data.

Data Quality Monitoring

ID: LSR-REQ-0040   **Last Modified: 3/16/2011**

Requirement: Level 2 Data Product production shall include the production and publication of sufficient SDQA data to allow the determination of the scientific usability of the data products and the assessment of the large-scale progress of the survey.

Level 3 Data Products

ID: LSR-REQ-0041   **Last Modified: 8/3/2016**

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).

Level 3 Data Processing

ID: LSR-REQ-0106   **Last Modified: 10/4/2013**

Specification: The LSST Observatory shall provide software, services, and hardware resources to enable the production and storage of Level 3 Data Products. It shall be possible to produce Level 3 Data Products using LSST computing resources or elsewhere, and bring them into federation with Level 1 and 2 Data Products at the LSST data center.

Discussion: Level 3 Data Products are the result of processing that utilizes Level 1 and Level 2 Data Products, of a nature specified by users (by the provision of code and/or processing configuration data).

Level 3 Data Product Federation

ID: LSR-REQ-0107   **Last Modified: 3/15/2011**

Specification: The manner of production of Level 3 Data Products shall facilitate their federation with related Level 1 and Level 2 Data Products, when archived.

Discussion: The LSST project may, over time, promote selected Level 3 Data Products and their production to Level 2 or Level 1, subject to scientific justification and the availability of resources, and with the agreement of their originators.

2.4.5.2 Science Flowdown

ID: LSR-REQ-0042   **Last Modified: 3/23/2011**

Requirement: The LSST Observatory shall produce the data products necessary to support the 4 primary science missions listed below.

Discussion: The 4 key science drivers listed below are meant to exercise the extremes of capability phase space , thereby enabling a broad range of parallel scientific research. Additionally, the repeating of these key science drivers from the SRD support the traceability of more detailed requirements at the OSS level.

Data Products for Dark Energy/Matter Science

ID: LSR-REQ-0043   **Last Modified: 3/23/2011**

Requirement: The LSST Observatory shall provide the necessary data products to support the **Constraining Dark Energy and Dark Matter** science as described in the LSST SRD.

Data Products for Solar System Science

ID: LSR-REQ-0044   **Last Modified: 3/16/2011**

Requirement: The LSST Observatory shall produce the necessary data products to support the **Taking an Inventory of the Solar System** science case described in the LSST SRD.

Data Products for the Transient Sky

ID: LSR-REQ-0045   **Last Modified: 3/16/2011**

Requirement: The LSST Observatory shall produce the necessary data products to support the **Exploring the Transient Sky** science case described in the LSST SRD.

Data Products for Milky Way Science

ID: LSR-REQ-0046   **Last Modified: 3/16/2011**

Requirement: The LSST observatory shall produce the necessary data products needed to support the **Mapping the Milky Way** science case described in the LSST SRD.

2.5   Data Archiving & Services

ID: LSR-REQ-0047   **Last Modified: 3/16/2011**

Requirement: The LSST shall archive all image, catalog, engineering, calibration, and environmental data collected during the course of the survey, and shall make this data available for analysis and distribution.

2.5.1   Raw Image Data Archiving

ID: LSR-REQ-0048   **Last Modified: 3/16/2011**

Requirement: The LSST system shall archive all raw science and calibration image data, collected in the course of the survey as well as data collected during engineering and calibration operations, as well as all wavefront sensor data. It shall also permit the archiving of such diagnostic image data as may be needed to support the commissioning, calibration, and maintenance of the observatory.

2.5.2   Meta Data Archiving

ID: LSR-REQ-0108   **Last Modified: 10/4/2013**

Requirement: The LSST system shall archive sufficient information to permit the reliable and reproducible retrieval of calibrated image data.

Discussion: Calibrated image data must be available to retrieve, but may be reconstructed on demand as an alternative to its direct archiving (see LSR-REQ-0049).

2.5.3   Data Product Archiving

ID: LSR-REQ-0049   **Last Modified: 10/4/2013**

Requirement: The LSST system shall archive all generated Level 1, Level 2, and Calibration Data Products, or provide services to reconstruct any given data product on demand. When regenerated on-demand, the Data Products shall be scientifically equivalent – i.e. at a level of precision sufficient to reproduce the primary and derived attributes well within their formal uncertainties.

Discussion: Floating-point operations can return slightly different results on different hardware and guaranteeing absolute bitwise reproducibility across generations of hardware platforms is infeasible. These differences are typically in the least significant bit(s) that are already dominated by numerical or measurement noise. Thus the scientific impact is minimal, if at all existent.

Nevertheless, whenever viable algorithmic alternatives exist they will be preferred to those that are potentially hardware dependent, indeterministic, or numerically unstable.

2.5.3.1 Level 3 Data Product Archiving

ID: LSR-REQ-0050   **Last Modified: 2/22/2011**

Specification: Level 3 Data Products shall be archived, subject to project approval, based on user applications. An administrative mechanism shall be established to allocate a certain fraction of project resources for this purpose and to allocate that fraction to approved user requests based on their assessed usefulness to the project and the achievement of its science goals, and their value to the LSST user community.

2.5.4   Engineering and Environmental Data Archiving

ID: LSR-REQ-0051   **Last Modified: 3/16/2011**

Requirement: The LSST system shall archive all ancillary (e.g. engineering and environmental) data collected by the observatory.

2.5.5   Public Data Release

ID: LSR-REQ-0052   **Last Modified: 3/16/2011**

Requirement: The LSST System shall provide open access to all LSST Level 1 and Level 2 Data Products, in accordance with LSST Corporation Board approved policies. This shall include access to all engineering, environmental, and ancillary data required for scientific interpretation of the Data Products.

Discussion: Level 3 Data Products may or may not be available for open access, depending on agreements with their creator. Whether the creator is willing to accept open access is a criterion that may be used to determine how the project's resources for Level 3 Data Product archiving and service are allocated.

The LSST Corporation reserves the right to retain confidential business records, proposals, personnel files, medical records, or other confidential documents, obtained from others.

2.5.5.1 No Proprietary Period

ID: LSR-REQ-0059   **Last Modified: 10/4/2013**

Requirement: The raw survey data and processed data products shall be shall be released as Open Data and Open Source to the US, Chile, and foreign partners without any proprietary period (via MOU as per LSST Board policy).

Discussion: A necessary step in releasing the processed data is to perform Science Data Quality Analysis (SDQA). If intermediate data products or products that have not undergone quality assessment are made available, they will be clearly marked and documented as such

2.5.5.2 Data Distribution

ID: LSR-REQ-0053   **Last Modified: 10/4/2013**

Requirement: The LSST shall permit and facilitate the bulk distribution of its public data to remote sites or users wishing to consume or host it, subject to the availability of resources and the data access policy from LSR-REQ-0052.

Discussion: This requirement is not intended to create an open-ended obligation to add bandwidth for data distribution. In cases where remote sites wish to host a large amount of LSST public data, it is anticipated that some cost-recovery arrangement may be needed to support the installation of additional data distribution capacity.

2.5.5.3 Data Product Access Interface

ID: LSR-REQ-0054   **Last Modified: 8/3/2016**

Requirement: The LSST shall provide access to all its public data products through an interface that utilizes, to the maximum practicable extent, community-based standards such as those for pixel-based images (e.g. FITS), as well as those being developed by the Virtual Observatory (VO) community, and that facilitates user data analysis and the production of Level 3 and other user-defined data products at LSST-provided facilities and at remote sites.

2.5.6 Community Computing Services

ID: LSR-REQ-0055   **Last Modified: 3/16/2011**

Requirement: The LSST shall provide and maintain an amount of computing capacity equivalent to at least **userComputingFraction** of the total LSST data processing capacity (computing and storage) for

the purpose of scientific analysis of LSST data and the production of Level 3 Data Products by external users.

Discussion: The detailed scope of this service is to be determined based on a representative set of system queries and analyses assembled from community input and based on MOUs with other organizations willing to serve part of the public access distribution.

The fraction set by this requirement refers only to project funded resources. The LSST Observatory expects and will facilitate community use of grid, peta-scale computing centers, etrc...

Description	Value	Unit	Name
Fraction of total computing capacity dedicated to user-defined processing and storage	10	Percent	userComputingFraction

2.5.7 Data Curation

ID: LSR-REQ-0056   **Last Modified: 3/16/2011**

Requirement: The LSST Observatory shall develop a data curation plan that is consistent with developing community standards (e.g. Open Archival Information System - OAIS, or the NSF DataNet Initiative) to the extent allowed by project budgets and schedules.

Discussion: It is important that all archival data products generated by the LSST Observatory be managed to ensure their long-term usability. This includes not only the preservation of the data itself, but the additional information required to make it understandable by scientific users.

3 Survey Operation & Administration

ID: LSR-REQ-0057   **Last Modified: 5/24/2011**

Requirement: The Observatory shall be designed and developed to efficiently manage the execution of the survey.

Discussion: The LSST Observatory will be a comprehensive project to capture, process, archive, and serve data.

3.1   Operational Safety

ID: LSR-REQ-0058   **Last Modified: 3/16/2011**

Requirement: The LSST shall be designed, constructed, and operated so that the safety of personnel, followed by safety of equipment, and then the integrity of the data are preserved.

Discussion: The detailed safety requirements and applicable external codes are documented in the **Observatory System Specifications Document**.

3.2   Science Priorities and Survey Monitoring

ID: LSR-REQ-0070   **Last Modified: 8/3/2016**

Requirement: The LSST project shall monitor the scientific and technical progress of the survey, communicate with the scientific user community and establish survey priorities, and adjust the survey design as needed to accomplish its goals given these priorities and achieved performance.

3.2.1 Science Objectives Definition

ID: LSR-REQ-0063   **Last Modified: 3/16/2011**

Requirement: The Observatory system shall provide the ability to define a set of scientific objectives and associated performance metrics, which shall be used to assess and control the sequence of observations to optimally satisfy these objectives.

Discussion: The reference survey can be accomplished with many different observing cadences or sequences that impact the scientific reach of the accumulated data.

3.2.2 Adjustment of Survey Priorities

ID: LSR-REQ-0064   **Last Modified: 8/3/2016**

Requirement: The operation of the LSST Observatory shall allow for periodic adjustment of the survey priorities based on community input.

Discussion: This requirement is intended to ensure that the survey priorities and scheduling can be adapted to address any changes in the scientific landscape that can occur on a 10-year timescale. It is intended that these adjustments be assessed on relatively long time scales (e.g. every 6 months).

3.2.3 Survey Performance Reviews

ID: LSR-REQ-0065   **Last Modified: 3/16/2011**

Requirement: The Observatory shall have the ability to provide periodic status reports on the progress of the survey to allow both operations staff and the community to assess the survey progress.

3.2.4 Survey Performance Evaluation

ID: LSR-REQ-0066   **Last Modified: 3/16/2011**

Requirement: The Project shall create the necessary survey performance evaluation tools to predict the final results of the ten year survey based on the actual survey completed to date, assess the impacts of survey strategy changes resulting from changes in scientific priorities, and support the planning of the survey on a variety of time scales, from nightly through the entire 10 year duration.

3.3 Overall Operational Efficiency

ID: LSR-REQ-0073   **Last Modified: 3/16/2011**

Requirement: The LSST system shall meet the Survey Design Specifications for number of visits and area coverage, including the constraints of weather, system dynamics, scheduled maintenance, and unscheduled down time.

Discussion: The specifications for the allowed allocations to each of the terms for non-observable time are contained in the companion document *the Observatory System Specifications* (document LSE-30).

3.3.1   Survey Time Allocation

ID: LSR-REQ-0075   **Last Modified: 3/16/2011**

Requirement: The LSST Survey performance requirements shall be met utilizing approximately 90% of the historically available observing time, leaving the remaining time available for yet to be defined special programs (e.g. targeted deep drilling programs).

3.3.2   System Operational Lifetime

ID: LSR-REQ-0076   **Last Modified: 3/16/2011**

Requirement: The LSST system shall meet all its requirements and specifications over the full duration of the 10 year survey.

3.3.2.1 Preventive Maintenance

ID: LSR-REQ-0077   **Last Modified: 3/16/2011**

Requirement: The LSST system shall prepare a maintenance and reliability plan to ensure LSR-REQ-0076 (above) is met with an optimum balance between preventive maintenance and replacement strategies.

Discussion: Preventive maintenance implies servicing, repairing, and replacing components and subsystems based on their expected lifetime, as opposed to their failure.

3.3.3   Graceful Degradation

ID: LSR-REQ-0074   **Last Modified: 3/16/2011**

Requirement: The LSST system will be designed so that its performance degrades gracefully in the presence of adverse environmental and/or operating conditions.

3.4   LSST Broader Impacts

ID: LSR-REQ-0061   **Last Modified: 10/7/2013**

Specification: The LSST Observatory shall include an Education and Public Outreach program that supports Federal "Broader Impacts" requirements encompassing "the potential to benefit society and contribute to the achievement of specific, desired societal outcomes".

Discussion: The National Science Foundation supports programs based both on intellectual merit and broader impacts. The National Science Board strives for all American citizens to have the basic scientific, technological, and mathematical knowledge to make informed personal choices, to be educated voters, and to thrive in the increasingly technological global marketplace. The National Research Council, through its development of Science Education standards, addresses the critical issues of STEM Education, U.S. competitiveness and workforce preparation.

3.4.1   EPO Users

ID: LSR-REQ-0112   **Last Modified: 10/7/2013**

Specification: LSST-EPO shall be user-centered, building learning experiences to meet the needs of specific audiences while proactively engaging diverse learners and those who are traditionally underrepresented in STEM fields.

Discussion: The audience for LSST EPO is potentially quite large, being any non-science user with an internet connection. It is necessary to prioritize and target specific settings and user groups to maximize the impact of the system. Increasing diversity in the STEM workforce is essential to sustained national prosperity. The specific audiences are defined in the derived OSS requirements (OSS-REQ-0356, OSS-REQ-0357, OSS-REQ-0358).

3.4.2   EPO Products, Tools, and Interfaces

ID: LSR-REQ-0113   **Last Modified: 10/3/2013**

Specification: LSST EPO shall provide access to LSST data through tools, interfaces, and learning experiences that are designed to engage communities with different levels of knowledge, experience and skills.

Discussion: Astronomy is known to be an entryway to science for everyone, not just those who end up in STEM careers. Engaging learners in authentic science experiences is the best way for them to learn and gain an understanding of science topics and the research process. Boundaries between learning environments are becoming less defined, as learners become more self-directed and lifelong learning is recognized for its value. LSST EPO products, tools, and interfaces, which are to be innovative and user-friendly, can be used in multiple settings; for example, citizen science projects can take place online, incorporated into classroom settings, and introduced in informal science settings through a kiosk or interactive planetarium show.

3.4.3   EPO User Impacts

ID: LSR-REQ-0114   **Last Modified: 10/3/2013**

Specification: LSST EPO shall conduct an evidence-based evaluation program that measures (user-centered) performance metrics as well as outcomes defined as demonstrated changes in understanding, appreciation, skills, knowledge, or awareness.

Discussion: It is important to use, identify, and share evidence based approaches to program development and evaluation for maximum impact as described in the OMB STEM Strategic Plan.

3.4.4 EPO Longevity

ID: LSR-REQ-0115   **Last Modified: 10/3/2013**

Specification: The LSST EPO plan shall be agile and remain relevant and effective for the full survey duration, making adjustments that reflect technology trends and educational priorities.

Discussion: In addition to using flexible interface designs and elastic computing resources, it will be necessary to build strong partnerships with external organizations to maximize the longevity of the system.

3.4.5 EPO Fully Integrated

ID: LSR-REQ-0116   **Last Modified: 10/3/2013**

Specification: LSST EPO shall be fully integrated into the design of LSST so that effort can be shared and leveraged during construction. Additionally, Citizen Science results that extend the science goals of LSST shall be made available to science users during operations.

Discussion: The LSST EPO subsystem is not an add-on to the observatory conceptually or functionally. The science and education goals have been developed in tandem as has the implementation of the system to support those goals. Big Understandings of the EPO learning activities are aligned with the LSST science mission and the DM/EPO interface allows for both transfer of data to the EPO system and the return of EPO-generated results that can be integrated with science data products for the community. In this way the education and science from LSST are collaboratively maximized.