Opportunities for Early Science with Rubin Observatory / LSST

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LIneA Webinar
4 March 2021

VERA C. RUBIN OBSERVATORY

OUTLINE

- Introduction to the Vera C. Rubin Observatory and the Legacy Survey of Space and Time (LSST)
- Brief Construction update
- Early Science with LSST and opportunities to get involved

VERA C. RUBIN
OBSERVATORY

Vera C. Rubin Observatory and the Legacy Survey of Space and Time (LSST)

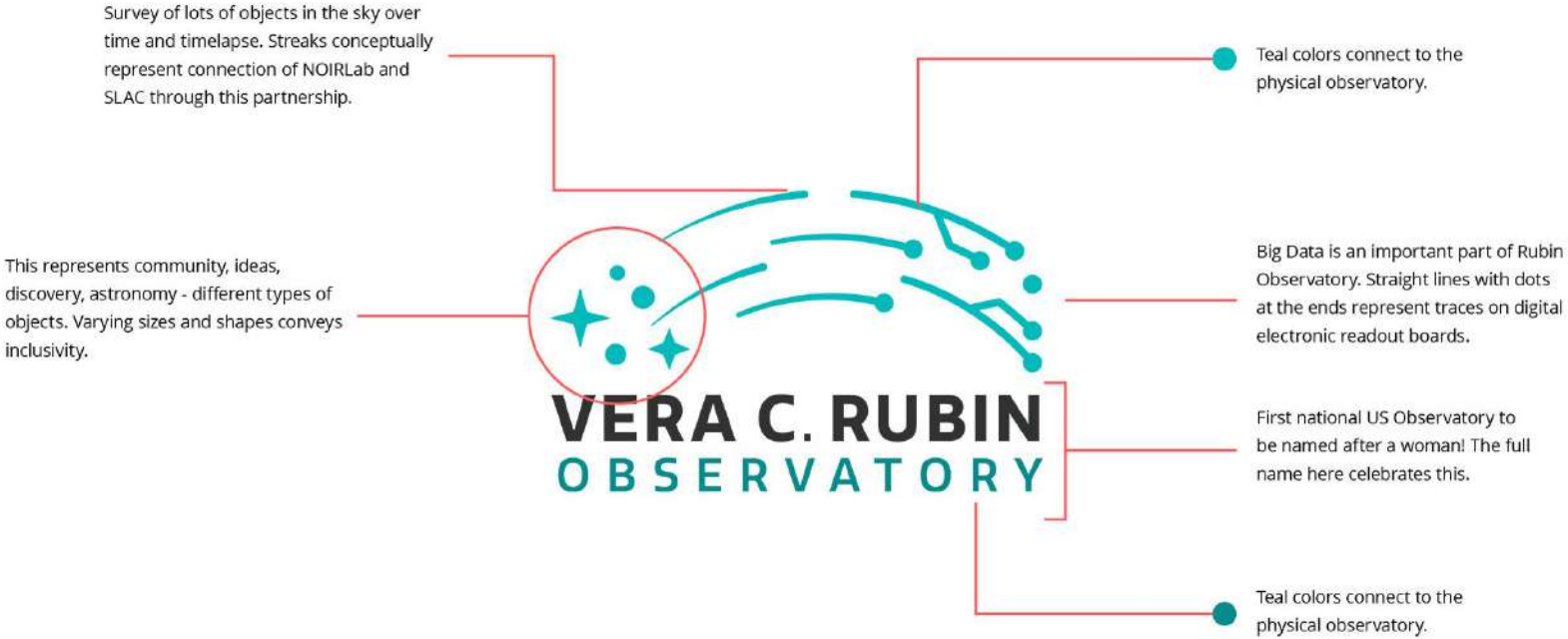
Vera C. Rubin Observatory

- Located on Cerro Pachón in Chile.
- Simonyi Survey Telescope has an 8.4 m diameter primary mirror (6.5 m effective)
- 3.2 Gpix camera with a wide 9.6 deg^2 field-of-view - the size of 40 full moons
- 6 optical-NIR filters: ‘ugrizy’
- High étendue (AΩ) of 319 m^2 deg^2
- Fully automated data processing system

Renaming LSST

- The Large Synoptic Survey Telescope project was formally renamed the Vera C. Rubin Observatory through an act of Congress in early 2020.
- The Rubin Observatory is the first major national scientific facility named after a female scientist. We are proud to be named after Vera Rubin, a pioneering astronomer who made major contributions to our understanding of dark matter.
- The proper short form is the **Rubin Observatory**.
- To continue to honor Vera by maintaining her name "front and center" in scientific papers that result from this high profile observatory, please do not use acronyms such as VRO or VCRO.

New Logo

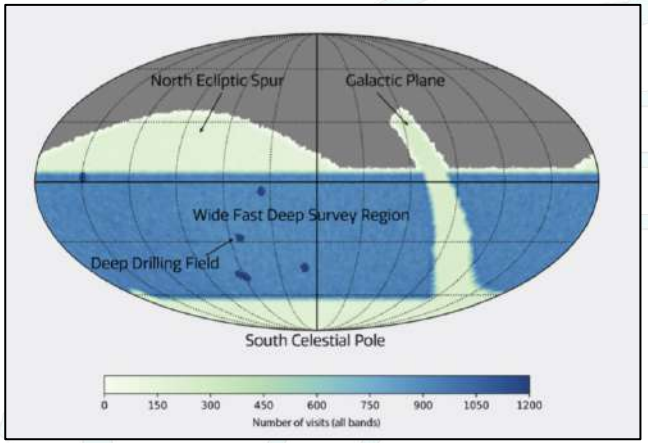


Rubin Visual identity Manual

Legacy Survey of Space and Time (LSST)

In the first 10 years of operation, the Vera C. Rubin Observatory will deliver the Legacy Survey of Space and Time (LSST)

- Covers the southern sky every three nights
- 40 billion Objects over the 10 yr survey
- 20 TB of data per night & 10 million transient alerts per night served by community brokers
- 11 ~annual Data Releases over 10 years
- 15 PB final DR catalog
- 500 PB of image data products
- Data releases have a 2 yr proprietary period

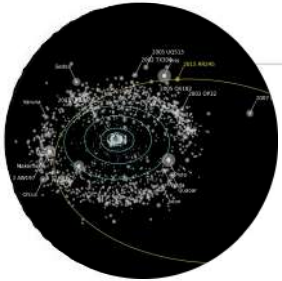


2023-2033

Four Science Drivers

Dark Matter, Dark Energy

- Weak Lensing
- Baryon acoustic oscillations
- Supernovae, Quasars

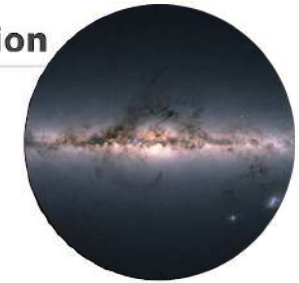


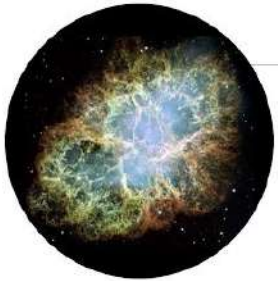
Cataloging the Solar System

- Potentially Hazardous Asteroids
- Near Earth Objects
- Object inventory of the Solar System

Milky Way Structure & Formation

- Structure and evolutionary history
- Spatial maps of stellar characteristics
- Reach well into the halo





Exploring the Transient sky

- Variable stars, Supernovae
- Fill in the variability phase-space
- Discovery of new classes of transients

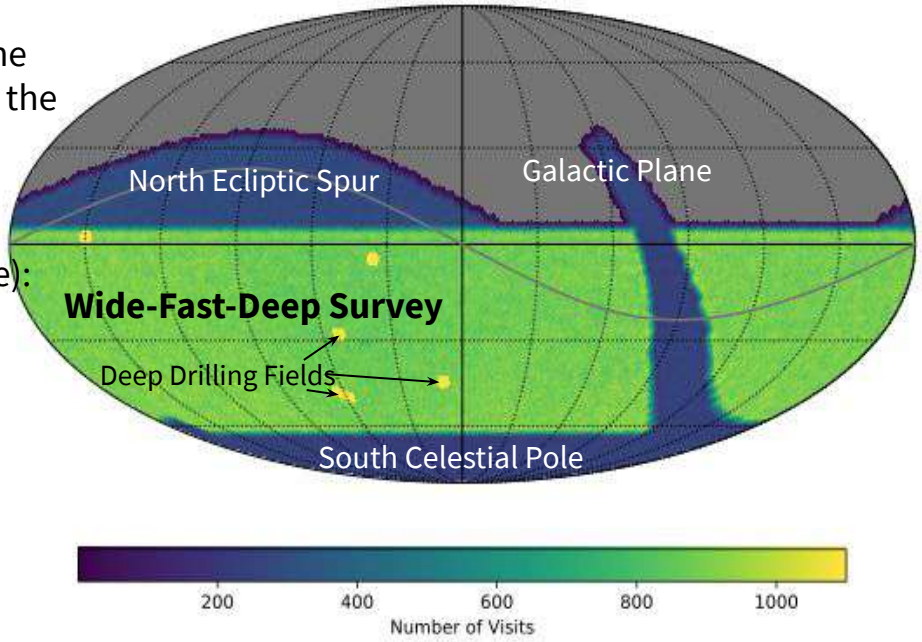
"From Science Drivers to Reference Design", Ivezić et al. (2008), arXiv:0805.2366

LSST Survey Strategy

The **Baseline Survey Strategy** was designed to meet the basic requirements to achieve the core science goals of the **Legacy Survey of Space and Time** (LSST; requirements described in ls.st/srd).

Baseline design elements for the WFD area (90% of time):
- should cover at least 18000 deg^2
- average of 825 visits per field over 10 years
- same-night same-field re-visit “pairs”

Additional areas covered should include:
- at least 4 deep drilling fields
- the North Ecliptic Spur, the Galactic Plane, and the South Celestial Pole



How to optimize the LSST to maximize scientific return is an open question.

Open Questions About Survey Strategy

Wide-Fast-Deep (WFD) or "Main Survey" characteristics:

- **footprint**: How should the Wide-Fast-Deep (WFD) area be defined?
- **cadence**: How often should WFD fields be revisited -- within a night and between nights?
- **filters**: What is the optimal filter distribution for WFD fields?
- **colors**: What are the optimal intra-night filter pairs for WFD field revisits?

Deep Drilling Fields and Mini-Survey Fields

- Should, e.g., Euclid Deep Field South, be added to DDFs? (ELAIS S1, XMM-LSS, Ex CDF-S, & COSMOS)
- What footprints to use for the three mini-surveys? (North Ecliptic Spur, Galactic Plane, South Pole)
- What cadence and filter sequences should be used for these areas?

Gravitational Wave Target-of-Opportunity (TOO) Observations

- How frequently could GW TOO be executed without risk to the core science goals?

Project report to the Survey Cadence Optimization Committee (SCOC) address these and other questions

SURVEY CADENCE OPTIMIZATION COMMITTEE'S TIMELINE FOR CHOOSING THE INITIAL LSST SURVEYING STRATEGY

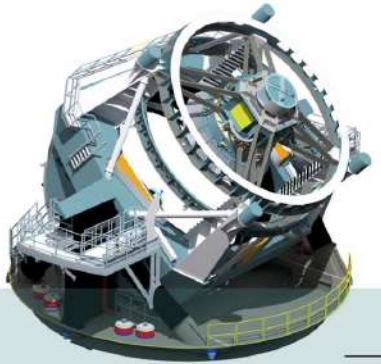
THE SCOC TIMELINE IS SUBJECT TO CHANGE, THIS VERSION IS FROM AUGUST 2020:

- PCW2020: cadence report by the Project delivered to stakeholders
- Nov 2020: the **1st workshop** (virtual)
- Apr 15, 2021: the white paper deadline, followed by SCOC deliberations
- Mar-summer, 2021: a series of Science Collaboration-SCOC liaison telecons
- May 1, 2021: publish details about the 2nd workshop
- Fall 2021: draft SCOC recommendation ready and the **2nd workshop**
- Dec 31, 2021: finalized SCOC recommendation
- Mar 1, 2022: simulations of the recommended strategy available (detailed variations to enable a discussion of fine tuning all the knobs)
- Summer 2022: possibly the **3rd workshop** to fine-tune the recommended strategy, including "early science optimization"
- Dec 31, 2022: the simulation of the adopted observing strategy (the new baseline) produced and made publicly available
- Apr 1, 2023: the observing strategy fixed and implemented in the Scheduler and the Observatory Control Software

Data Processing System

Raw Data: 20TB/night

Sequential 30s images covering the entire visible sky every few days



LSST SCIENCE PIPELINES

Prompt Data Products

Alerts: up to 10 million per night

60s via nightly alert streams

Results of Difference Image Analysis (DIA): transient and variable sources

Solar System Objects: ~ 6 million

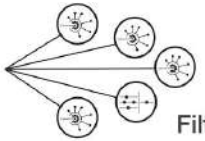
24h via Prompt Products Database

Data Release Data Products

Final 10yr Data Release:

- Images: 5.5 million x 3.2 Gpx
- Catalog: 15PB, 37 billion objects

via Data Releases



Community Brokers

LSST Alert Filtering Service

LSST DACs (Chile & NCSA)

Independent DACs (iDACs)

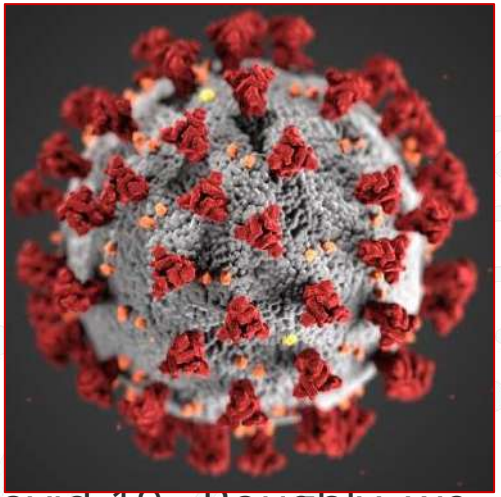
Access to proprietary data and the Science Platform require LSST data rights

LSST Science Platform

Provides access to LSST Data Products and services for all science users and project staff

Current Survey Schedule

The covid-19 pandemic has had a major impact on the Rubin Observatory construction project.



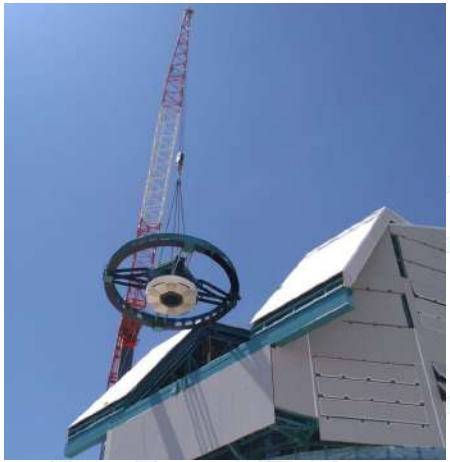
- Engineering First Light ~ May 2022
- LSSTCam first light ~ October 2022
- Rubin Operations is planning for a 01 October 2023 start to full survey operations
- 10 year Legacy Survey of Space and Time: 2024 - 2033

The schedule is in flux as we wrestle with the impacts of covid-19. Roughly, we are planning for a 1 year delay.

Construction Status

Dome has progressed

Telescope Mount Assembly

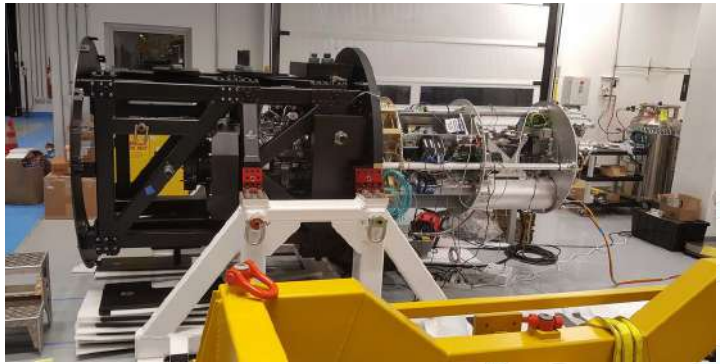


- Work on the Telescope Mount Assembly (TMA) has restarted
- Still travel issues to Chile due to covid-19

Camera System


3.2 Giga Pixel Focal Plane


filter exchange system



- All hardware for the Camera system has been fabricated except for the filters – 22 science and 5 corner rafts, lenses, DAQ, auxiliary electronics, cryostat, utility trunk, shutters, filter exchange system, camera body
- ComCam is now on the summit

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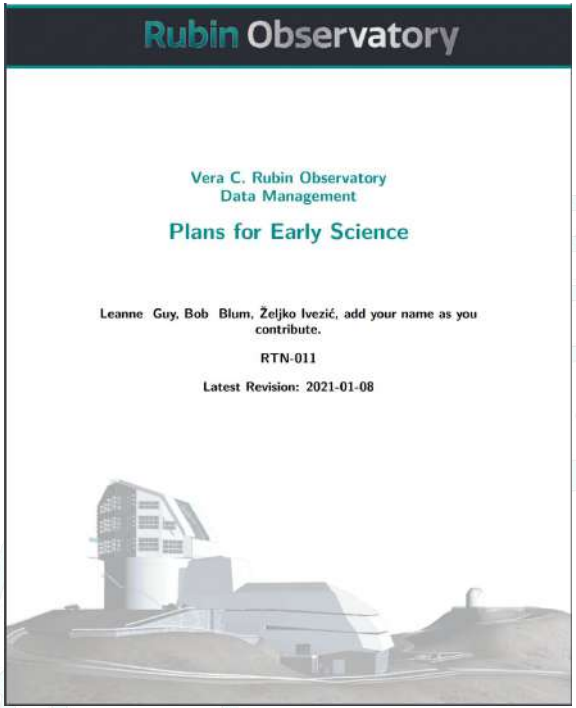
Early Science

Plans for Early Science

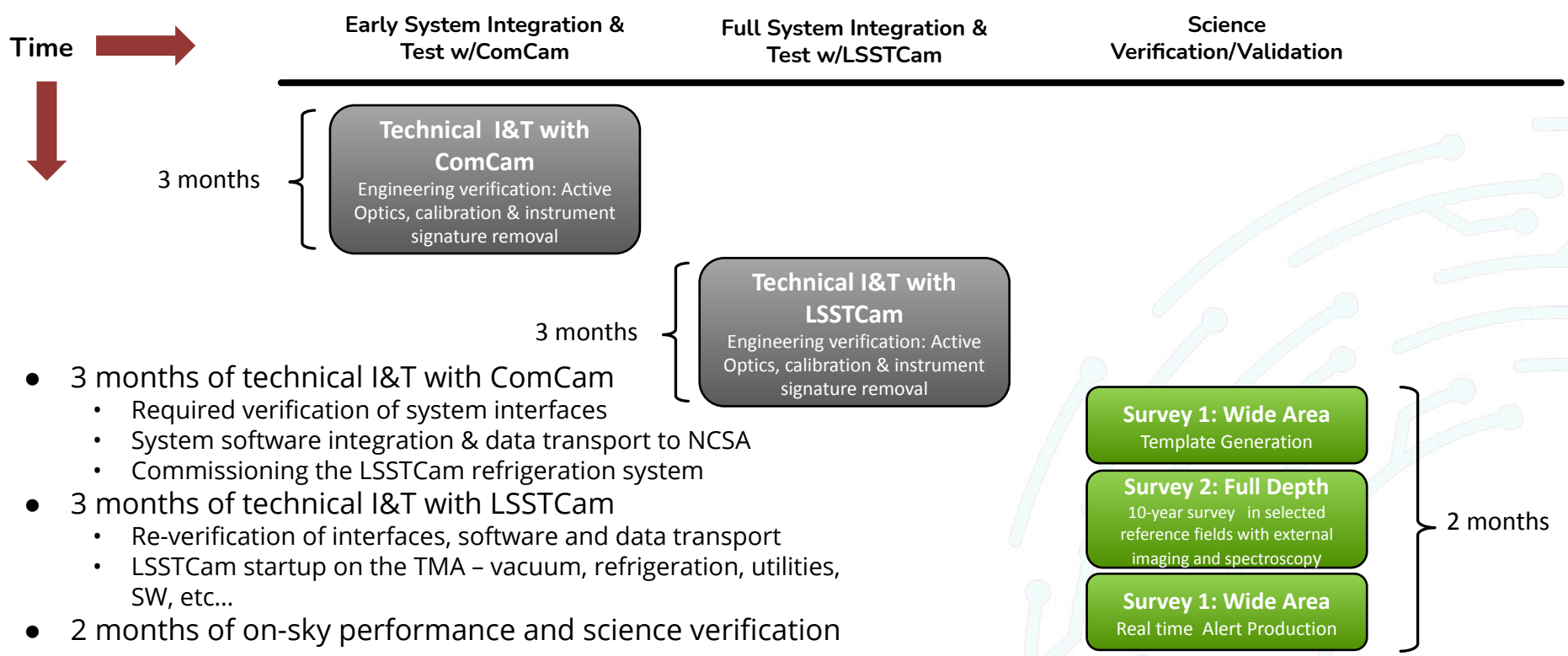
- Science during year one is a priority for Rubin Observatory operations; we are actively planning for Early Science with Rubin.
- RTN-011 will plans and options that Rubin is considering to ensure early science is robust and successful *(draft: work in progress)*
- Initial publication to accommodate uncertainty in Ops start to ~ June 2021.
- Living document ; will evolve over the course of pre-operations



What do we mean by Early Science?

- Early Science is any science enabled prior to the first data release, DR1.
- DR1 is scheduled for release for 12 months after the start of operations (and based on the first 6 months of data),
- Expectations of early science have been built on the basis of substantial science verification and validation surveys, and data previews coming out of commissioning (Rubin PCW2019).
- We have also informal guidance from NSF to ensure early science is evident (i.e. year 1).

Current On-Sky Observing Schedule



- 3 months of technical I&T with ComCam
  - Required verification of system interfaces
  - System software integration & data transport to NCSA
  - Commissioning the LSSTCam refrigeration system
- 3 months of technical I&T with LSSTCam
  - Re-verification of interfaces, software and data transport
  - LSSTCam startup on the TMA – vacuum, refrigeration, utilities, SW, etc…
- 2 months of on-sky performance and science verification

Current Commissioning Data Expectations

Phases of planned on-sky data collection:

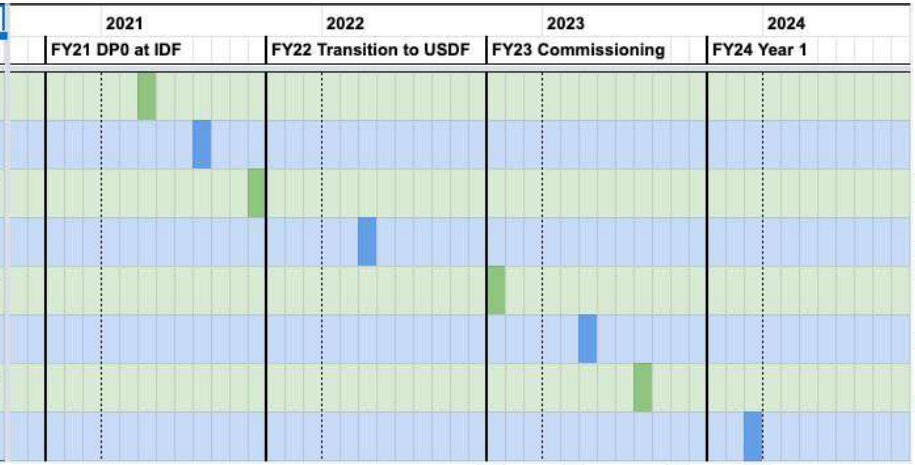
- ComCam and LSSTCam Integration and Test
  - Expect to deliver modest amounts of science-quality imaging (e.g., few hours to few nights)
- Science Verification Surveys (example “minimal” plan)
  - Single-visit Performance:
    - 6 star flats in *ugrizy* * 4 epochs = 4 nights
  - Nominal observing for scheduler testing = 3 nights
  - Challenging regions = 1 night
  - Full-Depth Survey:
    - 20-year depth in *ugrizy* overlapping at least 1 external reference field, allowing multiple dither tests (factor ~3) → ~5K visits = 8 nights
  - Wide-Area Survey:
    - 800 deg^2 in *griz* filters to 1-year equivalent depth, repeated in two phases → ~12K visits = 20 nights

From: Commissioning Science Verification Session, Bechtol & Claver

Pre-Operations Data Previews

Rubin Operations Milestones

Date	Quarter	Milestone
2021-03-31	FY21 - Q2	DP0.1 Early Access: Provide access to processed images and visit level catalogs from the IDF
2021-06-30	FY21 - Q3	DP0.1 Data Release: science-ready catalogs released from the IDF
2021-09-30	FY21 - Q4	DP0.2 Early Access: Provide access to reprocessed images and visit level catalogs from the IDF
2022-03-31	FY22 - Q2	DP0.2 Data Release: science-ready catalogs from reprocessed DP0 images released from the IDF
2022-10-31	FY23 - Q1	DP1 Early Access: provide access to processed images and visit level catalogs from the USDF
2023-03-31	FY23 - Q2	DP1 Data Release: science-ready catalogs released from the USDF
2023-06-30	FY23 - Q3	DP2 Early Access: provide access to processed images and visit level catalogs from the USDF.
2023-12-15	FY24 - Q1	DP2 Data Release: science-ready catalogs from the final Data Preview (LSSTCam SV) released to community from the USDF.



- We are planning a sequence of three pre-survey data releases, the “Data Previews,” in order to develop our capabilities to produce, verify and release LSST data.
- DP0: We are collaborating with the LSST DESC to use their large scale simulated LSST dataset throughout FY21 in the IDF.
- DP1 and DP2: release and support of commissioning data in preparation for the start of survey operations.

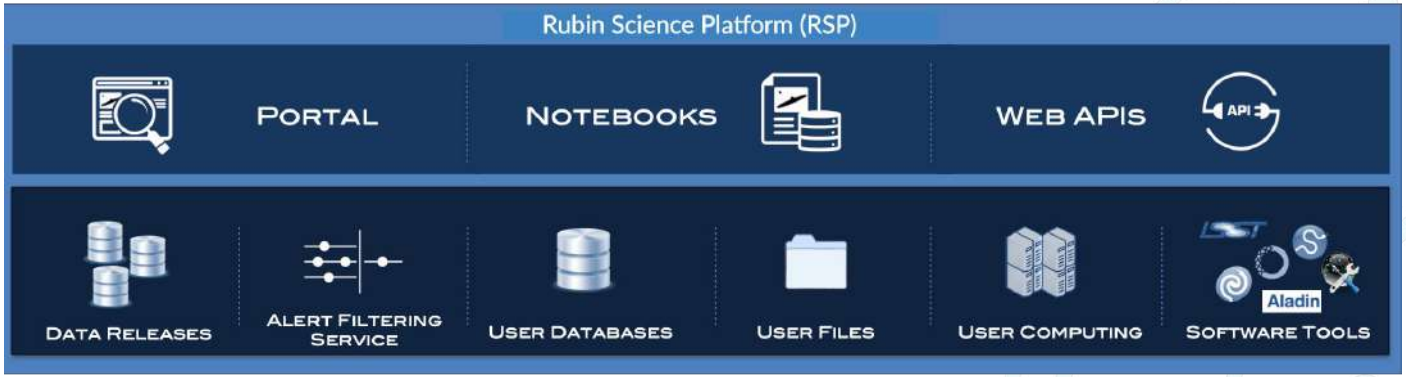
Rubin Science Platform (RSP)

A set of integrated web applications & services deployed at Data Access Centers (DACs) through which the scientific community will access, visualize, subset and perform next-to-the-data analysis of Rubin Data products.

Portal Aspect
exploratory analysis and visualization of the Rubin archive

Notebook Aspect
in-depth 'next-to-data' analysis and creation of added-value data products

API Aspect
remote access to the archive via industry-standard APIs



Rubin Science Platform Vision


LARGE SYNOPTIC SURVEY TELESCOPE

Large Synoptic Survey Telescope (LSST)
Systems Engineering

LSST Science Platform Vision Document

M. Jurić, D. Ciardi, G.P. Dubois-Felsmann, L.P. Guy

LSE-319

Latest Revision: 2019-07-24

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- Enable peta-scale analysis of LSST data
- Exploratory analysis through browsing and visualisation
- Enable discovery by ‘bringing the analysis to the data’
- Supports User-Generated product creation
- Integration with extant archives via IVOA protocols
- Collaborative working environment
- Provision of backend computation and analysis resources

Data Preview Zero

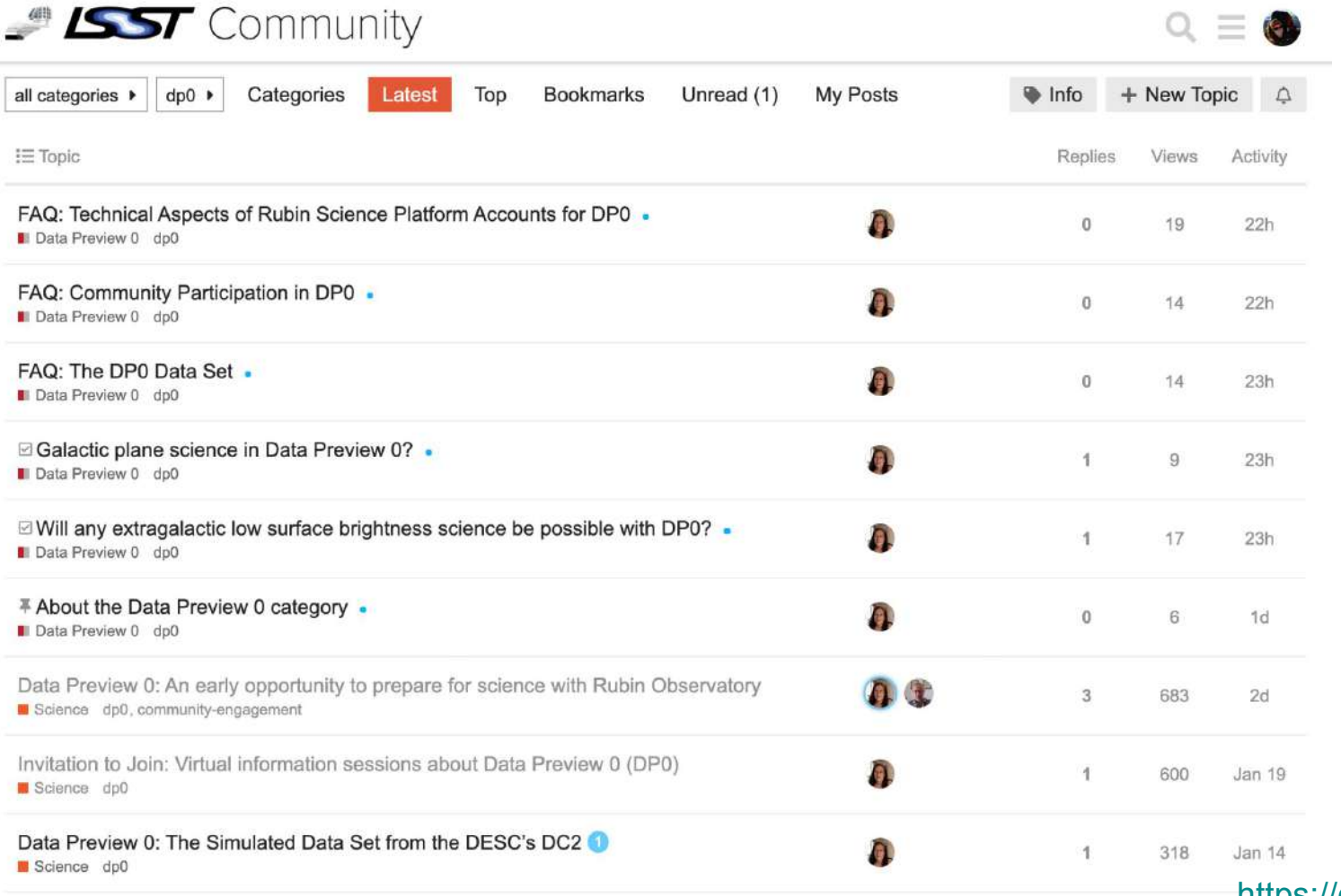
Why: To begin to prepare the community for early science with LSST and to serve as an early integration test of the LSST science pipelines and the RSP.

Who: Up to **300 scientists and students** (+Rubin Obs. staff).

What: Analyzing ***simulated* LSST-like data products** – Images and catalogs from Data Challenge 2 (DC2) by the Dark Energy Science Collaboration (DESC) – "The LSST DESC DC2 Simulated Sky Survey"

Where: In the **Rubin Science Platform** (RSP) at the cloud-based Interim Data Facility (IDF)

When: Applications open in early March, due 30 Apr for access starting 30 June 2021 for individuals with data rights. Rubin Data Policy in ls.st/rdo-013.



https://community.lsst.org/

Ensuring Early Science

Rubin Operations Team is developing a plan to ensure Early Science based around three possible scenarios:

1. Hugely successful commissioning and SV, with many templates generated before year 1 covering a large sky area and filters and a rich dataset.
2. Commissioning goes well but there is little template generation in SV. The system is “ops ready” but templates from commissioning and SV surveys do not cover the full sky nor in all filters.
3. There is still commissioning work work left to do in year 1 for full operations readiness, which would constrain any early science and also the ability to generate lots of templates.

Early Science with minimal SV surveys

- A ~3/6 month “campaign for early science” is a possibility
  - Non-survey activity could delay DR1 and must be reconciled with survey cadence 10-yr science goals.
- What is the best use of time in this period?
  - Align early science as closely as possible with regular survey operations
  - Time domain science enabled by incremental template generation (do SV survey 1?)
  - Provide catalogs (e.g. Magellanic Clouds, DDFs, and other calibration fields)
  - What is needed for cosmology and galaxies?
  - Peer review for one month of community proposals
- We plan to work with the Rubin community to develop this process.

Alert Production in year one

- Alerts are a product of Difference Image Analysis (DIA), which requires coadded transient-free template images.
- Templates are built during Data Release Production (DRP) and made available through LSST Data Releases.
- The LSST Data Release Scenario currently envisages Data Release 1 (DR1) for one year after the start of LSST operations, and to be based on the first six months of data.
- Consequently, Alert Production cannot run at full scale nor full fidelity in year 1.
- “Baseline” science thus implies from year 2.

Strategy for Alert Production in year one

- The DM Science team (DM-SST), recently 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 LSST-PST, DM-SST and LSST Operations Project reviewed the proposed DM-SST options at a meeting in October and converged on a proposed 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.

Template construction during year one

- In year one, template images in each of the u,g,r,i,z,y passbands may be constructed by an independent execution of the Template Generation payload. 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.
- 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.

Implications for year 1 cadence

- Science collaborations have started to publish research notes highlighting early science opportunities in year 1 based on detections in difference images and the requirements on templates (e.g maximize area vs noisier difference images.)
- Different cadences/filters will favour different science; need to run simulations and present the possibilities to stakeholders; choices will need to be made.
- If the year 1 cadence is different, we need to understand the impact on the 10-yr science goals of the survey.

Early Science Data Products

- Data products will include alerts, images and catalogs. The exact set of early science data products will be decided when we are closer to the date.
- All Rubin data rights holders will have access to early science data.
- Distributed via the same services as for data releases; the Rubin Science Platform (RSP), the alert stream, and US Data Facility (USDF) and IDACs.
- Early science data products will differ from the data releases in several ways:
    - May only be a subset of what will be offered in a full data release,
    - Alert production cannot run at full scale nor fidelity until after DR1,
    - Will not have full sky coverage nor in all filters.
- The commissioning data used for early science will not look anything like that of the main survey data - e.g. the temporal sampling for most fields will be considerably more dense.

Community Input to Early Science

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[1], F. B. Bianco[2], R. Bonito[3], T. Giannini[4], M. L. Graham[5], R. Margutti[6], E. Mason[7], A. Pastorello[8], M. C. Stroh[6], P. Szkody[5] +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[1], F. Bianco[2], G. Clementini[3], M. Dall'Ora[4], R. Egeland[5], N. Hernitschek[6,7], M. B. Lund[8], I. Musella[9], A. Prša[1], V. Ripepi[10], K. G. Stassun[6,7], R. A. Street[11], R. Szabó[12,13], and
On Behalf of the Rubin Observatory Transients and Variable Stars Science Collaboration

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Research Notes of the AAS, Volume 4, Number 3

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

Megan E. Schwamb[1], Mario Jurić[2], Bryce T. Bolin[3,4], Luke Dones[5], Sarah Greenstreet[6,2], Henry H. Hsieh[7,8], Laura Inno[9], R. Lynne Jones[10,11], Michael S. P. Kelley[12], Matthew M. Knight[13,14], William T. Reach[15], Tom Seccull[16], Colin Snodgrass[17], And David E. Trilling[18]
for the LSST Solar System Science Collaboration

LSST Community

Any opinions, statements (including statements about LSST and what it will deliver), or recommendations expressed on this forum are those of the author and do not necessarily reflect the views of the LSST Project.

Please take a moment to review our community guidelines.

Science-driven prioritization of sky templates during commissioning plans

Science observingstrategy, commissioning

This is the first time fedhere has posted – let's welcome them to our community!

fedhere Federica 1 Nov '19

Let's generate a science-driven optimization of the template collection and generation plan for LSST during commissioning.

Nov 2019

1 / 18
Nov 2019

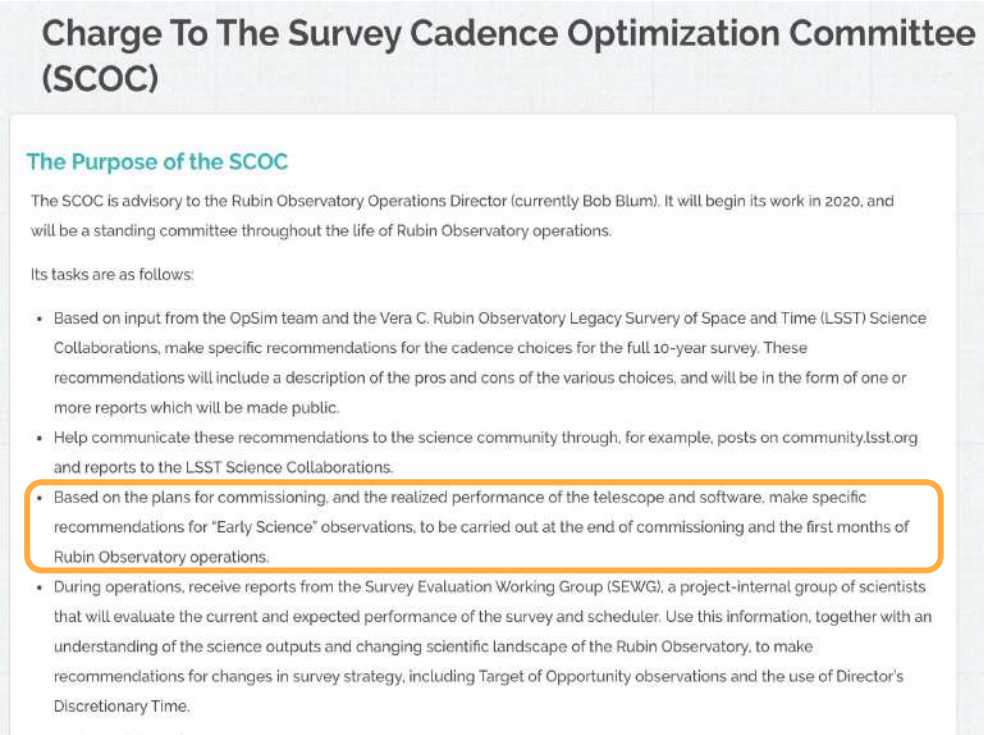
Community Input to Early Science

Some science-based observations and considerations from community input:

- High impact Solar System science prefers template generation options that maximize the sky coverage.
- Time critical TVS science enhanced by templates in multiple filters, preferably r and g bands
- To address the large range of variability timescales templates generated from images collected at a range of time separations is desirable
- DESC SN and SL WGs emphasize important of building good DDF templates in commissioning for SN science operations to begin in year 1,
- Noisier image subtraction compared to DR1 preferred to no DIA at all

Coordination of Early Science

- Working with the Survey Cadence Optimization Committee (SCOC) and Science Advisory Committee (SAC) to coordinate the Early Science and the initial survey cadence.
- SCOC recommendations on Early Science will be considered by Operations Director.



Charge To The Survey Cadence Optimization Committee (SCOC)

The Purpose of the SCOC

The SCOC is advisory to the Rubin Observatory Operations Director (currently Bob Blum). It will begin its work in 2020, and will be a standing committee throughout the life of Rubin Observatory operations.

Its tasks are as follows:

- Based on input from the OpSim team and the Vera C. Rubin Observatory Legacy Survery of Space and Time (LSST) Science Collaborations, make specific recommendations for the cadence choices for the full 10-year survey. These recommendations will include a description of the pros and cons of the various choices, and will be in the form of one or more reports which will be made public.
- Help communicate these recommendations to the science community through, for example, posts on community.lsst.org and reports to the LSST Science Collaborations.
- Based on the plans for commissioning, and the realized performance of the telescope and software, make specific recommendations for "Early Science" observations, to be carried out at the end of commissioning and the first months of Rubin Observatory operations.
- During operations, receive reports from the Survey Evaluation Working Group (SEWG), a project-internal group of scientists that will evaluate the current and expected performance of the survey and scheduler. Use this information, together with an understanding of the science outputs and changing scientific landscape of the Rubin Observatory, to make recommendations for changes in survey strategy, including Target of Opportunity observations and the use of Director's Discretionary Time.

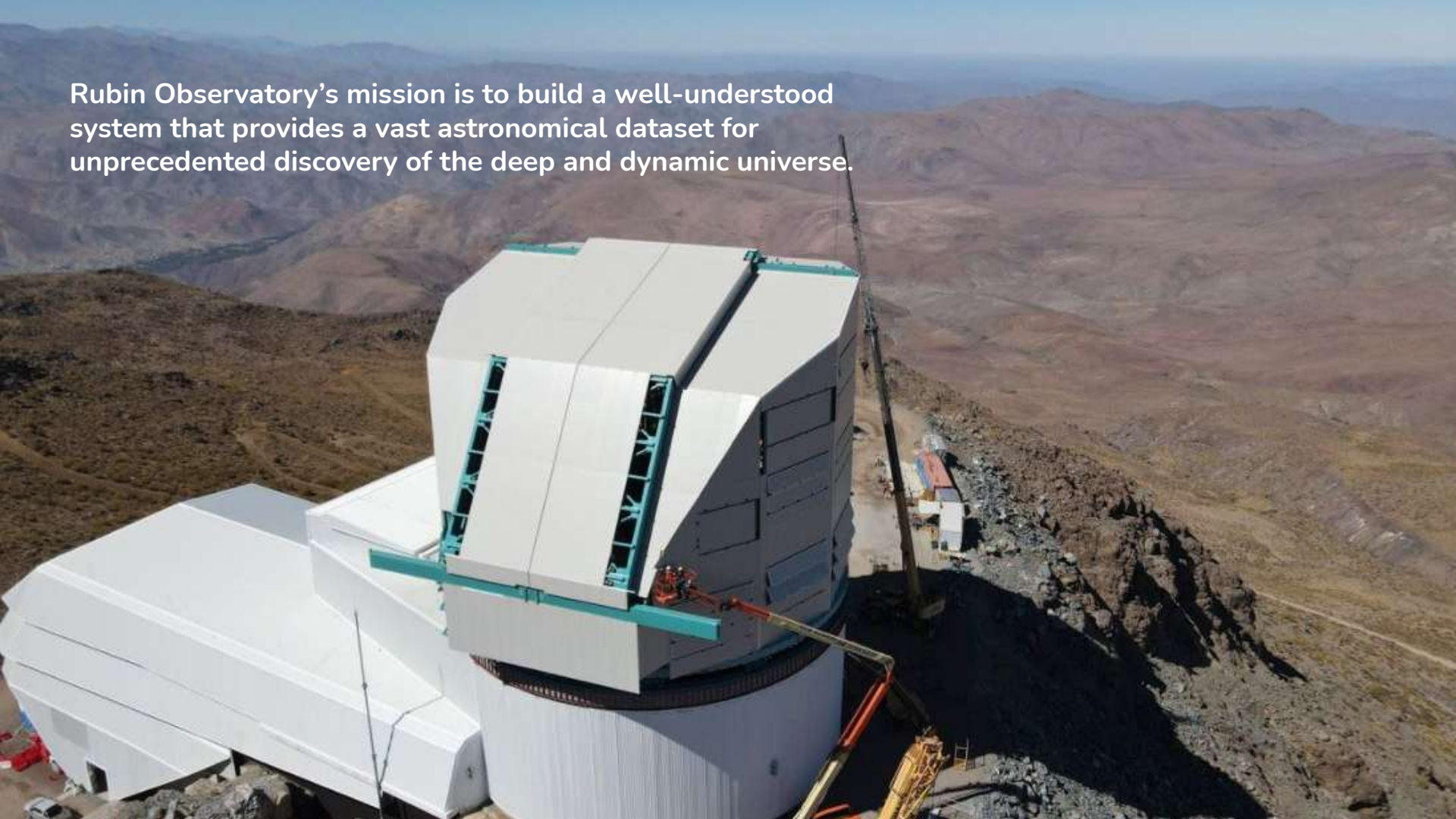
Timeline for Early Science

- Reach out to all science collaborations, ensure they have had the chance to give input. Agree on a process for providing input. ~ July 2021
- Review community feedback on Alert Generation in year 1, understand what is possible and what the implications of the various scenarios are, and then present it to the SCOC for their recommendation.
- Rubin full operations proposal now planned for Dec 2021.

Resources

- Science Drivers to Reference Design and Anticipated Data Products (Ivezic et al. 2008, Version 5: May 2018) : ls.st/lop
- LSST Science Requirements :
- LSST Data Products Definitions Document
- LSST DM Science Pipeline Design
- LSST Science Platform Vision Document

- Rubin Observatory Community Forum



Rubin Observatory's mission is to build a well-understood system that provides a vast astronomical dataset for unprecedented discovery of the deep and dynamic universe.