Vera C. Rubin Observatory
Systems Engineering

Construction Completeness and Operations Readiness Criteria

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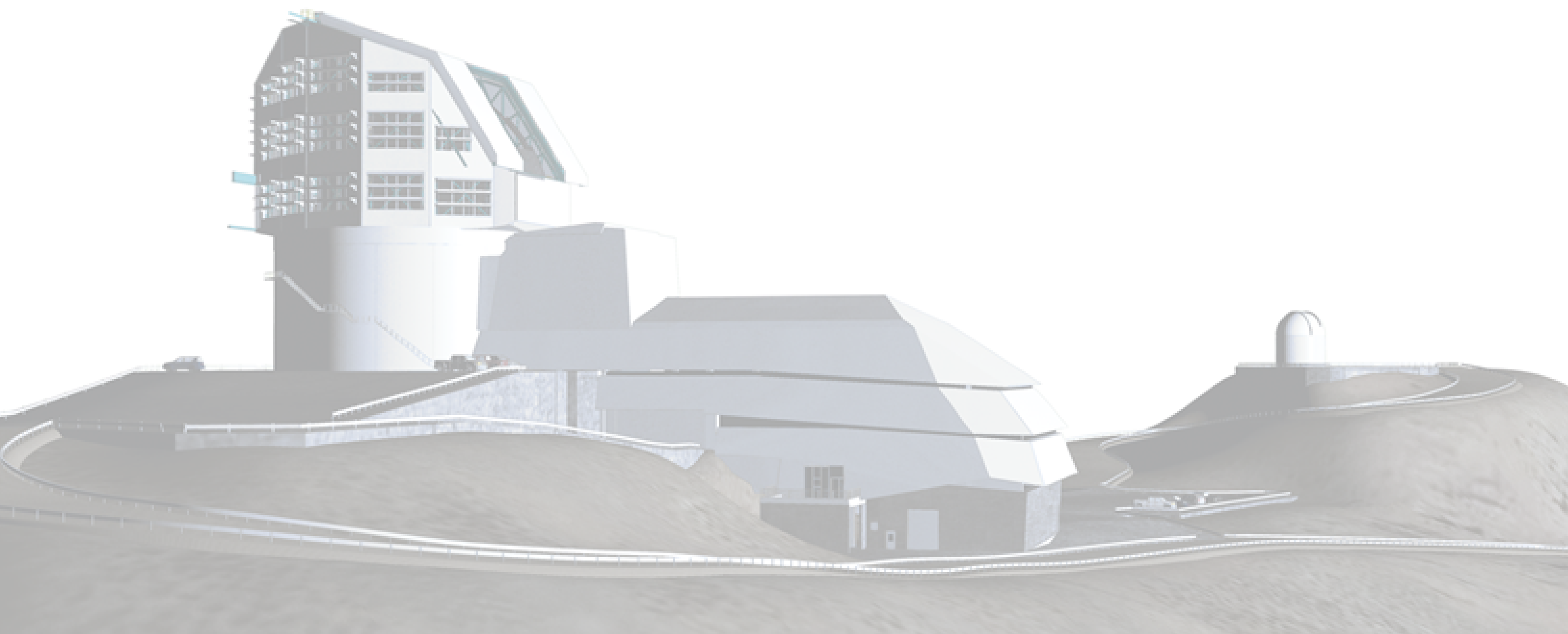

Abstract

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 Rubin Observatory operations 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 combined NSF – DOE Rubin Construction project.

The completeness evaluation will be done through a series of four joint NSF and DOE Constructions Compelness Reviews, covering the two main aspects: 1) The Project's construction requirements as outlined in this document and 2) The Rubin Operations team's readiness to begin the 10-year Legacy Survey of Space and Time (LSST). In addition to this document and references herein, the completion of the Rubin Observatory Project will be evaluated based on the LSST Project Execution Plan (**?**), the Commissioning Execution Plan (LSE-390), and the Cooperative Services Agreement (CSA) between AURA and NSF.
These reviews and criteria outlined in this document are consistent with the requirements in the NSF's Major Facilities Guide (NSF-19-68) Sections 2.4.2.1 – *Project Close–out Process*, 3.4.2.15 – *Commissioning*, 4.4 – *System Integration, Testing and Acceptance* and 4.5 – *Documentation Requirements*.

Change Record

Version	Date	Description	Owner name
1	2020-08-06	First draft	Leanne Guy
2	2020-08-08	Claver Updates	Chuck Claver
3	2020-08-20	Initial version for internal review	Chuck Claver
4	2021-04-30	Updated version for Project Change Control review	Chuck Claver
5	2024-10-08	Updated version for first Construction Close-out Review (CCR1)	Keith Bechtol and Holger Drass

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Construction Completeness and Operations Readiness Criteria

1 Introduction

One of the primary high-level strategic inputs to developing the *System AI&T and Commissioning Plan* (LSE-79) is the set of construction completeness requirements. In (LSE-79), the Project has identified 10 general requirements for ”construction completeness”, including one requirement for ”operations readiness”, summarized as:

1. Verification of LSST System Requirements (LSE-29) and survey performance as described in SRD (LPM-17)
2. Verification of the Observatory System Specifications (LSE-30)
3. Verification of Data Processing, Products and User Services
4. Demonstrating Science Data Quality Assessment (SDQA)
5. Conduct a Science Validation Survey
6. Demonstrate the system state is recorded and archived for each observation
7. Verify Education and Public Outreach has met its requirements and construction scope
8. Operational procedures and documented and accessible
9. Provided a record of the as-built system, including modification since the as-build and non-compliance
10. Demonstrate Rubin Operations Team readiness.

At the conclusion of the Rubin Observatory Construction Project’s commissioning phase, a series of Construction Closeout Reviews (CCRs) will be undertaken by an external panel jointly appointed by the DOE and NSF in consultation with the Project Team. The successful completion of the CCRs will signify the end of the NSF MREFC-funded construction project and DOE Commissioning. The CCRs are consistent with the NSF guidance given in the *Major facilities Guide* (NSF-19-68) Sections 2.4.2.1 – *Project Close–out Process*, 3.4.2.15 – *Commissioning*, 4.4 –

System Integration, Testing and Acceptance, and 4.5 – *Documentation Requirements*. There will be four reviews in the series covering

1. evaluation of the Rubin Construction Project completeness criteria and
2. the Rubin Observatory Operations team's readiness to receive the construction deliverables and begin planned operations for conducting the Legacy Survey of Space and Time – the 10-year science survey for which the Rubin Observatory was designed and constructed to perform.

The expected timeline and focus areas for the four CCRs are summarized in Figure 1.

	CCR1	CCR2	CCR3	CCR4
Where	Chile	Chile	Virtual	Virtual/ Washington/Tucson
Project condition	ComCam on-sky campaign. Telescope operational, LSSTCam ready for install	After System First Light Coordinated with Operations Readiness	Construction Scope complete and only final verification data analysis remain	Final Accounting and reporting
Key charge elements	1) Are proposed Scope items complete 2) Is test plan and verification plan for remaining elements sound	1) Are proposed scope Items complete 2) Is the Project on Track to complete remaining construction completeness criteria 3) Is the Operations team on track to accept the Observatory Responsibility 4) Are proposed hand-over conditions appropriate	1) Has the Construction team completed the Scope of work and met the completion criteria 2) Is the Operations team in place to accept the Observatory	
Verification status	**CCR1 requirements** can be verified prior to LSSTCam First Photon, including those that can be verified w/ ComCam on-sky testing and precursor data. **Examples:** optical prescriptions and mirror reflectivity, TMA performance, Science Pipeline functionality, science data quality monitoring tools	**CCR2 requirements** demonstrate that the integrated hardware+software have the system performance capabilities to deliver science-ready observations; verified w/ on-sky LSSTCam data leading up to System First Light milestone **Examples:** single-visit image quality and optical throughput	**CCR3 requirements** demonstrate that the integrated system has the demonstrated reliability for survey operations **Examples:** integrated entendue including operational efficiency, distribution of Prompt data products	**CCR4 requirements** demonstrate the ability to distribute survey-scale Data Release Production data products **Examples:** science performance verification of full suite of Prompt and DRP data products

FIGURE 1: Construction Closeout Review overview

In this document, we collect and detail the elements that constitute the criteria for construction completeness and operations readiness. Each topic has its own or will reference well-defined requirements – in some cases, these include 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 the estimated 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 some combination thereof. For each requirement, there will either be a clean pass or a waiver process that documents why it is acceptable to proceed to operations (or the reason we must postpone the transition to operations).

Some topics summarized in this document 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 requirements for verifiability. Some topics, such as the Science Validation surveys, have requirements that are a combination of performance and functionality that do not easily flow directly from the high-level system requirements; in those cases, we identify the minimum requirements and performance that must be met to proceed to operations, along with a range of goals and stretch goals and the accompanying rationale.

For each of the general construction completeness requirements, we provide:

- the statement of the requirements;
- an expansion of objective and intent;
- specific criteria for completeness;
- indication of any pre–Operation interactions; and
- the expected delivered artifacts.

2 Sequence of Construction Closeout Reviews

Describe the sequence of four Construction Closeout Reviews.

3 LSST System Requirements & SRD Verification/Validation

3.1 Operations Readiness Requirement

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).

3.2 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 verification 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); and
- 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; and
- 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 $i < 25$).

3.3 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 strategy, 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; and
- 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.

3.4 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.

3.5 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.; and
- 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.

4 Observatory System Specifications (LSE-30) Verifcation

4.1 Operations Readiness Requirement

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).

The requirements in LSE-30 have been marked according to the CCR where they can be earliest verified. The distribution between the CCRs is shown in Figure 1.

FIGURE 2: Distribution of the the LSE30 requirement verification over the course of the CCRs

4.2 Objectives

The main objective of 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 LSR on the following broad topics:

- System Composition and Constraints
- Common System Functions and Performance, including:

- System Control The System Control is implemented by combining a Service Abstraction Layer (SAL) and a number of Commandable SAL Components (CSC). A CSC represents each System and Subsystem in the observatory. Each CSC has a well-defined interface with the SAL. All other CSCs are required to comply with the definition of the interface. Therefore, the interface definitions are handled as requirements and verified as such. Each interface requirement is verified through unit testing on the teststands at each new release and with the hardware during system usage. Artifact?
- System Monitoring and Diagnostics As part of the communication between the CSCs, messages with Commands, Events, and Telemetry are exchanged. These are stored in real-time in the Engineering database and can be displayed through Chronograph, Rubin TV, and others. To verify these efforts, we demonstrate the capabilities during the observatory visit.
- System Maintenance Maintenance started as soon as the Observatory started to use components that needed maintenance, such as generators. We have implemented a Computerized Maintenance Management System (CMMS) and connected it to our work management system (Jira)
- System Availability The system availability depends on several technical aspects. Principally power and cooling. We have a staged system with the national grid as a primary power source to ensure power. As a backup, we have three power levels with decreasing capabilities: two generators and UPS batteries. Cooling consists of redundant Chillers and pumps that can make the best use of the cooling power stored in the system. At CCR1, the power and cooling installations are presented.
- System Time References For the time reference, we have a local time server connected to the internet providing high precision time reference at any given moment.

• Detailed Specifications:

  - Science and Bulk Data
  - Optical System The optical system consists of the three mirror surfaces, the camera lenses, and the detectors. Each element has been tested indiv idually. At CCR1, we present an overview of the artifacts collected during the fabrication and coating processes.
  - System Throughput

    This is addressed in the SRD section.

- Camera System The LSSTCam is still in verification during the time of the CCR1 We will present the actual state of the testing, integration, and commissioning activities and a plan to finalize the commissioning.
- Photometric Calibration The calibration system is still being verified during the time of the CCR1. We will present the actual state of the testing, integration, and commissioning activities and a plan to finalize the commissioning.
- System Timing and Dynamics We present the status of the TMA testing and integration with the attached subsystems.

- Education and Public Outreach EPO has already entered operations. During CCR1, we briefly present their status.

4.3 Criteria for Completeness

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

4.4 Pre–Operations Interaction

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

4.5 Artifacts for Completion

- Verification matrix containing entries for all OSS requirements and specifications. The verification method: inspection, 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.

5 Verification of Data Processing, Products and User Services

The Data Management System provides the functionality necessary to process the raw image data into usable data products, and to make those data products accessible to the Rubin scientific community.

5.1 Operations Readiness Requirement

The project team shall demonstrate that the integrated LSST Data Management Subsystem has met its technical specifications as enumerated in the Data Management System Requirements LSE-61, specifically those designated as 1a and 1b priority.

5.2 Objectives

The objective of this operational requirement is to ensure that the integrated as-delivered Data Management System (DMS), including all supporting infrastructure, has been verified against its requirements. The top-level requirements for the DMS are given in the Data Management System Requirements LSE-61, and are derived from the Observatory System Specifications (OSS), LSE-30, which in turn are derived from the LSST System Requirements (LSR), LSE-29 and the Science Requirements Document (SRD) LPM-17. The DMSR is complemented by the Data Product Definition Document (DPDD), LSE-163, which describes the data products to be delivered by the Large Synoptic Survey Telescope (LSST).

5.2.1 Approach to verification and validation

The approach to verification and validation adopted by the LSST Data Management Subsystem is described in detail in the DM Test Plan (LDM-503), which provides a series of high-level milestones and the accompanying the test schedule. 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 approach to verifying each individual requirement is described in the DM Acceptance Test Specification, (LDM-639), which provides the dedicated test specifications.

Prior to start of commissioning and Operations, the data processing system will be verified to the extent possible using precursor data. Final verification and construction completeness will be determined with data obtained during the commissioning phase of the project and in collaboration with the commissioning team, 7. Functional verification will be achieved through a series of operations rehearsals and data challenges.

All requirements in the DMSR have been prioritized as follows:

1. ”This must be done to enter commissioning (a) or Operations (b); no waivers will be granted if not met.”
    - 1a: Must be demonstrated to be working before the start of the commissioning period.
    - 1b: Must be demonstrated to be working before the start of the observing.
2. “Should be done to enter Operations; but waiver likely to be granted if not met,” i.e., we could enter Operations without this fulfilled, for first 3 years.
3. “Overall capability/efficiency/ease of use/etc., may be reduced but science will not critically suffer if not done.” Could enter Operations without this requirement fulfilled, and have the soperations team decide whether they want to pursue it.

The verification status of requirements in the DMSR will be reported at each of the Construction Closeout Reviews. Most priority 1a requirements are expected to be verified by CCR1, coinciding with the start of on-sky commissioning with ComCam. Those that are not will be verified by the end of ComCam on-sky commissioning and ready for the start of on-sky commissioning with LSSTCam. Priority 1b requirements are expected to be fully verified by CCR3 to demonstrate readiness for the handover to Operations. Most priority 2 requirements are expected to be verified during the course of on-sky commissioning and early operations. For those that are not, a waiver will be sought to enter Operations and they will be completed within the first three years of Operations.

5.3 Criteria for Completeness

The DM system will be considered successfully complete when all high-level requirements in the DMSR have been verified. At a minimum, all priority 1 requirements must be verified at the end of construction. The DM Verification Control Document, LDM-692, provides an overview of the verification status of the Data Management Subsystem with respect to its requirements.

5.4 Pre-Operations Interaction

None, unless there are non-compliance issues against the CCR requirements and specifications.

5.5 Artifacts for Completion

The following artifacts will be provided:

- A verification matrix containing entries for all DMSR requirements (LSE-61) and specifications (LDM-639). Methods, inspections, demonstration, analysis or test, shall be identified for every DMSR requirement. This verification matrix is provided by the DM Verification Control Document (LDM-692);
- Final compliance status, including all non-compliance reports;
- All Data Management test plans and reports for all test campaigns;
- A Performance characterization report;
- System documentation and code repositories;
- Drafts of all construction papers.

5.6 Prompt Processing

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.

5.6.1 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.

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.

We expect to provide a machine-learned spuriousness classifier for `DIASources`. Good performance of such classifiers requires a large sample of labeled data representative 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.

5.6.2 Criteria for Completeness

The criteria for completeness are described in 5.3.

5.6.3 Pre-Operations Interactions

Validation and operations readiness will be assessed via the operations rehearsals and the DPs. Distribution of DPs by the early operations teams Results will be made available to the community - early operations team Through the planned data previews

5.6.4 Artifacts for Completion

The high-level artifacts for completion of the Prompt Processing pipelines are detailed in 5.5.

5.7 Data Release Processing

5.7.1 Objectives

The objective of this Operational Requirement is to ensure that the Data Release Processing pipelines have been verified against requirements and produce the Data Release data products necessary for LSST science.

Data Release Production involves not just the image processing pipeline, which is the component most visible to scientists, but integration with and usage of many other DM deliverables as well, including:

- data access middleware that archives and organizes both raw data from the observatory and processing outputs;
- process control middleware that provides a harness for running the pipelines at scale;
- systems for transferring processing outputs to components of the Rubin Science Platform (RSP) for user access, including database ingest;
- hardware, operators, and other production services.

5.7.2 Criteria for Completeness

The criteria for completeness are described in 5.3. The project team shall process the data from the one (or more) of the Science Validation Surveys to produce a Data Preview and make it available to the Commissioning Team through the Rubin Science Platform as well as a subset for the EPO Public User Interface.

5.7.3 Pre-Operations Interactions

None, unless there are non-compliance issues against the DMSR requirements and specifications.

5.7.4 Artifacts for Completion

The high-level artifacts for completion of the DRP pipelines are detailed in 5.5.

5.8 Rubin Science Platform

5.8.1 Objectives

The objectives of this Operational Requirement are to ensure that the Rubin Science Platform (RSP) has been verified against requirements, and that the LSST science community can access, visualize, interact with, and analyze LSST data products. The high-level vision of the Rubin Science Platform describing an integrated platform of three distinct aspects is described in LSE-319

5.8.2 Criteria for Completeness

The high-level criteria for completeness are detailed in 5.3. Specifically for the RSP, this means that the scientific community can retrieve the Rubin data products with a reasonable latency. The RSP will not be complete at the stage of commissioning.

5.8.3 Pre-Operations Interactions

None, unless there are non-compliance issues against the DMSR requirements and specifications.

5.8.4 Artifacts for Completion

The high-level artifacts for completion of the RSP are detailed in 5.5.

6 Science Data Quality Assessment

6.1 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.

6.2 Objectives

Science Data Quality Assessment is made up of a comprehensive system of tools to monitor and assess quality of all data as it is being collected including raw and processed data. The suite of tools have been designed to collect, analyze and record required information to assess the data quality and 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.

The fast cadence of data collection requires highly automated data diagnostic and analysis methods (such as data mining techniques for finding patterns in large datasets, and various machine learning regression techniques). he Science Data Quality Assessment is mostly be automated, however it includes human-intensive components allowing further investigation and visualization of SDQA status.

Data quality assessment for Rubin must be carried out at a variety of cadences, which have different goals:

- Near real-time assessment of whether the data is scientifically useful;
- Monitoring telemetry and imaging data to track the state of the integrated observatory, including the telescope, camera, networks and other supporting systems;
- Analysis of the prompt processing properties and performance to determine if the alerts stream meets its requirements; and
- Analysis of the data release processing properties and performance to determine if the static sky processing meets its requirements.

By the time we make a data release the accumulated data quality analysis must be made available as part of the release artifacts.

6.2.1 Near Real–time Monitoring & Assessment of the raw data quality

The quality assessment of the raw image data combines the results from the state of the telescope, the camera (see below) and technical properties of the images. Each will be analyzed as it is taken to a measure its technical properties both on the at the Summit Facility using the LSSTCam Diagnostic cluster and from properties determined during the prompt processing for alert production. Performance properties will be based on measurements and characteristics derived from the images themselves and from daily calibration data, these include:

- Sensor readnoise, bias and gain variations, bitwise integrity etc... from the CCD data;
- Properties of the measured PSF, based on the three second moments, or equivalently effective FWHM, e1, e2;
- Measured sky background level over the full FPA at amplifier level resoution;
- Measured source positions and errors relative to a reference catalog (*e.g. GAIA*) to monitor FPA stability and pointing accuracy; and
- Measured source fluxes and errors relative to a reference catalogue (*e.g. GAIA*) to monitor system throughput, sensitivity and algorithm processing.

At a minimum, these metrics enable the Project to determine if the data are within performance parameters to label the visit as ”good”. Tooling will be provided by the Construction

Project that enable users to monitor trends in these quantities (it. e.g. as a function of time and where the telescope is pointing and as a function of position in the focal plane. A reference set of tools will initially be provided by the LOVE interface along with more detailed analysis tooling (as described below). In some cases, data from the Rubin Auxiliary Telescope (RAT) will be used to interpret trends the LSSTCam data. The quality analysis needed to determine that the RAT is taking sufficiently good data will use the same tooling as provided for the main survey data.

6.2.2 Longer Term Assessment

TBD

6.2.3 Assessing the 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.

6.3 SDQA Tools for analysis

Science Data Quality Assessment will rely on a suite of tools including as the electronic logging, the engineering facility database (EFD), and the Rubin Science Platform (RSP). There is also a complementary set data visualization tools to facilitate the understanding of the correlation between the data quality and the observatory state.

These tools include:

- Rubin Science Platform (RSP) – used for investigative ad–hoc analysis (LSE-319); the RSP itself through it's web based porthole and Jupyter Lab interface provides significant visualization capabilities;
- Engineering Facility Database – accessible through science platform and pre-defined dashboards;
- LOVE - LSST Observing Visualization Environment used to have standardized dashboards and visualization of the system state;

- SQuaSH - the Science Quality System Harness (SQR-009)

6.4 Criteria for Completeness Description

The SDQA shall monitor and record the properties of the system error budget tree, including image quality and throughput, and define pass or fail status at each of the primary entries entries. These include the following terms of the image quality:

- PSF FWHM;
- PSF shape ellipticity as described by second moments;
- System wavefront measurements for each visit; and
- Throughput measurements over the entire field of view.

Tooling for evaluating SDQA shall demonstrate the ability to display performance on a visit by visit basis as well as being able to show the history of performance metric over a user defined span of time.

6.5 Pre-Operations Interactions

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

6.6 Artifacts for ORR

- Demonstrated functional tool kit as described above;
- Code validation tool kit to quantify software performance;
- Derived reporting from the Science Verification/Validation survey(s)

7 Science Validation Survey

7.1 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;

7.2 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 Science Validation Survey(s) should be science quality to allow a summative assessment of the delivered scientific performance of the as-built system.

Discussion

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. These surveys would begin after the early system integration and test period for LSSTCam, and assume that stable science quality imaging capability has been established prior to beginning sustained observing campaigns.

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 Science Validation 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 Science Validation surveys.

In the event of a compressed 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 (e.g., dense stellar fields) = 1 night
- Full-Depth Survey: 20 year depth in $ugrizy$ overlapping at least 1 external reference field, allowing 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

The example compressed on-sky observing program above is ~ 36 nights total.

The essential elements of any observing strategy for the Science Validation surveys are (1) the need to reach at least 10-year WFD equivalent depth in all 6 bands in at least one field, (2) to reach 1-year WFD equivalent depth in at least 2 bands over an area exceeding 100 deg^2, (3) to exercise the nominal scheduler for LSST operations continuously for at least 2 nights, and (4) to have coverage to at least 1-year WFD equivalent depth in all 6 bands in fields spanning a range of stellar density. These minimum requirements would allow verification of the highest priority system-level science performance metrics, with more limited opportunities for science validation and characterization. The baseline and compressed observing programs described above illustrate how these minimal datasets for system verification could be acquired within a window of at least 30 nights.

7.3 Criteria for Completeness Description:

A 30-day Science Validation survey period of sustained on-sky observations, routinely delivering science-quality images, is considered the minimum to cover the range expected environmental conditions, provide sufficient opportunities for science verification, and demonstrate operational procedures. The observatory should operate continuously in scheduler-driven mode for at least 10 days to demonstrate stable operation. The baseline plan with at least two months of Science Validation Surveys would offer further opportunities for science validation and optimization of survey operations, likely enhancing the delivered data quality and observatory efficiency during Early Operations, as well as informing science pipeline development and refinements leading up to the production of LSST DR1.

7.4 Pre-Operations Interactions:

At the conclusion of the Science Validation 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 back into 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

7.5 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 Rubin Science Platform (RSP)
- 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

8 Recording and Archiving of the System State & Technical Data

8.1 Operations Readiness Requirement

The Rubin Project Team shall demonstrate that relevant technical data about the system state and surrounding conditions during which the survey data are being collected are recorded and archived.

8.2 Objectives:

The objective of this requirement is to ensure that the technical state of the hardware/software systems and the surrounding environment are recorded during the time of survey data collection 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 science data as the survey progresses and statistics improve. Additionally, this includes the technical data record required to ensure efficient operation and maintenance of the observing facility. The primary repository of this technical data is the Engineering Facility Database (EFD) - it has two components: 1) a searchable database that captures the time-dependent ”housekeeping” data 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 data at the time of each observation (*e.g.* visit) includes but is not limited to:

- Technical ”housekeeping” data, which includes telemetry, events and commands from each subsystem component as published to the EFD;
- Software version including the history of the
  1. low-level, hardware-related software,
  2. the Engineering User Interfaces, and
  3. Comandable SAL Components

  Software written by or modified at the Observatory is documented, reviewed and version-controlled on GitHub.
- The configurations of all subsystems, including their history Configurations are handled through the following workflows:
  - For DM, it is here
  - For T&S, it is here
- Meteorological and the environmental state on the Summit The observatory has a weather station and uses satellite images from Meteoblue to monitor and predict the meteorological conditions at and around the Observatory.

- Environmental conditions in the dome interior The Environmental awareness system foresees a large number of sensors to monitor the environmental conditions in the dome.
- State of atmospheric turbulences – *e.g.* seeing; and A dedicated DIMM is part of the observatory.
- State of sky transparency. A dedicated all-sky camera and the DREAM camera are part of the observatory monitoring cloud coverage. The AuxTel is equipped with a spectrograph to make detailed characterization of the sky at the same time and direction as the Simonyi telescope is observing.

8.3 Criteria for Completeness

Satisfying these criteria includes, at a minimum:

- Demonstrate the technical data (see above) are being recorded at the Summit Facility by the EFD at >99% (TBC) reliability level for a period of at least 30 days - e.g., no significant dropouts in the live database at the Summit Facility;
- Demonstrate the Summit Facility database is being mirrored to an EFD at the ~~Base Facility~~ US Data Facility with a lag time of no more than 35 seconds, (*e.g.* one nominal visit); The Base Facility will only hold a backup copy of the EFD that is not instantly queriable.
- Demonstrate the recorded data are being archived for long-term access - a copy at the Base Facility in Chile and a copy at SLAC;
- Access to the technical data is achievable through standard monitoring dashboards from all support centers, including the Summit Facility, Base Facility, Headquarters for Operations in Tucson and US Data Center;
- Access to the technical data through the use of customizable GUI interface(s) and dashboards; and
- Technical data are queryable through Rubin Science Platform tools - e.g., Jupyter Lab notebooks and WEB interface.

8.4 Pre–Operations Interactions

~~Transfer and archive the EFD from the Base Facility to the US Data Center. The US Data Center is located at SLAC for the purpose of construction completeness evaluation. The US Data Center is required for external queries from users outside the immediate Rubin Observatory Project.~~

8.5 Artifacts for the CCRs

- A report documenting minimum criteria as defined in the criteria section above;
- ~~An SDK and example code for custom dashboards and dashboard templates available through a software repository(s) - *e.g.* GitHub or similar~~ This is now done in Chronograf and does not need code to be written; and
- Example code for Rubin Science Platform queries to the EFD available through a software repository - *e.g.* GitHub or similar.

9 Verification of Education and Public Outreach

9.1 Operations Readiness requirement

In order for the Rubin Observatory program to declare that the construction is complete and is ready to enter its Operations Phase, the Project shall demonstrate that EPO program elements have been verified against requirements, the interfaces aimed at the general public are functional and accessible, and content is sufficiently populated to represent Rubin Observatory and its services.

9.2 Objectives

The objectives of this Operational Requirement are to ensure that the public-facing interfaces are functional and accessible by members of the general public. These include the Education Hub, news pages, multimedia gallery, and Citizen Science infrastructure. Additionally, the Communications Strategy should be documented and the EPO Data Center should be functional.

9.3 Criteria for Completenes

The following breaks down the overall EPO Program into distinct elements with associated completeness descriptions:

9.3.1 Citizen Science

At completion, researchers who want to lead citizen science projects with Rubin Observatory data can create a sample set using the tools in the Rubin Science Platform (RSP) with whatever data is available at the time.

Rubin Observatory users will be able to create citizen science projects with any LSST data. At completion, we will have demonstrated that:

- Users can use the tools in the Rubin Science Platform (RSP) with whatever data is available at the time then move data to the Zooniverse Project Builder Tool, with applicable data rights observed.
- This procedure is successful having tested two citizen science projects following this workflow.

9.3.2 Website

The public-facing website will be ready and live. The EPO team will have demonstrated that at minimum the following functions are operable:

- The Rubin Observatory EPO website featuring:
  - A News page;
  - the Skyviewer;
  - A multimedia Gallery;
  - Staff profiles,
  - Ready to highlight features from the Alert Stream; and

  - Relevant material from the existing lsst.org pages will have been migrated to the new site.
- The Skyviewer as an interactive page allowing the display of color images over large patches of sky and allows users to pan and zoom, and that the Skyviewer features at least one tour of astronomical objects relevant to Rubin science goals;
- The Multimedia Gallery featuring free assets that follow AVM metadata standards:
  - A set of videos for Planetarium use;
  - Image highlights and a virtual tour of Rubin Observatory; and
  - A short videos describing Rubin science and facilities.

9.3.3 Formal Eduction

The Formal Education Program offers a suite of online investigations that are web applications where users interact with astronomical data via widgets. The investigations and educator support materials will be accessible through the "Education Hub." At completion, the EPO team will have demonstrated that:

- The investigations and educator support materials are accessible through the Education website;
- Documentation describing the Professional Development plan for educators is completed.
- Infrastructure for providing education materials in Spanish language is complete.

9.3.4 EPO Data Center

At completion, the EPO team will have demonstrated that the EPO Data Center is cloud-based and is serving data to the EPO website and products.

9.4 Pre–Operation Interactions:

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

9.5 Artifacts for ORR

The EPO Team will provide evidence of verifying requirements in the Jira system and provide general documentation about each part of the program described above.

10 Operational Procedures

10.1 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 to conduct a 10-year survey.

10.2 Objectives:

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

10.3 Criteria for Completeness

The documentation is to include but is not limited to:

- Process procedures describing user-level standard operations The documentation for the Observing specialist as the main users of the observatory is under development in Confluence and can be found here under *Training and Skills*
- *Maintenance needs and procedures for all systems in use The observatory has implemented a Computerized Maintenance Management System (CMMS). It holds a growing number of the latest versions of repeatedly used maintenance procedures.*
- *A history of maintenance carried out during construction and commissioning The CMMS allows for documenting the execution of maintenance activities and provides the history of all maintenance executions.*

- *System software documentation - including their operating versions, functionality, and interactions with other systems*
- *The observatory feature-based scheduler algorithms and documentation for modification and refinement The feature-based scheduler is realized as a Comandable SAL Component. Its code and documentation are stored in GitHub.*
- *A definition of initial delivered science data products (see previous sections)*

Note: At the time of this update, the Project has recently set up a ”Documentation Working Group”. This working group is responsible for defining the architecture of the delivered documentation repositories.

10.4 Pre–Operations Interactions

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

10.5 Artifacts for CCR

See Criteria above.

11 As-Built Record, Modifications, non-Compliance and Recommendations

11.1 Operations Readiness Requirement

The project team shall deliver all reports documenting the as-built hardware and software, including drawings, source code, modifications, compliance exceptions, and recommendations for improvement.

11.2 Objectives:

The objective of this readiness requirement is to ensure that the Construction Project provides a record of the current technical state of the Rubin Observatory system and that the knowledge transfer necessary for operations and further development of the Rubin Observatory is provided in a form that allows the operations team to conduct the 10-year planned survey.

A point of clarification: The Data Management science pipelines will be undergoing continuous development. Commissioning will work with a specific release of the Rubin software stack. The timing of which release will be used in commissioning will coincide with the readiness of the science camera – LSSTCam. Reporting of science pipeline functionality non-compliance will be measured against this static release of the Rubin software stack.

11.3 Criteria for Completeness

The criteria for completeness of this requirement will be the production and delivery of the reports listed in the artifacts below. These reports shall document the final state of the observatory and non-compliance as known at the time of the conclusion of the commissioning phase of the project. The reporting shall include recommendations for corrective measures for requirements found to be non-compliant and any recommendations for operational improvements based on the knowledge learned from the commissioning program.

Specific items include:

- A configuration management plan for observatory-wide software systems
- A clearly defined and documented architecture and implementation for the Project's varied documentation. This includes:
  - Design documents describing the technical implementation for all major subsystems This can already be found in DocuShare. A new DocuShare structure for Operations is under development here
  - 3D CAD models and fabrication drawings These models are stored in a dedicated SolidWorks server. Solidworks is the program the project chose to develop mechanical designs. Vendors could choose their preferred drawing program. Draw-

ings made with other programs were converted, and the original version is archived in Docushare.

- Operating software versions and their documentation Software written at or modified at the Observatory is documented, reviewed and version-controlled on GitHub.
- Definition of delivered data properties Here is the can find the "Data Products Definition Document".
- Software source codes and their documentation Software and its documentation, written by or modified at the Observatory, are documented, reviewed, and version-controlled on GitHub.
- As-built drawings, diagrams and metrology This is stored in DocuShare. The test results of the metrology for verification purposes are added to the execution of test cases in our test manager (Zephyr Scale) connected to Jira.
- Clear traceability between the systems requirements and how they were verified Requirements are either verified by results captured in test cases or lower-level requirements. The test cases are grouped by test cycles, and test cycles are grouped by test plans. There is full traceability between the requirement and its verification.
- Clear traceability and documentation for deviations/waivers to the systems requirements Deviations/waivers are traced to the impacted requirements On the other hand, deviations/waivers are traced to the corresponding change request and the related processes in the Change Control Board.
- Verification artifacts, including test results, analyses, and inspection reports Verification artifacts are connected to test cases. Either the test case execution includes the information directly in the test steps or is attached as a file to the test case. The code needed to reproduce the results is stored in GitHub when available.
- FRACAS reportable failures during integration, verification, and commissioning The FRACAS system is implemented as a Jira project and has been actively updated since the early integration phase.
- Hazard Analysis including hazard mitigation verifications Hazards have been imported into the Jira system as part of the LVV project. The Hazards are analyzed during a weekly meeting. Hazard mitigations are suggested by the meeting members, implemented by the summit technical team, and documented by the systems engineering team. The hazard mitigation artifact is added to the ticket, and a safety specialist reviews the measures and evaluates the residual risk.

- FMEA for all major subsystems Failure modes are registered as they are experienced in the FRACAS. Critical lifts have an FMEA attached, and failure modes are mitigated as much as possible before.
- A WEB-based (and associated document) roadmap/directory for the Project's document repositories (see above).

Note: At the time of this update, the Project has recently set up a "Documentation Working Group". This working group is responsible for defining the architecture of the delivered documentation repositories.

11.4 Pre–Operations Interactions

The documentation provided by the Rubin Construction Project will conform to the document archiving architecture developed by the Rubin Operations team. The final delivered documentation will be negotiated between the Rubin Construction Project and Rubin Operations.

11.5 Artifacts for CCRs

- Report(s) documenting final as–built configuration of the hardware and software (see previous section)
- Report(s) documenting any modifications to the observatory that deviate from planned implements - *e.g.* field modifications made during the course of final commissioning activities;
- Report(s) of any non-compliance with system requirements and specifications;
- A report on the unresolved "punch list" items – these are technical items that will need attention post construction completeness to improve operational performance but extend beyond verification of system requirements; and
- A report from the Construction of recommendations for improvements based on results from commissioning.

12 Rubin Operations Team Readiness

12.1 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 shall demonstrate they can operate the delivered Rubin System to efficiently capture, store, and process science quality images.

12.2 Objectives

The primary objective of this element of the ORR is that the Operations Team demonstrates 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 not done in commissioning but which do not prevent completion criteria from being satisfied.

12.3 Criteria for Readiness

- Demonstrate planning and staff for safe 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 deployments 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 oper-

ations 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 ability to execute Alert Processing in the US DF including connectiing to community brokers.
- Demonstrate ability to execute Data Release Processing including delivery of data to non US DF Data Facilities and ingest of data products from same for Data Access at USDF and Chile DAC.
- 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.

12.4 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 managing organization and agency approved Detailed Observatory Operations Plan, including:

- Work Breakdown Structure;
- Activity based plans for each department;
- Milestones for each department though several years of operations;
- Performance metrics;

- Performance requirements;
- Maintenance Management plans;
- Fully populated staffing plan;
- Budget profile; and

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B Acronyms

Acronym	Description
3D	Three-dimensional
AI	Artificial Intelligence
AP	Alert Production
AURA	Association of Universities for Research in Astronomy
AVM	Audio–Visual Management
CAD	Computer Aided Design
CCD	Charge-Coupled Device
CMMS	Computerized Maintenance Management System
CSA	Cooperative Support Agreement
CSC	Commandable SAL Component
DAC	Data Access Center
DF	Data Facility
DIA	Difference Image Analysis
DIMM	Differential Image Motion Monitor
DM	Data Management
DMS	Data Management Subsystem
DMSR	DM System Requirements; LSE-61
DOE	Department of Energy
DPDD	Data Product Definition Document
DR1	Data Release 1
DREAM	Dutch Rubin Enhanced Atmospheric Monitor
DRP	Data Release Production
EFD	Engineering and Facility Database
EPO	Education and Public Outreach
FMEA	failure modes and effect analysis
FPA	Focal Plane Array
FRACAS	Failure Reporting, Analysis and Corrective Action System
FWHM	Full Width at Half-Maximum
GAIA	Global Astrometric Interferometry for Astrophysics
GUI	Graphical User Interface
LDF	LSST Data Facility
LDM	LSST Data Management (Document Handle)

LOVE	LSST Operators Visualization Environment
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)
LVV	LSST Verification and Validation
M1M3	Primary Mirror Tertiary Mirror
MPC	Minor Planet Center
MREFC	Major Research Equipment and Facility Construction
NOIRLab	NSF's National Optical-Infrared Astronomy Research Laboratory; `https://noirlab.edu`
NSF	National Science Foundation
ORR	Operations Readiness Review
OSS	Observatory System Specifications; LSE-30
PSF	Point Spread Function
QA	Quality Assurance
QC	Quality Control
RAT	Rubin Auxiliary Telescope
RSP	Rubin Science Platform
SAL	Service Abstraction Layer
SDK	Software Development Kit
SDQA	Science Data Quality Assessment
SE	System Engineering
SITCOMTN	System Integration, Test and Commissioning Technical Note
SLAC	SLAC National Accelerator Laboratory
SQuaSH	Science Quality Analysis Harness
SRD	LSST Science Requirements; LPM-17
SSP	Solar System Processing
TBC	To Be Confirmed
TBD	To Be Defined (Determined)
TMA	Telescope Mount Assembly
UPS	uninterruptible power supply
US	United States

USDF	United States Data Facility
WEB	World Wide Web
WFD	Wide Fast Deep