Introduction to Rubin Commissioning

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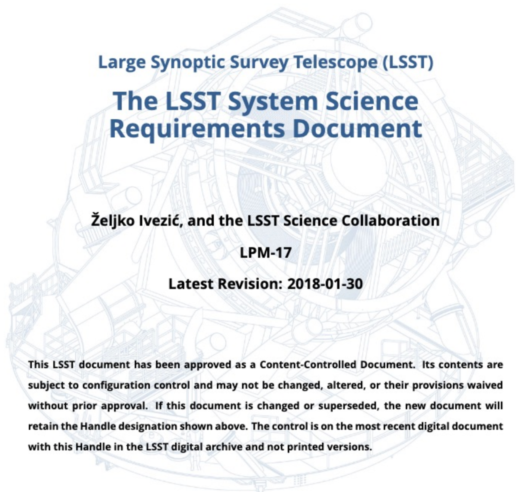
Many slides by Keith Bechtol, Rubin Observatory System Verification and Validation Scientist

ASTR 597A
7 March 2023

Rubin Requirements

The scope of Rubin construction is defined by requirements documents.



LARGE SYNOPTIC SURVEY TELESCOPE

Large Synoptic Survey Telescope (LSST)

The LSST System Science Requirements Document

Željko Ivezić, and the LSST Science Collaboration

LPM-17

Latest Revision: 2018-01-30

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3.3.2.1 The overall image depth distribution

Specification: The distribution of the 5σ (SNR=5) detection depth for point sources for all the exposures in the r band will have a median not brighter than D1 mag, and no more than DF1 % of images will have a 5σ depth brighter than Z1 mag. The implication of many exposures only formally violates the paradigm of a single image specification in this section; this requirement can be understood as a probability distribution for the attained depth (DF1 is the fraction not of all exposures, but of those in the r band in good seeing on photometric dark nights and close to the zenith, corrected to the fiducial parameters listed in Table 5).

Quantity	Design Spec	Minimum Spec	Stretch Goal
D1 (mag)	24.7	24.3	24.8
DF1 (%)	10	20	5
Z1 (%)	24.4	24.0	24.6

TABLE 5: Single image depth in the r band (SNR=5 for point sources). The D1 and Z1 values are expressed on the AB magnitude scale and assume a source with spectral energy distribution F_ν=constant, fiducial seeing of 0.7 arcsec (FWHM), fiducial dark sky brightness of 21 mag/arcsec^2, airmass of 1.0, and a total exposure time of 30 sec. The sky brightness is a conservative estimate corresponding to solar maximum. Solar minimum value may be 0.3-0.4 mag fainter, resulting in ~0.2 mag deeper data. On the other hand, about ~0.2 mag loss of depth is expected for data obtained at airmass of 1.4 (mostly due to seeing degradation).

For a given exposure time and observing conditions, the required depths primarily constrain the effective primary mirror diameter and overall (hardware + atmosphere) system throughput. The chosen exposure time per visit (2×15 sec) is a result of the survey optimization and satisfies both the required final coadded depth, single visit depth, and the revisit time if the effective primary mirror diameter is 6.5m. The single visit depth is driven by transient sources and motion measurements (for both Solar System objects and stellar proper motions) and the coadded depth is driven by the required number of galaxies for cosmological studies (see §3.4.0.1).

The scope of Rubin construction is defined by requirements documents.

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Specification: Images and catalog data will be released to publicly-accessible repositories as soon as possible after they are obtained. This latency, and the exact form of the data to be continuously released, are left unspecified at this time pending further discussion within the project. Data on likely optical transients, however, will be released with a latency of at most OTT1 minutes.

Quantity	Design Spec	Minimum Spec	Stretch Goal
DRT1 (year)	1.0	2.0	0.5
OTT1 (min)	1.0	2.0	0.5

TABLE 28: Requirements for the data release cadence and for the transient reporting latency.

The scope of Rubin construction is defined by requirements documents.

Rubin Observatory

Vera C. Rubin Observatory

LSST System Requirements (LSR)

Charles F. Claver and the LSST Systems Engineering Integrated Project Team

LSE-29 (rel7.1)

Latest Revision Date: March 5, 2020

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LSST System Requirements | LSE-29 (rel7.1) | Latest Revision Date 2020-03-05

1.5.1.1 Data Processing for Single Visits and Transients

ID: LSR-REQ-0101

Requirement: The LSST shall meet the following specification for reporting of data on optical transients detected in single-visit data: **OTT1**, **transN**, and **transSNR**.

Discussion: It is unclear whether the SRD specification of **transN** refers to the number of alerts that can be generated for a single visit (i.e. an instantaneous limit), or the number per visit averaged over time.

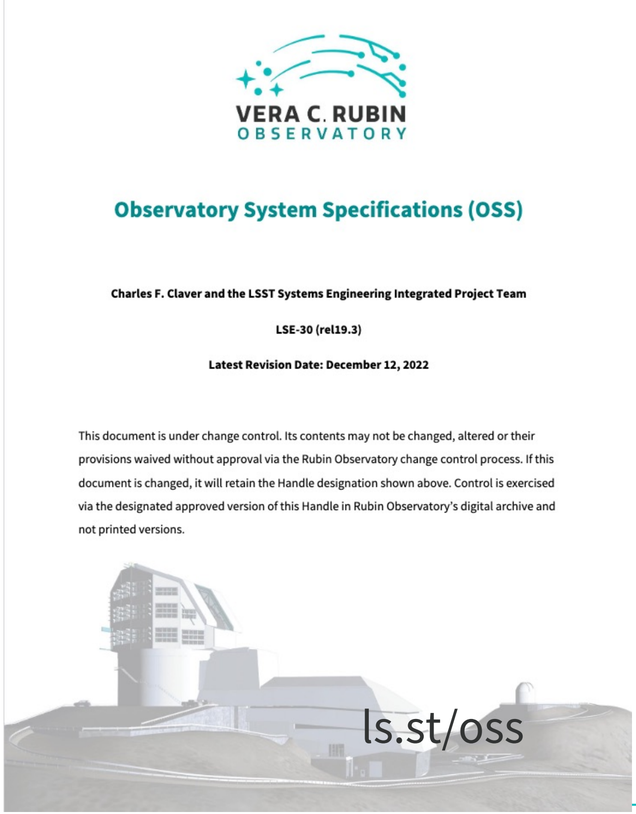
Description	Value	Unit	Name
The latency of reporting optical transients following the completion of readout of the last image of a visit	1	minute	OTT1

Description	Value	Unit	Name
The minimum number of optical transients for which data can be reported per visit	1.0e4	unitless	transN
The signal-to-noise ratio in single-visit difference images above which all optical transients are to be reported.	5	float	transSNR

Derived from requirements:

LSR-REQ-0023: Optical Transient Event Detection

The scope of Rubin construction is defined by requirements documents.


VERA C. RUBIN OBSERVATORY

Observatory System Specifications (OSS)

Charles F. Claver and the LSST Systems Engineering Integrated Project Team

LSE-30 (rel19.3)

Latest Revision Date: December 12, 2022

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Description	Value	Unit	Name
Maximum time from the acquisition of science data to the release of associated Level 1 Data Products (except alerts)	24	hour	L1PublicT
Fraction of detectable alerts for which an alert is actually transmitted within latency **OTT1** (see LSR-REQ-0101).	98	percent	OTR1
The latency of reporting optical transients following the completion of readout of the last image of a visit	1	minute	OTT1
Time images and other products (except alerts) will be embargoed before release to the consortium (or the public)	6	hour	L1PublicTMin

Derived from requirements:

LSR-REQ-0104: Level 1 Data Product Availability

LSR-REQ-0118: Level 1 Data Product Availability for Solar System Objects

The scope of Rubin construction is defined by requirements documents.

Data Management System (DMS) Requirements

Gregory Dubois-Felsmann, Tim Jenness

LSE-61 (rel9.1)

Latest Revision Date: December 12, 2022

ls.st/dmsr

2.2.3.1 Alert Stream Distribution

ID: DMS-REQ-0391 (Priority: 2)

Specification: LSST shall be capable of supporting the transmission of at least **numStreams** full alert streams out of the alert distribution system within **OTT1**.

Discussion: This requirement establishes the minimum capacity needed for timely transmission of alerts to community brokers.

Description	Value	Unit	Name
The minimum number of full streams that can be transmitted out of the alert distribution system.	5	integer	numStreams
The latency of reporting optical transients following the completion of	1	minute	OTT1

We need to verify and validate those requirements to complete Rubin.

Verification: does what we built meet the specified requirements?

Validation: does what we built work? Can users accomplish the science goals we set for the LSST?

Commissioning is the period in which we verify and validate Rubin and prepare to enter operations.

Commissioning Goals

Big Picture Goals

Is the as-built system capable of routinely acquiring raw pixel-level data that will support the science goals of the 10-year LSST survey?

(e.g., throughput, delivered image quality, capability to calibrate)

Do we understand the distribution of delivered data quality and how **hardware, software, and observatory operations together** contribute to generating science-ready data products?

Science Verification View of Commissioning

LSSTCam

Electro-optical Testing at Level 3	In-dome Engineering	On-sky Engineering	System Optimization	Science Validation Survey(s)
EO testing	EO testing in-dome calibration systems	optical alignment pointing tests AOS look-up table initial science verification	tuning control loops scheduler testing observing efficiency and science performance over range of conditions	>30 days sustained observing exercising operations procedures continued science validation of coaddition and difference imaging
Level 3 System Integration Complete	**Start On-Sky Engineering**	**Start System Optimization**	**Start Science Validation Surveys**	**Start 10-year LSST**
LSSTCam reverification complete DM ready for bulk data collection	calibration products pipeline verified	routinely producing science-grade images over the full field of view verified system throughput, delivered image quality	verified ISR application for on-sky images verified visit-level PSF modeling, astrometric + photometric calibration	Science Pipelines delivered science verification complete

Prioritization of Commissioning SVV Studies

Fixed by the telescope, camera, and observing strategy

Image quality (PSF profile, ellipticity), system throughput, ghosts/scattered light, sky brightness and readout noise, detector anomalies

Instrument signature removal

Threshold for starting System Optimization

Visit-level PSF modeling, photometric, and astrometric calibration

Coaddition, difference imaging, deblending, galaxy photometry including shape measurement, moving object link-age, and proper motions

Potential to be continually improved through refinements of the Science Pipelines

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Potential to be continually improved through refinements of the Science Pipelines

Image quality (PSF profile, ellipticity), system throughput, ghosts/scattered light, sky brightness and readout noise, detector anomalies

Instrument signature removal

Operations Readiness Review

Visit-level PSF modeling, photometric, and astrometric calibration

Coaddition, difference imaging, deblending, galaxy photometry including shape measurement, moving object link-age, and proper motions

Commissioning Science Units

Science Units Overview

System-level science verification and validation efforts organized around a collection of **Science Units** to

- Inform commissioning activities
- Ensure coverage (and spread the load) of science analyses needed to demonstrate construction completeness / operational readiness
- Perform additional science validation studies across a range of topics that will stress the system in different ways related to the primary LSST science drivers and beyond
    - Science Units should feel empowered to develop science validation analyses that extend beyond formal requirements / quantitative specifications
- Bring together expertise from across Rubin Observatory and in-kind contributions
    - Science Units include both Rubin Observatory staff and SIT-Com in-kind contributors
    - All SIT-Com in-kind contributions (SITCOMTN-050) are considered directable effort

Science Units Overview

Each Science Unit has 1-2 “coordinators” / “leads” (Rubin staff) to provide scientific leadership and coordination for the effort

The list of individuals named as SIT-Com Science Unit coordinators is not intended to be exclusionary in any way, but rather to ensure that *someone* is accountable for the substantial amount of effort needed to evaluate and document the scientific performance of the as-built system

Everyone will be working on commissioning when we are on sky

The boundaries between Science Units are intentionally soft, and individuals can contribute in multiple areas

Science Units

- **Throughput for focused light** – Merlin Fisher-Levine
- **Delivered image quality and PSF modeling** – Josh Meyers
- **Instrument signature removal / detector characterization** – Chris Waters and Yousuke Utsumi
- **Sky background / low surface brightness / ghosts and scattered light** – Lee Kelvin
- **Photometric calibration** – Jeff Carlin
- **Astrometric calibration / proper motions** – Clare Saunders
- **Survey performance / survey strategy optimization** – Lynne Jones and Leanne Guy
- **Object detection, quality flags, V&V sample production, survey property maps** – Peter Ferguson
- **Difference image analysis – transient and variable objects** – Eric Bellm
- **Difference image analysis – Solar System objects** – Mario Juric
- **Galaxy photometry / photo-z** – Dan Taranu and Melissa Graham
- **Weak lensing shear** – Arun Kannawadi
- **Crowded stellar fields** – TBD
- **Eyeball squad / beautiful images** – TBD
  Science Pipelines representative and EPO science representative

Charge to Science Units

- Develop **methods/algorithms for evaluating science performance of the as-built system**, including identifying needs for on-sky observations and external reference datasets, for a set of formal requirements from the OSS and LSR (see charge for details)
- Assist Science Pipelines to **implement and test software to generate diagnostic metrics and plots**; develop additional code for specialized analyses
- **Suggest, prioritize, and perform ad hoc and science validation investigations** using on-sky commissioning data; report issues and recommend potential solutions and/or further studies
- **Document the results** in the form of tech notes and (sections of) Construction Papers

Science Verification and Validation Deliverables for Operational Readiness Review

- **Verified system-level requirements** in LSR + OSS
  - Roughly 200 normative "science performance" requirements for which verification involves using data from science pixels
  - Detailed specifications, test plans and reports, final compliance status
  - Impact studies in cases of non-compliance
- Documented set of **science verification and validation analysis software and visualization** capabilities to provide to Operations
- **Studies to inform LSST Operations** based on commissioning on-sky observations, e.g.,
  - Correlating delivered data quality with environmental conditions / telemetry
  - Minimum number of visits and quality of visits to use for template generation for difference imaging
  - Dithering strategy in both WFD and Deep Drilling Fields
  - Visit definition as 2 x 15 sec snaps versus 1 x 30 sec
- Drafts of **construction papers**
  - Additional publications and tech notes to document details
- Press **images**

See Science Unit deliverables on next slide

Science Unit Deliverables

- For system-level requirements, document science methodology to evaluate performance in dedicated technote linked from Jira LVV system
  - Target audience includes Systems Engineers, developers, and general LSST science users
  - Contains algorithmic description at the level of pseudo-code, including mathematical procedures as well as pass / fail criteria
  - Rubin Science Performance Metrics (RTN-038) – placeholder at the moment
- Implementation of science performance analyses as software
  - Science Pipelines (e.g., ComputeExposureSummaryStatsTask, analysis_tools, cp_verify)
    - Recommended default for analyses that touch calibration, image, or catalog-level data products directly
  - Stand-alone analyses
    - Utilities / scripts / notebooks residing in separate (Project-controlled) code repos?
- "Narrative" documentation
  - Technotes to describe detailed analyses
  - Sections of relevant construction papers
  - Additional infrastructure papers on specific topics

Overview of Commissioning On-sky Observing Campaigns

Sequence of planned on-sky activities are designed around verification objectives

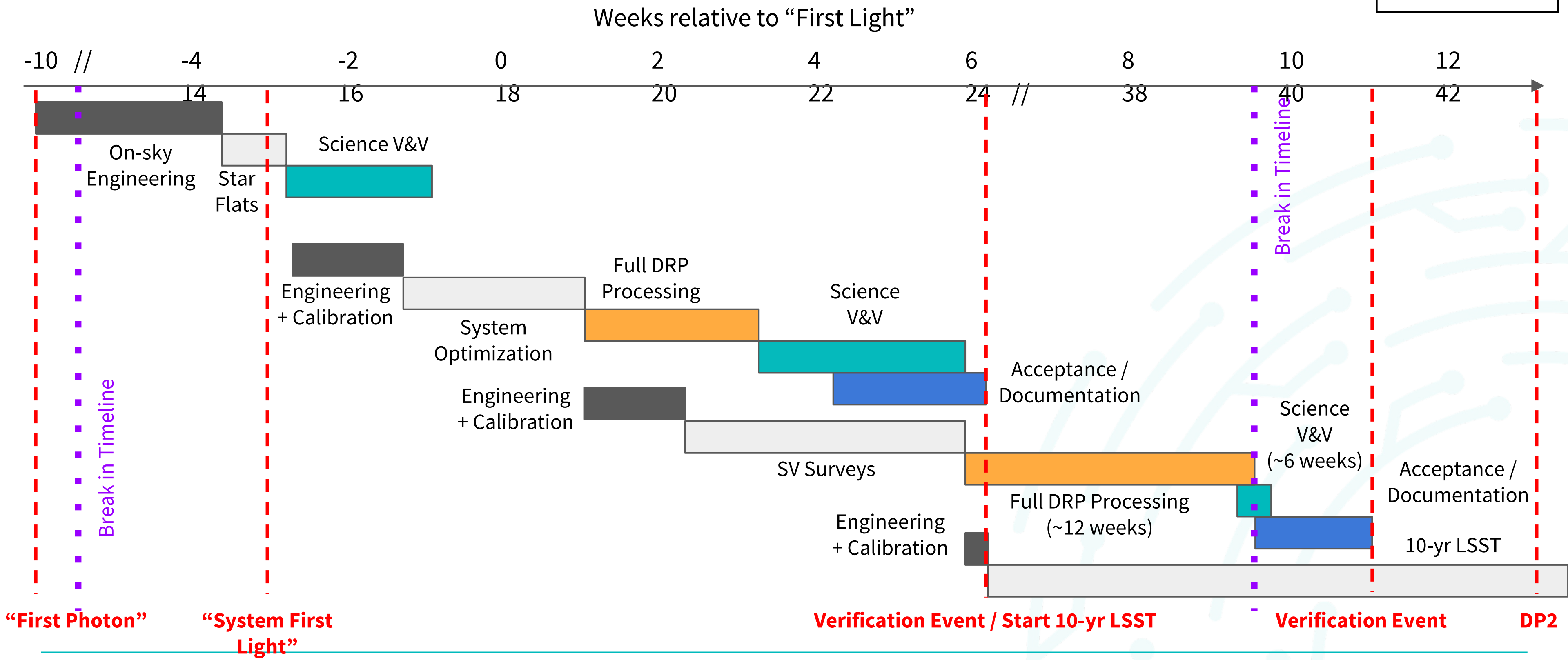
1. Have we built a functional observatory that is capable of safely acquiring science-grade images at a range of (alt, az) coordinates with the expected system throughput and image quality, and provide near-realtime feedback on the single-visit image health to inform nighttime operations
   - **On-sky Engineering**
2. Do we understand the system performance under a range of conditions, and have we demonstrated the ability to generate and scientifically verify the full set of expected data products including from deep coadds and difference image analysis
   - **System Optimization**
3. Is the Operations Team ready to continuously operate the Rubin Observatory in survey mode, including all daytime and nighttime tasks at the summit and data processing facilities, as well as maintenance
   - **“Science Validation Survey” (Operations Rehearsal Observing Campaign)**
4. Is the Operations Team ready to serve scientifically validated and documented Prompt and Data Release data products at the scale of an LSST Data Release to the LSST Science Community
   - **Data Previews**

Assumptions

- Time between first photons and first light is ~10 weeks (TBC)
  - Dominated by on-sky engineering activity rather than science-driven activity
  - Some AOS commissioning that would have been done with ComCam now will done with LSSTCam
- Allocate time for data processing after completion of observing campaign to consistently re-process and to build deep coadds as well as templates for DIA
  - ~2 weeks for star flat dataset
  - ~4 weeks for 20-year depth test dataset
  - ~12 weeks for Science Validation Surveys
  - Plan to process and analyze subsets of data as it is being acquired to preview expected data properties and make adjustments to data processing
- Allocate time for scientific interpretation
  - Estimated time increases with range of data products and complexity of analyses
- Allocate ~4 weeks between completing scientific analysis and "verification event"
  - Acceptance testing, documentation, preparing materials for stakeholders, etc.

* Higher fidelity representation would show interleaved engineering, multiple data processing campaigns + iteration, etc.

Highly Simplified LSSTCam Timeline



Commissioning LSSTCam Data Processing Campaigns

Trying to describe commissioning needs rather than detailed process / mechanism

- LSSTCam daily calibrations
- LSSTCam “rapid analysis” for feedback to inform nighttime operations
  - Requires measurements of basic delivered image quality, optical throughput, on bright stars in individual visits across the focal plane; produce science performance metrics
- LSSTCam more comprehensive single-frame processing to inform 24 hour cycle of commissioning activities
  - Begin single-visit science verification and validation; evaluate observing campaign progress; evaluate which visits are suitable to begin building coadds / templates
  - Most useful if available by the “next morning”
- LSSTCam coadd / template building campaigns to verify and validate data release products
  - Propose to concentrate our efforts on a smaller number of coherent datasets that each have a clear purpose
  - Anticipate that data processing campaign is incremental in the sense that we are evaluating intermediate data products and testing on subsets of data (e.g., a few tracts at a time) as it is being collected before bulk processing on the full dataset
  - Anticipate multiple processing
  - Specialized processing with different configurations, different subsets of visits, etc.
- LSSTCam processing to verify and validate prompt products
  - Could start with canned replays and move towards realtime

Community Input

Managing Expectations

Data content from commissioning is a “shared risk” / “best effort” situation:

- **Rubin Observatory needs to prioritize technical and scientific verification of formal system requirements to demonstrate construction completeness in a timely fashion**
- The detailed schedule for on-sky commissioning observations is TBD
- The Commissioning Team has already been planning to acquire on-sky observations that would enable science validation studies for the four main LSST science drivers
  - Guidance from science community is welcome and appreciated to enhance opportunities for science validation studies based on commissioning data
- Commissioning observations are NOT an observing proposal / TAC process
- We cannot ensure that any particular observations will be taken during commissioning

Rubin Observatory Operations plans to release subset of commissioning on-sky data products from ComCam and LSSTCam as Data Preview 1 and Data Preview 2, respectively (draft RDO-011)

Community Input to On-sky Observing Strategy

Phase 1 (2020):

- LSST Community Post welcoming community input in the form of brief "commissioning notes"
- Parallel Session at PCW 2020, including 6 presentations from representatives of SCs
- Participated in workshops with individual SCs as requested
- Commissioning notes received from SSSC, TVS + SMWLV, Galaxies, SLSC, and DESC
  - Many well motivated concepts for scientific and technical investigations that could be done using commissioning data; summary presented in Parallel Session at PCW 2021
  - Several suggested fields are currently on target list for AuxTel imaging survey

Phase 2 (2023-):

- Project will produce menu of candidate target fields, considering community input
- Iterate details with community as needed closer to time of first light

Emergent Themes from Commissioning Notes

Datasets that could serve as a reference for characterizing the Wide-Fast-Deep (WFD) survey:

- Deep (10-year to 20-year LSST WFD equivalent exposure)
- Fast cadence over several contiguous hours to several consecutive nights
- Multi-band (*ugrizy*)
- Uniform depth

Many goals can be met with a series of LSSTCam pointings each with 1000-2000 visits across multiple bands with dense temporal sampling

- Unique dataset with high legacy value; complementary to the nominal WFD survey strategy and could serve as a valuable reference during early years of LSST
- Consider a few contiguous fields each comprised of a few LSSTCam pointings (with dithering)
- Suggested high-priority targets include DDFs, Outer Solar System pointing (e.g., OSSOS, DEEP), moderately dense stellar fields (not too much PSF overlap; low interstellar dust extinction)

Current Planning

Science Verification View of Commissioning

From the first in-focus image during the **On-sky Engineering** phase, we intend to push data through Science Pipelines and produce catalogs as well as diagnostic metrics and plots, with an initial emphasis on single-visit performance

- Goal to quickly achieve science-grade image quality over full field of view
- Gradual transition from mostly engineering to mostly science-driven activities

System Optimization phase is first opportunity to explore the full science potential

- Data taking will be driven by the needs to complete formal science verification, and to produce datasets that will be of high scientific value to the LSST community (informed by input from LSST Science Collaborations)

Science Validation Surveys involve sustained scheduler-driven data taking to demonstrate that Rubin Observatory can smoothly transition to steady-state LSST Operations

- Includes full rehearsal of safety procedures, routine maintenance and system state monitoring, production and distribution of both Prompt and Data Release data products

What can be done in one night?

For purpose of estimation, take a typical night to be ~8 hours. Consider an average time between visits of ~40 seconds. This corresponds to ~720 visits per night, and realistically somewhat less due to filter changes, slews, variable conditions, etc. Allowing 85% efficiency, average of ~600 visits per night. Note that ComCam holds 3 filters. LSSTCam holds 5 filters.

For comparison, the 10-year depth from SRD is

Specification: The sum of the median number of visits in each band, Nv1, across the sky area specified in Table 22, will not be smaller than Nv1 (Table 23).

Quantity	Design Spec	Minimum Spec	Stretch Goal
Nv1	825	750	1000

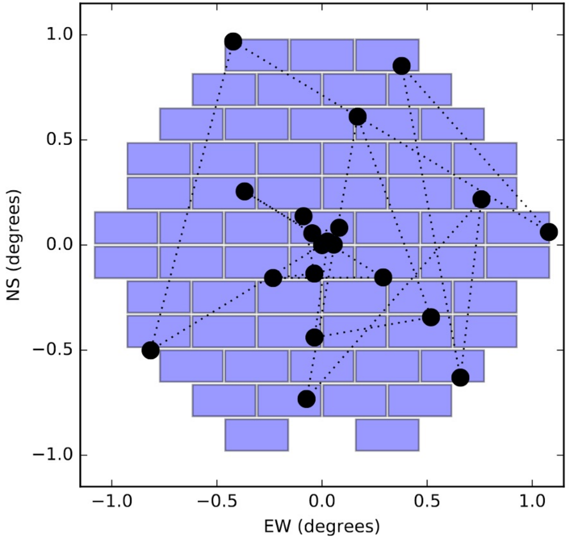
Distribution by band

Quantity	u	g	r	i	z	y
Nv1 (design spec.)	56 (2.2)	80 (2.4)	184 (2.8)	184 (2.8)	160 (2.8)	160 (2.8)
Idealized Depth	26.1	27.4	27.5	26.8	26.1	24.9

What can be done in one night?

A few representative possibilities:

- **An LSSTCam star flat with with 20 visits in each of 5 bands would take ~80 minutes**
    - Area includes ~10^5 Gaia reference stars
- ~325 deg^2 to ~1-year WFD equivalent depth (18 visits) in a single filter
- 10-year WFD equivalent depth in 4 bands for a single pointing, spanning range of airmass



Example DECam star dither pattern
Bernstein et al. 2017
arXiv:1703.01679

Table from DESC Note

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- ~325 deg^2 to ~1-year WFD equivalent depth (18 visits) in a single filter
- **10-year WFD equivalent depth in 4 bands for a single pointing, spanning range of airmass**

Field Name	Optimal Date	Optimal Airmass	$T_{1.4}$ (hr)	$T_{2.0}$ (hr)	Dates $\sec(z) < 1.4$	Dates $\sec(z) < 2.0$
LSST DDF ELIAS S1	Oct-01	1.03	7.1	9.6	May-15 to Jan-21	Apr-25 to Feb-18
LSST DDF XMM-LSS	Oct-28	1.11	5.1	7.5	Jun-23 to Feb-04	Jun-05 to Mar-03
LSST DDF Chandra Deep Field South	Nov-14	1.00	6.7	8.1	Jun-26 to Mar-17	Jun-09 to Apr-13
LSST DDF COSMOS	Feb-21	1.18	4.2	6.9	Nov-24 to Jun-21	Oct-28 to Jul-10

Observability of LSST DDFs from DESC Note

On-sky Engineering

Gradual transition from mostly engineering initially to mostly science-driven activities

From the first in-focus image on sky, we intend to push data through Science Pipelines and produce catalogs as well as diagnostic metrics and plots, with an initial emphasis on single-visit performance

In parallel with testing of telescope/camera, we will attempt to formally verify as many science performance requirements as possible

Example observations: star flats, dithering around bright stars to study scattered light, observations at a range of airmass, etc.

On-sky Engineering

Example Active Optics Commissioning Observing Campaign:

- Laser tracker characterization/calibration (~2 hours)
- Measure sensitivity matrix in-situ (~15 hours)
- Measure influence matrix in-situ (~30 hours)
- Open loop only (~1 hour each night for a week)
- Open+Close loop donuts (~2 hours each night for 30 nights)
- Characterize the atmosphere (~1 hour on 10 nights)
- Stellar density study (~1 hour)
- Exposure time / # snaps (~1 hour)
- Giant donuts (~1 hour)

On-sky Engineering

Example Menu of Engineering Observations:

- Observations of bright stars to evaluate scattered light and ghosting
- Airmass scans; observations at constant airmass
- Dense stellar field, e.g., Galactic plane
- Performance testing with respect to telescope (alt, az) coordinates
- Performance testing with respect to wind speed and direction
- Twilight observations
- Scan range of exposure times
- Initial scheduler testing
    - “LSST pilot survey”; transition between WFD and DDF observations
    - Scheduler response to system telemetry
    - Interrupt recovery; Target-of-Opportunity

System Optimization

Mostly science driven activities with interspersed engineering; this phase represents the start of a sustained effort to characterize observatory performance

Emphasis on data processing through coaddition and difference imaging; first opportunity to explore the full science potential of Rubin Observatory

Data taking will be driven by the needs to complete formal science verification, and to produce datasets that will be of high scientific value to the LSST community (informed by input from LSST Science Collaborations)

Example observations: deep fields (e.g., 20-year LSST Wide-Fast-Deep equivalent exposure) for extragalactic, Galactic, and Solar System science covering ~100 deg^2 in multiple bands with dense temporal sampling

System Optimization

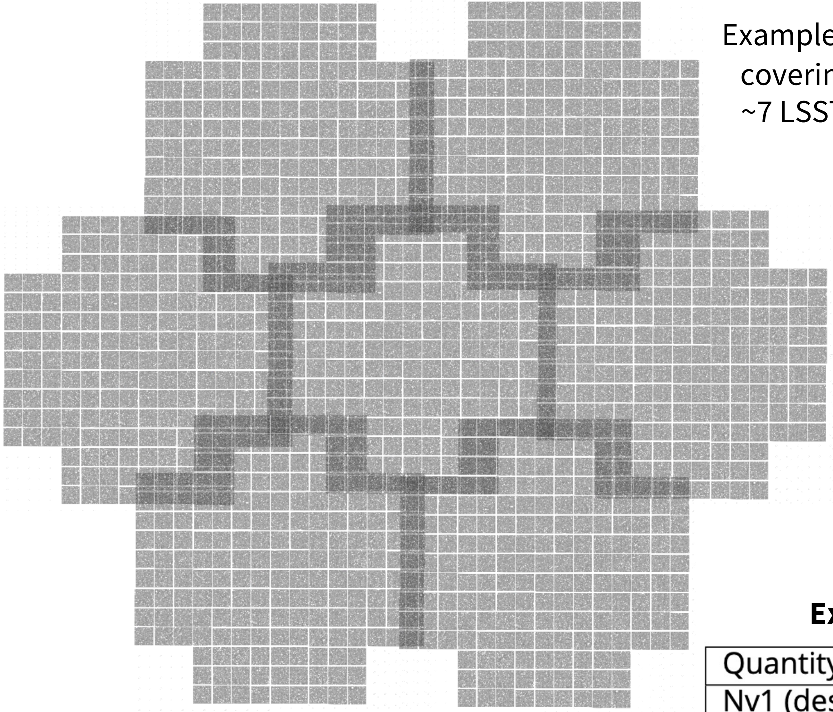
Example Observing Campaign:

- Observe three regions selected for extragalactic, Galactic, and Solar System science
- For each field, consider contiguous 4 LSSTCam dithered pointings each observed to 20-year equivalent LSST WFD exposure in 6 filters (ugrizy)
- (1442 visits per pointing) x (12 pointings) / (600 visits per night) = 28 nights

Objectives:

- Test variety of dither patterns for LSST WFD and LSST DDFs
- Collect sufficient data to
  - construct deep coadd,
  - test template-building for difference image analysis, and
  - build coadds with subsets of data (e.g., best/worst seeing)
- Span range of observing conditions (wind, atmosphere transparency, airmass, moon, etc.)

System Optimization



Example contiguous field covering ~70 deg^2 with ~7 LSSTCam pointings

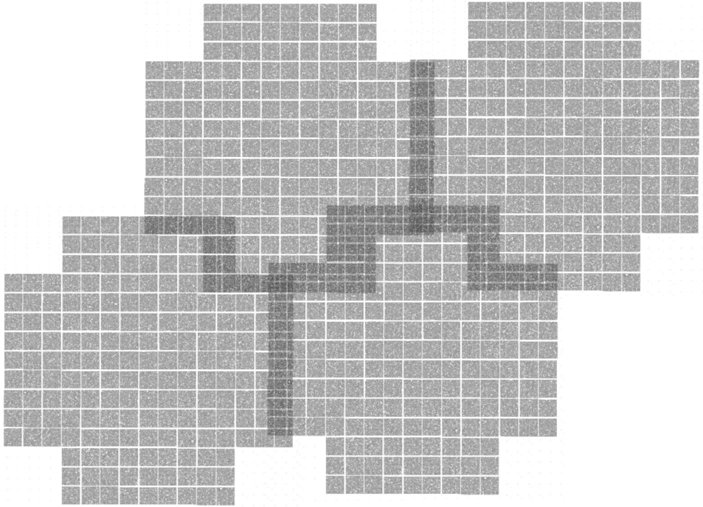
Obtain deep exposures in multiple bands in a few such contiguous fields aimed at extragalactic, resolved stars, and Solar system science cases, with rapid observing cadence to support time domain studies

Roughly 700-800 visits per night

Example 10-year LSST visit distribution across the survey footprint

Quantity	u	g	r	i	z	y
Nv1 (design spec.)	56 (2.2)	80 (2.4)	184 (2.8)	184 (2.8)	160 (2.8)	160 (2.8)
Idealized Depth	26.1	27.4	27.5	26.8	26.1	24.9

System Optimization



Example contiguous field covering ~40 deg^2 with ~4 LSSTCam pointings

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Idealized Depth	26.1	27.4	27.5	26.8	26.1	24.9

Science Validation Surveys

Sustained scheduler-driven data taking to demonstrate that Rubin Observatory can smoothly transition to steady state LSST Operations, including

- Full rehearsal for science operations including safety procedures, personnel training, and documentation
- Routine daytime maintenance of the observatory
- Collection and processing of routine calibration data and generating associated calibration products
- Demonstration of near real time data quality assessment
- Production and distribution of both Prompt and Data Release data products

Example observations:

- **Pilot LSST Wide-Fast-Deep survey** covering to increase areal coverage, increase breadth of opportunities for science validation, and to begin generating templates for difference imaging
  - For example, ~1000 deg^2 in multiple bands to 1-2 year LSST equivalent exposure
- Increased coverage of LSST Deep Drilling Fields
- Astrophysical targets of interest
- Target-of-Opportunity tests

Science Validation Surveys

Example "Pilot LSST Wide-Fast-Deep" Observing Campaign:

- 1000 deg^2 to 2-year LSST WFD equivalent depth in 6 bands
- (100 pointings) x (144 visits per pointing) / 600 visits per night = 24 nights

Objectives:

- Test template generation and difference image analysis over a broad range of conditions
- Validation of scheduler over continuous observing campaign

Process

AuxTel is already conducting imaging surveys and we are exercising the workflow of planning and executing on-sky observations