Vera C. Rubin Observatory
Systems Engineering

Construction Completeness and Operations Readiness Criteria

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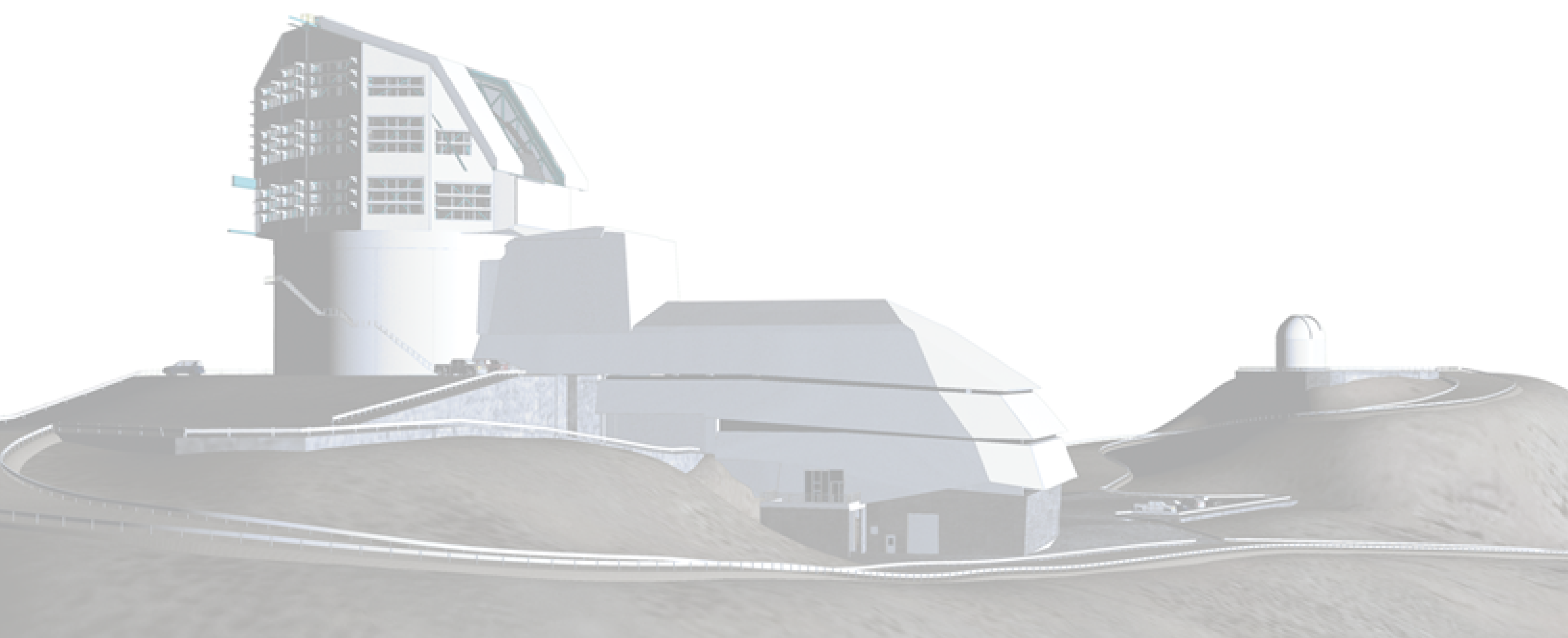

Abstract

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 Closeout 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	2024-10-22	Updated version for first Construction Close-out Review (CCR1)	Keith Bechtol and Holger Drass
6	2025-06-17	Add description of enhanced baseline SV surveys design	Keith Bechtol and Holger Drass

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

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Construction Completeness and Operations Readiness Criteria

1 Introduction

There are two main criteria to evaluate the readiness of the as-built Vera C. Rubin Observatory:

1. completion of the Rubin Observatory Construction Project and
2. readiness of Rubin Observatory Operations to recieve the construction deliverables and begin the Legacy Survey of Space and Time (LSST) – the 10-year science survey for which the Rubin Observatory was designed and constructed to perform.

These two main considerations have been expanded into 10 points of Construction Completeness and Operations Readiness as defined in the Rubin Observatory *System AI&T and Commissioning Plan* (LSE-79):

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 concluding stages of the Rubin Observatory Construction Project's commissioning phase, a series of four 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*. The expected timeline and focus areas for the four CCRs are summarized in Section 1.1.

In this document, we collect and detail the elements that constitute the criteria for construction completeness and operations readiness. Each topic has its own and/or references 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 criteria 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 criteria 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.

1.1 Phasing of Construction Closeout Reviews

	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

The phasing of the four CCRs is intended to clarify the prioritization of activities during the end stages of commissioning, provide opportunities for feedback and iteration with stakeholders regarding the Construction Project deliverables, and coordinate the transition to Operations. Each of the four CCRs is associated with a different Project condition, as shown by Figure 1. The objectives for each of the four CCRs can be concisely summarized as:

- **CCR1** – *readiness* for the start of on-sky commissioning, as exemplified by substantial completion and integration of subsystems, and evidenced by direct measurement of the optical throughput of the integrated system
- **CCR2** – *capability* to support LSST science goals, as exemplified by the System First Light

technical milestone, and evidenced by delivered single-visit image quality (including active control of optics)

- **CCR3 –** *reliability* to initiate the LSST survey, as exemplified by Science Validation surveys, and evidenced by the readiness of Rubin Observatory Operations to accept the as-built observatory
- **CCR4 –** *closeout* of the Construction project, as exemplified by service of scientifically validated survey-scale data products as part of the Operations Early Science Program, and evidenced by completed scope of system-level requirement verification, reporting, and final accounting

2 LSST System Requirements & SRD Verification/Validation

2.1 Operations Readiness Requirement

The Project team shall characterize and document the performance of the integrated Rubin Observatory system with respect to the survey performance requirements and specifications enumerated in the LSST System Requirements (LSR; LSE-29) and Science Requirements Document (SRD; LPM-17) Section 3.

2.2 Objectives

The scope of system-level 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 specific objective of this requirement is to quantify the range of scientific performance of the as-built Rubin Observatory with respect to LSR and SRD requirements through analysis of on-sky commissioning observations and informed simulations, and thereby demonstrate that system performance at delivery is consistent with meeting the primary science goals of the 10-year LSST. The LSR is a comprehensive definition of the highest level Rubin Observatory system requirements. The LSR is derived from the SRD that describes the scientific motivations for the project, the survey capabilities of the Observatory, and the reference science missions used to develop detailed scientific specifications for the LSST. In nearly all cases, adopted LSR specifications directly correspond to design specification values in the SRD, such that LSR verification will satisfy the intent of the SRD.

2.2.1 Approach to verification and validation

For the purpose of evaluating readiness we define verification, validation, and characterization of Rubin Observatory 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 Rubin Observatory 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).

Verification studies include:

- Generation of all required data products and services;
- Demonstration that relevant metadata are being collected and archived;
- Astrometric performance (relative and absolute);
- Photometric performance (relative and absolute);
- Data throughput and processing requirements for prompt data products;
- Completeness and purity of sources detected in Alert Production (AP) and Data Release Production (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.

The verification will make use of Quality Assessment (QA) and Quality Control (QC) tools developed during Data Management construction, and performance with be compared against the tabular requirements in the LSR.

Each LSR requirement has been decomposed into individual verification tickets. Each verification ticket has a designated verification method and domain of test, and has been associated with one of the CCRs to indicate the phasing of verification. The phasing can be summarized as follows:

- CCR1: system-level functional capabilities to support on-sky commissioning; no system-level science performance requirements from the LSR are associated with CCR1

- CCR2: aspects of system-level science performance related to the intrinsic information content of the single-visit images, e.g., optical system throughout, image quality (PSF FWHM, ellipticity), ghosts/scattered light, sensor anomalies
- CCR3: aspects of system-level science performance that characterize an ensemble of visit images and/or which relate to capability to calibrate visit images, e.g., PSF modeling, astrometric repeatability, photometric repeatability
- CCR4: aspects of system-level science performance related to the survey performance and associated data products, e.g., photometric uniformity, PSF ellipticity residuals at full survey depth
- Beyond CCR4: aspects of system-level science performance that require one or more years of survey operations to verify, e.g., cadence of annual LSST Data Releases

This verification phasing is designed to establish confidence that the as-built Rubin Observatory is capable of routinely acquiring acceptable science-grade imaging across the LSSTCam full focal plane (i.e., attainment of the System First Light technical milestone SITCOMTN-061) early in the on-sky commissioning period. Science Validation surveys at the conclusion of the commissioning period (Section 6) are designed to collect a volume data $\gtrsim 1\%$ of the 10-year LSST to enable survey-scale validation and characterization studies. Allowing for time needed to process and scientifically analyze data from the Science Validation surveys, it is anticipated that Operations will commence prior to the final verification of all system-level science performance requirements to be reported at CCR4. Most CCR4 requirements are expected to be verified during the course of on-sky commissioning, including final analysis of the Science Validation Surveys, and early operations.

For system-level science performance verification, the majority of test cases described under the LSST Verification and Validation project will be implemented using metrics and/or data visualizations that are generated as part of Science Pipelines execution (e.g., analysis_tools), as separate test procedures (e.g., Jupyter notebooks on the Rubin Science Platform), or via inspection/demonstration (e.g., to show that a service or data produce has been delivered).

In addition to the normative data quality requirements defined in the OSS, LSR, and SRD, 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:

- Characterization of blending effects, e.g., prevalence of unrecognized blends and object photometry in blended scenes;
- Object classification, e.g., accuracy of star-galaxy separation;
- Galaxy photometry, e.g., for photometric redshifts;
- Difference image analysis photometry, e.g., for statistical variability metrics and lightcurves of transient objects;
- Low surface brightness features;
- Weak-lensing null tests and shear calibration;
- Treatment of crowded fields.

A collection of topical working groups for science verification and validation have been organized to provide coverage of these science validation areas.

In addition, more than 100 individuals in the Rubin science community are making non-financial contributions to the System Integration, Test, and Commissioning effort to facilitate an efficient transition to LSST Operations and increase the overall scientific output of the survey SITCOMTN-050. By sharing their technical and scientific expertise, these individuals enhance and diversify the Project's planned commissioning effort. The named participants will work directly alongside Rubin Observatory staff in completing their assignments and, in exchange, will have access to commissioning data products as they are acquired. The Project will not rely on the contributions from non-Rubin-staff team members to fulfill core construction requirements and operational readiness criteria. However, science validation analyses performed by these individuals will provide a preview of realistic scientific workflows using commissioning data, are thus are complementary to the Early Science Program (RTN-011) for the purpose of validating data access services and science data quality from a science user perspective. No papers presenting novel scientific results based on commissioning data may be posted/submitted by anyone before the associated release as part of the Early Science Program.

2.3 Criteria for Completeness

The characterization and documentation of science performance at the conclusion of the Construction project will be considered successfully complete when all requirements in the LSR have been verified. At a minimum, LSR requirements associated with CCR1, CCR2, and CCR3 must be verified at the end of Construction following the process defined in the Verification and Validation Process document (LSE-160) and associated documentation. For those that are not, a waiver will be sought to enter Operations and they will be completed within the first year of Operations.

2.4 Pre–Operations Interaction

Brief the Operations team on 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 and visualizations as needed.

2.5 Artifacts for Completion

The following artifacts will be provided:

- Minimum:
  - A verification matrix containing entries for all LSR requirements (LSE-29) and specifications, including verification methods (inspection, demonstration, analysis, or test) for each requirement;
  - Final compliance status, including all non-compliance reports and associated impact studies;
  - Test plans and reports for all test campaigns associated with system-level science performance;
  - Draft of at least one Construction Paper with scope sufficient to demonstrate the attainment of the System First Light technical milestone to support the Early Science Program (not released prior to the Rubin First Look media event – expected delivery by CCR3);

- Outline of at least one Construction Paper to provide an overview of the components of the as-built Rubin Observatory and technical performance at the time of delivery (planned to be released around the time of CCR4).

- Baseline:
  - Artifacts above;
  - Technotes published to `lsst.io` that describe a small collection of end-to-end studies to demonstrate realistic workflows used for science validation (see examples above). It is envisioned that these studies might mature into full scientific publications during the first year of Operations and might involve collaboration with the broader scientific community (SITCOMTN-076);
  - Drafts of additional Construction papers describing individual subsystems in greater detail.

3 Observatory System Specifications (LSE-30) Verifcation

3.1 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

3.2 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.

3.3 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.

3.4 Pre–Operations Interaction

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

3.5 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.

4 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.

4.1 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.

4.2 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).

4.2.1 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, 6. 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.

4.3 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.

4.4 Pre-Operations Interaction

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

4.5 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.

4.6 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.

4.6.1 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.

4.6.2 Criteria for Completeness

The criteria for completeness are described in 4.3.

4.6.3 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

4.6.4 Artifacts for Completion

The high-level artifacts for completion of the Prompt Processing pipelines are detailed in 4.5.

4.7 Data Release Processing

4.7.1 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.

4.7.2 Criteria for Completeness

The criteria for completeness are described in 4.3. 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.

4.7.3 Pre-Operations Interactions

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

4.7.4 Artifacts for Completion

The high-level artifacts for completion of the DRP pipelines are detailed in 4.5.

4.8 Rubin Science Platform

4.8.1 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

4.8.2 Criteria for Completeness

The high-level criteria for completeness are detailed in 4.3. 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.

4.8.3 Pre-Operations Interactions

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

4.8.4 Artifacts for Completion

The high-level artifacts for completion of the RSP are detailed in 4.5.

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

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). The Science Data Quality Assessment is mostly be automated, however it includes interactive 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.

5.2.1 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 sensor 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 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, 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 (AuxTel) will be used to interpret trends the LSSTCam data. The quality analysis needed to determine that the AuxTel is taking sufficiently good data will use the same tooling as provided for the main survey data.

5.2.2 Longer Term Assessment

long term monitoring, characterization, and optimization of system performance is handled by the System Performance department in Operations.

5.2.3 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.

5.3 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:

- LOVE - LSST Observing Visualization Environment includes dashboards and other visualizations of the system state;
- RubinTV – front-end for data quality visualization to support nighttime operations
- Engineering Facility Database – engineering data accessible through Rubin Science Platform and pre-defined dashboards;

- Consolidated Database – relational database that holds items such as the exposure log and provids capability to rendezvous system telemetry and science performance metrics;
- Sasquatch – service for metrics and telemetry data; collecting, storing, and querying time-series data
- Chronograph – web-based graphical front-end with dashboards for time series data visualization;
- Camera Image Viewer – pixel-level camera image viewing tool with interactive features;
- analysis_tools – Science Pipelines package for computing science performance metrics and diagnostic plots as part of image reduction pipeline execution
- Plot Navigator – web-based tool for browsing diagnostic plots of science performance;
- Times Square – service for displaying parameterized Jupyter Notebooks as websites;
- Rubin Science Platform (RSP) – used for investigative ad–hoc analysis (LSE-319); the RSP is accessible via the web and includes a Jupyter notebook aspect and other interactive tools for data visualization.

5.4 Criteria for Completeness Description

The SDQA capabilities will be considered to be successfully complete upon verification of the System Monitoring and Diagnostics and Image Visualization requirements described in the OSS, including demonstration of this toolset using on-sky observations with LSSTCam. Each verification ticket has been assigned to a CCR to indicate phasing to support the start of on-sky commissioning and readiness for operations.

5.5 Pre-Operations Interactions

The pre-operation interaction include training the observing specialists to recognize and respond to warning and errors from subsystems during nighttime operations as well as data quality anomalies.

5.6 Artifacts for Completion

- Demonstrated functional tool kit as described above;
- Derived reports from the Science Verification/Validation survey(s);
- SDQA tooling documentation and code repositories

6 Science Validation Survey

6.1 Operations Readiness Requirement

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

6.2 Objectives

The main objective of this criterion is to demonstrate the reliability of the as-built Rubin Observatory, meaning that hardware, software, and infrastructure functionality do not limit Observatory operations until the next programmed maintenance event. To demonstrate reliability, one or more Science Validation Surveys will be conducted at the conclusion of the on-sky commissioning as a full rehearsal of science operations. The minimum 30-day time span for verification corresponds to $\sim 1\%$ of the 10-year LSST, and is intended to incorporate operations procedures over a full lunar cycle including:

- Filter swapping between bright and dark time;
- Active optics system, dome, and 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 Data Management system to sustained data rates including simultaneous execution of the Alert Production and Data Release Production pipelines.

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

- Full rehearsal of safety procedures for science operations;
- Scheduling shifts for daytime and nighttime operations;
- Communication protocols for observation planning, daytime and nighttime operations and decision-making, and requesting support;
- 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;
- Recovery from interruptions to observing (e.g., failure of the network)
- Demonstration of near real time data quality assessment;
- Prompt processing of alerts within the required latency time (i.e., 60 seconds);
- Capability for distribution of Prompt products;
- Prompt processing "24-hour" data products (e.g., Solar System Object orbit calculations);
- Cumulative Data Release Production with the full set of deep coadd and time-domain data products (at least once);
- Access to on-sky data products via the Rubin Science Platform.

Data acquired during the Science Validation Survey(s) should routinely deliver acceptable science quality imaging to allow a summative assessment of the delivered scientific performance of the as-built system. The Operations team plans to serve data products from the Science Validation Survey(s) as part of the Early Science Program RTN-011.

Baseline Science Validation Survey Design

(Updated June 2025)

On-sky engineering with LSSTCam began on 15 April 2025 and SV survey observations are expected to begin in late June 2025. As more information regarding the progress of on-sky commissioning and plans for LSST Operations becomes available, Rubin Observatory has identified opportunities to refine the detailed implementation of the SV surveys to facilitate a smooth transition from Construction to Operations, and to enhance the potential impact of the Early Science Program. The "enhanced" baseline SV survey design incorporates information regarding

- the expected months of SV survey observations and visibility of specific target fields,
- overall operational efficiency and system performance demonstrated during the first two months of the on-sky commissioning campaign with LSSTCam,
- guidance derived from the community process to develop the LSST Cadence, facilitated by the Survey Cadence Optimization Committee (SCOC),
- input from the Rubin science community regarding the evolving scientific landscape and emergent opportunities,
- and planned engineering activities around the transition from Construction to Operations.

Rubin Observatory has developed and simulated a Feature Based Scheduler (FBS) configuration for the enhanced baseline SV survey design that could be implemented and is expected to meet the Construction completeness criteria if executed.

As of early June 2025, the forecast of on-sky commissioning activities includes pilot observations for the SV surveys beginning in late June, and sustained SV survey observations running from early July to mid September. The objectives of the SV survey pilot observations are to

- evaluate the distribution of delivered image quality, including AOS performance, for wide-area survey observations,
- continue optimization of the AOS open loop and closed loop control systems,
- evaluate the overall operational uptime in wide-area survey mode observations similar to the nominal LSST cadence,

- and validate the FBS performance and the observing strategy for the SV surveys.

The enhanced baseline SV survey design includes two main survey components that are interleaved as part of a single FBS configuration:

- a **Deep Survey** that is optimized for testing deep coadds at the equivalent integrated exposure of the LSST 10-year survey and beyond, achieving a rapid temporal sampling in those fields, and validating the observing strategy for the LSST Deep Drilling Fields (DDFs);
- a **Wide Survey** that is optimized for testing template generation and Prompt Processing with difference image analysis at data rates that would be expected during the first year of LSST, thereby providing a sustained full-scale test of the Data Facility;

The enhanced baseline SV survey adopts many of the design elements of the standard LSST cadence, with modifications to increase the likelihood of delivering a stand-alone high-impact dataset to enhance opportunities for Early Science.

For the SV surveys, a visit consists of a single 30 second exposure for $grizy$ and a single 38 second exposure for u. The SV survey simulation assumes 55% of time between evening and morning nautical twilight will be available for observations starting around 1 July 2025, with losses coming from weather, engineering downtime, and operation constraints. The simulations assume that on-sky observations conclude 2 hours prior to sunrise, and a limited azimuth range 3 hours prior to sunrise.

Deep Survey

The Deep Survey is implemented using a configuration similar to that of the LSST DDFs, specifically, targeting the four DDFs located in the south Galactic cap that are visible in July-September: ELAIS S1, XMM LSS, ECDFS, and EDFSa + EDFSb. The combined area of these four fields is ~ 50 deg^2, noting that EDFS comprises two adjascent LSSTCam pointings. Observations for the SV survey itself will be complemented by prior Rubin/LSSTCam observations of the COSMOS DDF in $ugrizy$ acquired in May-June 2025, for a combined coverage of ~ 60 deg^2 considering all five LSST DDFs. By design, the LSST DDFs overlap many existing and planned ground-based and space-based imaging and spectroscopic datasets, as well as broad multi-wavelength datasets from radio to X-ray. There is approximately ~ 30 deg^2 of overlap with the

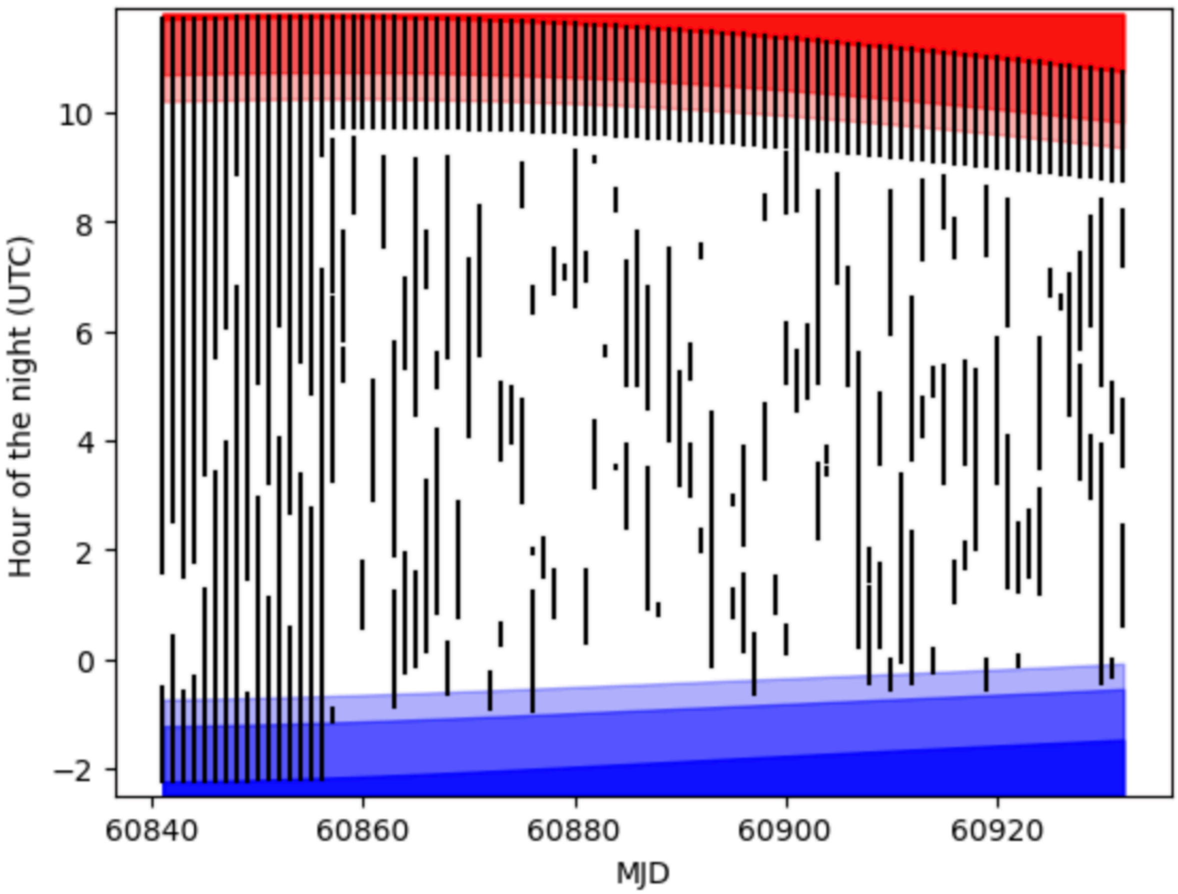

FIGURE 3: SV surveys model of efficiency and engineering downtime used for the simulation. Black lines indicate engineering time. Shaded bands indicate evening and morning astronomical, nautical, and civil twilight periods.

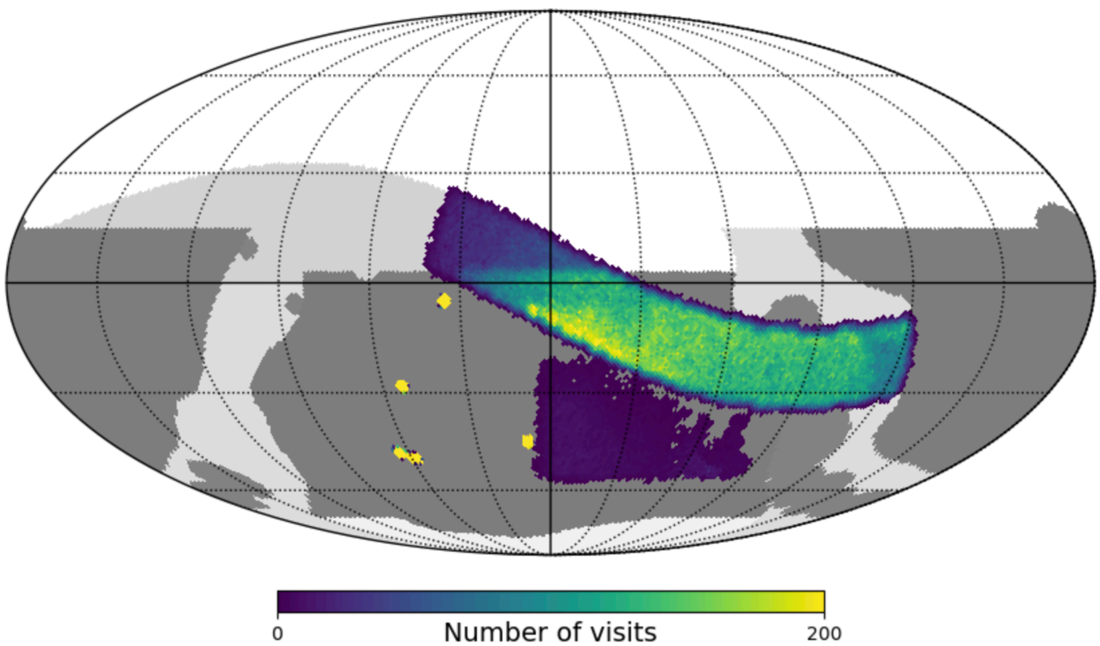

FIGURE 4: SV surveys coverage expressed as total number of overlapping visits across the ugrizy bands.

Euclid Q1 release, and overlap with deep fields recommended by the Roman Observations Time Allocation Committee.

The planned observing cadence for the DDFs during the SV surveys uses a modified form of the "ocean" strategy currently being considered by the SCOC. The "ocean" strategy features more frequent observing epochs to better sample night-to-night time-domain phenomena and provide more distinct epochs for validating the internal calibration during commissioning. The primary modification for the SV surveys is to increase the number of visits relative to the baseline "ocean" strategy in order to accumulate a deeper integrated exposure during the finite time period of the SV surveys. During the SV surveys, XMM LSS is designated for a "deep season", with longer sequences of visits in each epoch, particularly in the i and z bands. ELAIS S1, ECDFS, and EDFS are designated for "shallow seasons". Visits are split evenly across the EDFS A and B pointings.

Wide Survey

The Wide Survey is implemented using a configuration similar to that of the LSST Wide-Fast-

```
u 7.0
g 11.0
r 24.0
i 15.0
z 22.0
y 20.0
```

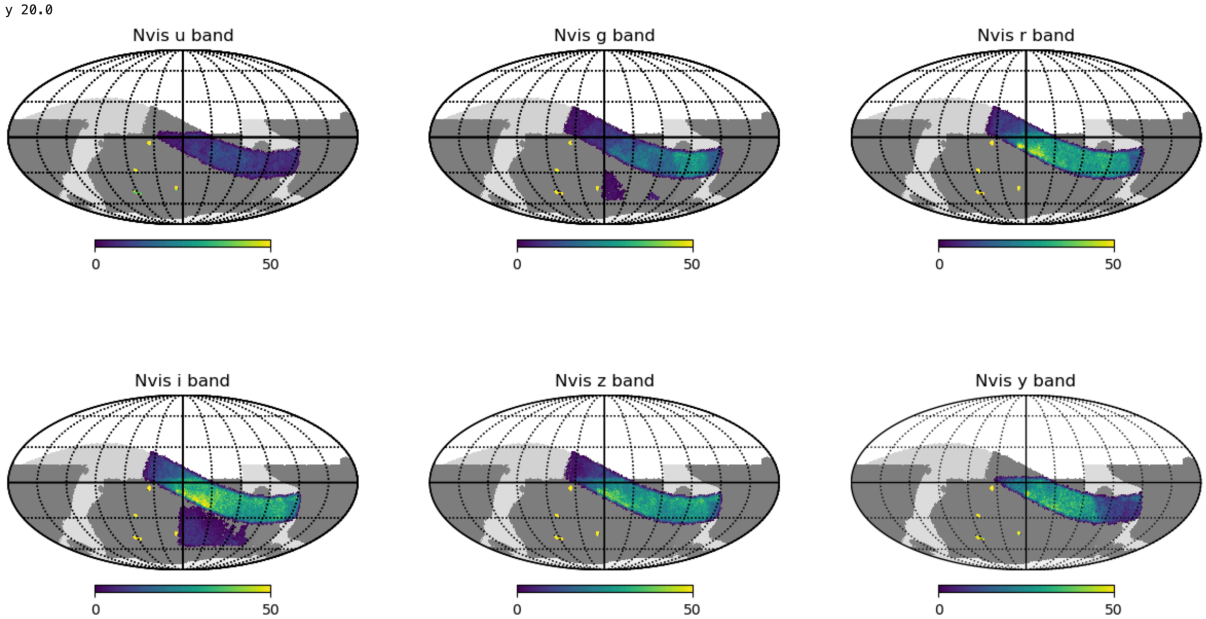

FIGURE 5: SV surveys coverage expressed as total number of overlapping visits in each of the individual ugrizy bands.

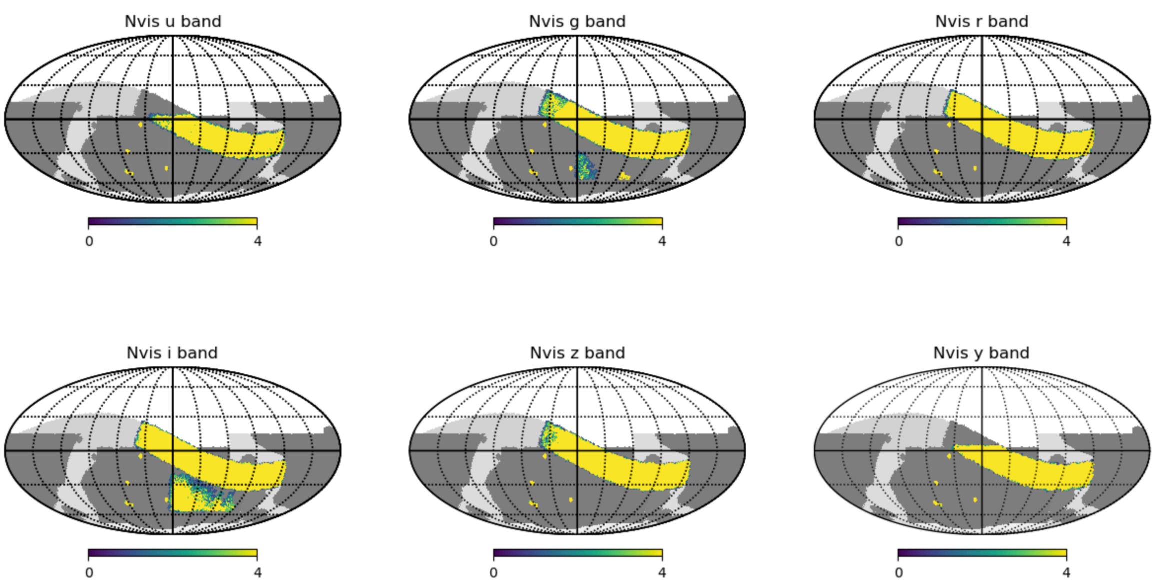

FIGURE 6: SV surveys template coverage expressed as total number of overlapping visits in each of the individual ugrizy bands, with a color scale selected to more easily visualize template coverage.

```
u 2865.9779749848317
g 3803.6788000970078
r 3859.7016509148534
i 5044.154807719113
z 3782.276812144123
y 3150.70834412272
```

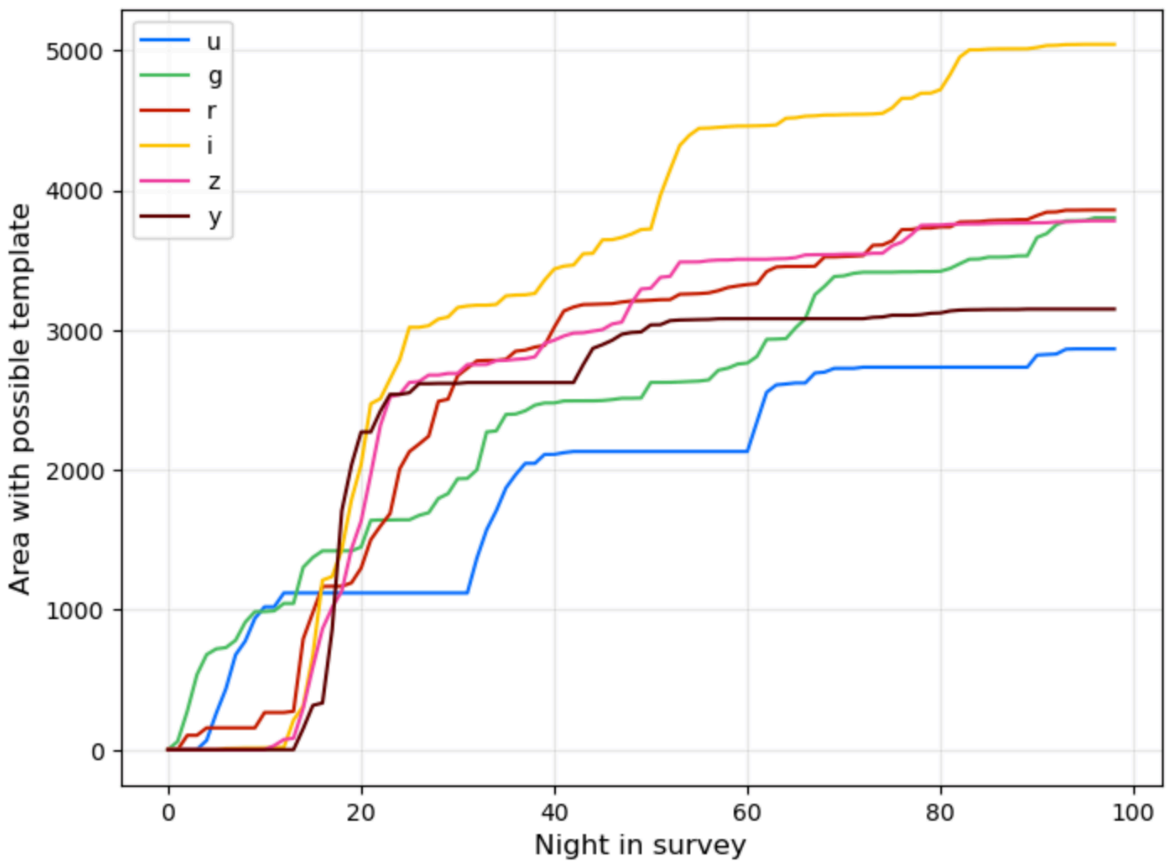

FIGURE 7: SV surveys coverage expressed as total number of overlapping visits in each of the individual ugrizy bands.

Deep, but constrained to a region of ± 10 deg in ecliptic latitude. By concentrating the observations within this region, it is possible to build several hundred degrees of template coverage in multiple bands within the first month the SV survey, thus enabling survey-scale tests of Prompt Processing with difference image analysis during the SV surveys. The ecliptic region is selected to test Solar System Object processing pipelines at LSST survey scale. The planned footprint extends across the southern Galactic cap, touching the Galactic plane on one side, thus covering regions with a range of stellar densities and stellar populations, as well as a large contiguous low-dust region at high Galactic latitude. The footprint spans a range of declinations, allowing access for other ground-based telescopes located in the southern and northern hemispheres. The footprint coincides with the low-dust WFD, Galactic plane, and North Ecliptic Spur from the standard LSST Cadence, with a ratio of visits and band coverage in each region matching that of the standard LSST cadence. For example, the band coverage in the low-dust WDF and Galactic plane is $ugrizy$, while the north ecliptic spur recieves a smaller total number of visits and limited to the $griz$ bands.

band	u	g	r	i	z	y	total
observation_reason							
DDF ECDFS	96.0	189.0	186.0	169.0	159.0	108.0	907.0
DDF EDFS_a	45.0	105.0	93.0	90.0	88.0	54.0	475.0
DDF EDFS_b	45.0	103.0	93.0	90.0	87.0	54.0	472.0
DDF ELAISS1	108.0	156.0	180.0	156.0	175.0	114.0	889.0
DDF XMM_LSS	144.0	93.0	333.0	1024.0	894.0	420.0	2908.0

FIGURE 8: SV surveys total number of visits for the LSST DDFs in the south Galactic cap.

Expanded Template Generation Survey (Best Effort)

In addition to the Deep Survey and Wide Survey, Rubin Observatory is exploring the technical feasibility of a **Expanded Template Generation Survey**, conducted on a best-effort basis, that would be optimized for expanding wide-area template coverage, including to support target-of-opportunity science cases during the first year of LSST.

The SV surveys are a Rubin Observatory Construction deliverable. While the primary objective of the SV surveys is to fulfill the Construction Completeness criteria defined in this document, a

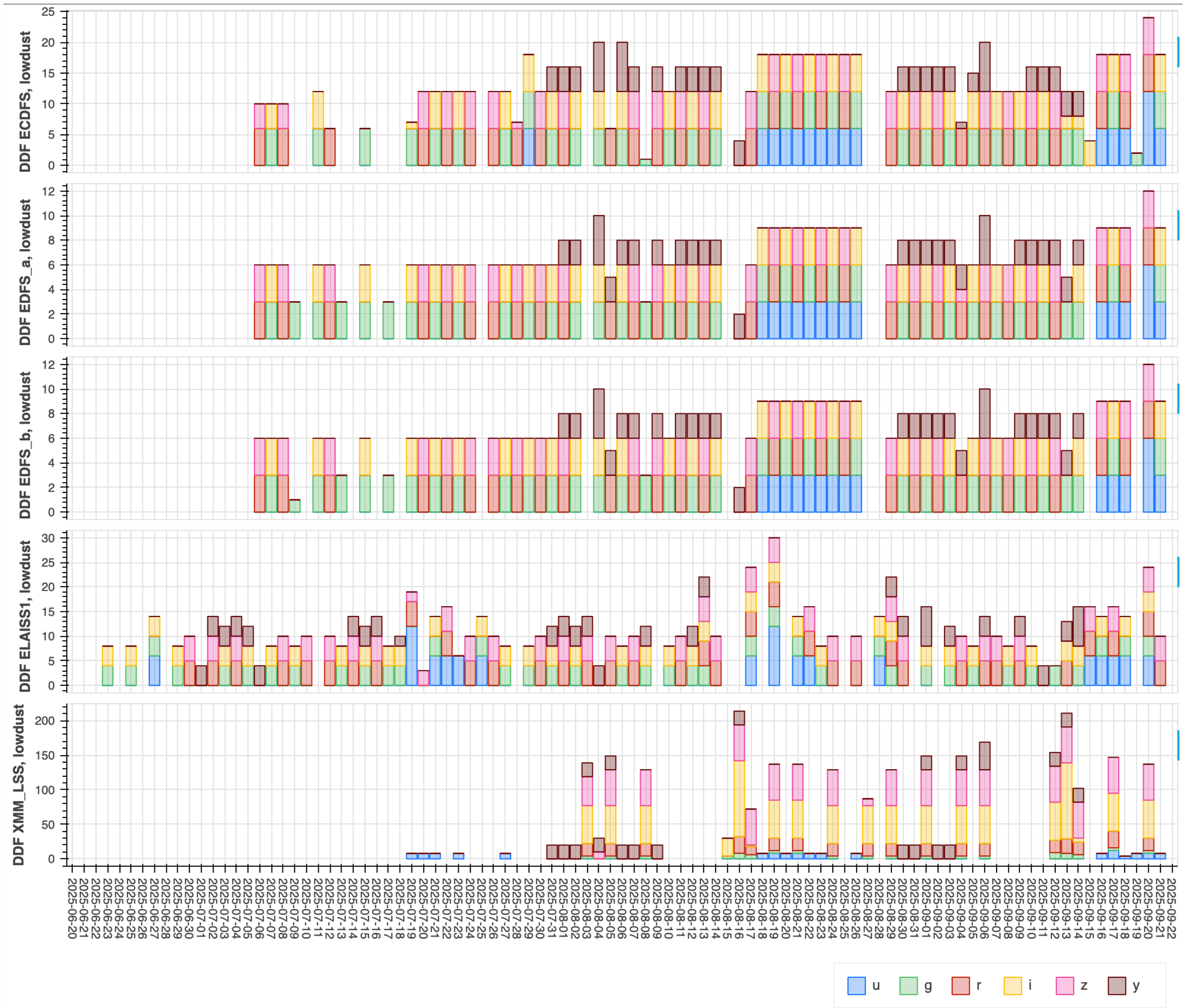

FIGURE 9: SV surveys observing cadence for the LSST DDFs in the south Galactic cap.

secondary goal of the SV surveys is to facilitate a smooth transition to operations, and where possible, enhance the impact of the early Science Program. Multiple science cases would benefit from acquiring wide-area template coverage during the on-sky commissioning period to enhance opportunities for time-domain science during the first year of LSST, including time-limited target-of-opportunity science cases that require contemporaneous observations with other facilities. Accordingly, Rubin Observatory is exploring the technical feasibility of such observations as part of the SV surveys on a best-effort basis.

During system commissioning, telescope pointings at the end of night prior to dome closure are limited to an azimuth range in the southwest, thus limiting the capability to observe the LSST DDFs and the footprint of the Wide Survey. During this end-of-night period, the current plans are to take observations to expand wide-area template coverage in 2 bands (likely gi) in regions located at declinations $[-55, -30]$ and Galactic latitudes $|b| > 15$ deg. In the simulations presented here, the Expanded Template Generation Survey has been included in the same FBS configuration as the Wide and Deep Surveys, to assess the additional template coverage that could be achieved.

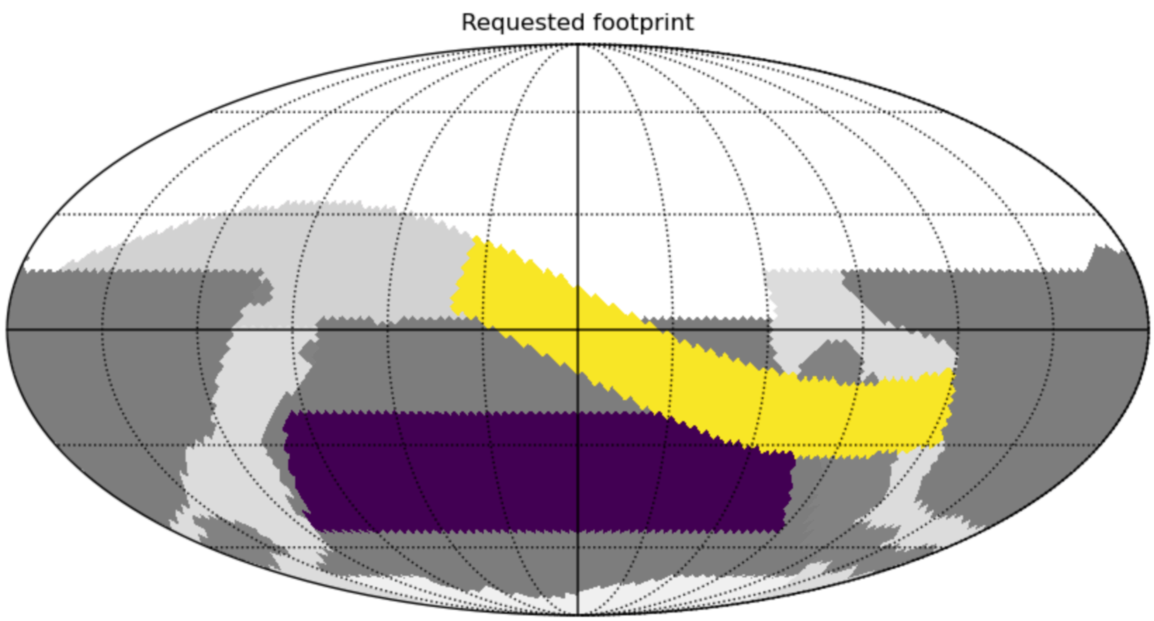

FIGURE 10: SV surveys requested footprint definition in equatorial coordinates. Yellow indicates the Wide Survey and purple indicates the Expanded Template Generation Survey. Gray shading indicates the standard LSST footprint.

Caveats

The enhanced SV survey described here represents a design target based on system specifications.

Rubin Observatory is still in the commissioning phase; the key objective of the SV surveys is to directly verify the as-built system and to evaluate the operational efficiency under realistic conditions. The actual volume of science-grade data collected will be directly related to the realized operational efficiency over the next several months, which includes uncertainty on the system-level performance, weather in Chilean winter, etc. The actual volume of delivered science-grade data from the SV surveys might be a fraction of the design, and still be consistent with meeting the commissioning objectives.

If the realized operational efficiency during the pilot observations is lower than expected, the current plan is to reduce the footprint area by a corresponding amount to increase the likelihood that the integrated exposure design goals of the SV surveys can be achieved.

The defition of the SV Surveys is understood to be sufficiently broad to include all types of observations driven by the FBS that are suitable for performance evaluation of in-focus science images and Science Pipelines commissioning.

6.3 Criteria for Completeness Description

The Science Validation Surveys construction completeness criteria are considered to be met upon verification by analysis of the System Availability requirements described in the OSS. The baseline is to conduct one or more scheduler-driven Science Validation surveys as the primary activity at the conclusion of the commissioning period, with the objective to verify system reliability over a minimum 30-day window coinciding with the Science Validation survey. This 30-day window is anticipated to begin around the System First Light milestone, although it could start somewhat before or after. Verification of System Availability requirements includes

- analysis of the operational uptime accounting for weather losses as well as scheduled and unscheduled system downtime and
- tests of the observing efficiency in terms of the rate of visits within scheduled observing time, including time intervals between visits for a nominal survey strategy (exposure time, slew time, readout time, filter exchange time) under the normal operating conditions defined in the OSS.

During the verification window, the commissioning team might choose to include some engineering activities to further optimize system performance. Planned engineering activities do not "count against" evaluation of the system reliability, so long as unplanned faults, etc., do not limit our ability to predictably operate the observatory.

A 30-day period of sustained on-sky observations, routinely delivering acceptable science-quality images, is considered the minimum to cover the range expected environmental conditions, provide sufficient opportunities for science verification, and demonstrate operational procedures.

Consistent Data Release Processing of the full dataset acquired during the Science Validation surveys, along with verification of the scientific performance at survey scale with the resultant data products, could continue in the period between the handover to Operations and CCR4 (Section 2), provided that the functionality to process and characterize on-sky observations has been demonstrated on smaller scales (Sections 4 and 5).

The Operations team might decide to conduct more extended Science Validation Survey and/or further system optimization work during first months of operations - "Scenario B" described in Early Science Program RTN-011.

6.4 Pre-Operations Interactions

In the current baseline schedule, the Science Validation surveys are the final activity prior to the acceptance of the Observatory by the Operations team. The progress of the Science Validation surveys will be routinely monitored and communicated to the Operations team in the period leading up to the handover.

The Science Validation Surveys represent an important opportunity to transfer knowledge of operational procedures to the Operations team. In practice, a substantial fraction of Operations team personnel hold similar roles in the Construction project. It is therefore anticipated that many Operations team members will be directly involved in running the Science Validation Surveys.

6.5 Artifacts for Completion

- 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)
- Observatory maintenance report summarizing the pre-operations engineering activities and status of the observatory
- Documentation for observatory operations, including recommendations for optimization of data quality and survey efficiency
- Documentation for Data Facility operations

7 Recording and Archiving of the System State & Technical Data

7.1 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.

7.2 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
  → 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.

7.3 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.

7.4 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.~~

7.5 Artifacts for Completion

- 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.

8 Verification of Education and Public Outreach

8.1 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.

8.2 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.

8.3 Criteria for Completenes

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

8.3.1 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.

8.3.2 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.

8.3.3 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.

8.3.4 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.

8.4 Pre–Operation Interactions

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

8.5 Artifacts for Completion

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.

9 Operational Procedures

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 to conduct a 10-year survey.

9.2 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:

9.3 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 specialists 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.

9.4 Pre–Operations Interactions

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

9.5 Artifacts for Completion

See Criteria above.

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

10.1 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.

10.2 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.

10.3 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. Drawings 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.

10.4 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.

10.5 Artifacts for Completion

- 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.

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

11.2 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.

11.3 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 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 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.

11.4 Artifacts for Readiness

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
AOS	Active Optics System
AP	Alert Production
AURA	Association of Universities for Research in Astronomy
AVM	Audio–Visual Management
B	Byte (8 bit)
CAD	Computer Aided Design
CMMS	Computerized Maintenance Management System
COSMOS	Cosmic Evolution Survey
CSA	Cooperative Support Agreement
CSC	Commandable SAL Component
DAC	Data Access Center
DDF	Deep Drilling Field
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
ECDFS	Extended Chandra Deep Field-South Survey
EDFS	Euclid Deep Field South
EFD	Engineering and Facility Database
EPO	Education and Public Outreach
FBS	Feature-Based Scheduler
FMEA	failure modes and effect analysis
FPA	Focal Plane Array

FRACAS	Failure Reporting, Analysis and Corrective Action System
FWHM	Full Width at Half-Maximum
GUI	Graphical User Interface
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
LSS	Large Scale Structure
LSST	Legacy Survey of Space and Time (formerly Large Synoptic Survey Telescope)
LVV	LSST Verification and Validation
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
Q1	Quarter one
QA	Quality Assurance
QC	Quality Control
RSP	Rubin Science Platform
RTN	Rubin Technical Note
SAL	Service Abstraction Layer
SCOC	Survey Cadence Optimization Committee
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
SRD	LSST Science Requirements; LPM-17
SSP	Solar System Processing

SV	Science Validation
TBC	To Be Confirmed
TMA	Telescope Mount Assembly
UPS	uninterruptible power supply
US	United States
USDF	United States Data Facility
WEB	World Wide Web
WFD	Wide Fast Deep
XMM	ESA X-ray Multi-mirror Mission