VERA C. RUBIN OBSERVATORY

Early Science

Research Proposal PI Briefing 2022

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LSST@Europe 4, October 2022
Rome, Italy

NSF AURA U.S. DEPARTMENT OF ENERGY SLAC CHARLES AND LISA SIMONYI FUND FOR ARTS AND SCIENCES LSST CORPORATION

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Early Science is defined as any science enabled by Rubin for its community through and including the first data release, Data Release 1 (DR1)

Motivations for an Early Science Program

- To **enable high-impact science prior to the first data release**, **DR1**, both before and during the first year of regular survey operations.
- To provide **early access to both static-sky and time-domain science-ready data products** to support the community as they develop their LSST analyses in preparation for DR1,
- To **enable time-domain astronomy via Alert Production** during commissioning and in the first year of operations. ǂ

ǂ Due to the need for Data-Release-derived templates, Alert Production cannot run at full scale nor full fidelity during commissioning and year one.

Elements of the Early Science Program

- A series of **Data Previews** based on reprocessed data taken during the Rubin Observatory commissioning period:
  - Data Preview 1 (DP1): based on ComCam data,
  - Data Preview 2 (DP2): based on LSSTCam data,
  - Data Release 1 (DR1): based on the first 6 months of LSST data.
- **Template generation** prior to the start of regular survey operations based on data collected during commissioning with LSSTCam to maximize the number of templates available for Alert Production at the start of the 10-year survey.
- **Incremental template generation** during the first year of operations, as and when sufficient images passing quality cuts have been acquired. These templates will then be used immediately during year 1 to generate alerts, thus steadily increasing the number of Alerts generated over the course of year 1.

Commissioning Data Collection – Timeline

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ComCam

Electro-optical Testing at Level 3	In-dome Engineering	On-sky Engineering (~1.5 months)	System Optimization (~2 months)
biases, darks, flats	suite of in-dome calibration	pointing, AOS testing star flats, dithering around bright stars, airmass scans	20-year LSST WFD equivalent depth, synthesizing LSSTCam FoV, prioritizing LSST DDF

LSSTCam

Electro-optical Testing at Level 3	In-dome Engineering	On-sky Engineering (~1.5 months)	System Optimization (~1.5 months)	Science Validation Survey(s) (~2 months)
biases, darks, flats	suite of in-dome calibration	pointing, AOS testing star flats, dithering around bright stars, airmass scans	20-year LSST WFD equivalent depth in fields for extragalactic, Galactic, and Solar System science, ~100 deg^2 in multiple bands with dense temporal sampling	Menu includes pilot LSST WFD survey, ~1000 deg^2 in multiple bands to 1-2 year LSST equivalent depth Increase coverage of LSST DDFs Astrophysical targets / ToO

Early Science Scenarios

We consider two scenarios to ensure Early Science:

- **Scenario A:** The full commissioning plan comprising system optimization and science validation is successfully executed as planned. The Operations team then carries out an 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. Data collected during commissioning and the SV Surveys is reprocessed to produce DP2, which will be released 6 months following the completion of the SV 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 spend up to 3 months prior to commencing the 10-year LSST survey carrying out any remaining SV Survey observations and* ***releasing DP2 with the same data products as planned in Scenario A.***

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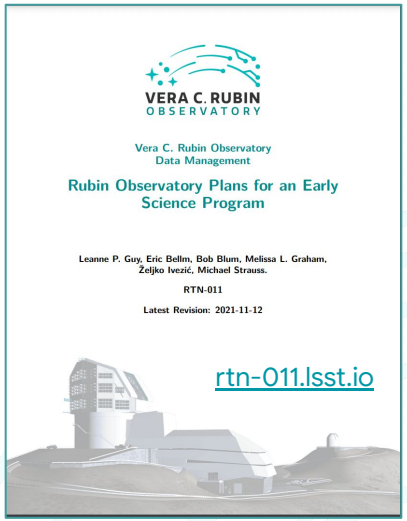
Early Science Scenarios – Key Points

- **Contents of DP2 will be the same irrespective of which Early Science Scenario materializes** – Only the timing of the release of DP2 and the start of the 10-year survey is different between the two scenarios.
- 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 full/survey 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.
- As we approach full/survey operations and the commissioning program emerges and is executed, a single scenario will be adopted and executed.

RTN-011: A Roadmap for Early Science – V2

RTN-011: Plans for Early Science is the guiding document for Early Science with Rubin. It is a living document that will evolve over the course of the pre-operations period.

- Provides the plans for a Early Science Program
- Describes the Early Science Data Products
- Describes plans to implement incremental template generation to augment alert production in the early phases of the survey.
- Provides a timeline for execution
- Describes how the community can contribute
- *Can and should be cited in research proposals*



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Cite RTN-011 as follows:

Leanne P. Guy, Keith Bechtol, Eric Bellm, Bob Blum, Melissa L. Graham, Željko Ivezić, Phil Marshall & Michael Strauss (2022). Rubin Observatory Plans for an Early Science Program (v2.1). Zenodo. https://doi.org/10.5281/zenodo.5683848

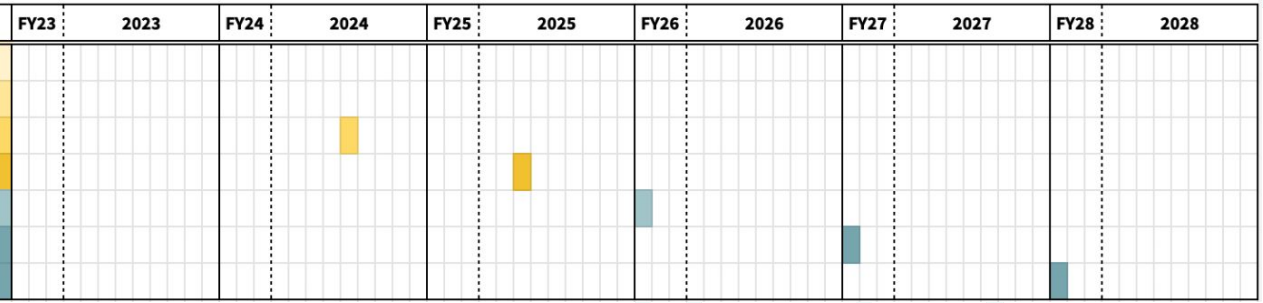
BibTex available via the DOI zenodo link, an in the back-ups

Timeline

Rubin Operations Top Milestones

- **Mar 2024 - Jul 2024** Complete Delivery of Data Preview One (DP1) (L1-RO-0060) (= Optical testing on TMA complete + 6 months)
- **Jul 2024 - Mar 2025** LSST Survey Start (L1-RO-0110) (= LSSTCam SV Surveys Complete + 1 months)
- **Jan 2025 - Aug 2025** Complete Delivery of Data Preview Two (DP2) (L1-RO-0070) (= LSSTCam SV Surveys Complete + 6 months)
- **Oct 2025 - May 2026** Complete Delivery of Data Release One (DR1) (L1-RO-0120) (= LSST Survey Start + 12 months)
- **Oct 2026 - May 2027** Complete Delivery of Data Release Two (DR2) (L1-RO-0130) (= LSST Survey Start + 24 months)

Data Preview/Release		Date
DP0.1	DC2 Simulated Sky Survey	June 2021
DP0.2	Reprocessed DC2 Survey	June 2022
DP1	ComCam On-Sky Data	Mar 2024 - Jul 2024
DP2	LSSTCam On-Sky Data	Jan 2025 - Aug 2025
DR1	LSST First 6 Months Data	Oct 2025 - May 2026
DR2	LSST Year 1 Data	Oct 2026 - May 2027
DR3	LSST Year 2 Data	Oct 2027 - May 2028



This is Early Science Proposal Year

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This academic year (FY23), grant and fellowship proposals will be for the 3-year Early Science period FY24-FY26:

- **Grant Period Year 1 (FY24):**
  - Preparation
  - DP1 (ComCam) FY24 Q3
- **Grant Period Year 2 (FY25):**
  - Survey Start
  - DP2 (LSST Cam)
- **Grant Period Year 3 (FY26):**
  - DR1 (first 6 months of LSST)

Early Science Data Products

Prompt Data Products

Alerts: Alert packet containing: alertId, DIASource, DIAObject or SSObject, previous up to 12 months of detections, science/template/difference image cutouts

Images: Single visit images, difference images, template

Catalogs: DIASource, DIAObject, SSObject, ForcedSource.

Prompt Products Database Timescale

The prompt products database, containing the prompt catalogs will be updated on a 24hr timescale.

Static Science Data Products

DR data products from DP1 and 2 based on commissioning and SV survey data, and DR1 based on the first 6 months of data.

Definitions

Source = A detection in an image with SNR>5
Object = Sources associated by coordinate
DIA = Difference Image Analysis
DIASource = A detection in a difference image with SNR>5
DIAObject = DIASources associated by coordinate
SSObject = Solar System Object
Template = Transient-free image

Data Preview/Release Schedule & Contents

Rubin Early Data Release Scenario	Jun 2021	Jun 2022	Mar 2024 - Jul 2024	Jan 2025 - Aug 2025	Oct 2025 - May 2026
	DP0.1	DP0.2	DP1	DP2	DR1
Data Product	DC2 Simulated Sky Survey	Reprocessed DC2 Survey	ComCam On-Sky Data	LSSTCam On-Sky Data	LSST First 6 Months 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 Alerts (Canned)	☐	☐	☑	☑	☑
PP Alerts (Live, Brokered)	☐	☐	☐	☑	☑
PP SSP Catalogs	☐	☐	☑	☑	☑
DRP SSP Catalogs	☐	☐	☐	☐	☑

The Rubin Data Products, Abridged

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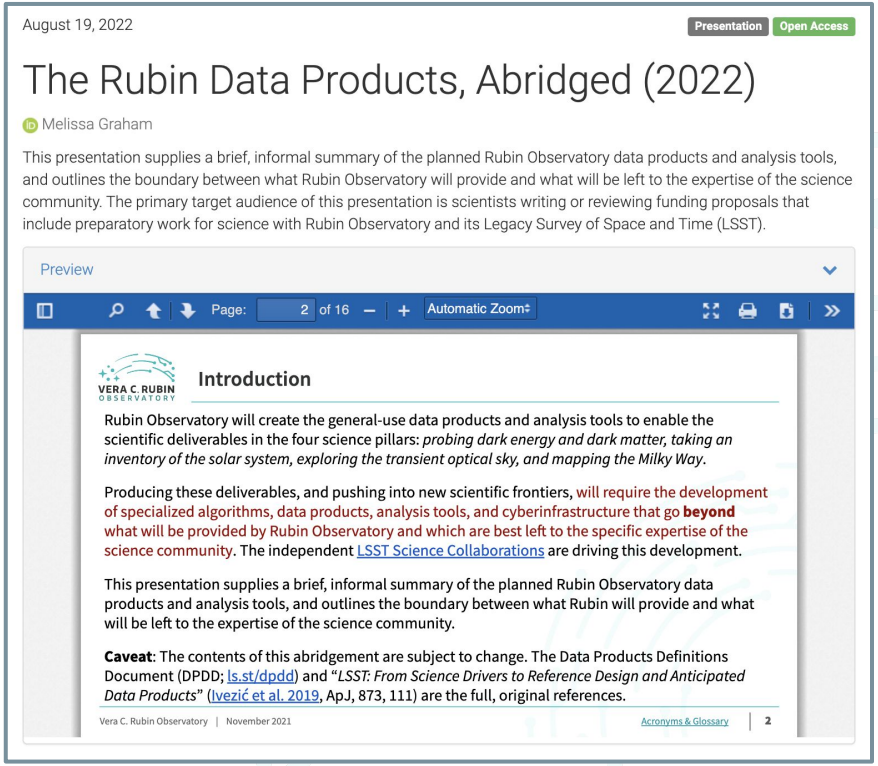
- Introduction to the Rubin Data Products and Rubin Science Platform
- Tells your proposal reviewers what Rubin will provide, and hence what will still need to be developed e.g. by you, if your proposal is successful
- *Can and should be cited in research proposals*



August 19, 2022 — Presentation — Open Access

The Rubin Data Products, Abridged (2022)

Melissa Graham

This presentation supplies a brief, informal summary of the planned Rubin Observatory data products and analysis tools, and outlines the boundary between what Rubin Observatory will provide and what will be left to the expertise of the science community. The primary target audience of this presentation is scientists writing or reviewing funding proposals that include preparatory work for science with Rubin Observatory and its Legacy Survey of Space and Time (LSST).

Preview

Page: 2 of 16 Automatic Zoom

Introduction

Rubin Observatory will create the general-use data products and analysis tools to enable the scientific deliverables in the four science pillars: *probing dark energy and dark matter, taking an inventory of the solar system, exploring the transient optical sky, and mapping the Milky Way*.

Producing these deliverables, and pushing into new scientific frontiers, will require the development of specialized algorithms, data products, analysis tools, and cyberinfrastructure that go **beyond** what will be provided by Rubin Observatory and which are best left to the specific expertise of the science community. The independent LSST Science Collaborations are driving this development.

This presentation supplies a brief, informal summary of the planned Rubin Observatory data products and analysis tools, and outlines the boundary between what Rubin will provide and what will be left to the expertise of the science community.

Caveat: The contents of this abridgement are subject to change. The Data Products Definitions Document (DPDD; ls.st/dpdd) and "*LSST: From Science Drivers to Reference Design and Anticipated Data Products*" (Ivezić et al. 2019, ApJ, 873, 111) are the full, original references.

Vera C. Rubin Observatory | November 2021 Acronyms & Glossary 2

Cite Graham (2022) as follows:

Melissa Graham. (2022, August 19). The Rubin Data Products, Abridged (2022). Zenodo. https://doi.org/10.5281/zenodo.7011229

BibTex available via the DOI zenodo link

Data Previews: a Path to Operations

Goal: To help scientists and students learn to use the RSP's tools and the LSST data products.

Data Preview 0: happening now, based on simulated LSST-like data from the DESC's DC2
Data Preview 1: ~Mar 2024, based on data from the Commissioning Camera (single-raft)
Data Preview 2: ~Jan 2025, based on commissioning data from the Science Camera

How many participants? For DP0, 600. The number of RSP users will scale up throughout the Data Previews, until everyone can have an account by the time of the start of full Operations.

Why is the number of users limited?

- The tools and data products are in *active development*: software is evolving.
- The DP0-era RSP offers limited functionality compared to the future version.
- There remain some risks (e.g., data sharing safeguards, finite compute resources).
- Rubin staff are still limited in their capacity to provide support during DP0.

Alert Generation in Year 1

To maximize the opportunities for Early Science, Rubin will incrementally generate templates during Commissioning and year 1 using the best images available and covering as much sky in as many filters as possible.

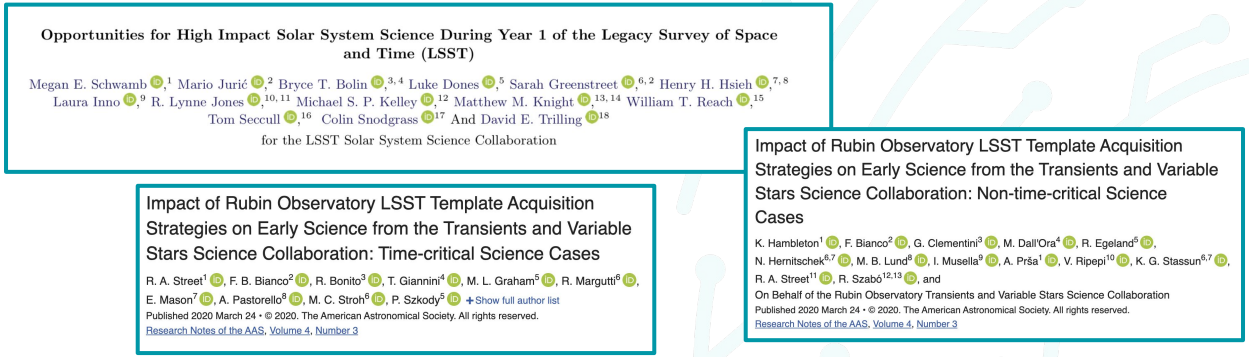
- **Commissioning Data Templates**: Build templates, where possible, from all science-quality commissioning data before the start of year one, and use them to generate alerts during year one
- **Year One Data Templates**: Build templates progressively from data obtained during year one (e.g., on a weekly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

See: DMTN-107: Options for Alert Production in LSST Operations Year 1

Commissioning Data Templates

- Where possible, if commissioning observations are agnostic to pointing and filter, we will endeavour to choose a pointing and filter that optimizes building templates to enable early science.
- Different science drivers naturally lead to different prioritization strategies
  - Milky way science would prefer templates that cover the galactic plane,
  - Time domain science prefes templates in multiple bands vs. single band for a larger area.
  - SN, transient and variable star science prefer templates for all bands in the Deep Drilling Fields.

Several science collaborations have already been pro-active in providing input on considerations for template generation in year one



Opportunities for High Impact Solar System Science During Year 1 of the Legacy Survey of Space and Time (LSST)

Megan E. Schwamb, Mario Jurić, Bryce T. Bolin, Luke Dones, Sarah Greenstreet, Henry H. Hsieh, Laura Inno, R. Lynne Jones, Michael S. P. Kelley, Matthew M. Knight, William T. Reach, Tom Seccull, Colin Snodgrass And David E. Trilling

for the LSST Solar System Science Collaboration

Impact of Rubin Observatory LSST Template Acquisition Strategies on Early Science from the Transients and Variable Stars Science Collaboration: Time-critical Science Cases

R. A. Street, F. B. Bianco, R. Bonito, T. Giannini, M. L. Graham, R. Margutti, E. Mason, A. Pastorello, M. C. Stroh, P. Szkody +Show full author list

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Research Notes of the AAS, Volume 4, Number 3

Impact of Rubin Observatory LSST Template Acquisition Strategies on Early Science from the Transients and Variable Stars Science Collaboration: Non-time-critical Science Cases

K. Hambleton, F. Bianco, G. Clementini, M. Dall'Ora, R. Egeland, N. Hernitschek, M. B. Lund, I. Musella, A. Prša, V. Ripepi, K. G. Stassun, R. A. Street, R. Szabó, and On Behalf of the Rubin Observatory Transients and Variable Stars Science Collaboration

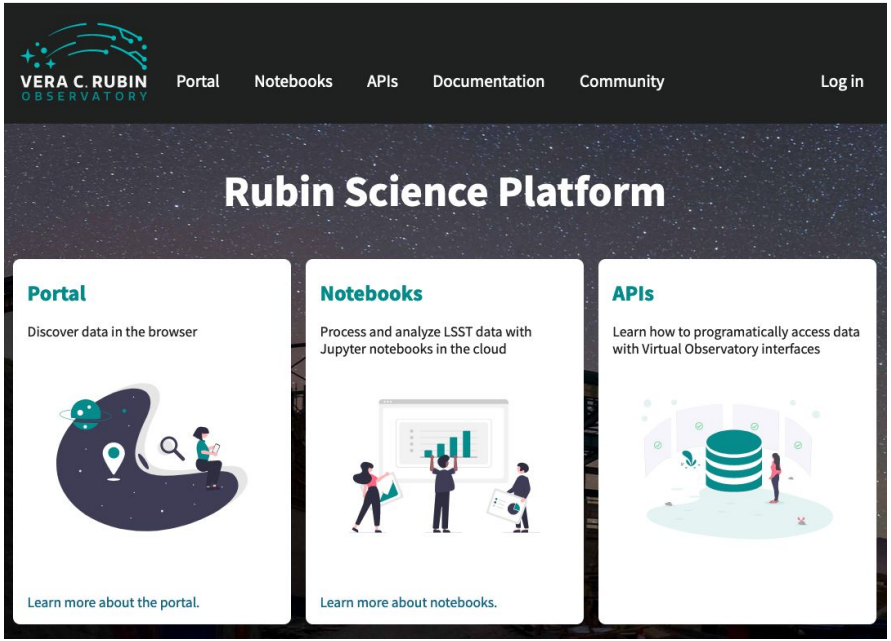
Published 2020 March 24 • © 2020. The American Astronomical Society. All rights reserved.

Research Notes of the AAS, Volume 4, Number 3

Incremental Template Generation

- DM has committed to constructing a system capable of building Image Differencing Templates outside of Data Release Processing:
  - **1.4.5 Template Coadds ID: DMS-REQ-0280 (Priority: 1b)**
    Specification: 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 in year 1 will be built with at least three images (five in subsequent years.)
- Templates are not necessarily built from the first N images that are collected,
- 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.

Access to Early Science Data



LSE-319: LSST Science Platform Vision Document

Next to data, collaborative, cloud computing environment, ~1TB storage and 2 cores per user

LSST Full-Stream Community Brokers

- Alerce
- AMPEL
- ANTARES
- BABAMUL
- Fink
- Lasair
- Pitt-Google

Downstream Brokers

- SNAPS
- POI/Variables

Strengthening your Research Proposal

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- **Position your program relative to Rubin**
  - Cite Graham (2022) to be very clear about what Rubin will *not* provide, and hence *what you need to be funded to do*
  - Cite RTN-011 for the data products expected in each of DP1, DP2 and DR1, to demonstrate your program's feasibility
- **Leverage Rubin and LSST Science Collaboration (SC) resources**
  - Cite your DP0 delegate experience, and/or explain your vision for how the LSST User resources (Graham 2022) on the Rubin Science Platform will enable your program
  - Describe how your research program will benefit from being embedded in your SC
  - Are there in-kind contributions for your SC that may be related to your expertise and that you would like to help direct? Add time to your proposal to technically and scientifically direct a related in-kind contribution for your SC. This will demonstrate leadership, and you can couple the incoming effort to support your planned program.

Getting the Details Right: Early Survey Observations and the SCOC

- Rubin's Survey Cadence Optimization Committee (SCOC) aims to deliver its Phase 2 recommendations for the baseline cadence in Dec. 2022. See: SCOC Handout and SCOC Information.
- The Survey Cadence Optimization Committee (SCOC) will work with the Rubin Survey Scheduling Team to study the impacts of optimizing the early survey (Year 1) observations for early science.
- The SCOC will continue to solicit input from the community on many aspects of the LSST cadence, including the details of the Year 1 observing strategy, see SCOC v2.0 and 2.1 simulations review timeline
- The SCOC will make recommendations for the details of the early survey observations, based on the plans for commissioning and the realized performance of the telescope and software

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Community forum

Science | Early Science | all tags | Latest | Top | Bookmarks | My Posts | + New Topic

Topic	Replies	Views	Activity
Early Science at LSST@Europe4	0	50	14d
ComCam key numbers commissioning, camera	2	94	Aug 14
Rubin Observatory Plans for an Early Science Program technote	2	210	Nov '21
About the Early Science category	0	677	Aug '21
Science-driven prioritization of sky templates during commissioning plans commissioning, observingstrategy	17	872	Mar '20

There are no more Early Science topics. Ready to start a new conversation?

Timeline for Early Science Decisions

Bob

- Very dependent on commissioning
- Will know a lot in a year and will check in every few months.
- Track the celebratory milestones page : DMTN-232

Early Science is coming: get ready!

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Questions and Answers

FAQ: Early Science

What is early science defined as?

- Any science enabled by Rubin for its community through and including the first data release, Data Release 1 (DR1)

Is this all of year 1 observing?

- No, Early Science includes the first 6 months of LSST data, which will be released one year after the start of the survey, as Data Release 1 (DR1)

Will there be any special observing surveys in the first six months?

- No, Rubin Operations will not conduct any observing that is different from the SCOC approved baseline. If the commissioning SV surveys are not completed during construction, they will be completed exactly as planned during the first 3 months of Operations.

FAQ: Incremental Templates

rtn-011.lsst.io states that plans have been revised to include the generation of incremental templates in year 1. Has the ability to create and handle incremental templates been incorporated into the Rubin codebase?

- No, not yet. The requirement to be able to build templates outside of Data Release Processing has been added to the Data Management Requirements.
- Functionality to coadd arbitrary input images does exist; what is needed is an algorithm for selecting those inputs, and some tooling to make this easy to do operationally.

If not, what is the timeline for this work to be completed?

- Start of the LSSTCam Science Verification surveys, ~mid 2024

FAQ: Timeline for decisions

What is the current timeline for early science considerations/decisions?

- Concrete plans for Early Science depend strongly on how we emerge from commissioning. We have defined two scenarios to cover different commissioning outcomes. We expect to be able to provide more details in about a year.

How does the SCOC recommendations on cadence and early science plans play into this?

- We will work together with the SCOC to maximize Early Science while not doing something that would be problematic for the survey cadence.

FAQ: Citing Rubin documents

How do I cite RTN-011 from my LaTeX proposal document?

- Using BibTeX, like this, to cite the latest version of RTN-011:

```
@manual{RTN011,
  title        = {{Rubin Observatory Plans for an Early Science Program}},
  author       = {Leanne  P. Guy and Eric Bellm and Bob Blum and Melissa L. Graham and
                  \v{Z}eljko Ivezi\'{c} and Michael Strauss and Keith Bechtol and
                  Phil Marshall and Robert Lupton},
  month        = oct,
  year         = 2022,
  doi          = {10.5281/zenodo.5683848},
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