Vera C. Rubin Observatory
Systems Engineering

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

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SITCOMTN-170

Latest Revision: 2025-10-30

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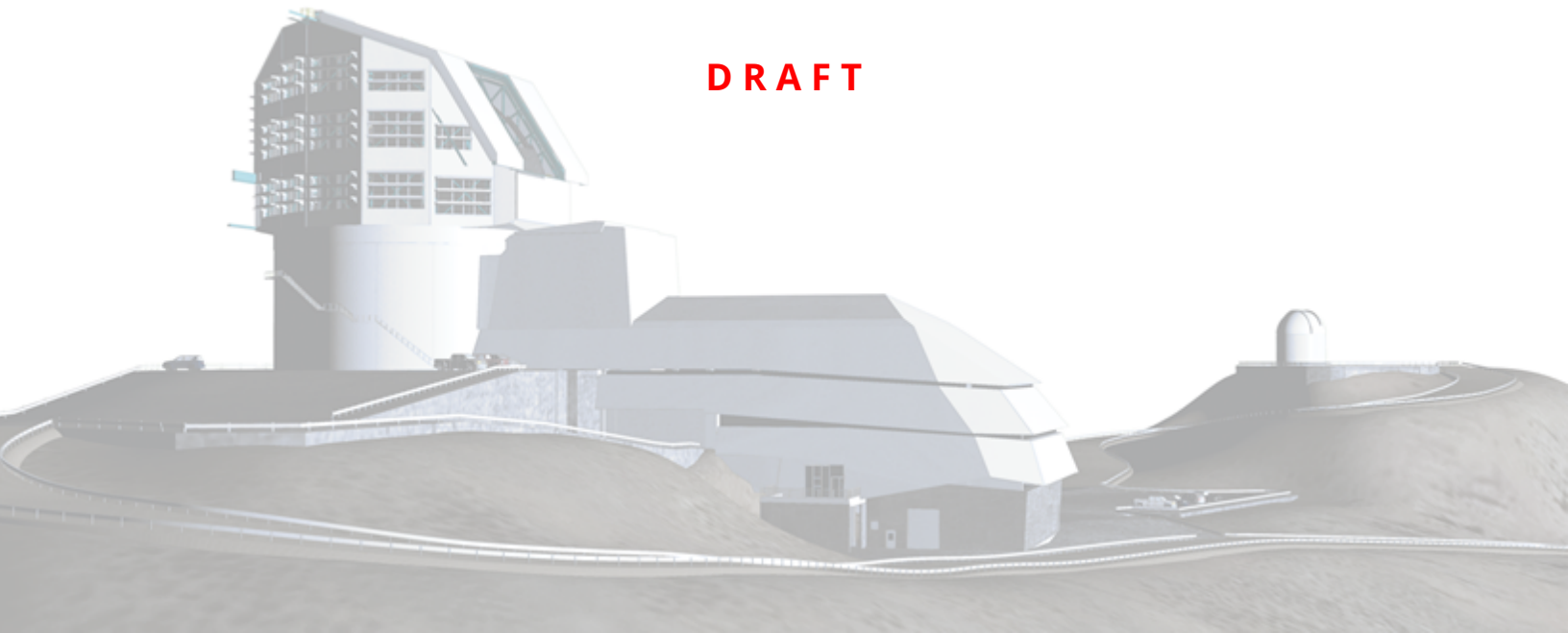

Abstract

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

Version	Date	Description	Owner name
1	YYYY-MM-DD	Unreleased.	Bechtol

Document source location: `https://github.com/lsst-sitcom/sitcomtn-170`

Contents

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 campaing 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 On-sky Commissioning Campaign with LSSTCam

- Brief summary of the time window of the observations, basic statistics on the number of visits, and overview of the types of observations.
- Brief description of core datasets used for this report. Table to summarize observations.
- Description of First Look dataset
- Potentially a figure to show sky coverage (could be a representative small field) used for evaluation of System First Light milestone

3.1 Science Program Observations

- Demonstrated Concept of Operations during 23 weeks of the on-sky campaign w/ LSSTCam
- Acquired ~80K total visits from 15 April to 21 September, including ~20K flat, ~9K bias, and ~5K dark exposures for in-dome calibrations, ~22K on-sky engineering images primarily for Active Optics System (AOS) commissioning, and ~22K images intended for Science Pipelines commissioning
  - Total volume of pixel data ~100 times larger than that from 7-week on-sky campaign w/ LSSTComCam
- Completed observations of selected fields to support Rubin First Look media event
- Demonstrated full-nights of wide-area survey-mode observations driven by Feature Based Scheduler (FBS)
  - Scheduler configuration similar to LSST using input telemetry sources from the summit
- Acquired core on-sky datasets for Science Pipelines commissioning, including
  - observations in every band reaching 10-year LSST equivalent exposure in at least one field
  - densely dithered star field observations in *ugrizy* bands to evaluate internal calibration

15 Apr	First night sky images w/ LSSTCam
4 May	Rubin First Look observations completed as part of Small Field Surveys
9 Jun	Start wide-area survey-mode observation engineering
20 Jun	Start of pilot SV Survey observations w/ ~2 hours per night
Early Jul	Multiple consecutive full nights of SV survey operations; System First Light technical milestone
Late Jul-Aug	Multiple winter storms substantially limit opportunities for on-sky observing
24 Jul	One of the five filter sockets on LSSTCam becomes non-operational until engineering downtime
Early Aug	Test priorities shift to emphasize improvements to consistency of delivered image quality
10 Aug	FBS configuration updated to reduce footprint of Wide from 3000 deg2 to 750 deg2
12 Aug	Last filter swap during on-sky campaign w/ LSSTCam; remaining observations use griz filters only
5 Sep	FBS configuration updated for longer DDF sequences; prioritize ECDFS and ELAIS-S1 DDFs
15 Sep	FBS configuration updated to target only regions with deployed template coverage
21 Sep	Last night of on-sky commissioning campaign w/ LSSTCam
22 Sep	Start final construction downtime and the first operations engineering downtime
20 Oct	Resumed on-sky observations; transition to Early Operations system optimization

TABLE 1: Events during on-sky campaign w/ LSSTCam.

  - observations to build templates and run difference imaging analysis w/ Prompt Processing for both individual fields and SV survey Wide area

- Observed Deep Drilling Fields (DDFs) using variety of dither patterns to inform LSST DDF observing strategy
- Demonstrated Target of Opportunity (ToO) Observations
- Provided regular updates for science community via weekly Commissioning Update posts, public nightly reporting (ls.st/svnightly), public summary reporting (survey-strategy.lsst.io/progress), in addition to internal survey progress monitoring tools (including NightlyDigest)

3.1.1 Field Surveys

Summary of pointings, distribution of visits, dither patterns

3.1.2 Science Validations Surveys

Some of the summary visuals can also be included in this technote

3.2 Overall On-sky Efficiency

Summary figures to show how the time was utilized during the on-sky campaign

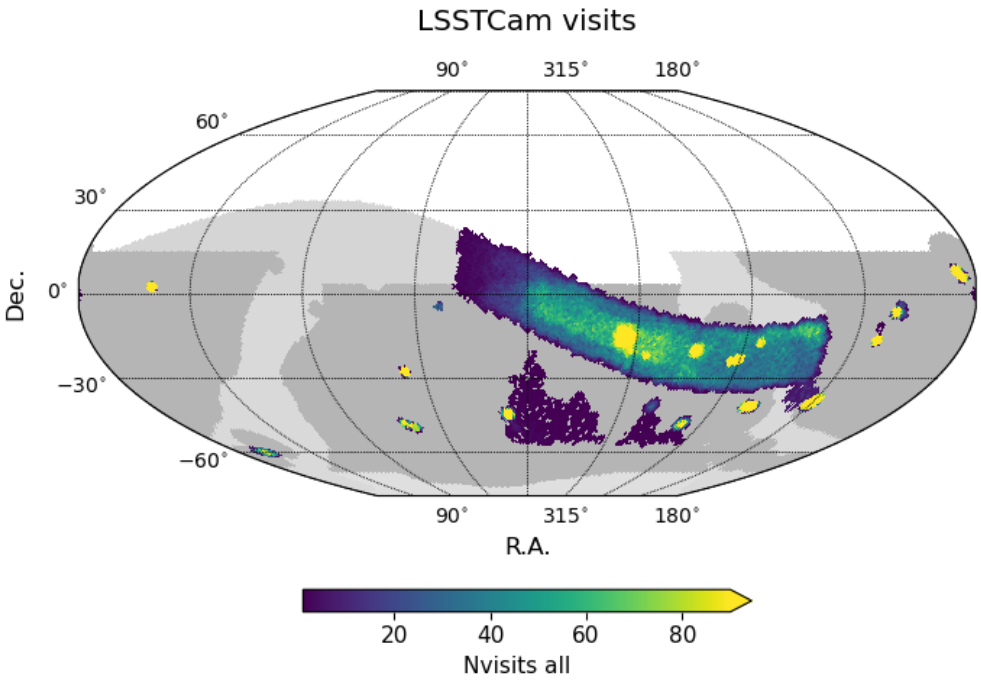

FIGURE 1: Sky coverage during the LSSTCam on-sky campaign.

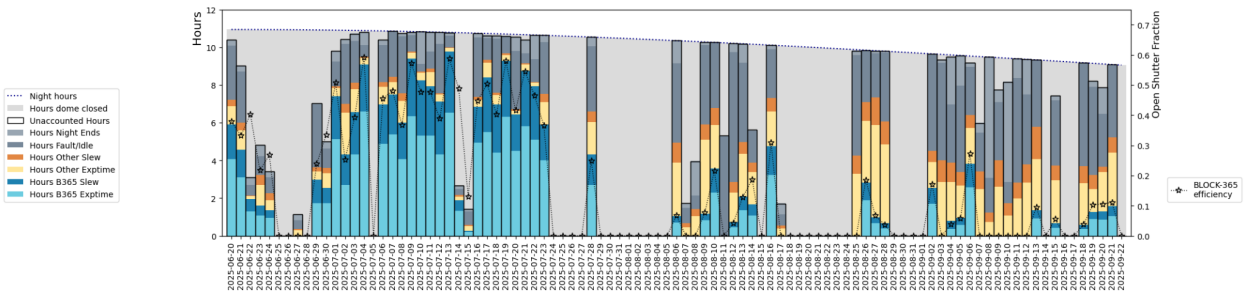

FIGURE 2: On-sky time during SV surveys.

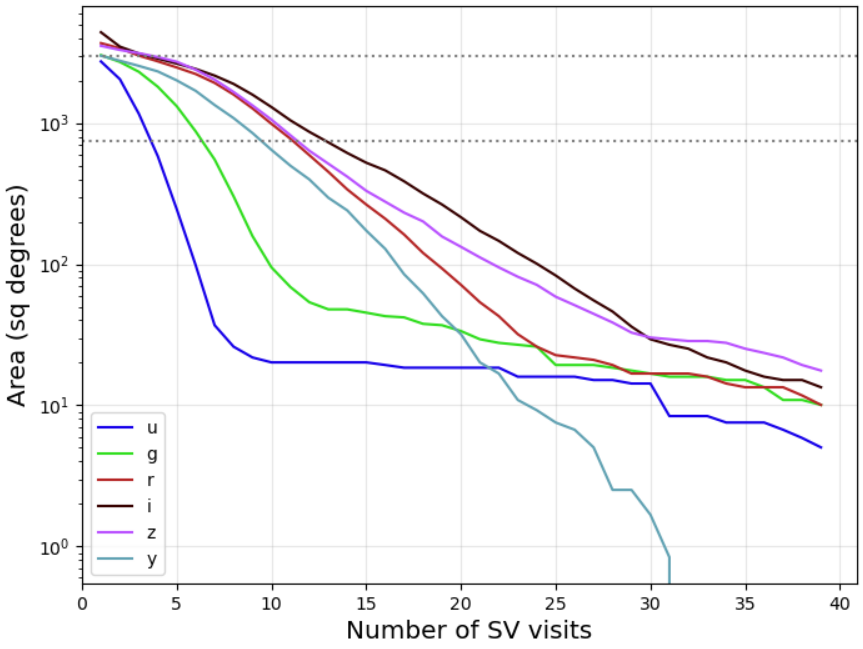

FIGURE 3: Area coverage per band.

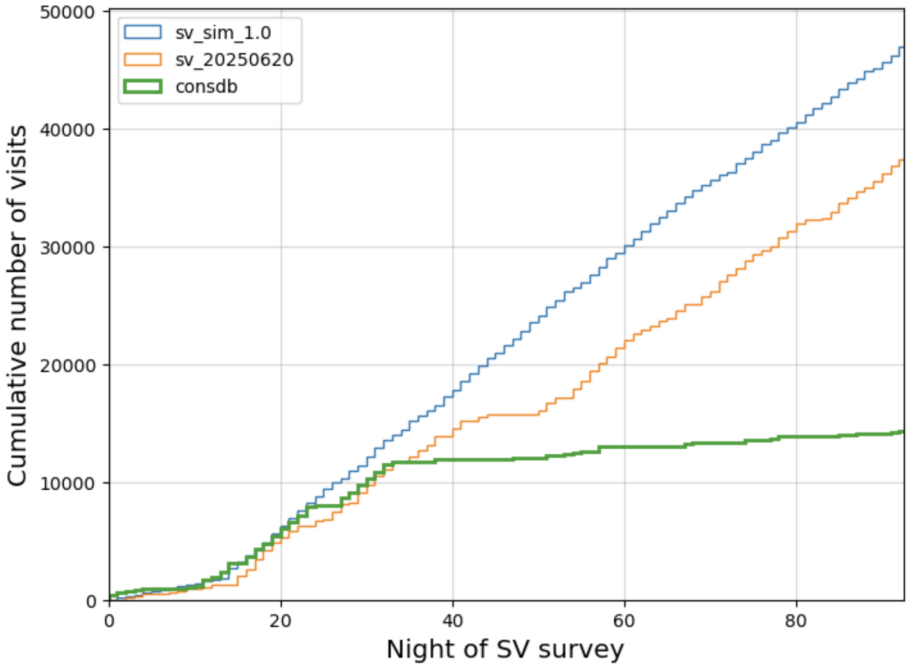

FIGURE 4: SV surveys cumulative visit counts.

Estimate of system availability during the SV surveys (could be that our best data for this purpose is from early July when we had full nights of SV)

4 Calibration Systems

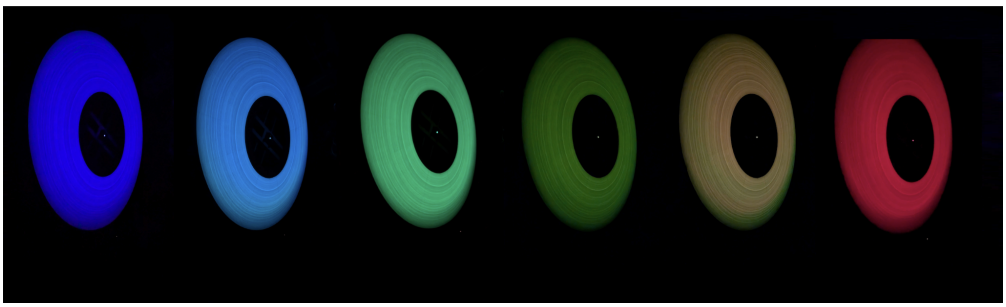

FIGURE 5: Single-LED flatfield screen.

- Calibration Data without external illumination
  - Biases

  - Darks
- Calibration System Sources
  - White Light (LED) w/ Fiber Spectrograph and Photodiode + Electrometer
  - Tunable Laser w/ Fiber Spectrograph and Photodiode + Electrometer
- Flat Field Projector system
  - (Single) LED flats
  - Photon Transfer Curve
- Collimated Beam Projector (CBP)
  - Filter scans (and no-filter scans)
  - Crosstalk spots

5 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?

5.1 Useable Pixels

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

Could include a figure to show focal plane

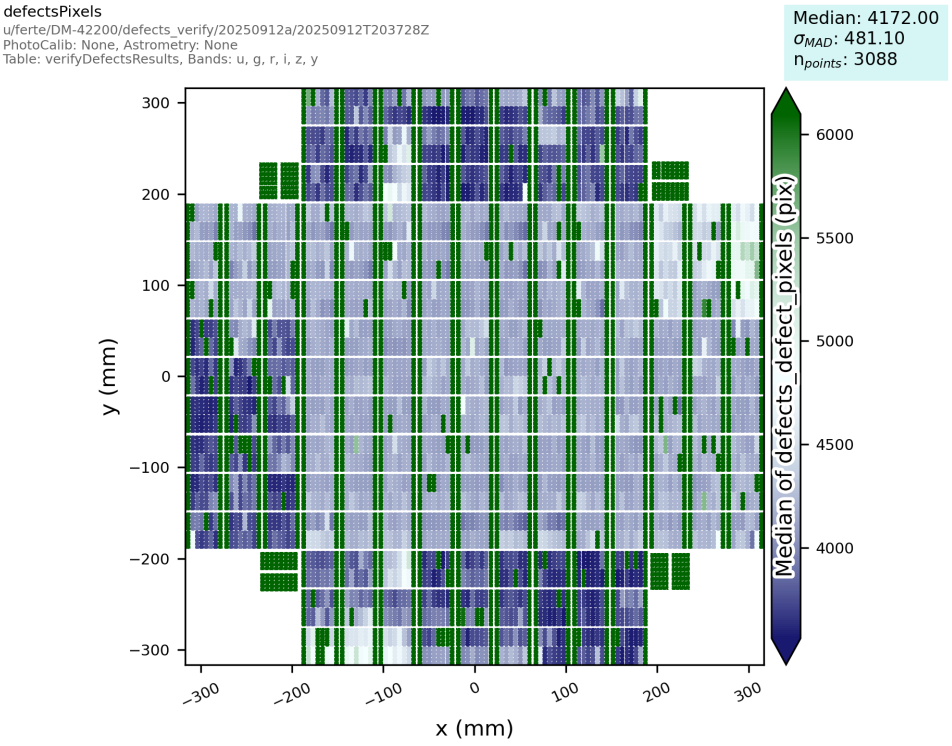

FIGURE 6: Useable pixels.

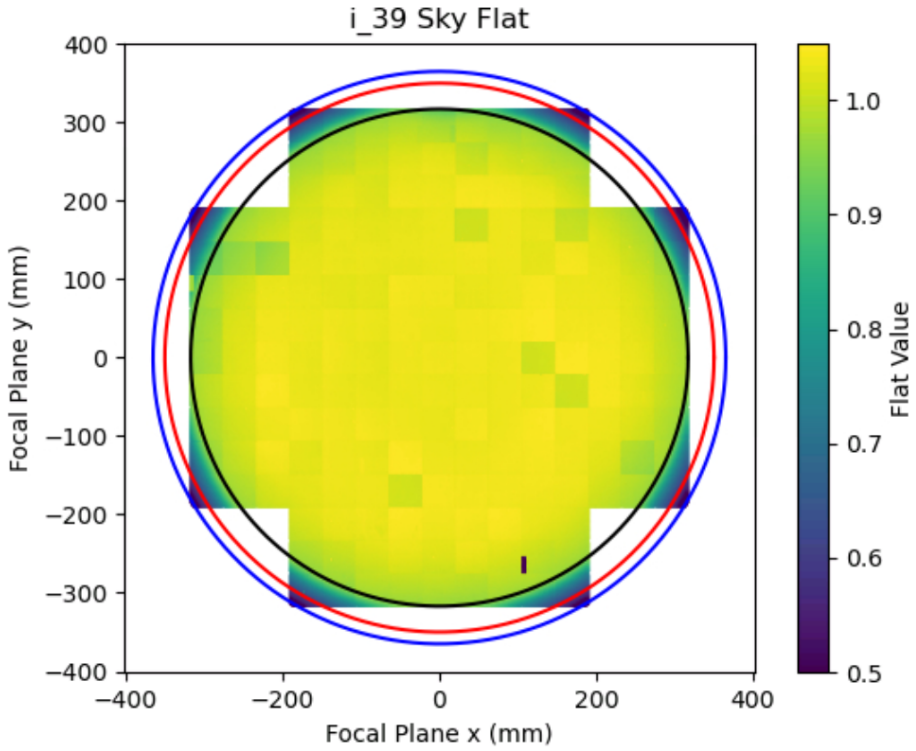

FIGURE 7: Vignetting.

5.2 Vignetting and Calibratable Pixels

5.3 Sensor Characterization

Summary discussion on

5.4 Bright Stars and Moon

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

5.5 Sensor Anomalies

Any sensor anomalies that are worth noting

5.6 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 susbsystems, e.g., focal plane optimization, filter exchange system, cryo, camera shutter, that should be highlighted

6 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 (fS) in the System Performance Diagram

6.1 Standard Bandpass

6.2 Measured Zeropoints

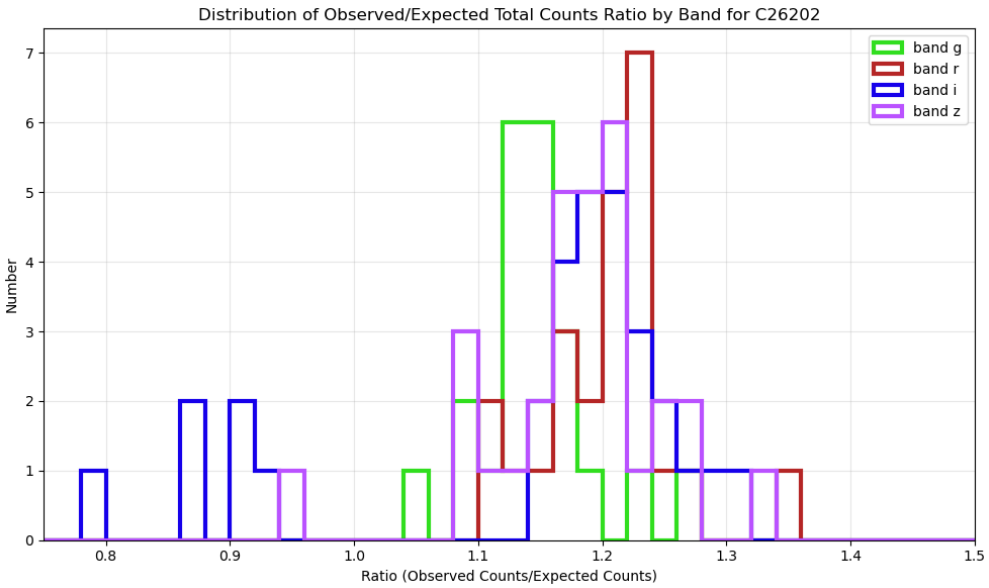

FIGURE 8: C26202.

7 Measured Sky Backgrounds

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

8 Delivered Image Quality

8.1 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

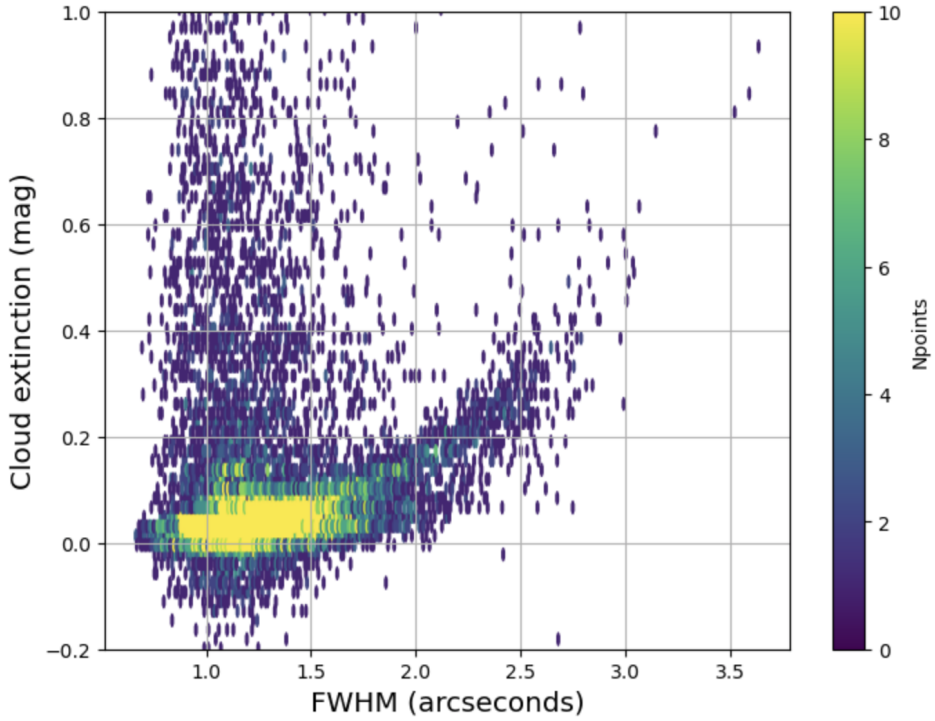

FIGURE 9: Zeropoint cloud extinction.

8.2 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

8.3 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

9 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

10 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

10.1 Standard Visit Definition

Discussion on decision to use 30-second exposures

10.2 Visit Timing and Interval between Visits

Camera readout time, filter change times

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

10.3 Effective Survey Speed

Observing efficiency factor (fO) for System Performance diagram

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

11 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?

To provide feedback on the quality of the data and the performance of the system, Data Management runs processing campaigns on multiple timescales

- Rapid Analysis framework - Quick Look payload @ summit
  - Single-visit processing pipeline that supports decision-making during the night (e.g., RubinTV plots)
- Prompt Processing framework - Alert Production payload @ USDF
  - Alert production and population of the Alert Production Database (APDB)
- Rapid Analysis framework - Nightly Validation payload @ USDF
  - Continuous near-real-time processing of individual visits during the night + daytime processing at USDF through coaddition, to support daily planning of commissioning observations
- Batch Production System - Cumulative Data Release Production (DRP) @ USDF
  - Full scale processing at USDF of 2 weeks of data on target fields, to develop our best understanding of the state of the system and pipelines

12 Calibration

12.1 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

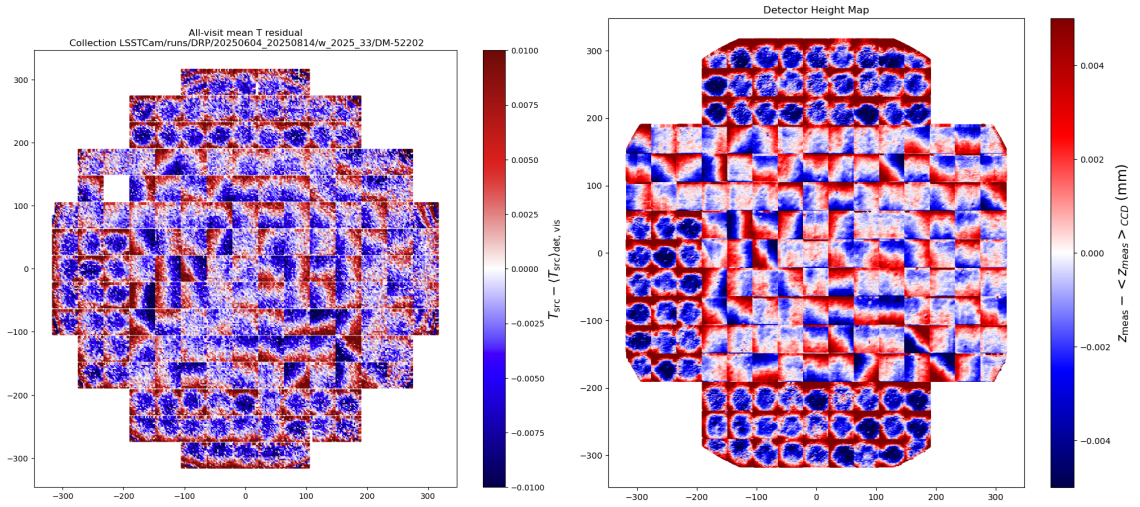

FIGURE 10: PSF size residuals and height map.

12.2 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

12.3 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

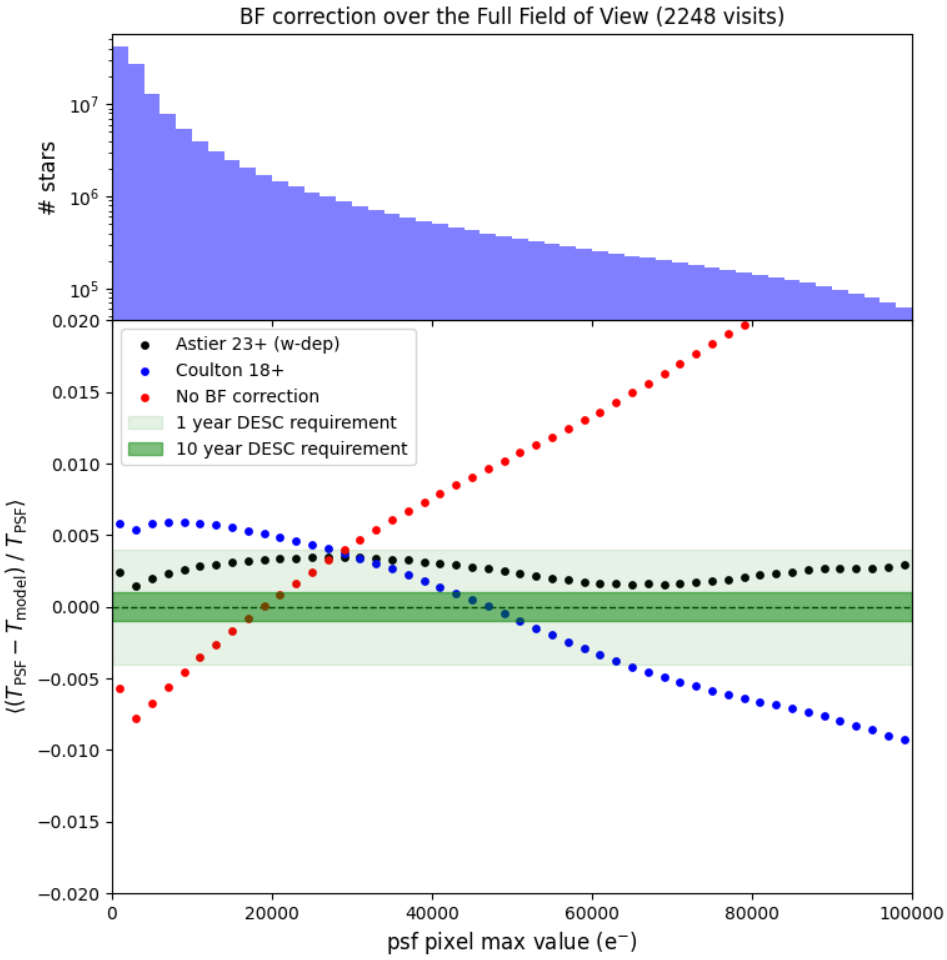

FIGURE 11: Brighter fatter.

- Any other correlations of photometry that are worth exploring further (e.g., residuals w/ respect to stellar color, stellar flux, airmass)

Excellent agreement between predicted and measured chromatic response across the focal plane

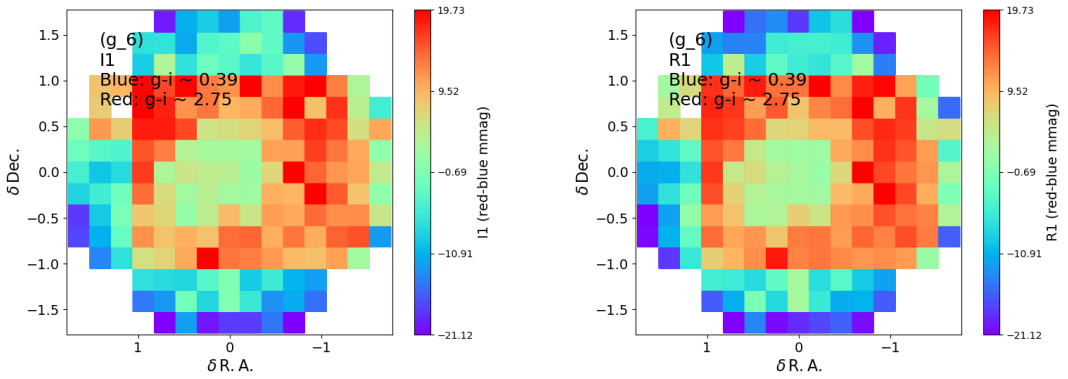

FIGURE 12: Photometry chromatic response across focal plane.

A Acknowledgements

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C Acronyms

Acronym	Description
AOS	Active Optics System
APDB	Alert Production DataBase
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
DDF	Deep Drilling Field
DE-AC02	Department of Energy contract number prefix
DOE	Department of Energy
DRP	Data Release Processing
ECDFS	Extended Chandra Deep Field-South Survey
FBS	Feature-Based Scheduler
FWHM	Full Width at Half-Maximum

ISR	Instrument Signal Removal
LED	Light-Emitting Diode
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
LSSTComCam	Rubin Commissioning 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
ToO	Target of Opportunity
USDF	United States Data Facility