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Data Management

Rubin Observatory Plans for an Early Science Program

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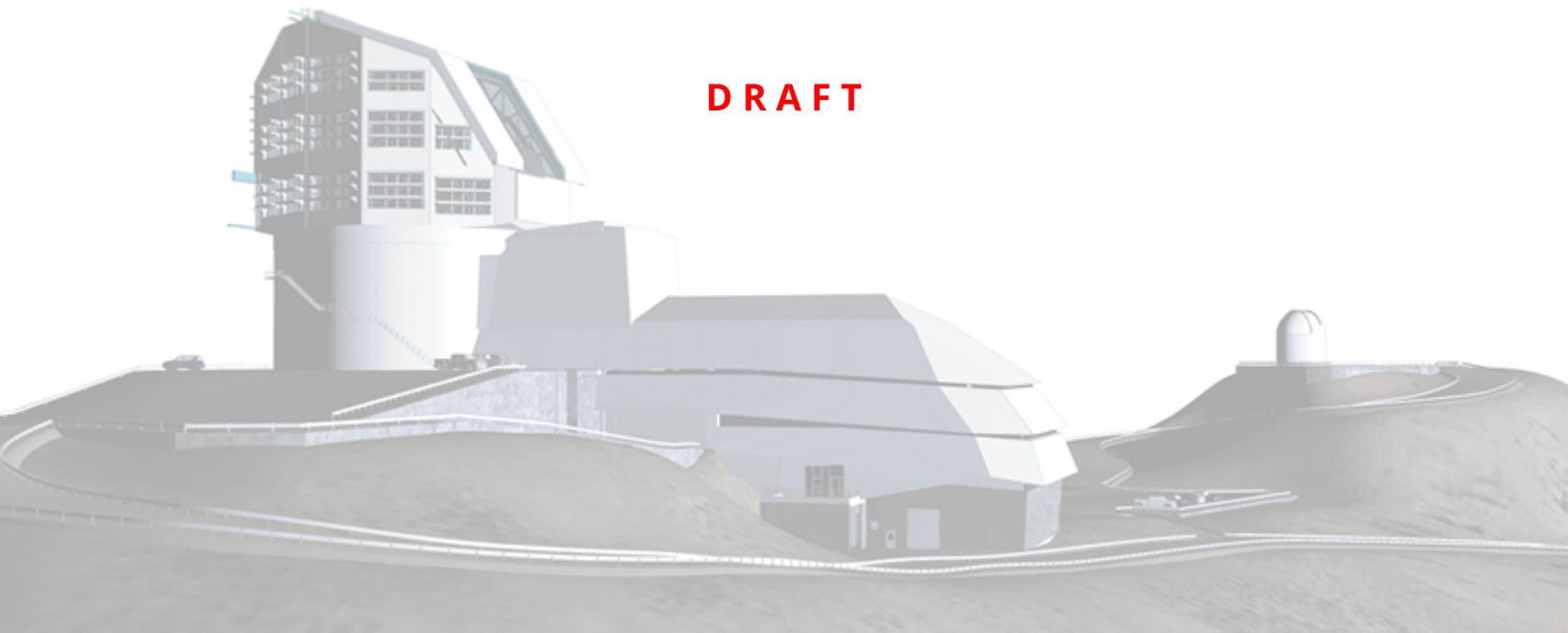

Abstract

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.

Change Record

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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
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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* was conceived to provide Rubin data rights holders with early access to the data products and services necessary to produce high-impact science during the 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 with LSST 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 LSST Data Release (DR1);
- enable early time-domain astronomy via Alert Production; and
- help drive the 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.
- 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 following the baseline survey strategy.

1.4 Transition to Operations and Early Science

The Rubin Construction project will deliver an integrated system that can capture, transfer and process science-grade data, following which, the Construction project will be declared complete and Operations will begin. The Operations team is tracking the progress of the commissioning activities (§ 2) to identify opportunities for Early Science and address the goals described in § 1.2. The data collected as part of the SV surveys in Construction will serve the dual goals of 1) ensuring that Operations is fully prepared to start the 10-year survey and 2) providing the community with an exquisite early dataset to work with while the survey begins its relentless coverage of the sky leading to DR1. All Early Science data products are opportunistic on the commissioning activities, meaning that a detailed description will only be possible once the commissioning data have been acquired and analyzed. Consequently, while the Operations team will do its best to deliver the maximum of early data, data product types and services, any statement on the contents of the Data Previews, early Alert Stream and supporting services is subject to change up until the release date.

1.5 Factors Impacting the Early Science Program

Factors affecting the schedule and contents of the Early Science program can be broadly grouped into technical considerations and policy considerations.

Technical considerations include:

- The operational status of the observatory and progress of system integration and test activities in commisioning;
- The nature and quality of the data collected during commissioning;
- The readiness of the data processing pipelines and data distribution and access services.

Policy factors include:

- There is a 30-day embargo on all pixel data during commissioning;
- There is an 80-hour embargo on all pixel data throughout the entirety of Pperations, including the SV surveys and the LSST;
- The construction security review, which must be successfully completed prior to the release of any Prompt data products;
- The Rubin First Look (RFL) media event, RTN-083. Currently scheduled for June 2025. No LSST data may be released before this date.

In this document, the term “stretch goal” will be used in cases where any uncertainty is due to a technical or scientific consideration and “TBD” (To Be Decided) will be used when the influencing factor is of a policy nature.

2 Rubin Observatory Commissioning

2.1 Commissioning Plan and Schedule

Figure 1 shows the detailed schedule of commissioning and early science activities relative to System First Light, as of January 2025. ComCam First Photon was successfully achieved on 24 October 2024. Rubin (LSSTCam) First Photon, is currently expected on 15 April 2025 and System First Light in July 2025 (§ 7).

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 will be carried out with both ComCam LSSTCam. Both the System Optimization and Science Validation

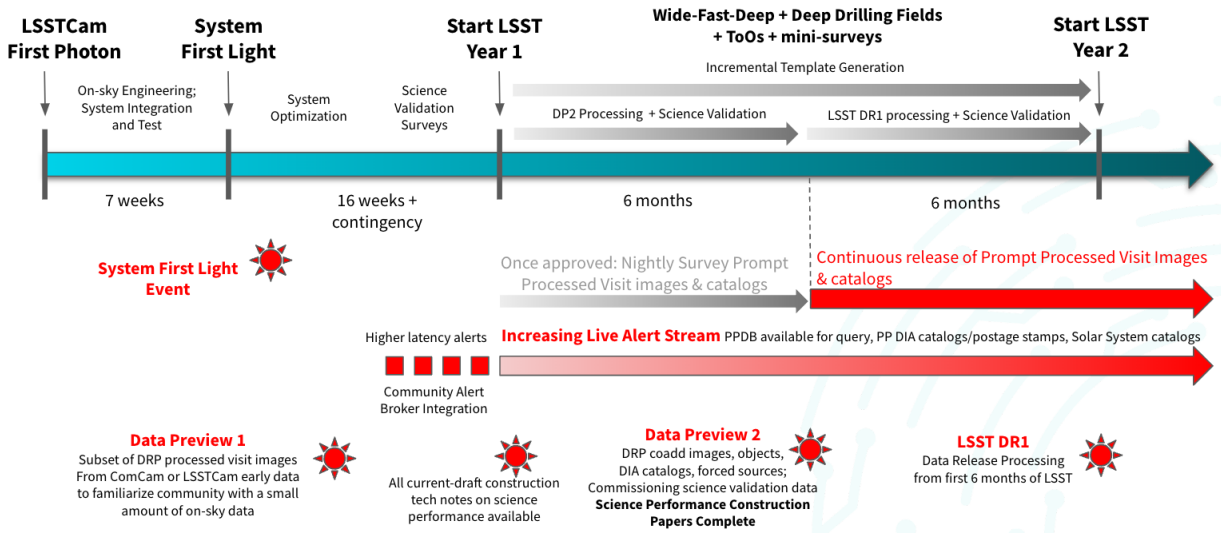


Figure 1: Detailed schedule of commissioning and early science activities relative to System First Light, as of January 2025 .

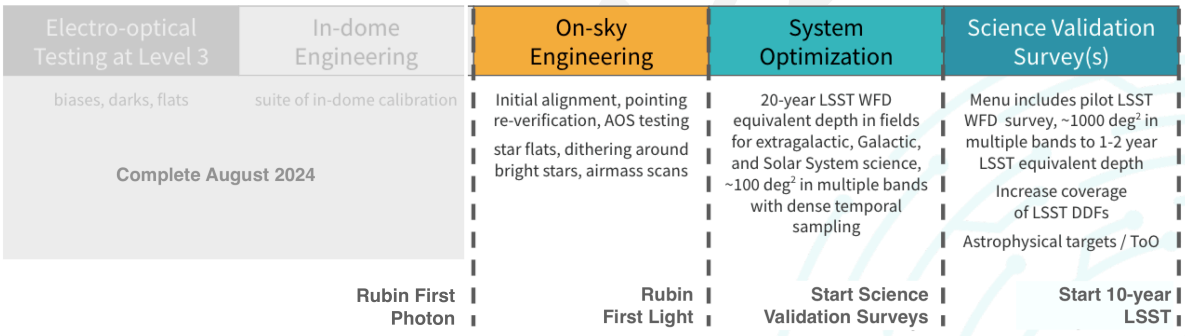


Figure 2: Outline plan for the collection of commissioning data, as of January 2025 .

(SV) phases will be carried out with LSSTCam. The System Optimization phase will collect a set of observations designed to help optimize the system prior to starting the Science Validation phase. During the Science Validation phase, a series of SV Surveys designed to support scientific analyses that validate the system's performance and allow Rubin to demonstrate operations readiness are carried out, see SITCOMTN-005. The System Optimization and SV phases contain a number of planned key components, including an LSST wide-fast-deep (WFD) 1-2 year equivalent depth "pilot" survey. In all phases, 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.

The System Optimization and SV survey phases are expected to last about 8 weeks each.

The project schedule will continue to evolve as the remaining subcomponents are delivered. Construction is expected to complete and LSST data taking start before the end of 2025.

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). This milestone was achieved on 24 October 2024.

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). Currently expected for 15 April 2025.

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. Currently expected for 4 July 2025.

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

2.3 ComCam Commissioning

ComCam is Rubin's engineering camera that is used for testing and validating the observatory's systems and processes prior to installation of the LSST Camera. The ComCam focal plane has single raft with a 3×3 mosaic of 4K×4K ITL science sensors, giving a total of 144Mpix.

ComCam has the same plate scale as LSSTCam (0.2 arcsec / pixel), with a field of view of 40 × 40 arcmin. The ComCam filter exchanger holds only three physical filters at a time.

The Rubin on-sky commissioning campaign using ComCam began on 24 October 2024 and ended on 11 December 2024, lasting a total of 7 weeks, and included observations to support both engineering and science pipelines commissioning. This highly successful campaign included a first series of on-sky engineering tests demonstrating the end-to-end functionality of the Simonyi Survey Telescope's hardware and software systems ComCam. The median delivered image quality for commanded in-focus images collected during the campaign, quantified in terms of the PSF FWHM, was ≈1.1 arcseconds. The best images have delivered PSF FWHM of ≈0.7 arcseconds. A full report on the ComCam on-sky commissioning campaign is available at SITCOMTN-149.

2.4 LSSTCam Commissioning

As of January 2025 , LSSTCam is being installed on the Simonyi Survey Telescope and on-sky observing is expected to begin in April 2025.

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

Rubin Early Science – Data Release Scenario

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

Table 1: Summary of Data Release data products expected in each data preview and early LSST data release. A dark teal dot denotes confirmed data products whereas a gray dot denotes data products that currently remain a stretch goal.

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; 30 days during commissioning and 80 hours during operations for pixel data.

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.

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

The following sections outline which data products can be expected in each Data Preview and Data Release, and on what time scale. See Table 5 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.

Table 2: ComCam target fields and pointing centers that are to be included in the DP1 dataset. ICRS coordinates are shared in units of decimal degrees.

Field Code	Field Name	Right Ascension	Declination
		deg	*deg*
47 Tuc	47 Tuc Globular Cluster	6.02	-72.08
Rubin SV 38 7	Low Ecliptic Latitude Field	37.86	6.98
Fornax dSph	Fornax Dwarf Spheroidal Galaxy	40.00	-34.45
ECDFS	Extended Chandra Deep Field South	53.13	-28.10
EDFS	Euclid Deep Field South	59.10	-48.73
Rubin SV 95 -25	Low Galactic Latitude Field	95.00	-25.00
Seagull	Seagull Nebula Seagull	106.23	-10.51

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

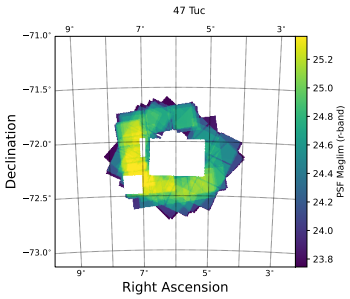
3.2 Data Preview 1

Data Preview 1 (DP1) will serve data products generated from a subset of science-grade astronomically useful images taken during the ComCam on-sky commissioning campaign (§ 2.3), to enable the community to prepare to work with LSST data.

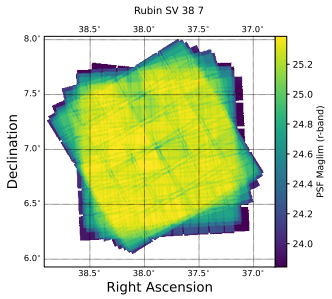
Seven target fields observed as part of the ComCam on-sky observing campaign have been selected as the basis for DP1 due to their quality and scientific usefulness. These seven fields, listed in table 2 together with their central pointing coordinates, span a range of stellar densities, have good overlap with external reference datasets, and span the breadth of the four primary LSST science themes.

Table 3 provides a summary of the band coverage for the DP1 fields and figure 3 shows the resulting integrated depth, expressed in terms of the flux of an unresolved source that would be measured with signal-to-noise ratio $S/N = 5$, using the r band as an example. A typical observing epoch on a given target field consisted of 5-20 visits in each of the three loaded filters. Nearly all the visits were taken with one single 1x30 second exposure time and not 2x15 second snaps[2]. DP1 is expected to include of the order of 2000 science images.

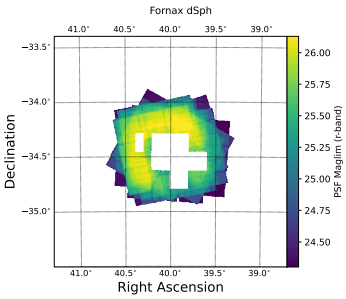
[2]At this time, studies as to whether the LSST will use a 1x30 single exposure or 2x15 snaps as the default standard visit are ongoing with LSSTCam data, and a decision will be made prior to starting the LSST.



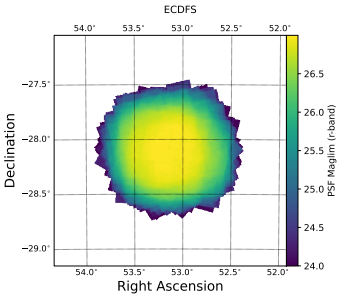
(a) 47 Tuc



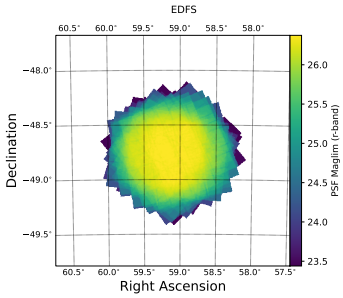
(b) Rubin SV 38 7



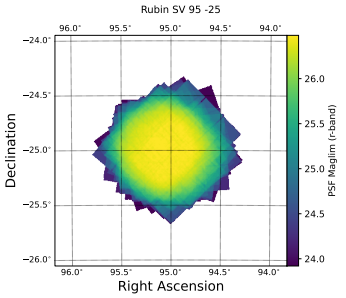
(c) Fornax dSph



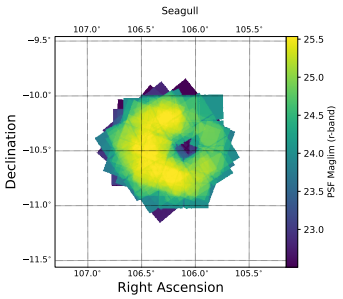
(d) ECDFS



(e) EDFS



(f) Rubin SV 95 -25



(g) Seagull

Figure 3: Cumulative imaging depth expressed in terms of the $S/N = 5$ limiting magnitude for unresolved sources for seven ComCam Deep Drilling Fields.

Table 3: Band coverage for seven fields observed during the ComCam on-sky observing campaign that are to be included in the DP1 dataset.

Target	u	g	r	i	z	y
47 Tuc	6	10	33	19	0	5
Rubin SV 38 7	0	44	55	57	27	0
Fornax dSph	0	5	26	13	0	0
ECDFS	53	230	257	177	177	30
EDFS ComCam	20	61	90	42	42	20
Rubin SV 95 -25	33	86	97	29	60	11
Seagull	10	37	49	3	13	0

The processing and preparation of ComCam data for DP1 will take place during the first half of 2025, with an expected DP1 release data in June or July 2025. The planned data products for DP1 are presented in table 1. Data products that are marked as a stretch goal, DRP ForcedSource Catalogs, Difference Images and DIA Catalogs, will not be confirmed until close to the DP1 release date. DP1 will not contain any DRP SSP data products in order to focus on readiness for LSSTCam and on providing high quality live LSSTCam SSP Prompt data products as part of the ramp up of Alert Production starting roughly contemporaneously with the DP1 release.

ComCam observations that are expected to be included in Data Preview 1.

Keep in mind that this is “expected” in a general sense. Exact image counts and coadd depths may change.

For example, it is conceivable that a few individual exposures might not, in the end, meet the quality control standard of being “science-grade, astronomically useful” images.

3.3 Data Preview 2

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.

Table 1 presents a summary of the data products expected in DP2. DRP Solar System Processing (SSP) is currently a stretch goal for DP2. DRP SSP is intended to be a Rubin-only product;

meaning that It does not start with the catalog from the Minor Planets Center (MPC).

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

The DPDD summarizes the pipelines that will be used during Prompt Processing to produce alerts as well as other prompt data products, including Solar System Processing. Both Alert Production and Solar System Processing depend on the existence 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. To enable alert production to proceed during commissioning and early operations, it is necessary build templates incrementally as data become available, as recommended by the study described in DMTN-107. Because we have a smaller set of input images to choose from and uncertain knowledge about future observations, incremental template generation necessarily must balance the trade off of earlier template availability against template quality and spatial completeness. 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.

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.

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 ≈ 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 (§ 7). RTN-061 describes the criteria for sending the first Rubin alerts. Once begun, Alert Production will then proceed continuously into the full LSST survey. Alerts generated during commissioning may be produced with higher latency, and access to images and the PPDB may not be immediately available.

Table 4 lists the various alert and prompt processing data products currently planned at each phase of alert production during commissioning and the first two years of the LSST survey. Phase 1 covers the commissioning period and phase 2 covers early survey operations. During routine LSST operations, prompt image data products, including raw images, processed single visit images (PVIs), difference images, and template images, will be made available no earlier than 80 hours following camera readout. Access to prompt PVIs and difference images in the first 6 months of the LSST is still to be decided.

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.

[3] `data.lsst.cloud`

Rubin Early Science – Alerts & Prompt Products Scenario		
	Phase 1: 3 – 16 weeks post System First Light	Phase 2: 18 – 17 weeks post System First Light
Data Product	**LSSTCam Commissioning**	**Year 1 Survey Operations**
Alerts	Alert volume and latency will improve throughout the commissioning period. Aiming for "near-live" brokered Alert stream by the end of LSSTCam Commissioning.	Continued ramp up of the alert stream contingent on the availability of templates. Alerts expected to reach near full volume and fidelity after DR1. Alert stream latency in year 1 is 120 seconds.
PP Processed Visit Images	Commissioning of the PP image differencing and incremental template building. Prompt image release is embargoed during commissioning (§ 1.5).	Access to unvetted processed visit images as prompt products in the first 6 months of the LSST is TBD.
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 (§ 1.5).	Difference imaging will steadily increase as incremental template building increases the templates available. Prompt access to unvetted PP difference images is TBD.
PP Catalogs (DIASources, DIAObjects, DIAForcedSources)	Queryable PPDB available at shared risk.	PPDB available for query.
PP SSP Catalogs	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 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 4: Summary of Prompt data products expected during commissioning and year 1 of survey observations..

A 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.

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 sometime following System First Light RTN-061.

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 5 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 June and July 2025. The start of Rubin Operations is currently expected to be sometime between September and October 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.

Table 5 will continue to be refined and updated in future version of this document as the

[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: October 2025

Event	Date Range	2025	2026	2027	2028
Data Preview 0.1/2/3 (DP0)	Delivered Jun 2023				
Data Preview 1 (DP1)	Jun 2025 – Jul 2025				
System First Light (SFL)	Jul 2025				
Rubin First Alerts (RFA)	Jul 2025 – Sep 2025				
Start of Operations (OPS)	Sep 2025 – Oct 2025				
Start of LSST (SVY)	Sep 2025 – Nov 2025				
Start Regular Alert Production (RAP)	Sep 2025 – Nov 2025				
Data Preview 2 (DP2)	Mar 2026 – May 2026				
Data Release 1 (DR1)	Sep 2026 – Jan 2027				
Data Release 2 (DR2)	Sep 2027 – Jan 2028				
Data Release 3 (DR3)	Sep 2028 – Nov 2028				
		J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D

Table 5: Rubin Operations Key Milestones for Early Science

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 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

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

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
DAC	Data Access Center
DC2	Data Challenge 2 (DESC)
DESC	Dark Energy Science Collaboration
DIA	Difference Image Analysis
DM	Data Management
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
ECDFS	Extended Chandra Deep Field-South Survey
EDFS	Euclid Deep Field South
FWHM	Full Width at Half-Maximum
ITL	Imaging Technology Laboratory (UA)
IVOA	International Virtual-Observatory Alliance
LSE	LSST Systems Engineering (Document Handle)
LSST	Legacy Survey of Space and Time (formerly Large Synoptic Survey Telescope)
MAF	Metrics Analysis Framework
MPC	Minor Planet Center
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
PSF	Point Spread Function
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)
SSP	Solar System Processing
SV	Science Validation
TBD	To Be Defined (Determined)
TOO	Target of Opportunity
US	United States
VO	Virtual Observatory
WFD	Wide Fast Deep