



Vera C. Rubin Observatory
Systems Engineering

An Interim Report on the On-Sky Commissioning Campaign with LSSTCam

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DRAFT

Abstract

From 15 April to 21 September 2025, the NSF-DOE Vera C. Rubin Observatory conducted on an on-sky commissioning campaign using the LSST Camera (LSSTCam) to test the end-to-end functionality of hardware and software, as well as operational procedures. This interim report provides a preliminary technical overview of our understanding of the integrated system performance based tests and analyses conducted during the on-sky commissioning campaign with LSSTCam. The objectives are to synthesize what we have learned about the system in a timely way to inform Early Operations optimization, and to inform the Rubin science community on the progress of the LSSTCam on-sky campaign. The report is organized into sections that describe major activities during the campaign, as well as multiple aspects of the demonstrated system and science performance. All of the results presented here are to be understood as work in progress using engineering data and the initial versions of the data processing pipelines; the report is a living document that will be updated as analyses are refined.

Change Record

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An Interim Report on the On-Sky Commissioning Campaign with LSSTCam

1 Introduction

The NSF-DOE Vera C. Rubin Observatory on-sky commissioning campaign using the LSST Camera (hereafter LSSTCam) began on 15 April 2025 and ended on 21 September 2025. This interim report provides a concise summary of our understanding of the integrated system performance based tests and analyses conducted during the LSSTCam on-sky campaign. We seek to distill, and to communicate in a timely way, what we have learned about the system to support the transition from Rubin Observatory Construction to Operations. The report is organized into sections that describe major activities during the campaign, as well as multiple aspects of the demonstrated system and science performance.

Warning: Preliminary Results

All of the results presented here are to be understood as work in progress using engineering data and the initial versions of the data processing pipelines. It is expected at this stage, immediately following the completion of the on-sky commissioning campaign, that several analyses are still in progress, and that some of the discussion will concern open questions, issues, and anomalies that are actively being worked by the team to enhance the system reliability. Additional documentation will be provided as our understanding of the demonstrated performance of the as-built system progresses.

1.1 Charge

Charge Development Historical Note

The initial version of the charge developed in September 2025 is provided below for reference.

We identify the following high-level goals for this interim report:

- **Document our current understanding of the integrated system performance** to support systems engineering verification activities associated with demonstrating Construction Completeness [SITCOMTN-005].
- **Transfer knowledge to support the transition from Construction to Operations** to inform the Early Operations optimization period and to support the Early Science Program [RTN-011].
- **Inform the Rubin Science Community** on the progress of the on-sky commissioning campaign using LSSTCam.

Formal acceptance testing with respect to system-level requirement specifications (LSE-29 and LSE-30) will be recorded using the LSST Verification & Validation (LVV) system. By design, several of the analyses presented in this report correspond to system-level requirements, and therefore, this report is anticipated to serve as a verification artifact to support several of those systems engineering activities.

The groups within the Rubin Observatory project working on each of the activities and performance analyses are charged with contributing to the relevant sections of the report. The anticipated level of detail for the sections ranges from a paragraph up to a page or two of text, depending on the current state of understanding, with **quantitative performance** expressed as summary statistics, tables, and/or figures. The objective for this document is to **summarize the state of knowledge of the system**, rather than how we got there or “lessons learned”. The sections refer to additional supporting documentation, e.g., analysis notebooks, other technotes with further detail, as needed. Given the timelines for commissioning various aspects of the system, it is natural that some sections will have more detail than others.

The anticipated milestones for developing this interim report are as follows:

- 18 Sep 2025: Define charge
- 22 Sep 2025: On-sky commissioning campaign with LSSTCam completed; start of final construction downtime and its first operations engineering downtime
- 8 Oct 2025: Detailed outlines with initial versions of essential figures and performance statistics for report sections made available for internal review (content can be on un-

merged development branches); a goal is to help systems engineering with mapping of report content to requirements verification

- 15 Oct 2025: Revised drafts of report sections made available for internal review; development branches merged to main branch; editing for consistency and coherency throughout the report
- 22 Oct 2025: Start of Construction to Operations Transition Workshop; advanced draft ready for review by full Rubin Observatory team
- 31 Oct 2025: Initial version of report is released

2 Executive Summary

Executive summary here.

Versioning Note

This interim report provides a preliminary technical overview of the LSSTCam on-sky campaign based on analyses through October 2025.

2.1 Accomplishments

- **Accomplishment.** Description.
- **Accomplishment.** Description.
- **Accomplishment.** Description.

2.2 Areas of Ongoing Investigation and Further Development

- **Issue.** Description.
- **Issue.** Description.
- **Issue.** Description.

3 Sensor Performance and Instrument Signature Removal

- Usable pixels, effective field of view, fill factor
- Read noise
- Crosstalk
- Dynamic range (brightest and faintest objects)
- Summary table of key Camera performance metrics
- Section needs at least one figure to visualize focal plane; maybe a flat?
- Standard visit (i.e., snaps) evaluation?

3.1 Useable Pixels

Field of View Area Factor (fA) for System Performance diagram

Could include a figure to show focal plane

3.2 Sensor Characterization

Summary discussion on

3.3 Bright Stars and Moon

On-sky validation that the Camera can survey the night sky in the presence of bright sources

3.4 Sensor Anomalies

Any sensor anomalies that are worth noting

3.5 LSSTCam Performance during the LSSTCam On-sky Campaign

Brief summary of LSSTCam performance during the campaign, any open questions, outstanding issues

This could include any discussion on Camera subsystems, e.g., focal plane optimization, filter exchange system, cryo, camera shutter, that should be highlighted

4 System Optical Throughput for Focused Light

- Standard bandpass; includes the sensors, filters, lenses, mirrors, and (a standard) atmosphere. Measured with CBP? Monochromatic flats with flat field screen?
- Imaging depth in multiple bands (LSR-REQ-0090); also express as zeropoint to separate out the effects of image quality; could be comparison to refcats and/or spectrophotometric standards
- Figure to show throughput variation of throughput across field of view (LSR-REQ-0109); potentially separating out vignetting and CCD response
- Discussion on Sensitivity Factor (f_S) in the System Performance Diagram

4.1 Standard Bandpass

4.2 Measured Zeropoints

5 Measured Sky Backgrounds

- Comparison to predicted sky background levels
- Distribution of limiting surface brightness

6 Delivered Image Quality

6.1 Delivered Image Quality Distribution

- Examples of some of our best images to demonstrate system capability
- Figure: distribution of PSF FWHM for an ensemble of visits
- Figure: PSF size and ellipticity distribution across field of view for an ensemble of visits

6.2 Image Quality Budget

Discussion on current assessment of the various contributions to the delivered image quality, accomplishments, open questions, outstanding issues

Discussion on current state of characterizing the atmosphere contribution

6.3 PSF Characterization

- Figure: PSF residuals across the field of view
- Figure: measured PSF size as a function of magnitude (could include brighter-fatter discussion)
- Figure: measured PSF size as a function of stellar color
- Figure: wings of PSF and encircled energy as a function of radius

7 Stray and Scattered Light

- Figure: examples of ghosts; are the features understood?
- Figure: examples of stray and scattered light; are the sources of stray and scattered light understood?
- Summative discussion on the impacts of stray and scattered light; how prevalent, amplitude and structure of the features, to what extent will additional baffling (e.g., with LWS) mitigate the features

8 System Timing and Dynamics

- Standard Visit Duration (OSS-REQ-0288)
- Readout time – discussed with the Camera?
- Time Interval Between Visits (OSS-REQ-0289)
- Maximum time for operational filter change (OSS-REQ-0293)
- Telescope Azimuth Slewing Rate (TLS-REQ-0029)
- Telescope Elevation Slewing Rate (TLS-REQ-0159)
- Summative assessment on rate of acquiring observations

8.1 Standard Visit Definition

Discussion on decision to use 30-second exposures

8.2 Visit Timing and Interval between Visits

Camera readout time, filter change times

Telescope motion settings, slew and settle, distribution of time between visits

8.3 Effective Survey Speed

Observing efficiency factor (f_O) for System Performance diagram

Survey simulations combined with telescope motion capabilities; compare with actual rate of acquiring visits during SV surveys

9 Data Management

The primary purpose of this section is to describe that data management has been able to support the operational aspects of running Rubin Observatory during commissioning

- Calibration products and ISR during commissioning
- Brief description (paragraph or two; maybe a table) of data processing campaigns during on-sky commissioning, mainly reporting on the functional capabilities; algorithms and data products are discussed elsewhere; pointers to other references
- Figure with representative pixel-level color coadd images?

10 Calibration

10.1 Astrometry

- Figure: histogram of astrometric repeatability for ensemble of visits
- Figure: static camera astrometric distortion model
- Figure: average astrometric residuals in focal plane coordinates for ensemble of visits; two-panel figure to show full focal plane and an individual detector
- Figure: average E/B mode across ensemble of visits; expect to see mostly a pure E-mode astrometric field indicative of residuals dominated by astrometric turbulence
- Item any further discussion of astrometric residuals worth exploring further

10.2 Photometry

- Figure: histogram of photometric repeatability for ensemble of visits; panel for each band?
- Figure: illumination correction
- Figure: average photometric residuals in focal plane coordinates for ensemble of visits; maybe a two-panel figure to show full focal plane and an individual detector
- Any other correlations of photometry that are worth exploring further (e.g., residuals w/ respect to stellar color, stellar flux, airmass)

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B References

[SITCOMTN-005], Claver, C., Bauer, A., Bechtol, K., et al., 2025, *Construction Completeness and Operations Readiness Criteria*, Commissioning Technical Note SITCOMTN-005, NSF-DOE Vera C. Rubin Observatory, URL <https://sitcomtn-005.lsst.io/>

[LSE-29], Claver, C.F., The LSST Systems Engineering Integrated Project Team, 2017, *LSST System Requirements (LSR)*, Systems Engineering Controlled Document LSE-29, NSF-DOE Vera C. Rubin Observatory, URL <https://ls.st/LSE-29>

[LSE-30], Claver, C.F., The LSST Systems Engineering Integrated Project Team, 2018, *Observatory System Specifications (OSS)*, Systems Engineering Controlled Document LSE-30, NSF-DOE Vera C. Rubin Observatory, URL <https://ls.st/LSE-30>

[RTN-011], Guy, L.P., Bechtol, K., Bellm, E., et al., 2025, *Rubin Observatory Plans for an Early Science Program*, Technical Note RTN-011, NSF-DOE Vera C. Rubin Observatory, URL <https://rtn-011.lsst.io/>, doi:10.71929/rubin/2584021

C Acronyms

Acronym	Description
AST	NSF Division of Astronomical Sciences

AURA	Association of Universities for Research in Astronomy
B	Byte (8 bit)
CBP	Collimated Beam Projector
CCD	Charge-Coupled Device
DE-AC02	Department of Energy contract number prefix
DOE	Department of Energy
FWHM	Full Width at Half-Maximum
ISR	Instrument Signal Removal
LSR	LSST System Requirements; LSE-29
LSST	Legacy Survey of Space and Time (formerly Large Synoptic Survey Telescope)
LSST-DA	LSST Discovery Alliance
LSSTCam	LSST Science Camera
LVV	LSST Verification and Validation
LWS	Light-Wind Screen
NSF	National Science Foundation
OSS	Observatory System Specifications; LSE-30
PSF	Point Spread Function
RTN	Rubin Technical Note
SLAC	SLAC National Accelerator Laboratory
SV	Science Validation
TLS	Transport Layer Security