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Data Management

Rubin Observatory Plans for an Early Science Program

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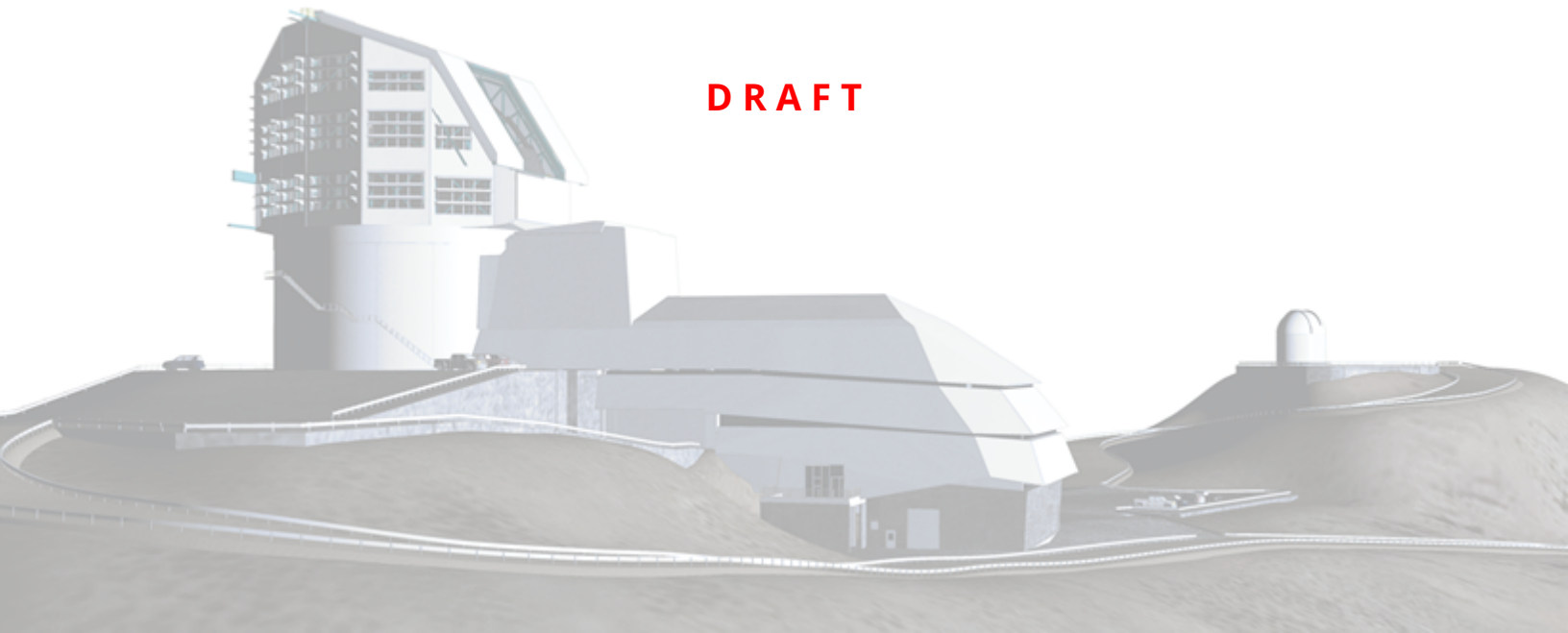

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Abstract

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.

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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**: Rubin Observatory is ready to execute the 10-year LSST at the completion of the construction project. The operations team may decide to first conduct a *full dress rehearsal* of science operations to demonstrate team readiness prior to commencing execution of the LSST. In this scenario, we expect this rehearsal to take a few days to no longer than two weeks.
- **Scenario B**: Prior to commencing the 10-year LSST, the operations team decides to spend up to a maximum of 2 months collecting more on-sky data to complement and extend the datasets collected during commissioning. This additional data would serve the dual goals of 1) ensuring that we are fully prepared to start the 10-year survey and 2) providing the community with an exquisite early dataset to work with before DR1. As per Scenario A, the operations team may decide to first conduct a *full dress rehearsal* of science operations to demonstrate team readiness prior to commencing execution of the LSST.

As the survey begins, all 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 start of operations.

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 subset of System First Light observations that form the basis of DP1 must be taken and analysed in order to support 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.

2 Rubin Observatory Commissioning

2.1 Commissioning Schedule

Following the October 2023 project schedule workshop, the Rubin Construction Project is re-optimizing the sequence of integration activities in light of recent subcomponent delays, in particular, (i) delay in shipment of the Camera and (ii) necessary repairs to the summit dome crane. If current estimates hold, it will be beneficial to re-implement on-sky data-taking with ComCam (previously removed from the schedule in order to install LSSTCam sooner). The updated plan calls for on-sky data to be taken with ComCam for approximately two months, around July-August 2024 to support Telescope commissioning, primarily the Active Optics System. This is approximately four months earlier than could be done with LSSTCam.

Figure 1 shows the detailed schedule of commissioning and early science activities relative to System First Light, as of October 2023. System First Light is currently expected in January 2025 (§ 7), about 7 weeks after LSSTCam First Photon. The total amount of science validation time currently planned is about 8 weeks. LSST data taking is expected to start 4-10 months after System First Light depending on construction schedule uncertainty and Rubin Operations readiness to start the survey.

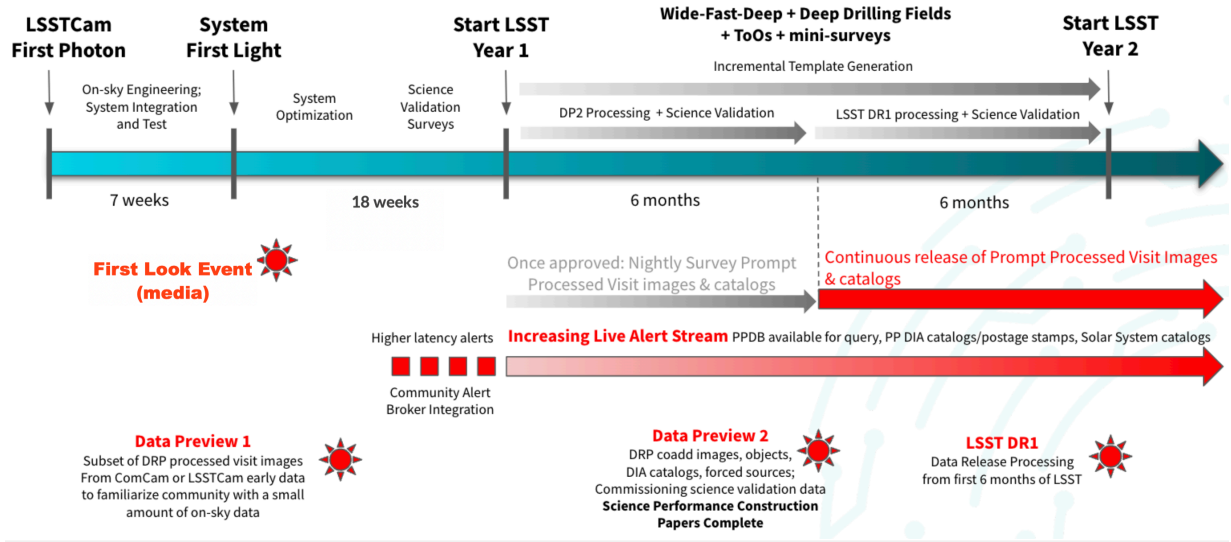

FIGURE 1: Detailed schedule of commissioning and early science activities relative to System First Light, as of October 2023.

The project schedule will continue to evolve as the remaining subcomponents are delivered. The final decision concerning ComCam on-sky data taking will be taken in February 2024.

2.2 Commissioning Milestones

Commissioning work is being planned around three major milestones, *ComCam First Photon*, *LSSTCam First Photon* and *System First Light*.

ComCam First Photon: The first image of the night sky produced by photons passing through the Rubin optical system and detected by the Commissioning Camera (ComCam).

LSSTCam First Photon: The first image of the night sky produced by photons passing through the Rubin optical system and detected by the LSST Science Camera (LSSTCam).

System First Light: Defined as the point at which we can routinely acquire science-grade imaging across the LSSTCam full focal plane and have a well understood technical path towards meeting the Construction Completeness criteria SITCOMTN-061. Also referred to as **First Light**.

As the Project continues to optimize the sequence of integration activities and if it becomes

no longer beneficial to go on-sky with ComCam, the ComCam First Photon milestone will be descoped. LSSTCam First Photon occurs following the successful completion of system integration. There are no quality criteria applied to achieving neither the ComCam nor LSSTCam First Photon milestones. System First Light marks the end of the on-sky engineering phase and the start of the System Optimization and Science Validation phases of commissioning. During the period between ComCam First Photon and System First Light will focus on fine tuning the system including optical alignment and improving the image quality, collecting calibration data, and carrying out *First Look* science programs.

For a detailed description of all the commissioning milestones and the most current dates, see DMTN-232.

2.3 Commissioning Observations

Figure 2 shows the high level plan for the Rubin commissioning observations. Commissioning data collection is planned to take place in phases. The *On-Sky Engineering* phase may be carried out with either ComCam and/or LSSTCam, depending on future re-optimization of the sequence of integration activities (§ 2.1) During the *System Optimization* phase, 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.

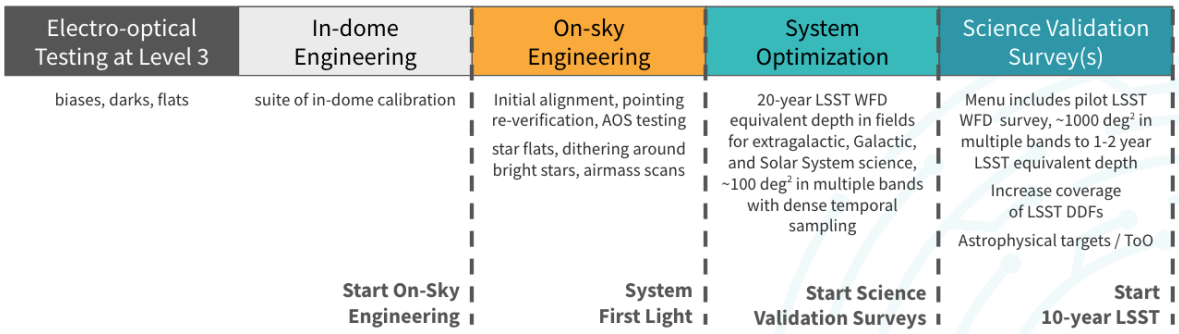

FIGURE 2: Outline plan for the collection of commissioning data, as of October 2023.

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) and one Data Release (DR) are planned 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 subset of early science-grade commissioning data taken with either ComCam or LSSTCam.
- Data Preview 2 (DP2): Based on a full reprocessing of all science-grade LSSTCam data taken during commissioning.
- Data Release 1 (DR1): Based on the first six months of LSST data.

Due to the relatively short time periods available for commissioning observations (§ 1.4), the Data Previews will necessarily be limited in their area and temporal coverage relative to a full Data Release.

The data products that comprise the Data Previews and Data Releases 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 Data Preview and LSST Data Release will be accompanied by its own release-specific DPDD[1], 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. All LSST data products will be subject to the embargo periods described in DMTN-199.

[1]For an example data release DPDD, see the online DP0.2 documentation `https://dp0-2.lsst.io/data-products-dp0-2/`.

Rubin Early Science – Data Release Scenario

	Jun 2021	Jun 2022	Jun 2023	Oct 2024 – Jul 2025	start Jun– Nov 2025	Nov 2025 – May 2026	May 2026 – Jan 2027	May 2027 – Jan 2028	May 2028 – Nov 2028
	DP0.1	**DP0.2**	**DP0.3**	**DP1**	**AP**	**DP2**	**DR1**	**DR2**	**DR3**
Data Product	**DC2 Simulated Sky Survey**	**Reprocessed DC2 Survey**	**Solar System PPDB Simulation**	**ComCam Data**	**Realtime LSSTCam Data**	**LSSTCam Science Validation Data**	**LSST First 6 Months Data**	**LSST Year 1 Data**	**LSST Year 2 Data**
Raw Images	●	●	–	●	●	●	●	●	●
Processed Visit Images and Catalogs	●	●	–	●	●	●	●	●	●
Coadded Images	●	●	–	–	–	●	●	●	●
Object and ForcedSource Catalogs	●	●	–	–	–	●	●	●	●
Difference Images and DIASources	–	●	–	–	●	●	●	●	●
ForcedSource Catalogs including DIA	–	●	–	–	–	●	●	●	●
Alerts	–	–	–	–	●	–	–	–	–
SSP Catalogs	–	–	●	●	●	●	●	●	●

TABLE 1: Summary of data products expected in each early LSST data release.

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.

The following sections outline which data products can be expected in each Data Preview and Data Release, and on what time scale. See Table 2 in the Timeline section below for a combined view of the expected data preview schedule and its uncertainties.

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 deg^2 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

Delivered in June 2023, DP0.3 is the last in the DP0 series of Data Previews based on simulated LSST-like data. DP0.3 supports the Solar System Science Collaboration by hosting their simulated 1-year and 10-year Prompt Products Database (PPDB) catalog to enable moving object analysis development in RSP at the US DAC.

For full details on DP0.3 including an exact description of the data products served, see the documentation at `https://dp0-3.lsst.io/`

3.2 Data Preview 1

Data Preview 1 (DP1) will serve data products generated from a subset of science-grade astronomically-useful images as soon as possible following the end of either ComCam on sky or System First Light (§ 2.2), to enable the community to prepare to work with LSST data. In the current schedule, which re-implements on-sky data-taking with ComCam for 2 months, DP1 would be based on science-grade data taken from the 2 months of ComCam data.

In both DP1 scenarios, the exact processing pipelines and data products are still to be determined and depend strongly on the dataset that emerges from the commissioning on-sky observing program. At minimum, DP1 will deliver visit-level calibrated images and catalogs

to enable initial studies of observational and instrumental effects. Rubin will do its best to deliver the maximum of data products possible with the commissioning on-sky dataset, however at this time, for DP1, all other data products described in the DPDD remain a stretch goal. Table 1 presents a current best idea of the data products that might comprise DP1.

A final decision on the dataset on which DP1 will be based will be taken in February 2024 following the Project's confirming decision about ComCam on-sky data-taking (§ 2.1)

3.3 Data Preview 2

Data Preview 2 will serve a full consistent reprocessing of all data collected as part of the LSSTCam Science Validation Surveys (SV Surveys) together with any other science-grade commissioning images taken throughout the Science Optimization phase of commissioning, including the DP1 data.

Table 1 presents a summary of the data products expected in DP2.

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. Table 1 presents a summary of the data products expected in DR1.

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). [2]
- 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.

[2]The 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.

4.3 Beginning Alert Production

A variety of technical, scientific, and organizational criteria must be met prior to the release of the first public alerts from LSSTCam. The prerequisites, which include formal agency approval, are summarized in RTN-061. Accordingly, alert production is expected to begin around the time of the Science Validation Surveys with LSSTCam and the start of the full LSST survey. Incremental template generation, difference imaging, and Real/Bogus pipelines will be tested and optimized during commissioning with ComCam and LSSTCam prior to first alert release. These efforts will contribute to data release DIA products released in DP1 and DP2. Full-volume, full-fidelity alert production is expected in the second year of the LSST survey after DR1.

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. The commissioning period also provides an excellent opportunity to investigate how many visits in a given band are sufficient to construct a usable template.

Rubin aims to begin routine Alert Production as soon as is feasible and scale up alert production as more templates become available. Once begun, Alert Production will proceed continuously through the full LSST survey. Alerts generated prior to DR1 may be produced with higher latency and/or lower fidelity. All Rubin alerts sent to community alert brokers are world-public.

Other data products produced during Alert Production (processed visit and difference images, DIA catalogs in the Prompt Products Database, direct image catalogs) may be accessed by Data Rights holders through the RSP. Access to these products may be delayed early in the survey (Figure 1).

5 Data Access Environment

The Rubin data access environment provides data rights holders with access to all Rubin data products and services. Prior to the start of Operations, all services for data access will be under active development and are provided on a shared-risk basis. The Rubin data rights policy is described in RDO-013.

5.1 Data Access Centers

Rubin data products will be served to the community from the US Data Access Center (US DAC) hosted on the Google Cloud Platform[3]. DP0.1 and DP0.2 are already available via the RSP running at the US DAC.

An number of Rubin Independent Data Access Centers (IDACs) is also under construction to provide additional user computing resources to LSST users around the globe (RTN-003).

5.2 Rubin Science Platform

The Rubin Science Platform (RSP), described in LSE-319, is a set of integrated web-based applications, services, and tools to query, visualize, subset, and analyze LSST data. It comprises three different "Aspects": a *Portal* Aspect designed to provide an environment for data discovery, query, filtering, and visualization, a *Notebook* Aspect to enable next-to-the-data analysis, and an *API* Aspect that enables programmatic access to the Rubin data products via Virtual Observatory (VO) interfaces. The Portal and Notebook Aspects of the RSP make use of the same APIs as the API Aspect to internally access the LSST datasets.

An early version of the RSP is currently running at the US Data Access Center (US DAC) that provides access to Data Preview 0.

[3] `data.lsst.cloud`

5.2.1 Image services

Image services is the term to describe the set of interfaces that provide access to LSST image data products[4] through IVOA-style services in the API Aspect. A detailed description of the Rubin Image Service Architecture can be found in DMTN-139.

As of DP0.2 a first version of the Rubin's image services has been deployed as part of the RSP running at the US DAC and includes: an ObsCore data model and ObsTAP service for image metadata, image retrieval via https, an IVOA SODA service for making image cutouts, DataLink annotations to the ObsTAP service for access to the SODA service, and an authenticated HiPS service. Future releases will include difference-image and PVI re-creation services and a forced-photometry-on-demand service. Image services are accessible via the *Portal*, *Notebook* and *API* aspects of the RSP.

Access to image data products via the Butler was deployed as part of DP0.1.

5.3 Community Brokers

Alerts are fully world-public and will be accessible via one or more of the nine Rubin-endorsed Community Brokers[5]. During the commissioning period, Rubin will work with the Community Brokers to integrate them [RTN-010]. Community access to early alerts will depend on the readiness of the Community Brokers. At this stage, we are expecting the first alerts from commissioning to become available via Community Brokers near the start of the LSST survey (§4.3).

6 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.

[4] Image data products includes single-epoch images both raw and calibrated, difference images and coadded images of various types

[5] See `https://www.lsst.org/scientists/alert-brokers`

There is no non-sidereal observing in the Rubin baseline survey plan and consequently there will be no non-sidereal tracking available during the early science era.

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.

6.1 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.

6.2 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.

6.3 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 “Commission-

ing Notes" from the community in 2012 that are being considered as part of the planning for the on-sky observing strategy during commissioning. [6]

6.4 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.

7 Roadmap and Timeline

Table 2 shows the Operations timeline and provides nominal date ranges for the various elements of the Early Science Program. The date ranges are derived from the Rubin "Celebratory Milestones", which are published monthly on the Rubin Project website[7]. For completed milestones the delivered date is given. 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. The shaded region contains roughly 80% of the probability, while the lefthand edge of the shaded range indicates the earliest date the milestone could be reached. The darker regions give a very rough indication of the +/-1 sigma error bars. Over the course of the commissioning period, we expect these data ranges to shrink as our understanding of the remaining schedule uncertainty improves. However, there is still the possibility of the assumptions underlying these distributions being wrong; this is just our best estimate at the current time.

The next key milestone in the Early Science Program is the release of DP1, expected sometime between October 2024 – July 2025. The start of Rubin Operations is currently expected to be sometime between May 2025 and September 2025. The timing of the Commissioning observations and their release to the community can only be projected to within a few months at the time of writing. 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 spends less time on-sky with LSSTCam. In this eventuality, the operations team would spend up to 2 months prior to com-

[6] See https://community.lsst.org/t/community-input-to-the-on-sky-observing-strategy-during-commissioning/4406

[7] ls.st/dates

Rubin Operations Survey and Data Release Timeline

Nominal LSST Start Date: August 2025

Event	Date Range
Data Preview 0	Delivered Jun 2023
Rubin First Light	Mar 2025 – Apr 2025
Data Preview 1	Apr 2025 – May 2025
Start of Operations	Jun 2025 – Aug 2025
Start of LSST (SVY)	Jun 2025 – Sep 2025
Start of Alert Production	Jun 2025 – Nov 2025
Data Preview 2	Dec 2025 – Mar 2026
Data Release 1	Jun 2026 – Nov 2026
Data Release 2	Jun 2027 – Nov 2027
Data Release 3	Jun 2028 – Sep 2028

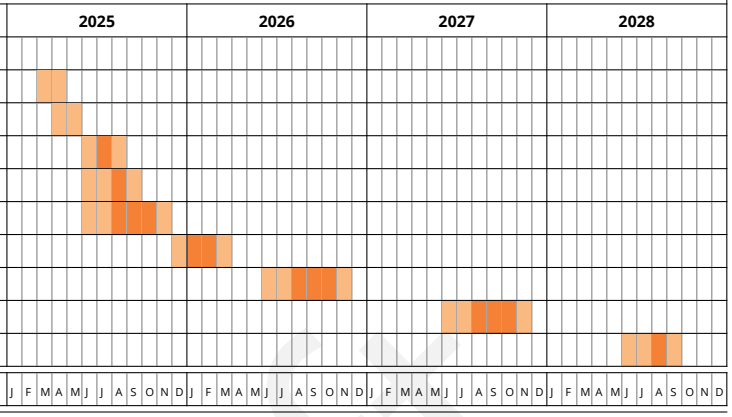

TABLE 2: Rubin Operations Key Milestones for Early Science

mencing the 10-year LSST survey collecting more on-sky data to complement and extend the datasets collected during commissioning (see § 1.4).

Table 2 will continue to be refined and updated in future version of this document as the Early Science Program progresses.

8 Community

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

8.1 Survey Cadence Optimization Committee

The Rubin Survey Cadence Optimization Committee (SCOC)[8] 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

[8] See https://www.lsst.org/content/charge-survey-cadence-optimization-committee-scoc

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 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)).

8.2 Community Forum

The Rubin Observatory Community Platform has a dedicated category for Early Science[9], 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.

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B Acronyms

Acronym	Description
AGN	Active Galactic Nuclei
API	Application Programming Interface
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
DIA	Difference Image Analysis
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
DR	Data Release
DR1	Data Release 1
DRP	Data Release Production
IVOA	International Virtual-Observatory Alliance
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
OSS	Observatory System Specifications; LSE-30
ObsCore	Observation Data Model Core Components (IVOA standard)
ObsTAP	Observation (metadata) Table Access Protocol (part of IVOA ObsCore standard)
PCW	Project Community Workshop
PPDB	Prompt Products DataBase
PST	Project Science Team

PSTN	Project Science Technical Note
PVI	Processed Visit Image
RDO	Rubin Directors Office
RSP	Rubin Science Platform
RTN	Rubin Technical Note
SCOC	Survey Cadence Optimization Committee
SIT	System Integration, Test
SODA	Server-side Operations for Data Access (IVOA standard)
SRD	LSST Science Requirements; LPM-17
SST	Subsystem Science Team
SV	Science Validation
TOO	Target of Opportunity
US	United States
VO	Virtual Observatory
WFD	Wide Fast Deep