



Vera C. Rubin Observatory
Data Management

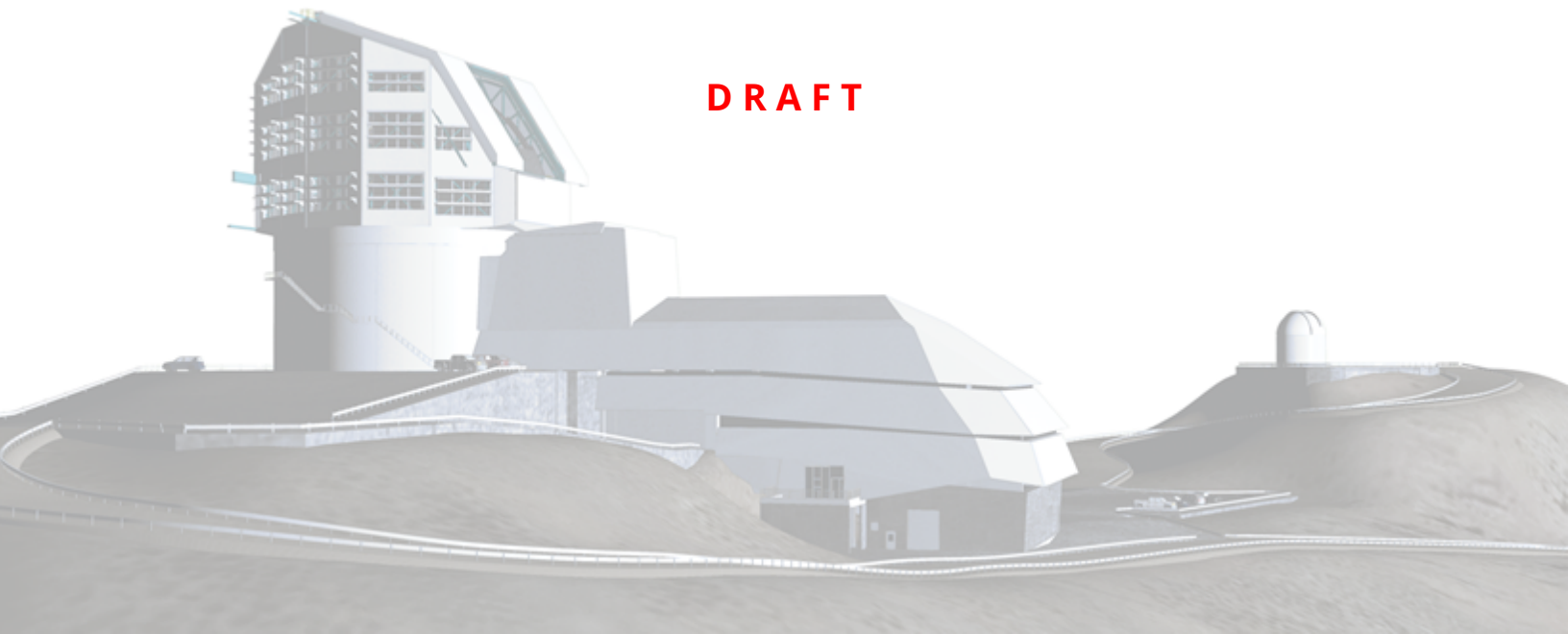
Rubin Observatory Plans for an Early Science Program

Leanne P. Guy, Keith Bechtol, Eric Bellm, Bob Blum,
Melissa L. Graham, Željko Ivezić, Robert H. Lupton, Phil Marshall,
Colin T. Slater, Michael Strauss.

RTN-011

Latest Revision:

DRAFT



Abstract

This document outlines Rubin Observatory's plans for a dedicated *Early Science Program* to enable high-impact science prior to the first annual data release of the Legacy Survey of Space and Time (LSST). Components of the Early Science Program include releasing science-grade commissioning data products via a series of "Data Previews," ramping up of the transient alert stream during commissioning, implementing a program of incremental template generation to augment alert production in the early phases of the survey, and the first LSST Data Release, DR1, based on the first 6 months of data from the LSST. A detailed breakdown of which data products can be expected when is provided. The Rubin Operations team is working closely with the science community to optimize the Early Science Program for the time-domain and solar system science achievable in the first year of operations. This is a living document; both it and the Early Science Program will continue to evolve over the course of commissioning and pre-operations in response to the state of the as-built system and to community guidance.

Change Record

| Version | Date | Description | Owner name |
|---------|------------|---|----------------------------|
| 1 | 2020-10-30 | First draft | Leanne Guy |
| 2 | 2020-12-16 | Draft 1.1 | Bob Blum |
| 3 | 2021-10-08 | Rework structure | Leanne Guy |
| 4 | 2021-10-21 | Add timeline | Leanne Guy |
| 5 | 2021-11-05 | Edits throughout | Eric Bellm |
| 6 | 2021-11-09 | Global edits and consolidation | Leanne Guy |
| 7 | 2022-10-14 | Data Preview content, and incremental templates, revision of Early Science scenarios, address feedback from PCW 2022 | Phil Marshall & Leanne Guy |
| 8 | 2022-10-21 | Release version 2.0 | Leanne Guy |
| 9 | 2022-10-24 | Changes to SCOC and survey text. Release version 2.1 | Leanne Guy |
| 10 | 2022-11-16 | Clarifications on alert production during commissioning. Release version 2.2 | Leanne Guy |
| 11 | 2023-01-10 | Updates following the construction project re-plan, refactoring of document to remove duplication. Release version 3. | Leanne Guy |
| 12 | 2023-01-12 | Correct Table 1 DP1 data products, Release version 3.1 | Leanne Guy, Phil Marshall |

Document curator: Leanne Guy

Document source location: <https://github.com/rubin-observatory/rtn-011>

Cite as: Leanne P. Guy, Keith Bechtol, Eric Bellm, Bob Blum, Melissa L. Graham, Željko Ivezić, Robert H. Lupton, Phil Marshall, Colin T. Slater, Michael Strauss. (2023). Rubin Observatory Plans for an Early Science Program (3.0). Zenodo <https://doi.org/10.5281/zenodo.5683848>.

Contents

| | |
|---|-----------|
| 1 Rubin Early Science Program | 1 |
| 1.1 Definition of Early Science | 1 |
| 1.2 Motivation for an Early Science Program | 1 |
| 1.3 Elements of the Early Science Program | 1 |
| 1.4 Early Science scenarios | 2 |
| 1.5 Access to Early Science Data Products | 3 |
| 2 Rubin Observatory Commissioning | 4 |
| 2.1 Commissioning Schedule | 4 |
| 2.2 Commissioning Observations | 5 |
| 3 Data Previews and Data Release 1 | 5 |
| 3.1 Data Preview 0 | 7 |
| 3.2 Data Preview 1 | 8 |
| 3.3 Data Preview 2 | 8 |
| 3.4 Data Release 1 | 9 |
| 4 Alert Production in Commissioning and Early Operations | 14 |
| 4.1 Processing Overview | 14 |
| 4.2 Supporting Incremental Template Generation | 15 |
| 4.3 Alert Generation during Commissioning | 16 |
| 5 Science Considerations for Optimizing Early Science | 17 |
| 5.1 Time Domain | 18 |
| 5.2 Solar System | 18 |
| 5.3 Static Science | 18 |
| 5.4 Target of Opportunity | 18 |
| 6 Roadmap and Timeline | 19 |

| | |
|---|-----------|
| 7 Community Engagement | 20 |
| 7.1 Survey Cadence Optimization Committee | 20 |
| 7.2 Community Forum | 21 |
| A References | 21 |
| B Acronyms | 22 |

Draft

Rubin Observatory Plans for an Early Science Program

1 Rubin Early Science Program

Community expectations for early science with Rubin are high due to the transformative nature of the LSST data and the densely-sampled observations planned during the commissioning period. Rubin Observatory's *Early Science Program* is designed to provide Rubin data rights holders with access to the data products and services necessary to produce high-impact early science during time between commissioning through, and including, the first data release, Data Release 1 (DR1).

1.1 Definition of Early Science

Early Science is defined as any science enabled by Rubin for its community through and including the first LSST Data Release, DR1. This includes the commissioning period and the first year of survey operations.

1.2 Motivation for an Early Science Program

The Early Science program is motivated by the desire to:

- enable high-impact science as early as possible;
- provide early access to both static-sky and time-domain science-ready data products to support the community to prepare in advance of the first survey data release;
- enable early time-domain astronomy via Alert Production; and
- help drive development of Rubin operations capabilities prior to survey start and prepare the team to be operations-ready.

1.3 Elements of the Early Science Program

The Early Science Program consists of the following elements:

- A series of three **Data Previews (DP)**, DP0, DP1 and DP2, based on either simulated LSST-like data or data taken during the Rubin Observatory commissioning period with the LSST Science Camera (LSSTCam).
- A world-public **stream of Alerts** from transient, variable, and moving sources that will be scaled up continuously during commissioning and the first year of the survey.
- **Template generation**, both prior to the start of regular survey operations based on data collected during the commissioning period with LSSTCam, and incrementally during the first year of regular survey operations to maximize the number of templates available for Alert Production in year 1.
- **LSST Data Release 1 (DR1)**, which will be based on the Data Release Processing (DRP) of the first six months of LSST data.

1.4 Early Science scenarios

The Operations team is tracking the progress of the commissioning activities (§ 2) as they relate to Early Science opportunities to ensure that the community has timely access to science-ready data products while the survey begins its relentless coverage of the sky leading to DR1. We broadly envisage two possible scenarios emerging from the commissioning phase of the construction project:

- **Scenario A:** The full commissioning plan comprising system optimization and science validation is successfully executed as planned. Rubin Operations then carries out an Operations Rehearsal and Operations Readiness Review (ORR) to effectively conduct a *full dress rehearsal* of science operations and demonstrate the readiness of the Operations team to execute the 10-year survey. Science-grade data collected during the commissioning System Optimization period and subsequent Science Validation Surveys, § 2, is reprocessed to produce the final Data Preview, DP2, which will be released 6 months following the completion of the Science Validation Surveys.
- **Scenario B:** On-sky time in commissioning is reduced as the construction work draws to an end, resulting in the SV surveys not being completed prior to the end of the construction phase. The Operations team would spend up to 3 months prior to commencing the 10-year LSST survey completing any remaining SV Survey observations. As per Scenario A, data collected during commissioning and the SV Surveys is reprocessed to produce

DP2 and an Operations Readiness Review carried out to demonstrate readiness to execute the 10-year survey.

In both scenarios it is assumed that the Rubin Construction project delivers an integrated system that can capture, transfer and process science-grade data at the time Operations begins. Both scenarios will include alert generation of some type, with the major distinction being the relative availability of templates in time, sky position, and filter.

The First Light observations that form the basis of DP1 must be taken and analysed in order to declare construction completeness, meaning that DP1 is identical in each scenario. The DP2 data products will be the same irrespective of which scenario materializes; only the timing of the release of DP2 and the start of the 10-year survey are different between the two scenarios. These two scenarios presented are current as of December 2022, but are subject to change as the commissioning program is executed. At some future point, a single option will be adopted and executed, and at that time, the details will be more fully specified.

1.5 Access to Early Science Data Products

Alerts are fully world-public and will be accessible via one or more of the nine Rubin-endorsed Community Brokers¹. All other data products listed in § 3 will be accessible to the Rubin Data Rights community via the Rubin Science Platform (RSP), [LSE-319]. DP0.1 and DP0.2 are already available via the RSP running at the US Data Access Center (US DAC), hosted on the Google Cloud Platform². The Rubin data rights policy is described in Blum & the Rubin Operations Team (RDO-013).

During pre-operations, Rubin is also using Google Cloud resources for some image processing runs (including DP0.2), as its “Interim Data Facility” (IDF). Data processing is now in transition to the US Data Facility at SLAC, and the DP1 and DP2 processing will be carried out there. The French Data Facility (FRDF) at CC-IN2P3 in Lyon, and the UK Data Facility (UKDF) on the IRIS network, are also being commissioned in parallel in time to participate in LSST data processing. Rubin data will continue to be served from the US DAC throughout pre-operations and into the LSST survey. An assortment of Rubin Independent Data Access Centers (IDACs) is also under construction, to provide additional user computing resources to LSST users around the

¹See <https://www.lsst.org/scientists/alert-brokers>

²data.lsst.cloud

globe.

2 Rubin Observatory Commissioning

2.1 Commissioning Schedule

In December 2022, as a result of reoptimizing the sequence of integration activities, the Rubin Construction Project decided to install the LSST Science Camera (LSSTCam) on the telescope earlier in the assembly sequence than previously planned. As a consequence, no on-sky data will be taken with the Commissioning Camera (ComCam). This change in strategy will produce more early-commissioning data than would have been available with ComCam on a similar timeframe.

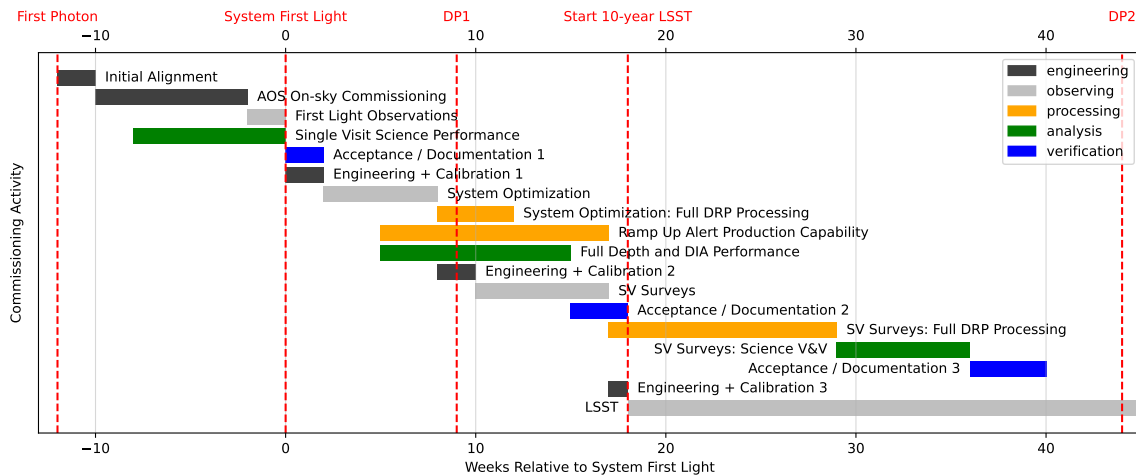


FIGURE 1: Detailed schedule of commissioning activities relative to System First Light, as of December 2022.

Figure 1 shows the detailed schedule of commissioning activities relative to System First Light, as of December 2022. System First Light is currently expected between July and August 2024 (§ 6), about 3 months after First Photons. The System First Light milestone marks the end of the the on-sky engineering phase and the start of the System Optimization and Science Validation phases. The total amount of science validation time currently planned is about 8 weeks. LSST data taking is expected to start about 4 months after System First Light.

As Rubin construction moves through the challenging phase of System Integration, Test and Commissioning, this schedule may change.

2.2 Commissioning Observations

Figure 2 shows the high level plan for the Rubin commissioning observations with the LSST Science Camera. Commissioning data collection is planned to take place in phases. Following the System First Light milestone, a set of observations designed to help optimize the system will be taken during the System Optimization phase before the Science Validation Surveys are carried out. The SV Surveys are designed to support scientific analyses that validate the system’s performance, and allow Rubin to demonstrate operations readiness SITCOMTN-005.

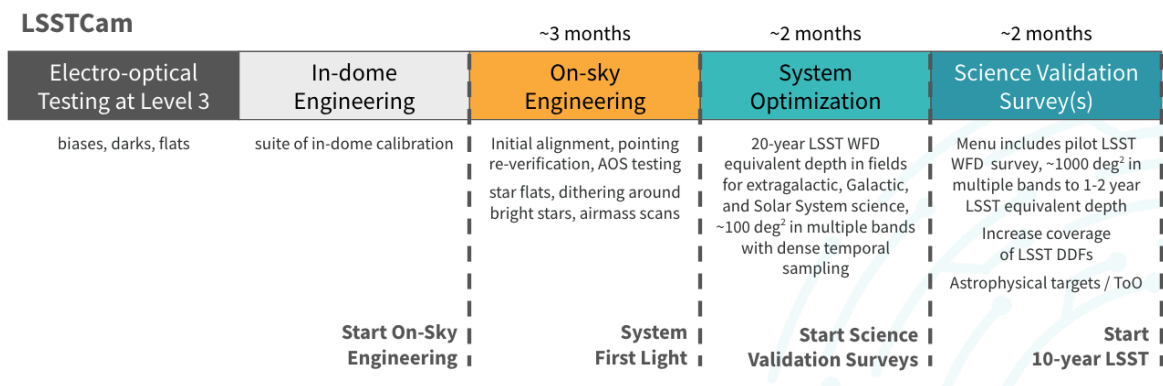


FIGURE 2: Outline plan for the collection of commissioning data, as of December 2022.

Figure 2 also indicates a number of planned key components of the System Optimization and SV phases. These include a LSST wide-fast-deep (WFD) 1-2 year equivalent depth “pilot” survey. Field selection will be carried out by the Commissioning Team, taking into account a wide variety of constraints as well as a “menu” of science opportunities to which the LSST Science Community has contributed. Details of the plans for commissioning observations will be made available as those plans converge, in this technote and other documents as cited.

3 Data Previews and Data Release 1

A series of three Data Previews (DP) are planned based on commissioning data to support the community as they develop their LSST analysis software and workflows, and to enable high-impact science as soon as possible.

- Data Preview 0 (DP0): Based on simulated LSST-like data.
- Data Preview 1 (DP1): Based on a few nights of early science-grade commissioning data

taken with LSSTCam.

- Data Preview 2 (DP2): Based on a full reprocessing of all science-grade LSSTCam data taken during commissioning.

Due to the relatively short time periods available for commissioning observations (§ 1.4), these Data Previews will necessarily be limited in their area and temporal coverage relative to full a Data Release, however all Data Preview data products will be in the same science data model format as for future Data Releases.

The data products that comprise a Data Preview are produced by the LSST Science Pipelines (Bosch et al., 2019, 2018). For an introduction to the LSST data products, see Graham (2022) and for a detailed description, see the LSST Data Products Definition Document (DPDD), [LSE-163]. Each pre-operations Data Preview and survey Data Release will be accompanied by its own release-specific DPDD³, giving e.g. the database schema for the catalogs included in that dataset.

Table 1 provides a summary of the expected early science data products available in DP0, DP1, DP2 and the LSST Data Release 1, as of January 2023. In the case of DP1, these expectations come with considerable uncertainty, see Table 3 for more details.

| Rubin Early Data Release Scenario | Jun 2021 | Jun 2022 | Jun 2023 - Sep 2023 | Sep 2024 - Oct 2024 | May 2025 - Aug 2025 | Nov 2025 - Apr 2026 | Nov 2026 - Apr 2027 | Nov 2027 - Feb 2028 | Nov 2028 - Feb 2029 |
|--|--------------------------|------------------------|------------------------------|--------------------------|---------------------------------|--------------------------|---------------------|---------------------|---------------------|
| | DP0.1 | DP0.2 | DP0.3 | DP1 | DP2 | DR1 | DR2 | DR3 | DR4 |
| Data Product | DC2 Simulated Sky Survey | Reprocessed DC2 Survey | Solar System PPDB Simulation | First Light LSSTCam Data | LSSTCam Science Validation Data | LSST First 6 Months Data | LSST Year 1 Data | LSST Year 2 Data | LSST Year 3 Data |
| Raw images | ✓ | ✓ | □ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| DRP Processed Visit Images and Visit Catalogs | ✓ | ✓ | □ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| DRP Coadded Images | ✓ | ✓ | □ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| DRP Object and ForcedSource Catalogs | ✓ | ✓ | □ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| DRP Difference Images and DIASources | □ | ✓ | □ | □ | ✓ | ✓ | ✓ | ✓ | ✓ |
| DRP ForcedSource Catalogs including DIA outputs | □ | ✓ | □ | □ | ✓ | ✓ | ✓ | ✓ | ✓ |
| PP Processed Visit Images | □ | □ | □ | □ | □ | ✓ | ✓ | ✓ | ✓ |
| PP Difference Images | □ | □ | □ | □ | □ | ✓ | ✓ | ✓ | ✓ |
| PP Catalogs (DIASources, DIAObjects, DIAForcedSources) | □ | □ | □ | □ | ✓ | ✓ | ✓ | ✓ | ✓ |
| PP SSP Catalogs | □ | □ | ✓ | □ | ✓ | ✓ | ✓ | ✓ | ✓ |
| DRP SSP Catalogs | □ | □ | □ | □ | □ | ✓ | ✓ | ✓ | ✓ |

TABLE 1: Summary of data products expected in each data preview and early survey data release, as of January 2023.

The tables presented in each section below outline which data products can be expected in

³For an example data release DPDD, see the online DP0.2 documentation <https://dp0-2.lsst.io/data-products-dp0-2/>.

each Data Preview and Data Release, and on what time scale. See Table 7 in the Timeline section below for a combined view of the expected data preview schedule and its uncertainties.

3.1 Data Preview 0

Data Preview 0 (DP0) is the first of three Data Previews to be released during the period leading up to the start of Rubin Observatory Operations. Data Preview 0 contains three stages, all based on simulated LSST-like data products. The goals of DP0 are to serve as an early integration test of the LSST Science Pipelines and the Rubin Science Platform (RSP), and to enable a limited number of astronomers and students to begin early preparations for science with the LSST.

3.1.1 Data Preview 0.1

Data Preview 0.1 (DP0.1) was released to a group, approximately 300, of early adopters from the community in June 2021. It is based on the the simulated, LSST-like images generated by the Dark Energy Science Collaboration (DESC) for their Data Challenge 2 (DC2), (LSST Dark Energy Science Collaboration (LSST DESC) et al., 2021). DP0.1 only uses the 300 deg² of DC2 images that were simulated for five years of the LSST’s wide-fast-deep component (WFD) using a baseline cadence, [PSTN-055]. The DESC processed the simulated DC2 images with Version 19 of the LSST Science Pipelines. DP0.1 makes the DESC’s DC2 images and catalogs available to users through an early version the Rubin Science Platform (RSP) running at the US DAC.

For full details on DP0.1 including an exact description of the data products served, see the documentation at <https://dp0-1.lsst.io/>

3.1.2 Data Preview 0.2

Data Preview 0.2 (DP0.2) was released to approximately 600 early adopters from the community in June 2022, exactly 1 year after DP0.1. The dataset used for DP0.2 was the same as that used for DP0.1. Rubin processed the simulated DC2 images with Version 23 of the LSST Science Pipelines. DP0.2 makes the Rubin reprocessed DESC DC2 images and catalogs available to users through an early version the Rubin Science Platform (RSP) running at the US DAC.

For full details on DP0.2 including an exact description of the data products served, see the

documentation at <https://dp0-2.lsst.io/>

3.1.3 Data Preview 0.3

Scheduled for between June and September 2023, DP0.3 will be the last in the DP0 series of Data Previews based on simulated LSST-like data. The main goal of DP0.3 is to support the Solar System Science Collaboration by hosting their simulated 10-year catalog and serving it via the RSP at the US DAC. Table 2 presents a summary of the expected DP0.3 data products, as of January 2023. The exact data products for DP0.3 are still to be decided.

3.2 Data Preview 1

Data Preview 1 was originally defined to be based on reprocessed on-sky data taken with ComCam. Following the replan of the Construction project in December 2022, no on-sky data will be taken with ComCam, § 2. Consequently DP1 has been redefined to be based on a subset of science-grade images taken with LSSTCam during a period of a few days around the System First Light milestone, § 2.2. The processing pipelines and exact data products that will comprise DP1 are still under discussion. At minimum, DP1 will deliver visit-level images and catalogs to enable initial studies of observational and instrumental effects.

Note that the DP1 period of time during which data for DP1 are collected is *very short*: the data products released in DP1 will be generated from relatively few observations taken in the few days around System First Light. Table 3 presents a summary of the data products expected in DP1, as of January 2023.

3.3 Data Preview 2

Data Preview 2 will serve a full consistent reprocessing of all data collected as part of the LSST-Cam Science Validation Surveys (SV Surveys) together with any other science-grade commissioning data taken throughout the Science Optimization phase of commissioning, including the DP1 data. Table 4 presents a summary of the data products expected in DP1, as of January 2023.

3.4 Data Release 1

LSST Data Release 1 will be based on the first six months of data taken as part of the 10-year survey. Data Release Processing of this dataset is estimated to take six months, making the expected delivery date 1 year following the start of the 10 year survey. DR1 will be the first Data Release in which all data products will be provided.

During routine LSST operations, prompt image data products will be made available 80 hours following camera readout. They include raw images, processed single visit images (PVI), difference images, and template images. Access to unvetted PVIs and difference images in the first 6 months of the LSST is still to be decided.

Table 5 presents a summary of the data products expected in DR1, as of January 2023.

Draft

| DP0.3 | | Solar System PPDB Simulation | |
|--|-------------------------------------|-------------------------------------|--|
| <i>Serving the Solar System Science Collaboration's simulated Prompt Product Database to enable moving object analysis development in the RSP.</i> | | | |
| Milestone ID: | L1-RO-0180 | | |
| Data Products Available Prior to the Data Release: | None | | |
| Data Release: | Jun 2023 - Sep 2023 | | |
| Data Product | | Date | Notes |
| DRP Processed Visit Images and Visit Catalogs | <input type="checkbox"/> | | |
| DRP Coadded Images | <input type="checkbox"/> | | |
| DRP Object and ForcedSource Catalogs | <input type="checkbox"/> | | |
| DRP Difference Images and DIASources | <input type="checkbox"/> | | |
| DRP ForcedSource Catalogs including DIA outputs | <input type="checkbox"/> | | |
| PP Processed Visit Images | <input type="checkbox"/> | | |
| PP Difference Images | <input type="checkbox"/> | | |
| PP Catalogs (DIASources, DIAObjects, DIAForcedSources) | <input type="checkbox"/> | | |
| PP SSP Catalogs | <input checked="" type="checkbox"/> | Data Release | <i>Exact data products TBD, but focus is squarely on serving familiar mock catalogs but in Rubin format from the Rubin Science Platform.</i> |
| DRP SSP Catalogs | <input type="checkbox"/> | | |

TABLE 2: Summary of data products expected in DP0.3, as of January 2023.

| DP1 | | First Light LSSTCam Data | |
|--|---|---------------------------------|---|
| <p><i>Serving data products generated by both the Rubin Construction Project Commissioning Team and the Rubin Operations team, from astronomically-useful images taken with LSST Cam in the first few days after System First Light, to a larger number of users from the LSST Science Community on the RSP.</i></p> | | | |
| Milestone ID: | L1-RO-0060 | | |
| Data Products Available Prior to the Data Release: | The DP1 pipeline is still under discussion, but is unlikely to extend to a full data release processing; shown here is the minimal set of data products that can be expected. All products will be retained for | | |
| Data Release: | Sep 2024 - Oct 2024 | | |
| Data Product | | Date | Notes |
| DRP Processed Visit Images and Visit Catalogs | <input checked="" type="checkbox"/> | Data Release | <i>Visit-level products targeted to enable initial studies of observational and instrumental effects.</i> |
| DRP Coadded Images | <input type="checkbox"/> | | |
| DRP Object and ForcedSource Catalogs | <input type="checkbox"/> | | |
| DRP Difference Images and DIASources | <input type="checkbox"/> | | |
| DRP ForcedSource Catalogs including DIA outputs | <input type="checkbox"/> | | |
| PP Processed Visit Images | <input type="checkbox"/> | | |
| PP Difference Images | <input type="checkbox"/> | | |
| PP Catalogs (DIASources, DIAObjects, DIAForcedSources) | <input type="checkbox"/> | | |
| PP SSP Catalogs | <input type="checkbox"/> | | |
| DRP SSP Catalogs | <input type="checkbox"/> | | |

TABLE 3: Summary of data products expected in DP1, as of January 2023. Note the high degree of uncertainty in this table. DP1 will be planned in detail during 2023.

| DP2 | | LSSTCam Science Validation Data | |
|--|--|---------------------------------|--|
| <p><i>Serving data produced by both the Rubin Construction Project and Rubin operations re-processing, to the whole LSST Science Community on the RSP.</i></p> | | | |
| Milestone ID: | L1-RO-0070 | | |
| Data Products Available Prior to the Data Release: | Prompt products will be generated, alerts streamed, and the PPDB made available, but images will be retained for internal use only, prior to the data release. | | |
| Data Release: | May 2025 - Aug 2025 | | |
| Data Product | | Date | Notes |
| DRP Processed Visit Images and Visit Catalogs | <input checked="" type="checkbox"/> | Data Release | |
| DRP Coadded Images | <input checked="" type="checkbox"/> | Data Release | |
| DRP Object and ForcedSource Catalogs | <input checked="" type="checkbox"/> | Data Release | |
| DRP Difference Images and DIASources | <input checked="" type="checkbox"/> | Data Release | |
| DRP ForcedSource Catalogs including DIA outputs | <input checked="" type="checkbox"/> | Data Release | |
| PP Processed Visit Images | <input type="checkbox"/> | Data Release | <i>Commissioning of the PP image differencing and incremental template building will begin shortly after System First Light. Prompt image release is embargoed during commissioning.</i> |
| PP Difference Images | <input type="checkbox"/> | Data Release | <i>Difference imaging will be somewhat limited, since the image template sky coverage will be sparse. Prompt image release is embargoed during commissioning.</i> |
| PP Catalogs (DIASources, DIAObjects, DIAForcedSources) | <input checked="" type="checkbox"/> | Prompt Production | <i>PPDB available for query prior to the DR.</i> |
| PP SSP Catalogs | <input checked="" type="checkbox"/> | Prompt Production | <i>Measurements of known SSOBJECTS sent to the MPC whenever difference images are available.. Searches for new SSOBJECTS performed if appropriately-cadenced data is present. SSP Catalogs then available for query in PPDB prior to the DR.</i> |
| DRP SSP Catalogs | <input type="checkbox"/> | | <i>DRP SSP may be run in order to demonstrate operations readiness, but the products will likely not be released.</i> |

TABLE 4: Summary of data products expected in DP2, as of January 2023.

| DR1 | | LSST First 6 Months Data | |
|--|--|--------------------------|---|
| <p><i>Serving data produced by Rubin operations, from observations in the first 6 months of observations, at the US DAC at SLAC, Chilean DAC, and the IDAC network. Includes brokered alerts from templated sky regions.</i></p> | | | |
| Milestone ID: | L1-RO-0120 | | |
| Data Products Available Prior to the Data Release: | Alerts with image postage stamps, plus queryable PPDB, from prompt processing. Full FPA visit images will be available 3 days after observation. | | |
| Data Release: | Nov 2025 - Apr 2026 | | |
| Data Product | | Date | Notes |
| DRP Processed Visit Images and Visit Catalogs | ✓ | Data Release | |
| DRP Coadded Images | ✓ | Data Release | |
| DRP Object and ForcedSource Catalogs | ✓ | Data Release | |
| DRP Difference Images and DIASources | ✓ | Data Release | |
| DRP ForcedSource Catalogs including DIA outputs | ✓ | Data Release | |
| PP Processed Visit Images | ✓ | Data Release | <i>Access to unvetted processed visit images as prompt products in the first 6 months of the LSST is still TBD.</i> |
| PP Difference Images | ✓ | Data Release | <i>Difference imaging will steadily increase as incremental template building increases the templates available. Prompt access to unvetted PP difference images is still TBD.</i> |
| PP Catalogs (DIASources, DIAObjects, DIAForcedSources) | ✓ | Prompt Production | <i>PPDB available for query.</i> |
| PP SSP Catalogs | ✓ | Prompt Production | <i>Standard SSP Daily Data Products produced from difference images as they are available and reported to the MPC</i> |
| DRP SSP Catalogs | ✓ | Data Release | <i>DRP SSP uses only LSST data (no MPCORB info) to understand selection effects. This is only really valuable once we have a significant amount of LSST data, so DR1 at the earliest.</i> |

TABLE 5: Summary of data products expected in DR1, as of January 2023.

4 Alert Production in Commissioning and Early Operations

4.1 Processing Overview

The DPDD summarizes the pipelines which will be used during Prompt Processing to produce alerts as well as other prompt data products, including Solar System Processing. In brief, raw images have instrument signatures removed and are photometrically and astrometrically calibrated. When template images for the corresponding region of the sky are available, the template is subtracted from the new processed visit image and sources are detected on the image difference. Alerts are then generated for all DIASources detected at five sigma in the difference. At the end of the night, DIASources without a history of previous detection are input into Solar System Processing, which attempts to link them with other past detections and identify new Solar System objects.

Both Alert Production and Solar System Processing thus depend on the presence of template images. During steady-state operations, these templates will be constructed during the annual Data Releases and will be built from the best available subset of images taken. The input images for DRP-produced templates will accordingly have very good seeing and comprehensive spatial coverage. All of these template characteristics help to ensure that image differencing is highly complete and highly pure.

To enable alert production to proceed during commissioning and early operations, it is necessary to accept templates of lower quality. Because we have a smaller set of input images to choose from and uncertain knowledge about future observations, on-the-fly (or incremental) template generation necessarily must balance the trade off of earlier template availability against template quality and spatial completeness. Substantial validation will be required to determine when to build incremental templates to maximize the net throughput of Early Science. Nevertheless our goal is to enable Alert Generation to begin over at least a subset of the survey area as soon as the data are scientifically useful.

Coadding multiple images enables artifact rejection DMTN-080 and is formally required due to the noise-level requirements placed on the DM system. Additionally, the LSST survey is heavily dithered, so without coadding many images onto a common sky plane it is both difficult and inefficient to obtain image differences for a new pointing from past single images. Finally, single-image templates do not permit removal of artifacts, transients, and moving objects from the template, creating additional false positive sources in the resulting differences.

Scientifically it is important that once a template is constructed for a given region of sky, it is used exclusively until it can be updated in the next Data Release. Repeated changes to the template make it extremely difficult to construct usable lightcurves for objects from individual difference image sources: transient objects such as supernovae will be contaminated by changing flux levels from the evolving template, and variable objects such as variable stars and AGN will require repeated corrections for different template flux levels as well.

4.2 Supporting Incremental Template Generation

The Rubin Construction Data Management (DM) Science team (DM-SST) carried out a study of several options for Alert Production in Year 1, reported in DMTN-107 : Options for Alert Production in LSST Operations Year 1. Representatives of the Rubin Project Science Team (PST), DM-SST and Operations reviewed the proposed DM-SST options and converged on a the following strategy for Alerts in year 1:

- Commissioning Data Templates: Build templates, where possible, from all commissioning data before the start of year one, and use them to generate alerts during year one.
- Year One Data Templates: Build templates progressively from data obtained during year one (e.g., on a monthly timescale), and use them to generate alerts during year one, either instead of, or in addition to using commissioning data to build templates.

To handle alert generation outside the template building process attached to the annual DRP, the Construction project initiated a change request to include incremental templates in the DM system workflow. This change has been accepted and is now part of the baselined DM project in construction. A summary of the changes is the following:

- LCR-2273: Construct Image Differencing Templates Outside DRP, new requirement 1.4.6 Template Coadds ID: DMS-REQ-0280, The DMS shall periodically create Template Images in each of the u,g,r,i,z,y passbands. Templates may be constructed as part of executing the Data Release Production payload, or by a separate execution of the Template Generation payload. Prior to their availability from Data Releases these coadds shall be created incrementally when sufficient data passing relevant quality criteria is available.

- To enable artifact rejection, templates will be built with at least three images in year one, and five in subsequent years (Rubin OSS-REQ-0158).⁴
- Once a template is produced for a sky position and filter it will not be replaced until the next Data Release to avoid repeated baseline changes.
- Templates are not necessarily built from the first N images that are collected.

4.3 Alert Generation during Commissioning

Due to the need to verify the instrument characteristics, template quality, and image differencing and Real/Bogus performance, real-time alerts will not be immediately available during the commissioning period. However, the incremental template generation and alert production processes will be tested and optimized during commissioning with LSSTCam, resulting in a set of prompt data products, including alerts. Broker teams will be given access to these alerts for development purposes as soon as they are produced to understand their characteristics and to help to validate their quality, rather than to enable rapid followup and Early Science. The Alert and Prompt Product databases will be made available for query prior to the DP2 data release.

During commissioning templates will be generated incrementally over the maximal sky area supported by the available observations. By the end of the commissioning period, coadd templates for use in difference imaging will only be available for $\approx 10\%$ of the sky. Generating templates over a wide area is not an explicit goal of commissioning; however, where possible, if commissioning observations are agnostic to pointing and filter, we would endeavour to choose a pointing and filter that maximizes building templates to enable early science.

Rubin aims to scale up alert production during commissioning with the aim of beginning routine Alert Production as soon as is feasible following System First light. Once begun, Alert Production will then proceed continuously into the full LSST survey. Alerts generated during commissioning may be produced with higher latency. The commissioning period also provides an excellent opportunity to investigate how many visits in a given band are sufficient to construct a usable template.

⁴The LSST SRD places well-defined criteria on the quality of the difference image and the amount of noise that a template can contribute to a difference image. These criteria result in a minimum of three images being needed to construct a template for use in year one, and five in subsequent years.

The prompt data products, including Alerts, generated during commissioning and the first year of the LSST survey are summarized in Table 6.

| Rubin Alerts and Prompt Data Products | | |
|--|--|--|
| <i>Listing of the various prompt processing data products currently planned for each approximate phase of alert production during pre-operations and the first two years of survey operations.</i> | | |
| Phase 1: Commissioning (System Optimization and SV Surveys): 3-16 weeks after System First Light (SFL) | | |
| Phase 2: Y1 Survey Operations: 18-70 weeks after SFL | | |
| Data Product | Commissioning (System Optimization and SV Surveys) | Y1 Survey Operations |
| PP Processed Visit Images | Commissioning of the PP image differencing and incremental template building will begin shortly after System First Light. Prompt image release is embargoed during commissioning. | Access to unvetted processed visit images as prompt products in the first 6 months of the LSST is still TBD. PP PVIs available after DP2. |
| PP Difference Images | Difference imaging will be somewhat limited, since the image template sky coverage will be sparse. Prompt image release is embargoed during commissioning. | Difference imaging will steadily increase as incremental template building increases the templates available. Prompt access to unvetted PP difference images is still TBD. PP diff images available after DP2. |
| PP Catalogs (DIASources, DIAObjects, DIAForcedSources) | PPDB likely unavailable for query. | PPDB available for query. |
| PP Alerts (Live, Brokered) | Alert volume and latency will improve throughout the commissioning period. Aiming for "near-live" brokered Alert stream by the end of LSSTCam SV. | Alert latency to decrease smoothly to "live" between SV and early survey. |
| PP SSP Catalogs | Measurements of known SSOObjects sent to the MPC whenever difference images are available. Searches for new SSOObjects performed if appropriately-cadenced data is present. SSP Catalogs likely unavailable for query in the PPDB. | Standard SSP Daily Data Products produced from difference images as they are available and reported to the MPC. SSP catalogs available for query in the PPDB. |

TABLE 6: Summary of prompt data products expected during commissioning and year 1 survey observations, as of January 2023.

5 Science Considerations for Optimizing Early Science

It will not be possible to survey the whole sky in all filters and generate templates by the end of the commissioning period. A strategy for template generation in the early phases of the survey, which will require balancing a tradeoff between various factors such as smaller area with multiple filters vs a single filter over a large area, must be devised. Different science drivers naturally lead to different prioritization strategies, e.g., Milky Way science would prefer templates that cover the Galactic Plane, time domain science would prefer templates in multiple bands rather than a single band for a larger area. Supernova, transient and variable science strongly advocate for templates for all bands in the Deep Drilling Fields to be prioritized. Rubin Operations will work closely with the science community to develop a science-driven approach to template generation in the early phases of the survey that will benefit the maximum number of science cases.

5.1 Time Domain

The Transients and Variable Stars Science Collaboration (TVSSC) reviewed the opportunities for Early Science for non time-critical and time-critical science cases in (Hambleton et al., 2020) and (Street et al., 2020) respectively. In both cases, they recommend the prioritization of template acquisition in multiple bands as the preferred strategy rather than single-band coverage over a larger area of sky.

5.2 Solar System

The Solar System Science Collaboration (SSSC) reviewed opportunities for Early Science in (Schwamb et al., 2021) for several high impact solar system science opportunities that would be enabled by accelerated template generation and alert production in year 1. They find that template generation options that maximize the sky coverage in year 1 where LSST Solar System Processing can run daily are strongly preferred, even if the templates result in noisier image subtraction compared to later years.

5.3 Static Science

Datasets for static science will flow from the SV Surveys carried out during commissioning and released as Data Preview 2 (DP2). The commissioning team are planning to acquire on-sky observations that would enable science validation studies for the four LSST science drivers. Guidance is being sought from the community to enhance opportunities for science validation and early science based on commissioning data. Rubin Obs SIT-Com collected “Commissioning Notes” from the community in 2012 that are being considered as part of the planning for the on-sky observing strategy during commissioning.⁵

5.4 Target of Opportunity

Rubin Observatory will be prepared to take advantage of Targets of Opportunities (TOO) in the first year of operations (and hopefully SIT-Com). [RTN-008] describes potential data processing scenarios for TOO observations in the early operations era.

⁵See <https://community.lsst.org/t/community-input-to-the-on-sky-observing-strategy-during-commissioning/4406>

6 Roadmap and Timeline

Table 7 provides a list of key milestones for Rubin Operations and the Early Science Program, as of January 2023. It will continue to be updated as Rubin Construction and the Early Science Program progress. The date ranges are derived from the Rubin “Celebratory Milestones”, which are published monthly on the Rubin Project website⁶.

Rubin Operations Top Milestones

| | | |
|------------------------------|--|--|
| • Jun 2023 - Sep 2023 | Complete Delivery of Data Preview 0.3 (DP0.3) (L1-RO-0180) | |
| • Jul 2024 - Aug 2024 | System First Light (LSST-1520) | |
| • Sep 2024 - Oct 2024 | Complete Delivery of Data Preview One (DP1) (L1-RO-0060) | (= System First Light + 2 months) |
| • Nov 2024 - Feb 2025 | LSST Survey Start (L1-RO-0110) | (= Science Validation Surveys Complete + 1 day) |
| • May 2025 - Aug 2025 | Complete Delivery of Data Preview Two (DP2) (L1-RO-0070) | (= Science Validation Surveys Complete + 6 months) |
| • Nov 2025 - Apr 2026 | Complete Delivery of Data Release One (DR1) (L1-RO-0120) | (= LSST Survey Start + 12 months) |
| • Nov 2026 - Apr 2027 | Complete Delivery of Data Release Two (DR2) (L1-RO-0130) | (= LSST Survey Start + 24 months) |

TABLE 7: Top milestones for the Early Science Program, as of January 2023.

Milestone dates are given as min-max ranges to indicate the associated uncertainty. Typically the near date corresponds to the current Project forecast, plus any additional operational uncertainty. The late date corresponds (approximately) to the current Project “late date” plus any additional operational uncertainty and cannot be surpassed without the Project re-baselining its schedule. An intermediate (typically mid-range) date is used by the Rubin Operations teams for planning purposes.

The LSST survey will start shortly after the completion of the SV surveys, currently expected to be sometime between late 2024 and early 2025. The timing of the Commissioning observations is somewhat less uncertain and the timing of the release of those data to the community can be projected to within a few months at the time of writing.

Table 8 shows the nominal dates for the various elements of the Early Science Program. The next key milestone in the Early Science Program is the release of DP0.3. Scheduled for mid-2023, DP0.3 will be the last in the DP0 series, which is based on simulated LSST-like data. The late dates for the DP2 and DR1 milestones allow for the possibility that the Project completes within its late date, but in doing so reduces the amount of on-sky LSSTCam commissioning time. In this eventuality, the operations team would spend up to 3 months prior to commencing the 10-year LSST survey completing any remaining SV Survey observations, such that DP2 could be realized as planned.

⁶<https://www.lsst.org/about/project-status>

| Data Preview/Release | Date | FY22 | 2022 | FY23 | 2023 | FY24 | 2024 | FY25 | 2025 | FY26 | 2026 | FY27 | 2027 | FY28 | 2028 |
|----------------------|---------------------------------|---------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| DP0.1 | DC2 Simulated Sky Survey | June 2021 | | | | | | | | | | | | | |
| DP0.2 | Reprocessed DC2 Survey | June 2022 | | | | | | | | | | | | | |
| DP0.3 | Solar System PPDB Simulation | Jun 2023 - Sep 2023 | | | | | | | | | | | | | |
| DP1 | First Light LSSTCam Data | Sep 2024 - Oct 2024 | | | | | | | | | | | | | |
| DP2 | LSSTCam Science Validation Data | May 2025 - Aug 2025 | | | | | | | | | | | | | |
| DR1 | LSST First 6 Months Data | Nov 2025 - Apr 2026 | | | | | | | | | | | | | |
| DR2 | LSST Year 1 Data | Nov 2026 - Apr 2027 | | | | | | | | | | | | | |
| DR3 | LSST Year 2 Data | Nov 2027 - Feb 2028 | | | | | | | | | | | | | |

TABLE 8: Nominal dates for the various elements of the Early Science Program, as of January 2023.

Tables 7 and 8 will continue to be refined and updated in future version of this documents as the Early Science Program progresses.

7 Community Engagement

Rubin Observatory will work closely with the Survey Cadence Optimization Committee (SCOC) and Community on the detailed design of the Early Science Program.

7.1 Survey Cadence Optimization Committee

The Rubin Survey Cadence Optimization Committee (SCOC)⁷ is an advisory committee to the Rubin Observatory Operations Director consisting of 10 members drawn almost entirely from the science community. Convened in 2020, the SCOC will be a standing committee throughout the lifetime of Rubin Observatory operations and will be involved in all aspects of the development of the Early Science Program.

The SCOC will work with the Rubin Operations team and the Community to establish the best strategy for Early Science, including making specific recommendations in terms of, for example, the prioritization of sky coverage, filters, and other specific choices. Recommendations will take into account the plans for commissioning and the realized performance of the telescope and software, and should align as closely as possible with those of the main survey and ultimate long-term science goals. Optimizing the LSST Year 1 observing schedule for early science may mean that the time sampling looks somewhat different to that in subsequent years.

The SCOC has published its Phase 1 and 2 survey cadence recommendations in PSTN-053

⁷See <https://www.lsst.org/content/charge-survey-cadence-optimization-committee-scoc>

and PSTN-055. Work on recommendations for Early Science observations will begin in 2023. The SCOC will solicit input from the community on the specific observing strategy in year 1 to optimize early science. Several science collaborations have already been pro-active in providing input, both the community forum and as research notes ((Schwamb et al., 2021), (Hambleton et al., 2020), (Street et al., 2020)).

7.2 Community Forum

The Rubin Observatory Community Platform has a dedicated category for Early Science⁸, where community members are encouraged to open discussions on the topic of early science. Community feedback on the Early Science data products is welcomed and will help the Rubin to improve its data products and services.

A References

- [DMTN-080]**, AlSayyad, Y., 2019, *Coaddition Artifact Rejection and CompareWarp*, DMTN-080, URL <https://dmtn-080.lsst.io/>, Vera C. Rubin Observatory Data Management Technical Note
- [RTN-008]**, Bellm, E.C., 2022, *Rubin Observatory Processing of Gravitational Wave TOO Data in the Early Operations Era*, RTN-008, URL <https://rtn-008.lsst.io/>, Vera C. Rubin Observatory Technical Note
- [RDO-013]**, Blum, R., the Rubin Operations Team, 2020, *Vera C. Rubin Observatory Data Policy*, RDO-013, URL <https://ls.st/RDO-013>
- Bosch, J., Armstrong, R., Bickerton, S., et al., 2018, *PASJ*, 70, S5 (arXiv:1705.06766), doi:10.1093/pasj/psx080, ADS Link
- Bosch, J., AlSayyad, Y., Armstrong, R., et al., 2019, In: Teuben, P.J., Pound, M.W., Thomas, B.A., Warner, E.M. (eds.) *Astronomical Data Analysis Software and Systems XXVII*, vol. 523 of *Astronomical Society of the Pacific Conference Series*, 521, ADS Link

⁸See <https://community.lsst.org/t/about-the-early-science-category/5775>

- [SITCOMTN-005]**, Claver, C., Bauer, A., Bechtol, K., et al., 2021, *Construction Completeness and Operations Readiness Criteria*, SITCOMTN-005, URL <https://sitcomtn-005.lsst.io/>, Vera C. Rubin Observatory Commissioning Technical Note
- [PSTN-055]**, Committee, T.R.O.S.C.O., 2023, *Survey Cadence Optimization Committee's Phase 2 Recommendations*, PSTN-055, URL <https://pstn-055.lsst.io/>, Vera C. Rubin Observatory Project Science Technical Note
- Graham, M., 2022, *The Rubin Data Products, Abridged*. Zenodo, doi:10.5281/zenodo.7011229
- [DMTN-107]**, Graham, M.L., Bellm, E.C., Slater, C.T., et al., 2020, *Options for Alert Production in LSST Operations Year 1*, DMTN-107, URL <https://dmtn-107.lsst.io/>, Vera C. Rubin Observatory Data Management Technical Note
- Hambleton, K., Bianco, F., Clementini, G., et al., 2020, *Research Notes of the AAS*, 4, 40, URL <https://doi.org/10.3847/2515-5172/ab8129>, doi:10.3847/2515-5172/ab8129
- [PSTN-053]**, Ivezić, Z., 2022, *Survey Cadence Optimization Committee's Phase 1 Recommendation*, PSTN-053, URL <https://pstn-053.lsst.io/>, Vera C. Rubin Observatory Project Science Technical Note
- [LSE-319]**, Jurić, M., Ciardi, D., Dubois-Felsmann, G., Guy, L., 2019, *LSST Science Platform Vision Document*, LSE-319, URL <https://lse-319.lsst.io/>, Vera C. Rubin Observatory
- [LSE-163]**, Jurić, M., Axelrod, T., Becker, A., et al., 2022, *Data Products Definition Document*, LSE-163, URL <https://lse-163.lsst.io/>, Vera C. Rubin Observatory
- LSST Dark Energy Science Collaboration (LSST DESC), Abolfathi, B., Alonso, D., et al., 2021, *ApJS*, 253, 31 (arXiv:2010.05926), doi:10.3847/1538-4365/abd62c, ADS Link
- Schwamb, M.E., Jurić, M., Bolin, B.T., et al., 2021, 5, 143, URL <https://doi.org/10.3847/2515-5172/ac090f>, doi:10.3847/2515-5172/ac090f
- Street, R.A., Bianco, F.B., Bonito, R., et al., 2020, *Research Notes of the AAS*, 4, 41, URL <https://doi.org/10.3847/2515-5172/ab812a>, doi:10.3847/2515-5172/ab812a

B Acronyms

| Acronym | Description |
|----------------|--|
| AGN | Active Galactic Nuclei |
| CC | Change Control |
| CC-IN2P3 | Centre de Calcul de l'IN2P3 |
| ComCam | The commissioning camera is a single-raft, 9-CCD camera that will be installed in LSST during commissioning, before the final camera is ready. |
| DAC | Data Access Center |
| DC2 | Data Challenge 2 (DESC) |
| DESC | Dark Energy Science Collaboration |
| DM | Data Management |
| DM-SST | DM System Science Team |
| DMS | Data Management Subsystem |
| DMS-REQ | Data Management System Requirements prefix |
| DMTN | DM Technical Note |
| DP0 | Data Preview 0 |
| DP1 | Data Preview 1 |
| DP2 | Data Preview 2 |
| DPDD | Data Product Definition Document |
| DR1 | Data Release 1 |
| DRP | Data Release Production |
| IDF | Interim Data Facility |
| IN2P3 | Institut National de Physique Nucléaire et de Physique des Particules |
| IRIS | e-Infrastructure for Research and Innovation for STFC |
| LCR | LSST Change Request |
| LSE | LSST Systems Engineering (Document Handle) |
| LSST | Legacy Survey of Space and Time (formerly Large Synoptic Survey Telescope) |
| MAF | Metrics Analysis Framework |
| ORR | Operations Readiness Review |
| OSS | Observatory System Specifications; LSE-30 |
| PCW | Project Community Workshop |
| PST | Project Science Team |
| PSTN | Project Science Technical Note |
| RDO | Rubin Directors Office |

| | |
|------|---------------------------------------|
| RSP | Rubin Science Platform |
| RTN | Rubin Technical Note |
| SCOC | Survey Cadence Optimization Committee |
| SIT | System Integration, Test |
| SLAC | SLAC National Accelerator Laboratory |
| SRD | LSST Science Requirements; LPM-17 |
| SST | Subsystem Science Team |
| SV | Science Validation |
| TOO | Target of Opportunity |
| UK | United Kingdom |
| UKDF | United Kingdom Data Facility |
| US | United States |
| WFD | Wide Fast Deep |