Vera C. Rubin Observatory
Rubin Observatory Operations

Criteria to start the Legacy Survey of Space and Time

Robert Blum, Charles F. Claver, Željko Ivezić, Phil Marshall

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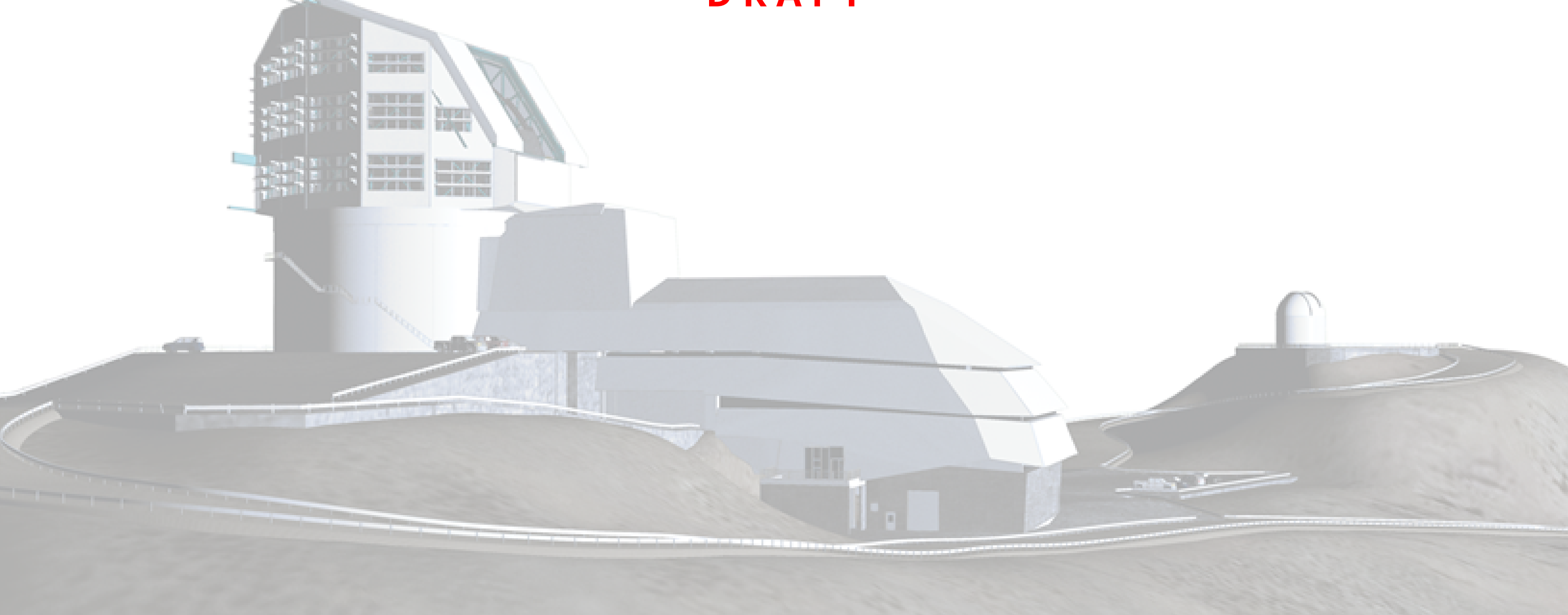

Abstract

This document concisely captures the criteria that must be satisfied by the Rubin Observatory System to begin regular survey operations for the Legacy Survey of Space and Time (i.e. to begin execution of the planned 10 year survey strategy currently documented in PSTN-056). The survey can start based on quantitative criteria described herein. The system contribution to the delivered image quality must reliably be better than 0.45′′ and the effective survey speed must be 0.7 or better. Both of these are attainable given our experience and knowledge of the current on sky system.

Change Record

Version	Date	Description	Owner name
1.0	2025-02-28	first draft	Robert Blum
1.1	2025-09-01	Criteria and Schedule updates	Robert Blum
2.0	2025-10-18	Rubin Management Board Feedback	Robert Blum
2.0	2025-11-10	CCR3-ORR2 Feedback	Robert Blum
2.0	2025-11-10	Final	Robert Blum
3.0	2025-11-16	New direction, Remove most the narrative, concentrate on quantitative criteria.	Robert Blum

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Criteria to start the Legacy Survey of Space and Time

1 Introduction

On October 255, 2025 the Rubin Observatory was declared substantially complete having passed its Construction Completeness Review #3 (CCR3) and ready for operations having passed its Operations Readiness Review #2 (ORR2). At the time of handover the construction team demonstrated the overall Rubin Observatory system is *capable* of meeting its required science driven technical performance as articulated in the Science Requirements Document Ivezić & The LSST Science Collaboration (LPM-17), LSST System Requirements Claver & The LSST Systems Engineering Integrated Project Team (LSE-29) and Observatory System Specifications Claver & The LSST Systems Engineering Integrated Project Team (LSE-30) documents.

The LSST strategy and it's associated cadence in the 10–year period (currently allowing for modest assumed degradation in year 1) are detailed by the Survey Cadence Optimization Committee (SCOC, Rubin's Survey Cadence Optimization Committee et al., PSTN-056). In this technote, we define the set of key performance criteria that the Operations team, in consultation with operations partners SLAC and NOIRLab, the post-handover Construction team, the Rubin Management Board, funding agencies, and the science advisory committee will use to guide the decision to begin the LSST.

2 System Performance

Rubin has developed a high level set of metrics summarizing the system performance with respect to overall survey efficiency. We need to simultaneously ensure that both 1) the system is producing viable science quality images and data products and 2) that the observing and acquisition of this data is efficient. To this end, we gauge the overall system survey capabilities in a 2–parameter space shown in Figure 1, marking the system + atmospheric contribution to delivered image quality versus the dimensionless survey efficiency or speed, *fE* – integrated Normalized Étendue. The combined summary Normalized Étendue metric (*fE*) is the product of 4 unitless *f-metrics* that gauge system contributions to the "survey speed", these are: 1) *fS* – *System Sensitivity* captures overall efficiency of recording photons from the sky and is driven by optical transmission, sensor quantum efficiency, sky brightness and image quality; 2) *fA* - *Fill Factor* captures the recorded area of the focal plane array relative to the area delivered by the optical system; 3) *fO - Observing Efficiency* captures the efficiency with which available observing time is scheduled and utilized for survey observations and 4) *System Availability* a final factor that captures overall operational efficiency that takes into account weather and observatory downtime. If the system is producing appropriate image quality and the system and team are acquiring data efficiently, we can confidently start the LSST. The ”start” criteria quantify the threshold in the 2-parameter performance space that is needed to achieve this goal.

Effective survey speed is product of instantaneous etendue (ability to capture photons = effective area x field of view), observing efficiency, and system availability

normalized etendue: fE = fA * fS * fO * System Availability

fA: FOV area factor – total solid angle of all live science pixels

fS: sensitivity factor – defined for fiducial observing conditions and based on knowledge of throughput (optics) and sensor properties (QE, read-out noise)

fO: observing efficiency factor – rate of visits within scheduled observing time, including time intervals between visits for a nominal survey strategy (exposure time, slew time, readout time, filter exchange time)

System availability – accounts for weather losses as well as scheduled and unscheduled system downtime

All factors normalized by their nominal (design) value

FIGURE 1: Dimensionless survey efficiency factor, fE. System Availability is the most uncertain at this time. The current state of each factor is discussed below and the quantitative criteria for starting the LSST with respect to each factor is assessed.

These *f–factors* are defined to be dimensionless and normalized by the corresponding SRD derived design values. They can be traded against each other as time gained or lost. For example, deterioration in the mirror reflectivity can be easily translated to factor fS, and traded against time (e.g. time lost to recoating, the system efficiency), or against loss of sensor area (fA). The key point is that it is possible to define a simple measurable quantity (fE) that is an excellent numerical approximation for LSST science goals. Thus, we can think of the effective speed of executing the LSST (in units of the nominal speed) in terms of recognizable elements: fE = effective area $\times$ effective FOV $\times$ cadence $\times$ 1-downtime.

In Figure 2, we show the state of our understanding of the image quality and survey speed before we went on sky with LSSTCam. The white circle is a forecast based on expectations before we went on sky with some as built elements of the system accounted for.

There are three regions defined in the diagram, green, light grey and dark grey, representing broad levels of operational performance towards meeting the 10–year LSST objectives. Clearly we want to be in the green shaded region and to the lower right in that space. The boundaries of the green box are defined by the minimum design specification from the SRD (upper)

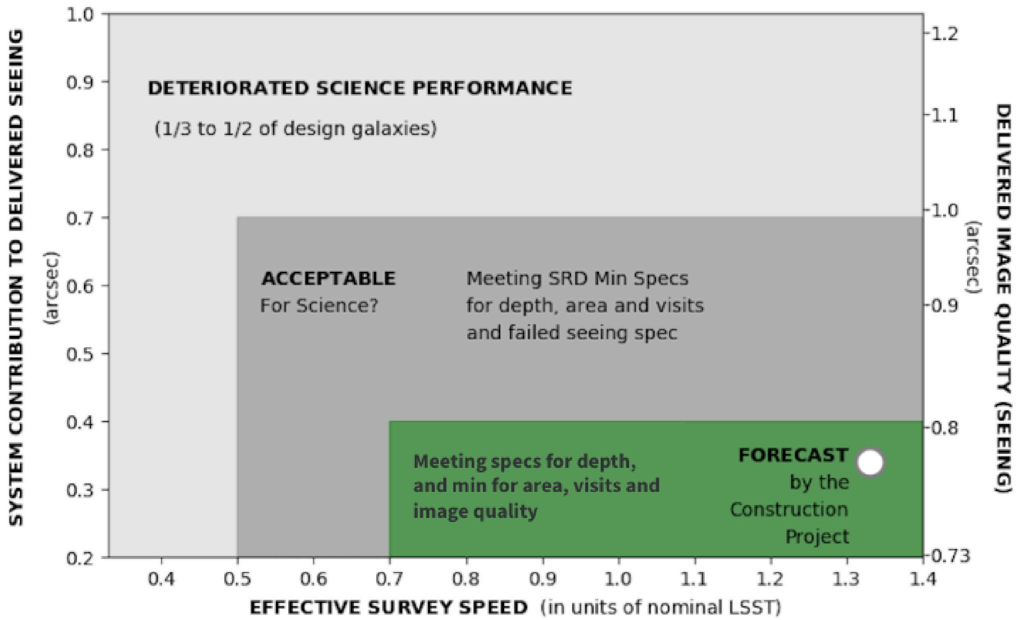

FIGURE 2: Image quality versus effective survey speed, fE. The system contribution to the delivered image quality (sDIQ) is shown on the left vertical axis and the delivered image quality including a fiducial atmosphere (added in quadrature) is on the right. The LSST specifications are accomplished with nominal speed fE = 1.0 and sDIQ = 0.4′′ in this diagram. Current performance is assessed below. The white circle is representative of where we want to drive the performance, but we have not reached it yet.

and stretch goals (lower) for the system image quality contribution. The light gray space is unacceptable for science and the dark gray space covers the area where SRD minimum specifications are met for depth, area of LSST, and visits, but fails to meet the specification for system contribution to the DIQ (0.4′′).

As of handover, the current values for the f factors are given in Table 1. For fA, the value is set by the number of science pixels available (each with 0.2×0.2 arcsec^2 on the sky). Accounting for the active pixels meeting specifications, the factor is fully 99%. The fS factor includes read noise, QE, vignetting, optical throughput (filter, lens transmission, mirror reflectance) and DIQ (so DIQ affects both axes in our diagram). The observing efficiency factor, fO, is a function of how many visits of the right exposure time can be observed given telescope performance (how fast we move and settle). Finally, system availability is defined as the open shutter science time compared to the total elapsed time working on the on–sky programs. System availability includes weather loss and typical down time, so a nominal LSST System Availability of 1.0 means idealized open shutter time of 71% (75% is open shutter equal to 53%).

TABLE 1: Current f factor status

factor	Description	Sustained Performance in SV	Performance at Start of LSST
sDIQ	System Contribution to the PSF FWHM	0.5′′	0.45′′
fA	FoV area factor	0.99	0.99
fS	Sensitivity factor	0.94	1.30
fO	Observing Efficiency	0.97	1.05
SA	System Availability (up and taking data)	0.75	0.75
fE	Normalized Étendue	0.68	0.7

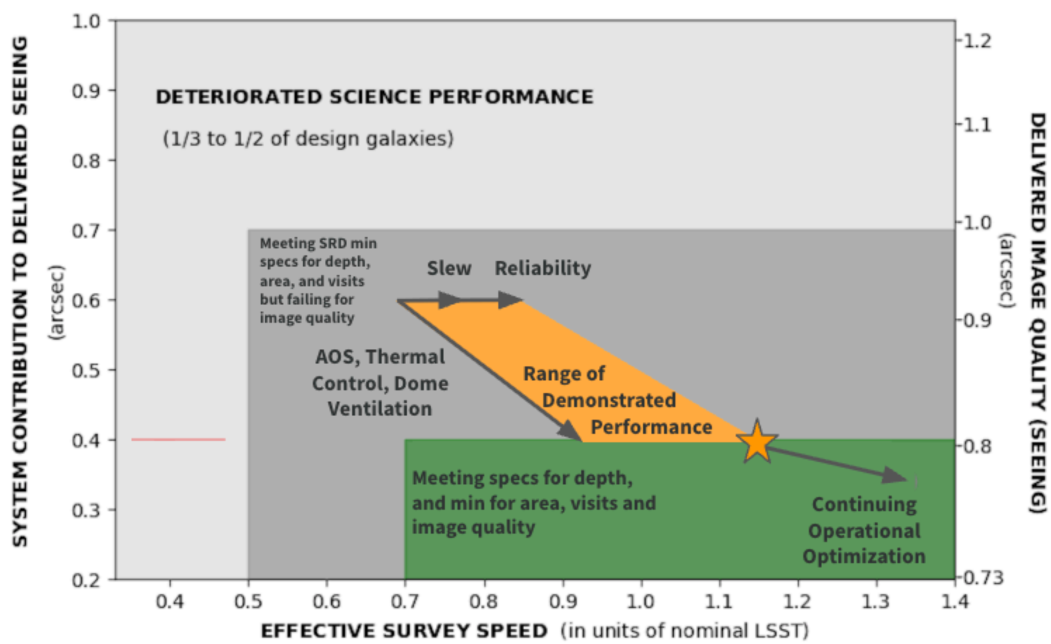

FIGURE 3: Image quality versus effective survey speed, fE with performance presented at CCR2-ORR1. Upper left of the orange performance region is sustained over week long periods in SV. The best performance (capability) is represented by the lower right vertex of the region. We are focused on getting reliable performance there and beyond as indicated. The minimum performance needed to begin the LSST is discussed below.

The range of performance between what has been achieved over periods of SV and the best performance is shown in Figure 3. The SV sustained performance noted in Table 1 is consistent with the upper left vertex of the orange area in Figure 3.

The current capability and reliability of the system as described in Table 1 and Figure 3 form the basis of the criteria described in the next section that the Operations team will use to gate starting the LSST.

3 Criteria to begin the LSST

The criteria to start LSST based on the needed performance described above are presented here in Table 2.

3.1 Delivered Image Quality (DIQ)

We will start the LSST when the sustained performance of the system contribution to DIQ is $\leq 0.45''$. This criteria is the combination of both the telescope + LSSTCam optics and the degradations caused from any thermal non-equilibrium. The system contribution for purposes of this calculation is obtained by subtracting quadrature the estimate of the atmospheric contribution obtained from the wave front sensor donut analysis. This approximation thus excludes the dome seeing.

Equally important for the scientific value of the images is that the typical LSST images meet the requirements for uniformity across the field of view and ellipticity for bright isolated stars. These are given in Table 2. For uniformity to start the survey, we identify the value of the allowed contribution in the worst quartile of the overall seeing profile given in the SRD. This is $0.52''$.

We will start the LSST when the residuals for ellipticity from the system component are met or well understood. This is because a calculation of the ellipticity (from the WFS) can result in residuals from the measured ellipticity which would allow us to detect the astrophysical weak lensing signal. This is described in the (Ivezić & The LSST Science Collaboration, LPM-17, Section 3.3.3.3), "This specification does not by itself address weak lensing systematics, because there are schemes for removing the influence of an anisotropic PSF on the observed shapes of galaxies. However, it is known that these schemes leave smaller residuals if initially given isotropic PSFs to begin with ..."

TABLE 2: Survey Start Criteria

Item	Criterion	Description	Status
1	sDIQ	The "System" contribution to the measured Delivered Image Quality is better than or equal to 0.45″	Currently 0.6″ system contribution
2	sDIQ Uniformity	The "System" contribution to the measured Delivered Image Quality can vary over the field of view such that 10% or less of the FOV has a system contribution of up to 0.52″ (see LSST system specifications LSR-REQ-0008.	Currently not meeting for typical images
3	Ellipticity	Ellipticity for a single image will typically be as specified in the LSST system requirements as LSR-REQ-0092. This is ≤ 0.04 with 5% or fewer outliers beyond 0.07. See below; we will gate the survey start with respect to the residuals between the measured ellipticity and the calculated value from the WFS.	not meeting
4	Normalized Étendue (*eF*)	Survey Speed is > 0.7.	Currently 0.68
5	Calibration	All necessary calibration data products are available at the time any LSST data are obtained or can be obtained after the fact without invalidating the observed data for inclusion in the LSST.	Check status at CCR3
6	Dome	The dome environment is not limiting typical performance.	Not controlled until after Handover
7	LHN ready	The Long Haul Network will be working reliably and not be a limiting factor in Alert Production	LHN is ready and not limiting Alert Production
8	DM ready	Data are routinely passed from the summit and ingested into storage at the USDF. Nightly processing including calibrations are routinely running, nightly alert production is running.	These elements are all met.
9	Survey Strategy Ready	The initial LSST strategy is available	This is ready (v 5.1 has been executed at night)

3.2 Dome Environmental Control

The dome will be the last major subsystem to be completed. Indeed it will not be done until mid 2026. However, the total contribution to sDIQ from the dome environment is modest. Including all sources of turbulence generated by the facility, the budget (i.e residual contribution after control) to contribute to the DIQ is only $0.09''$. We will start the LSST before the Dome work is complete.

3.3 Normalized Étendue

Much of the effective speed (Normalized Étendue) is already demonstrated to be sufficient to start the LSST, The field of view factor, fA, is excellent and stable. The sensitivity factor, fS, is also very good. This factor has the potential to help overall performance because of its dependence on delivered image quality. Getting the system contribution to the DIQ from 0.6 to 0.4 (coupled with site free air atmospheric seeing of $0.7''$) would raise fS from 0.94 to 1.3. Apart from this, all the optics are delivered as is the focal plane. Slew and settle performance are well understood and adequate. Modest gains on fO are forecast for the rest of SV and early operations. We expect the current value to go from 0.97 to 1.05.

This leaves the System Availability, Current performance of 0.75 needs to be improved but will not stop the survey start.

Using the combined SRD minimum specifications the lowest Normalized Étendue allowed is 0.7. This level is nearly in hand; see Table 1.

There remains the question of how reliably (often) we keep the performance in the green SRD box. Clearly some images will fall outside the box for any number of reasons, even in steady state operations. For purposes of starting the LSST. we will adopt a criteria that we can begin if nightly median performance of contiguous validation runs remain in the target area for two continuous weeks.

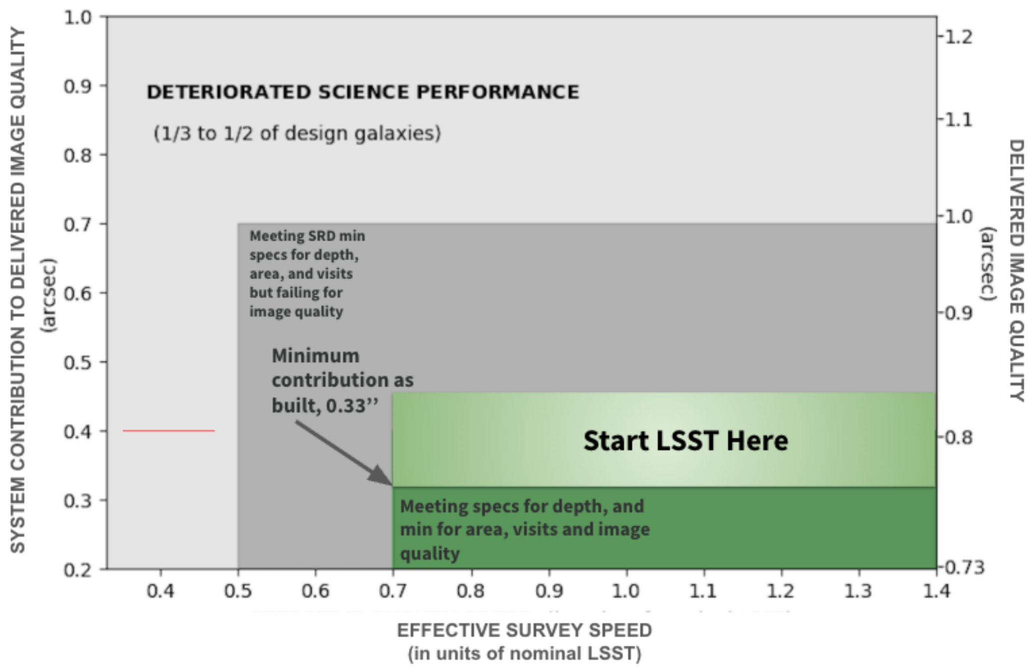

FIGURE 4: Image quality versus effective survey speed or Normalized Étendue. The large green rectangle represents the region in this space within which we can confidently start the LSST while working to maintain and improve performance. We expect to enter this box near the middle top where the shading is lighter.

4 Process to decide when to begin the LSST

In the following, we describe the process to reach the decision to start the LSST given an understanding of the state of the system and its performance as outlined above. We envision three phases to be able to successfully start the LSST. These are 1 Preparation phase; 2 Implementation phase; 3 Decision,–Approval–Launch phase.

4.1 Preparation Phase (now - Oct 25th)

We have set up an Early Operations Optimization Team which is distinct from the organization in the Rubin Operations steady state plan [RDO-018]. This team is largely made up of staff from the Construction era SIT-COM (System Integration and Test – Commissioning) team who have just finished commissioning the system. This team, it's daily workflows and planning coupled with the nightly execution of observations by the Nighttime Operations Team is best placed to drive the final performance gains needed to get to LSST in this Early Operations period. For now, we envision this period to be Q1 FY26, but it could be shorter or longer. The team reports up through the AD for Rubin Summit Operations (RSO) and ten to the Directorate.

We have set up with the Rubin team a Start of LSST Board (SLB). This board will consist of key members of the Early Operations Optimization team and is in fact a precursor to the Data Release Board (Blum, RDO-018, DRB; see). The membership will include the ADs of the operations departments, the Head of LSST and the Deputy Head of LSST, and the former leads of integration, commissioning, and science validation from SIT-COM. This board will monitor progress on performance optimization and recommend to the Directorate when the system is ready for the start of the LSST. The SLB will be chaired by the Head of LSST.

4.2 Implementation Phase (Oct 25 - Launch)

Going back on sky, we deploy engineering observation blocks to gather data on the changes to the system made as a result of the analysis of the data taken prior to the shutdown. Periodic observations sets (blocks) will be obtained in survey mode (known as Feature–Based Scheduler, or FBS, mode) to gauge our trajectory in the performance space (e.g. Figure 4. FBS Blocks will be sufficient in length to measure effective survey speed, median DIQ (and ellipticity and focal plane uniformity). The SLB will review the periodic performance and formally vote on starting the survey. If a consensus vote is not obtained, the Early Operations Optimization team, led by the AD or RSO, will make further tests for further analysis. This cycle will be repeated until consensus is reached.

4.3 Decision−Approval−Launch phase

Once the SLB votes to start, they will bring this recommendation to Rubin Directorate. If the Directorate concurs with the recommendation, they will take it to the RMB for approval.

5 References

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6 Acronyms

Acronym	Description
AD	Associate Director
CCR	Construction Completeness Review
CCR1	Construction Completeness Review 1
CCR2	Construction Completeness Review 2
CCR3	Construction Completeness Review 3
CCR4	Construction Completeness Review 4
DIQ	Delivered Image Quality
DM	Data Management
DOE	Department of Energy
DRB	Data Release Board

FBS	Feature-Based Scheduler
FOV	field of view
FTE	Full-Time Equivalent
FWHM	Full Width at Half-Maximum
FY26	Fiscal Year 2026
FoV	Field of View (also denoted FOV)
LHN	long haul network
LPM	LSST Project Management (Document Handle)
LSE	LSST Systems Engineering (Document Handle)
LSR	LSST System Requirements; LSE-29
LSST	Legacy Survey of Space and Time (formerly Large Synoptic Survey Telescope)
LSSTCam	LSST Science Camera
NOIRLab	NSF's National Optical-Infrared Astronomy Research Laboratory; `https://noirlab.edu`
NSF	National Science Foundation
ORR	Operations Readiness Review
ORR1	Operations Readiness Review 1
ORR2	Operations Readiness Review 2
PSF	Point Spread Function
PSTN	Project Science Technical Note
Q1	Quarter one
QE	quantum efficiency
RDO	Rubin Directors Office
RSO	Rubin Summit Operations
RTN	Rubin Technical Note
SA	System and Services Acquisition
SCOC	Survey Cadence Optimization Committee
SIT	System Integration, Test
SLAC	SLAC National Accelerator Laboratory
SRD	LSST Science Requirements; LPM-17
SV	Science Validation
USDF	United States Data Facility
WFS	WaveFront Sensor