Rubin Observatory

Vera C. Rubin Observatory
Systems Engineering

# Operations Readiness Criteria

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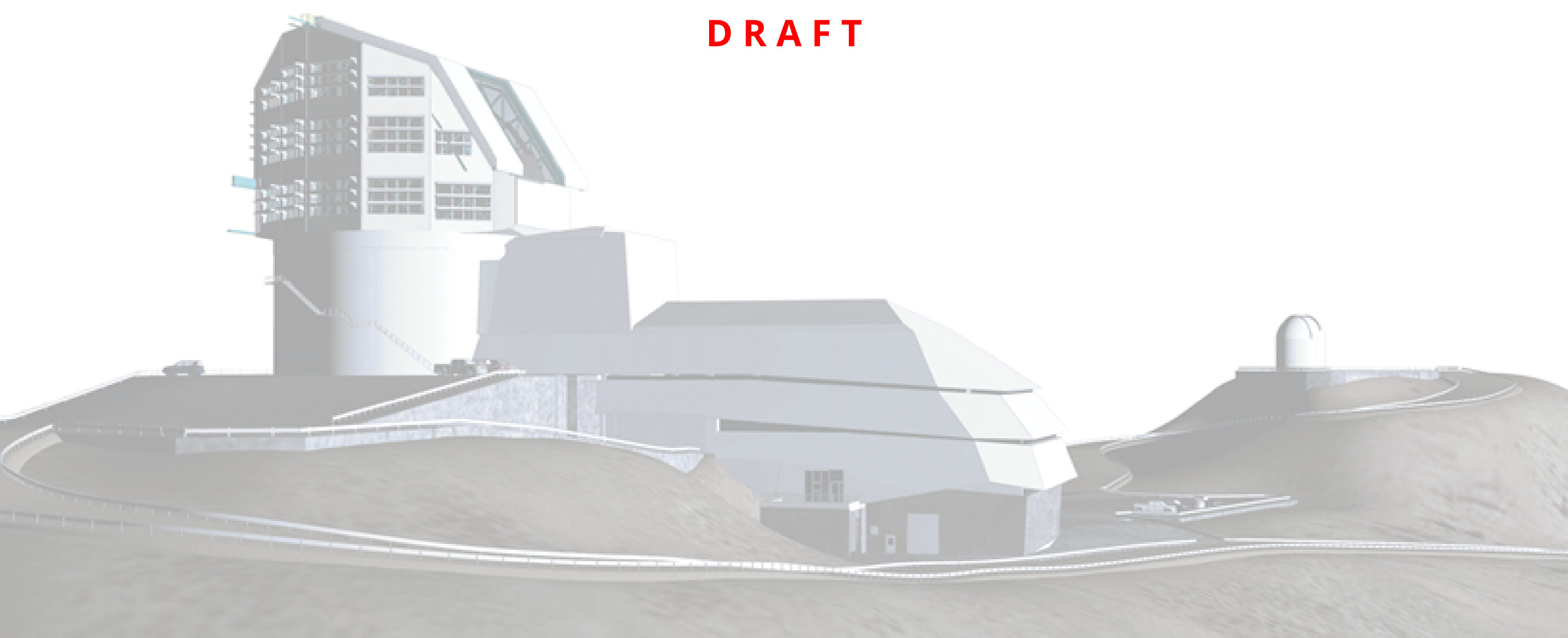

Rubin Observatory

## Abstract

This document collects together the elements that constitute the criteria for completeness of the Rubin Observatory MREFC Construction Project, DOE Rubin Observatory Commissioning, and the readiness for operations of the Rubin Observatory to conduct the 10–year Legacy Survey of Space and Time (LSST).

This is a living document and will be modified and refined as required throughout the remainder of the Project.

In addition to this document and references therein, the completion of the Rubin Observatory Project will be evaluated based on the LSST Project Execution Plan (LPM-17) and the Commissioning Execution Plan (**?**).

# Change Record

| Version | Date | Description | Owner name |
|---|---|---|---|
| 1 | 2020-08-06 | First draft | Leanne Guy |
| 1 | 2020-08-10 | Revised version for internal review | Chuck Claver |

*Document source location:* `https://github.com/lsst-sitcom/sitcom-005`

# Contents

# Operations Readiness Criteria

## 1 Introduction

One of the primary high-level strategic inputs to developing the System AI&T and Commissioning Plan (LSE-79) are the construction completeness requirements for the Operations Readiness Review (ORR). At the conclusion of the Commissioning Phase of the LSST construction project an ORR will be undertaken by an external panel, jointly appointed by the DOE and NSF, in consultation with the LSST Project Team. The ORR will signifiy the end of the NSF MREFC funded construction project and DOE Commissioning.

The ORR will consist of two parts: 1) The evaluation of the Rubin Construction Project completeness and 2) the readiness of Rubin Operations to receive the construction deliverables and begin routine operations for conducting the Legacy Survey of Space and Time – the 10-year science survey for which the Rubin Observatory was designed.

In this document, we collect together the elements that constitute criteria for Operations Readiness. Each topic has, or will reference defined requirements – in many cases along with goals and stretch goals – each will have the relevant supporting documentation for performance against the requirement. For those requirements that specify performance after some period of operations, the basis of estimate of projected performance will be provided. Unless otherwise specified, functional requirements will be verified by direct test, and performance requirements will be verified by direct test, analysis, or a some combination thereof. For each requirement, there will either be a clean pass, or there will be a waiver process that documents why it is acceptable to proceed to operations (or the reason we must postpone the transition to operations).

Some of the topics are already covered by existing verification plans. Some functional requirements (and any accompanying goals and stretch goals) are still in review (at the time of this document version) – in those cases, the requirements and associated verifications are being developed together to ensure clarity and crisp requirement for verifiability. Some topics, such as the Science Validation survaeys, have requirements that are a combination of performance and functionality that do not necessarily flow directly from the high-level requirements; in those cases, we identify the minimum requirements that must be met to proceed to operations, along with a range of goals and stretch goals and the accompanying rationale.

# 2 LSST System Requirements & SRD Verification/Validation

## 2.1 Construction Completeness Criteria

The project team shall characterize and document the performance of the integrated LSST system with respect to the survey performance requirements and specifications enumerated in the LSST System Requirements, Observatory System Specifications and Science Requirements Document (LSE-29, **?** & LPM-17 Section 3 respectively).

## 2.2 Objectives

The primary objective for this Operations Readiness Requirement is verify and validate that the data produced from the science validation surveys (and any additional observing campaigns) meets the science verfication requirements as described in the LSST Verification and Validation (LVV) elements and test cases. This will include:

- Verification of the generation of all required data products and services;
- Verification that the relevant metadata are being collected and archived;
- Verification of astrometric performance (relative and absolute);
- Verification of photometric performance (relative and absolute);
- Verification of data throughput and processing requirements for prompt data products;
- Completeness and purity of sources detected in AP and DRP;
- Image template generation;
- Completeness and purity of moving object orbit calculations;
- The impact of stray light and optical ghosts;
- Image quality (defined for each subsystem: telescope, camera, data management);
- Crosstalk, filter response, and calibration.

In addition to the normative data quality requirements above, there are several science validation and characterization objectives that represent important benchmarks of scientific capability. The optimization of associated algorithms is in many cases an active research topic, and performance is expected to improve throughout Operations. Potential science validation studies include:

- Object detection completeness;
- Object de–blending;
- Object classification – *e.g.*, star-galaxy separation;
- Galaxy photometry – *e.g.*, for photometric redshifts);
- Difference image analysis photometry – *e.g.*, for statistical variability metrics);
- Low surface brightness features;
- Weak-lensing null tests and shear calibration;
- Treatment of crowded fields.

The verification will make use of Quality Assessment (QA) and Quality Control (QC) tools developed during DM construction.

- Quality Assessment: versatile pipelines to calculate performance metrics and other diagnostics
- Quality Control: ensure that metrics are routinely calculated and track their distributions as the pipelines evolve and encounter new data

In particular, Key Performance Metrics produced by DM and the Commissioning team together with additional test cases will be compared against the tabular requirements in the LSST SRD.

**Discussion**

For the purpose of evaluating readiness we define the steps associated with verification, validation, and characterization of the LSST data and processing.

*Verification*: Demonstrate that the system as built is consistent with the design. Ensure that the requirements for the system are met using LSST and precursor data. Express the requirements in terms of metrics that can be evaluated using LSST and precursor data. Document the system performance for each of the verification metrics and requirements.

*Validation*: Demonstrate that the system is capable of meeting the scientific objectives of the survey. Ensure that the data products, data access, and science requirements can meet the objectives for LSST's four major science themes. Document the system performance for each of the validation metrics and requirements and verify that there exist mechanisms to monitor the system performance during operations. Validate that the derived data products and access tools meet the science requirements of the community.

*Characterization*: Determine how the performance of the system degrades as a function of environment and technical performance of the components of the system. Measure how the metrics used in verification change as a function of operational conditions (including weather, site, operations, telescope, instrument, and software).

The scope of science verification and validation activities includes:

- Determining whether the specifications defined in the OSS, LSR, and SRD are being met;
- Characterizing other system performance metrics in the context of the four primary science drivers;
- Studying environmental dependencies and technical optimization that inform early operations;
- Documenting system performance and verifying mechanisms to monitor system performance during operations; and
- Validating data delivery, derived data products, and data access tools that will be used by the science community.

The goal is to quantify the range of demonstrated performance by using a combination of on-sky data, informed simulations of the LSST system, and external datasets. Observations taken during this period will enable higher-level data quality assessments that are not explicitly identified as requirements in the LSR or SRD, but nonetheless represent important benchmarks of scientific performance (e.g., source detection completeness, accuracy of star-galaxy separation, precision of photometric redshifts, and weak-lensing null tests).

All test cases as described under the LSST Verification and Validation project will be implemented as either part of the DM Key Performance Metric validation system, as separate test procedures (e.g., Jupyter notebooks), or via visual inspection (e.g., to demonstrate that a service or data produce has been delivered). The LSST Science Platform will be the primary tool for data access and exploration. All metrics will be applied to data from the two main Science Validation surveys (the Wide-area Science Validation Survey and the 10-year Depth Science Validation Survey) and evaluated against the numerical values described in the LSST System Requirements, Observatory System Specifications and Science Requirements Document.

If the schedule for on-sky observations is compressed, there might be a tight timeline for data processing and subsequent analysis of the Science Validation surveys. The statistical power of tests may be more limited if there are fewer observations. In that case, the validation and characterization may be more limited. For example, if the baseline for the wide-area science verification survey is shortened we will have to verify variability measures (e.g., periods) to specific classes of object. We may want to specify which classes of variability we will prioritize. Similarly, for the data release products, priority might be assigned to the verification of science performance for a brighter sample of objects (e.g., magnitudes $i < 25$).

### 2.3 Criteria for Completeness

The Project team shall complete sufficient science verification, validation, and characterization studies to be confident that 10-year LSST survey can satisfy OSS, LSR, and SRD. Some aspects of science performance are fixed by the telescope, camera, and observing startegy, while others can be continually improved through refinements of the Science Pipelines. In this context, key objectives of science verification are to distinguish between anomalies that can be addressed in the science pipelines and those that are more fundamental to the raw data, and to establish confidence that more subtle anomalies do not fundamentally limit science reach during Early Operations.

To achieve this level of confidence, we identify several essential categories of science performance (in order of increasing algorithmic dependence):

- image quality (PSF FWHM, ellipticity), system throughput, ghosts/scattered light, sky brightness and readout noise, detector anomalies;
- instrument signature removal;
- PSF modeling, photometric calibration, astrometric calibration.

Construction completeness is achieved when LSR and SRD metrics in the categories above pass the design requirements as stated in the SRD. Non-compliance exceptions to the above requirements will be considered following internal and external reviews of the assessed performance and operational impacts.

In addition, substantial progress should be made on towards initial verification of difference imaging, de–blending, galaxy photometry including shape measurement, moving object linkage, and proper motions.

## 2.4 Pre–Operations Interaction

Brief the Operations Team on current status of science verification, validation, and characterization; and

Handoff of QA and QC tools. Ensure that operations team can run these tools, interpret the results, and add new metrics as needed.

## 2.5 Artifacts for Completion

- Minimum:
  - Summary report of system–level science performance metrics, with comparison to specifications in the OSS, LSR, and SRD;
  - Impact study in the case of non-compliance;
  - Documentation of Quality Assessment and Quality Control tools;
  - Draft of Construction Paper for Commissioning Science Verification and Validation (not released until time of public release of commissioning data products).
- Baseline:

- For each science performance requirement in the LSR and SRD, summary statistic(s) or diagnostic plot(s) demonstrating the distribution of performance and correlations with environmental conditions, astrophysical foregrounds, etc.;
- Brief reports for a small collection of end-to-end studies demonstrating realistic workflows used for science validation (see examples above). It is envisioned that these studies may mature into full scientific publications during the first year of operations and may involve collaboration with the larger scientific community.

# 3 Verification of Observatory System Specifications (LSE-30)

## 3.1 Construction Completeness Criteria

The project team shall demonstrate that the integrated LSST systems (Camera, Telescope & Site and Data Management subsystems) as well as the Education and Public Outreach (EPO) system have met the technical specifications enumerated in the LSST Observatory System Specifications (LSE-30).

## 3.2 Objectives

The main objective with this Operations Readiness Requirement is to verify the system specifications in the OSS (LSE-30) are proven and well documented.. The OSS is essentially the highest level document describing the basic LSST system technical architecture. It contains sections derived from the OSS on the following broad topics:

- System Composition and Constraints
- Common System Functions and Performance, including:
  - System Control
  - System Monitoring and Diagnostics
  - System Maintenance
  - System Availability
  - System Time References

- Detailed Specifications:
  - Science and Bulk Data
  - Optical System
  - System Throughput
  - Camera System
  - Photometric Calibration
  - System Timing and Dynamics
- Education and Public Outreach

### 3.3 Criteria or Completeness

Compliance with this objective will follow the process as defined in the Verification and ValidationProcess document (LSE-160) and associated documentation. All technical specifications in the OSS (LSE-30) and LSR (LSE-29) are expected be met at the end of construction.

### 3.4 Pre–Operations Interaction

None. Unless there are non-compliance issues against the ORR requirements and specifications.

### 3.5 Artifacts for Completion

- Verification matrix containing entries for all OSS requirements and specifications. Methods, inspections, demonstration, analysis or test, shall be identified for every OSS requirement. Final compliance status will be included.
- Analysis reports where the verification method has been identified as ”test” or ”analysis”.
- Non-compliance reports.

## 4 Verification of Data Management System Specifications (LSE-61)

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### 4.1 General Verification of Data Management System Requirements LSE-61

The Data Management (DM) subsystem will be verified and validated again the *Data Management System Requirements* – (LSE-61) and the *Data Product Definition Document* – DPDD (LSE-163).

Prior to start of commissioning and operations the data processing will be verified to extent possible using precursor data, final verification and construction completeness will be determined with data obtained during the commissioning phase of the project. In addition, functional verification will be achieved through testing and operations rehearsals/data challenges. The approach to verification and validation adopted by the LSST Data Management Subsystem is given in the DM Test Plan (LDM-503). The DM system will considered being successfully completed when all of the high-level requirements placed upon it, as defined in the *Data Management System Requirements* (DMSR, LSE-61 ) have been verified. The requirements have be categorized into by priorities, where 1a requirements will be verified to start commissioning, and 1b requirements are to be verified to complete the construction project and requirement in the categories 2 and 3 are essentially best effort for construction completeness (LSE-61).

Broadly, this approach consists of three aspects:

1. Verification that the Data Management system as delivered meets the requirements placed upon it;
2. Validation that the system as delivered meets the needs of the scientific community;
3. Rehearsing the sustained operation of the system in operational scenarios.

The DM system will be considered successfully completed when all of the high-level requirements placed upon it, as defined in LSE-61 the Data Management System Requirements (DMSR) have been verified.

The DM Test Plan provides a series of high-level milestones and the accompanying the test schedule.

We regard the DM system as being successfully completed when all of the high-level requirements placed upon it, as defined in LSE-61, the Data Management System Requirements, have been verified. These requirements are verified by running tests, and recording the results of those tests in the LSST Jira system. The approach that will be taken to verifying each requirement is described in the *DM Acceptance Test Specification,* (LDM-639), which provides the dedicated test specifications for major components of Data Management.

## 4.2 Objectives

The following is common for all Data Management/Processing elements:

The Data Management/Processing elements provide the functionality necessary to process the raw image data into usable data products and to make those data products accessible to the general user community.

## 4.3 Criteria for Completeness

Successful implementation all the requirements in the DMSR. This will be evidenced by the DM Verification Control Document (LDM-692).

The system as delivered meet the needs of the scientific community. This will be evidenced by the system validation and operations rehearsals.

## 4.4 Pre-Operations Interactions

Brief the Operations Team on current status of science verification, validation, and characterization. Ensure that operations team can run the DM system, interpret the results, and add make modifications as needed. This will be done through the sequence of Data Previews, hosted at the Interim Data Facility (IDF) planned by the pre-operations project. Interactions with selected community brokers to ensure both they and the operations project are ready to

## 4.5 Artifacts for Completion

The following artifacts will be provided for all Dm elements:

- All DM Test plans and reports;
- The DM Verification Control Document (LDM-692), which provides the verification matrix for all DMSR requirements and Specifications, as defined in LSE-61;
- Non-compliance reports.

## 4.6 Prompt Processing

### 4.6.1 Operations Readiness Requirement

The Project shall demonstrate the Prompt (Alert) Processing meets its requirements as defined in the DMSR (LSE-61) and the DPDD (LSE-163). In particular the Prompt (Alert) Processing shall demonstrate its technical ability to meet the 60–second latency requirement for the transfer of data, processing difference images, and publishing detect sources from the Difference Imaging Analysis (DIA). Additionally, we shall demonstrate that nightly Solar System Processing (SSP) meets the DMSR requirements for identification of Solar System Objects.

### 4.6.2 Objectives

The objective of this Operational Requirement is to ensure that the Prompt Processing pipelines have been verified against requirements and produce the Prompt data products necessary for LSST Transient, Variable, and Solar System science, and to enable rapid follow-up of time domain events.

Demonstration of an integrated LSST system for Prompt Processing must include, at some level, testing interfaces to the Minor Planet Center (MPC) for Solar System Data products and with Community Brokers (LDM-612) for Alerts.

Prompt Processing requires templates images to enable Difference Image Analysis. During normal survey operations, templates will be produced as part of Data Release Processing. During commissioning and early operations, however, templates can only produced incrementally through separate execution of the Template Generation Payload as data of sufficient quality is taken in various areas of the sky. Given the dependence of Prompt Processing on the availability of templates, validating DM's template generation capability is an important objective for Operations Readiness.

Where and when templates are available, we expect Prompt Processing to proceed normally. The Prompt Products Database should be populated and alerts generated. In the alert packets, there would be less than 12 months of previous DIASource records available, and, as there will be no available DR in commissioning, providing matching Object IDs would depend on what DRP data products were available.

We expect to provide a machine-learned spuriousness classifier for `DIASources`. Good performance of such classifiers requires a large sample of labeled data reperesentative of the entire survey, which may not be available prior to routine survey operations. Accordingly, initial validation of the spuriousness classifier and a plan for incremental retraining in operations is sufficient for operational readiness.

We will run Solar System Processing in commissioning to validate the solar system products pipelines, generate some solar system data products, and test the interfaces with the MPC. We should be able to attribute Solar System objects known from other surveys and previously catalogued by the MPC with single-apparition LSST `DIASources`. Once the astrometry is sufficiently good (for asteroids, $\sim 0.05 - -0.1''$), we can start regularly submitting to the MPC and testing the linking software.

It should be clear, that at least in early commissioning, alert distribution and submission to the MPC will be with substantial latency with respect to the SRD operations-era latencies. Similarly, OSS completeness and purity metrics for both transients and solar system objects may not be achievable prior to the availability of DR1 templates.

#### 4.6.3 Construction Completeness Criteria

TBD

#### 4.6.4 Pre-Operations Interactions

TBD

#### 4.6.5 Artifacts for Completion

TBD

## 4.7 Data Release Processing

### 4.7.1 Operations Readiness Requirement

TBD

### 4.7.2 Objective

The objective of this operational requirement is to ensure that the Data Release Processing (DRP) pipelines have been verified against requirements and produce the data release data products necessary for static science with LSST.

### 4.7.3 Construction Completeness Criteria

The project team shall process the data from the one (or more) of the Science Verification Surveys to produce a Data Release and make it available to the Commissioning Team through the DM Science User Interface as well as a subset for the EPO Public User Interface.

### 4.7.4 Pre-Operations Interactions

TBD

### 4.7.5 Artifacts for Completion

TBD

## 4.8 Rubin Science Platform

### 4.8.1 Operations Readiness Requirement

TBD

#### 4.8.2 Objectives

The objectives of this Operational Requirement are to ensure that the Rubin Science Platform (RSP), including the DM Science User Interface, have been verified against requirements, and that the LSST science community can access, visualize, interact with, and analyze LSST data products. The RSP will not be complete at the stage of commissioning. We need to understand what functionality and level of service is needed.

#### 4.8.3 Operations Readiness Criteria

The project team shall demonstrate that the Rubin Science Platform can deliver data and data products; and that the interfaces aimed at the general public are functional.

#### 4.8.4 Pre-Operations Interactions

TBD

#### 4.8.5 Artifacts for Completion

TBD

# 5 Science Data Quality Assessment

## 5.1 Operations Readiness Requirement

The project team shall demonstrate that the integrated LSST system can monitor and assess the quality of all data as it is being collected.

## 5.2 Objectives

The Science Data Quality Assessment is a comprehensive system as it requires to monitor and assess quality of all data being collected, including raw and processed data. The system will collects, analyzes and records required information about the data quality and will make that information available to a variety of end users; observatory specialist, observatory scientists, downstream processing, the science planning/scheduling process and science users of the data.

Also, due to the fast cadence, diagnostic will heavily involve automated data analysis methods (such as data mining techniques for finding patterns in large datasets, and various machine learning regression techniques). But while the Science Data Quality Assessment will mostly be automated, it will also include a human-intensive components, due to the vast needs driven by the variety of end users.

### 5.2.1 Quality of the raw data

The quality of the raw data is the results of the state of the telescope and the camera. This includes image quality, throughput performance and systematic errors. The throughput non-uniformity, especially for M2, can affect our ability of measuring fluxes across the focal plane for instance. The image quality is impacted by different aspect of the observatory such as: the dome seeing, the atmospherical seeing, the as-build qualities of the different optical systems, the active optics performance.

### 5.2.2 Quality of the processed data

The information of the processed data relies on the calibration data products and the pipeline properties. In other words, the data assessment at this stage shall include the correction of the systematic errors.

## 5.3 Data Analysis Tools

The Data Quality Assessment will rely on several tools such as the electronics logging, the engineering facility database, the science platform. It is also important to have the right data visualization tools to facilitate the understanding of the correlation between the data quality and the observatory state.

The following sections describe examples essential components of QA:

### 5.3.1 Image quality

As mentioned above, the image quality is an important component of the LSST science mission and can be reflected by two important metrics: the PSF FWHM and the ellipticity. It is important to note here that because the ellipticity is an important metric needed to characterize galaxies among other astronomical objects, it is crucial to estimate the ellipticity coming from instrument signature and atmospheric signature.

The first measurement of the image quality is done in the active optics pipeline, where the 4 wavefront sensors are directly measuring the wavefront in real time, in 4 different directions. The metric is the Zernike Polynomial up to the 22nd coefficient. This measurement should in theory average the atmospheric turbulence errors, giving an estimation of the optical error in the full system (Telescope + Camera). Warnings are in place for the cases when the error is out of the expected range. Note that tracking errors or vibrations of the Telescope Mount Assembly (TMA) or any other components can also be responsible for image quality degradations.

Also, for each observation, the science pipeline will automatically publish a measurement of the PSF moments, including the ellipticity on the processed data. These results are displayed in real time on the visualization system and ready for more human data analysis. The human interaction can happen at any time from the time we take the data and will correlate the PSF FWHM and ellipticity analysis with other metadata such as the integrated seeing, the dome seeing, temperature etc. It will involve simulation capabilities of the telescope, the camera systems and the atmosphere (such as PhoSim). The simulations use as built data for each elements (mirrors, lenses, etc..) measured during the diverse Integration and test phases.

Finally depending on the results from these measurements, the scheduler will proceed to another observation of that field, with the goal of improving the data quality.

### 5.3.2 Throughput

.....

### 5.4 Criteria for Completeness Description

We will work with the error budget tree and define pass or fail status at each of the entries. The different tools are giving the proper responses in term of degradation of the image quality: - PSF FHWM - Ellipticity - Wavefront measurements - Throughput measurements over the entire field - Display of these metrics

### 5.5 Pre-Operations Interactions

The pre-operation interaction include training the observing specialists to understand errors

### 5.6 Artifacts for ORR

## 6 Science Validation Survey

### 6.1 Operations Readiness Requirement:

The project team shall conduct at least one Science Validation Survey with the science camera (LSSTCam) over a limited area of the sky that will be autonomously driven by the scheduler and will last at least 30 days;

### 6.2 Objectives:

The main objective with this Operations Readiness Requirement is to effectively conduct a "full dress rehearsal" of science operations. The 30-day time span is intended to include operations affected by a full lunar cycle including:

- Filter swapping the u-band during dark time;
- Management of survey scheduling during the period around full moon;
- Scheduler response to a range of environment conditions encountered at the observatory over a 30-day period, including periods of cloud cover and variable atmospheric seeing, variable winds, and changes in daytime / nighttime temperature;

- Response of the LSST Data Facility to sustained data rates including simultaneous execution of the Alert Production and Data Release Production pipelines.

In addition, the following concepts of operations and their procedures will be rehearsed and demonstrated:

- Full rehearsal of safety procedures for science operations;
- Routine daytime maintenance of the observatory;
- Collection and processing of routine calibration data and data products consistent with the time allotted in the 24-hour operations cycle;
- Routine nighttime survey observing operations driven by the scheduler with minimal human interaction, including response to realtime telemetry, AuxTel;
- Demonstration of near real time data quality assessment;
- Prompt processing of alerts within the required latency time (i.e., 60 seconds);
- Recovery from interruptions to observing (e.g. failure of the network)
- Distribution of prompt products;
- Prompt processing and the "24-hour" data products (e.g., asteroid orbit calculations);
- Data Release Production (at least once) and publication to the LSST Science Platform.

Data acquired during the SV survey(s) should be science quality to allow a summative assessment of the delivered scientific performance of the as-built system.

## 6.3 Criteria for Completeness Description:

The baseline schedule of on-sky observations during commissioning concludes with a 8-week period to undertake two science validation surveys. The two surveys are designed to test the Prompt Products and Data Release Products, respectively.

Wide-area Science Validation Survey: In a first phase, observe a region of roughly 1000 $deg^2$ to an integrated exposure equivalent to 1 year of the Wide-Fast-Deep survey in multiple filters

(2 weeks). Create image templates with the Data Release Production pipeline to be used as input for difference imaging. In a second phase starting roughly 4 weeks after the completion of the first phase, observe the same region to an integrated exposure equivalent to 1 year of the Wide-Fast-Deep survey, running the Alert Production pipeline at full scale (2 weeks). The 4-week separation between phases is used for template generation and to allow evolution of variable and transient astrophysical sources between template and test images. 10-year Depth Science Validation Survey: Observe a region larger than 100 deg$^2$ to an integrated exposure equivalent to the 10-year Wide-Fast-Deep survey in multiple filters (4 weeks). Process the data with the Data Release Production pipeline.

Observation Timeline (baseline): 2 weeks Wide-area Science Validation Survey: Template Generation Phase 4 weeks 10-year Depth Science Validation Survey 2 weeks Wide-area Science Validation Survey: Realtime Alert Production Phase

The wide-area SV survey is designed to approximate the difference imaging templates and data rates that would be expected during early science operations, thus also providing a full-scale test of the LSST Data Facility. The scheduler will drive nighttime observatory operation during the SV surveys.

In event of a shortened period for on-sky observations, we have a draft minimum observing strategy:

- Single-visit KPMs: 6 Star flats in $ugrizy$ ×4 epochs = 4 nights
- Nominal observing for scheduler testing = 3 nights (Note: some scheduler testing will be done during ComCam and LSSTCam integration periods)
- Challenging regions = 1 night
- Full-Depth Survey: 20 year depth in $ugrizy$ overlapping at least 1 external reference field, allowing WFD dithers (factor 3) -> ~5K visits = 8 nights
- Wide-Area Survey: 1600 deg$^2$ in $gi$ filters to 1-year equivalent depth, repeated in two phases -> 12K visits = 20 nights

Program above is $\sim 36$ nights total. The essential elements of any observing strategy for the Science Validation surveys are (1) the need to reach 10-year WFD equivalent depth in at least

3 filters in at least one field, (2) to reach 1-year WFD equivalent depth in at least 2 filters over an area exceeding 100 $deg^2$, (3) to exercise the nominal scheduler continuously for at least 1 night, and (4) to have coverage to at least 1-year WFD equivalent depth in all 6 filters in at least three fields spanning a range of stellar density. The observatory should operate continuously in scheduler-driven mode for at least 5 days of the 30 days allocated to the Science Validation surveys.

### 6.4 Pre-Operations Interactions:

At the conclusion of the SV Survey(s), roughly two years will have elapsed since the start of Early System Integration and Testing, which places the LSST Observatory on schedule for its 2-year major maintenance and servicing.

M1M3 Mirror Recoating: Remove, strip, clean, and re-coat the M1M3 mirror surfaces. Reinstall M1M3 mirror backinto telescope. Associated activities include:

- Remove Top-End Integrating Structure with Camera and transfer to Summit Facility camera lab.
- Install camera dummy mass to allow the telescope to point to zenith for removal of the M1M3 mirror cell. Remove M1M3 mirror assembly and transfer to Summit Facility recoating plant.
- Strip old coating, clean and re-coat mirror surfaces.
- Re-install M1M3 in telescope and prepare to receive the top-end integrating structure with the camera.

Camera Maintenance and Servicing: Clean, service, perform maintenance, and replace shutter. Associated activities include:

- Replace camera shutter with ?fresh? operational unit;
- Inspect, service, or repair filter mechanisms;
- Clean internal camera optics;
- Inspect, service, and repair utility trunk electronics

### 6.5 Artifacts for ORR:

- Safety report from continuous observatory operations during the survey(s)
- Summary of daytime and nighttime activity for each 24 hour period of the survey(s)
- Metrics for the effective survey speed, including number of visits per night, telescope slew angles and slew times, filter changes, etc., which can be used to inform survey strategy during early operations
- Characterization of the distribution of data quality delivered by the as-built system, for example, distributions of single-visit image quality and image depth.
- Realtime alert stream
- Associated data release production products accessed via the LSST Science Platform (LSP)
- Pre-ORR observatory maintenance report summarizing the pre-operations engineering activities and current status of the observatory
- Documentation for observatory operations, including recommendations for optimization of data quality and survey efficiency
- Documentation for LSST Data Facility (LDF) operations

## 7 Recording and Archiving of System State Metadata

### 7.1 Operations Readiness Requirement

The Rubin Project Team shall demonstrate that relevant metadata are being collected and archived.

### 7.2 Objectives:

The objective with this requirement is to ensure that the technical state of the environment and hardware/software systems during the time of survey data collection is recorded with sufficient fidelity to be used in support of subsequent processing to produce the LSST science products. This is of particular importance for the determination and correction of systematics in the data as the survey progresses and statistics improve. Additionally, the metadata record in required to assure efficient operation and maintenance of the observing facility. The primary repository of this metadata is the Engineering Facility Database (EFD) - having two components: 1) a searchable SQL Cluster based capture of ”house keeping” telemetry and 2) the Large File Annex for non-telemetry records (e.g. configuration files, images, other binary files outside the science pixel data etc...).

Technical Metadata at the time of each visit includes but not limited to:

- Meteorological state on the Summit;
- Environmental conditions in the dome interior;
- Atmospheric seeing as measured by the tower mounted DIMM;
- Sky transparency map from the All-Sky Camera;
- Technical ”house keeping” telemetry from each subsystem component as published to the EFD;
- Software version configuration status of all operating systems; and
- Configuration parameters of all active subsystems.

## 7.3 Criteria for Completeness

Satisfying this criteria includes at a minimum:

- Demonstrate the technical data (see above) are being recorded by the EFD at >99% (TBC) reliability level - e.g. no significant dropouts in the live database at the Summit Facility;
- Demonstrate the recorded data are being archived for long term access - copy at Base Facility in Chile and Copy at NCSA (possibly Interim Data Facility);
- Access to the technical data is achievable through standard monitoring dashboards;
- Access to the technical data is chewable through use customizable GUI interface(s); and
- Technical data are queryable through Rubin Science Platform tools - e.g. Jupyter Lab notebooks and WEB interface.

### 7.4 Pre–Operations Interactions

Transfer and archiving the EFD at the Interim Data Center would be required for external queries.

### 7.5 Artifacts for ORR

- Report documenting minimum criteria as defined in the discussion section above
- SDK and example code for custom dashboards and dashboard templates available through software repository(s) - e.g. GitHub
- Example code for Rubin Science Platform queries through software repository - e.g. GitHub

## 8 Verification of Education and Public Outreach

## 9 Operational Procedures and Technical Documentation

### 9.1 Operations Readiness Requirement

The project team shall deliver a complete set of documented operational procedures and supporting technical documents needed to operate the LSST as a scientific facility for the purpose of conducting a 10-year survey.

### 9.2 Objectives:

The objective with this Operational Requirement is to ensure that the procedures necessary for operations and maintenance of the LSST Observatory System are documented and provided in a form that allows the operations team conduct the 10-year planned survey. The documentation is to include but is not limited to:

- Technical as-built design records - including functional descriptions; 3-D CAD files; drawing files used for fabrication; and software code and it's associated documentation and any as-built metrology;

- Process procedures describing user level standard operations;
- Maintenance needs and procedures for all systems in use;
- System software documentation - including their functionality, interacts with other systems and the observatory scheduler algorithm; and
- A configuration management plan for observatory wide software systems.

## 9.3 Criteria for Completeness

- A clearly defined and documented architecture and implementation for the Project's varied documentation. This includes:
  - As-built drawings, diagrams and metrology
  - Operating software versions and their documentations
  - CAD models and fabrication drawings
  - Documented operations procedures
  - Documented maintenance needs and procedures
  - Definition of delivered data properties
- A WEB based (and associated document) roadmap / directory for the Project's document repositories (see above).

## 9.4 Pre–Operations Interactions

The final delivered documentation will be negotiated between the Rubin Construction Project and Rubin Operations.

## 9.5 Artifacts for ORR

See Criteria above.

# 10 As-Built Record, Modifications, non-Compliance and Recommendations

# 11 Rubin Operations Team Readiness

## 11.1 Operations Readiness Requirement

- The Operations Team shall have a detailed operations plan approved by NSF and DOE.
- The Operations Team shall have a staffing plan with all roles in the operations plan filled with identified personnel.
- The Operations Team must understand the state of the system that is being handed over to them and be able to execute the detailed plan to efficiently in order to capture store and process science quality images.

## 11.2 Objectives

The primary objective of this element of the ORR is that the Operations Team needs to demonstrate that it is ready to smoothly continue running the full Rubin System as it exists at the end of the commissioning period. A successful initial phase of operations may include beginning the full Legacy Survey of Space and Time at the approved nightly schedule and cadence. It may also include other activities as necessary depending on the final outcome of commissioning. These could include special observing modes to enable Early Science and further development of detailed procedures for operations that not done in commissioning but which do not prevent completion criteria from being satisfied.

## 11.3 Criteria for Readiness

- Demonstrate planning and staff for safety in operations are in place.
- The team should demonstrate that all needed roles are filled, or will be, with trained staff at the time of hand over to full operations.
- All Human Resources processes for on-boarding operations staff should be complete or ready by the date of handover as appropriate. Expatriate staff for Chile based de-

ployments should have all necessary documents and requirements for work in Chile in place. Chilean staff should have any needed changes to their contracts made before operations begin.

- An operations budget profile fully covering the needs of the observatory should be agreed to with the agencies in advance of full operations beginning.
- All supplies and non-labor capital items should be in place.
- Contracts needed in year 1 for operations services or supplies should be in place.
- Any in-kind contributions necessary for operations should be demonstrated to be in place and functioning at the level needed for year 1. Any systems handed over to operations from construction in advance of this review should be demonstrated to be functioning at the required level of performance.
- Demonstrate all needed advisory committees/structures are ready and in place.
- Demonstrate that all construction related documentation is captured in an operations documentation management system.
- Demonstrate that a significant fraction of the community has been granted user accounts in the US DF, that the Rubin Science Platform supports their access and authorization and that they have been given suitable training or information to do science with the Rubin data products as they are delivered.
- Demonstrate a working alert stream and that the interface to the community brokers is working.

## 11.4 Artifacts for ORR

As prelude: the Construction team will be responsible for creating sets/lists of topics/documents that fully describe the characteristics and performance of the Rubin systems, how to maintain them, how to operate them, and anything else critical for the Operations Team (initial survey of documents suggested date November 2020. The Operations Team will review these lists and identify anything that needs to be added (or removed) from those lists. A collaborative negotiation will be carried out with the Construction Team.

Final approved detailed Observatory Operations Plan, including:

- Work breakdown structure;
- Activity based plans for each department;
- Milestones for each department though several year of operations;
- Performance metrics;
- Performance requirements;
- Maintenance Management plans;
- Fully populated staffing plan;
- Budget profile; and
- Work Breakdown Structure.

# A References



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## B Acronyms

| Acronym | Description |
|---|---|
| AP | Alert Production |
| ComCam | The commissioning camera is a single-raft, 9-CCD camera that will be installed in LSST during commissioning, before the final camera is ready. |
| DF | Data Facility |
| DIA | Difference Image Analysis |
| DIMM | Differential Image Motion Monitor |
| DM | Data Management |
| DMSR | DM System Requirements; LSE-61 |
| DOE | Department of Energy |
| DPDD | Data Product Definition Document |
| DR | Data Release |
| DRP | Data Release Production |
| EFD | Engineering and Facility Database |
| EPO | Education and Public Outreach |
| FWHM | Full Width at Half-Maximum |
| GUI | Graphical User Interface |
| IDF | Interim Data Facility |
| LDF | LSST Data Facility |
| LDM | LSST Data Management (Document Handle) |
| LPM | LSST Project Management (Document Handle) |
| LSE | LSST Systems Engineering (Document Handle) |
| LSP | LSST Science Platform (now Rubin Science Platform) |
| LSR | LSST System Requirements; LSE-29 |

| | |
|---|---|
| LSST | Legacy Survey of Space and Time (formerly Large Synoptic Survey Telescope) |
| M1M3 | Primary Mirror Tertiary Mirror |
| M2 | Secondary Mirror |
| MOPS | Moving Object Processing System (deprecated; see SSP) |
| MPC | Minor Planet Center |
| MREFC | Major Research Equipment and Facility Construction |
| NCSA | National Center for Supercomputing Applications |
| NSF | National Science Foundation |
| ORR | Operations Readiness Review |
| OSS | Observatory System Specifications; LSE-30 |
| PPDB | Prompt Products DataBase |
| PSF | Point Spread Function |
| QA | Quality Assurance |
| QC | Quality Control |
| RSP | Rubin Science Platform |
| SE | System Engineering |
| SQL | Structured Query Language |
| SRD | LSST Science Requirements; LPM-17 |
| SV | Science Validation |
| TBC | To Be Confirmed |
| TBD | To Be Defined (Determined) |
| TMA | Telescope Mount Assembly |
| US | United States |
| WFD | Wide Fast Deep |
| deg | degree; unit of angle |