Vera C. Rubin Observatory
Data Management
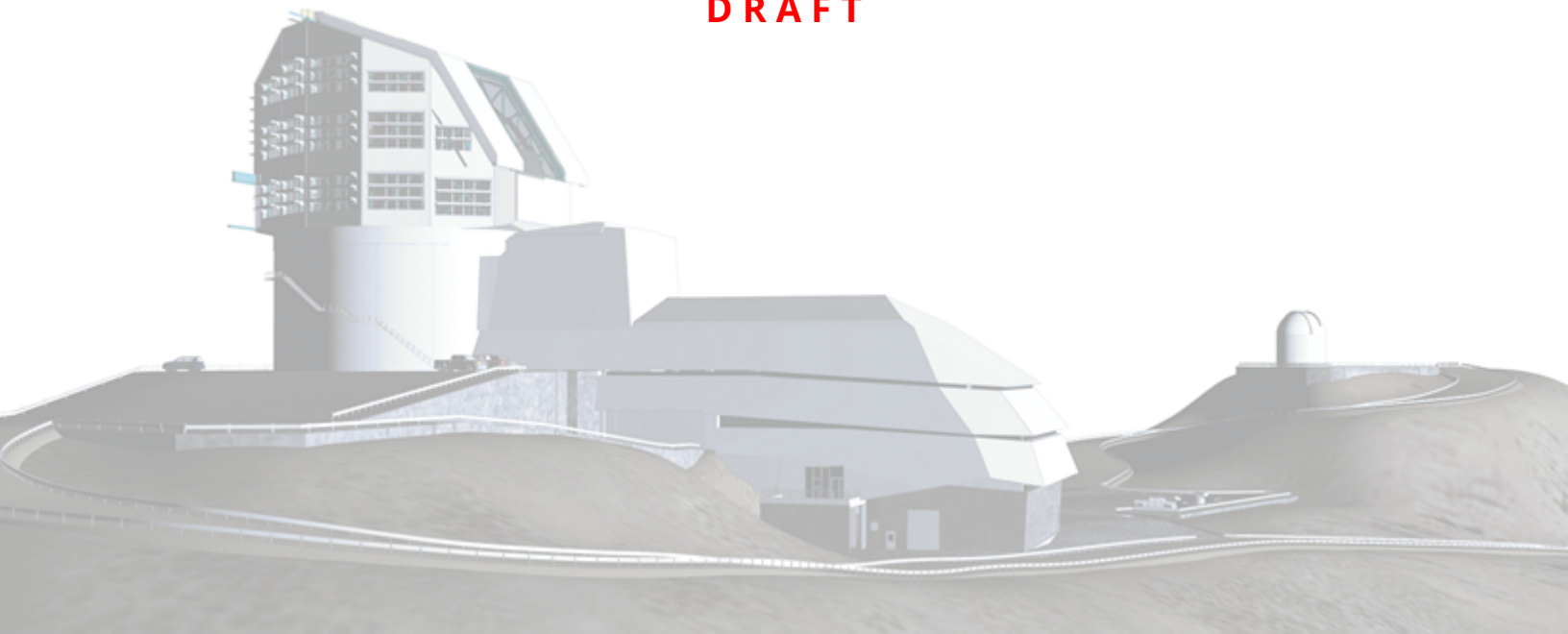
Characterization Metric Report: Science Pipelines Version 29.0

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DMTR-461

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D R A F T

Abstract

This brief report describes measurements of data quality metrics that were carried out for release v29.0.0 of the LSST Science Pipelines. The report for the previous version can be found in [DMTR-451].

Change Record

Version	Date	Description	Owner name
1.0	2025-07-14	Document issued; DM-50227	Jeff Carlin
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Document source location: `https://github.com/lsst-dm/DMTR-461`

Contents

Characterization Metric Report: Science Pipelines Version 29.0

In this report, we characterize the performance of the Rubin Observatory Science Pipelines Version 29.0.0. We illustrate the performance via metrics that are measured on the HSC-RC2 dataset. RC2 consists of 3 tracts of data taken from the HSC-SSP survey, and selected to provide a means of testing various "pathological" cases (e.g., difficult astrometric solutions, extremely good seeing that does not provide a well-sampled PSF, difficult fields for deblending, and large galaxies, among others). These three tracts each contain between 112–149 visits split between the HSC-G, HSC-R, HSC-I, HSC-Z, and HSC-Y (*grizy*) filters.

Between w_2024_42 (the source for pipelines version 28) and w_2025_09 (v29 source), there were a number of major changes to the science pipelines. The characterization and calibration process was completely refactored, with the new `CalibrateImageTask` introduced to replace (and improve upon) the former `CharacterizeImageTask` and `CalibrateTask`. Additionally, the initial photometric and astrometric calibration steps were switched to use the Monster (DMTN-277) reference catalog (datasetType `the_monster_20250219` in the Butler repositories). With LSSTComCam on-sky observations, new types of image defects were found, and new code was developed to mask or otherwise mitigate these defects. Another significant change was the renaming of many of the data products; the renaming of datasetTypes did not affect the contents of the data products.

Photometry and astrometry metrics reported here were calculated using the analysis_tools package, which is part of the standard pipeline distribution. The `analysis_tools` package builds on and supersedes faro (DMTN-211), which has been used for the past few years. The calculation of most metrics reported in this Report is unchanged between the two packages, though minor differences in how selection criteria are applied, or how catalog matching is done, between `analysis_tools` and `faro` could result in small differences in the resulting metrics. We are actively working on a revised definition of the residual ellipticity correlation metrics TE1 and TE2, to be implemented in `analysis_tools`. Because this work is still in progress, the ellipticity metrics are not reported here.

The metric calculation pipelines from `analysis_tools` were run on the three RC2 tracts to derive the photometry and astrometry metrics that are reported here. We exclude the two astrometry metrics (AM3 and AF3) that concern residuals on 200-arcminute scales, since the individual tracts of RC2 do not span large enough spatial scales to enable these measure-

ments.

For comparison, we provide the SRD required "design" value of each Key Performance Metric (KPM) as defined in the Science Requirements Document [LPM-17]. For the ellipticity correlation metrics, there are specifications only for *r* and *i* bands. The *ugzy*-band measurements are of interest primarily for historical tracking.

Some KPMs (e.g., PF1, AF1, AF2) involve thresholds that are different for "design", "minimum", and "stretch" specifications. Metrics in this report are all compared to the "design" thresholds. The assessment of these KPMs would be different if evaluated against different thresholds.

DP1 LSSTComCam On-sky Data: Version 29 of the Science Pipelines was used for processing of the Data Preview 1 (DP1) data (RTN-095), which derived from on-sky commissioning conducted with LSSTComCam, the commissioning camera (SITCOMTN-149). Here we report the photometry and astrometry metrics as measured on tract 5063, one of the tracts that overlaps the ECDFS field of view in DP1. This tract was selected because it has the most observations of all the discrete DP1 fields, as well as the most extensive coverage in all of the *ugrizy* bands. The metrics are presented in the tables and figures of this report for comparison to the same metrics measured on HSC-RC2 data.

We note that the observations that contributed to DP1 were intended for commissioning of the instrument and facility. Components such as the dome thermal controls and active optics mirror controls were still being commissioned and their optimal parameters for operation being determined. Additionally, the calibration screen was unavailable, so DP1 used twilight flats for flat-fielding of the images. Thus the DP1 data quality varied much more than can be expected in survey operations with LSSTCam. Despite these limitations, the campaign successfully demonstrated system integration and established a functional observatory, and as we show in this Report, already produced data products that nearly meet the design specifications for photometric and astrometric data quality metrics (and are well within the minimum requirements for these metrics). LSSTCam on-sky data are likely to significantly improve upon the performance shown here.
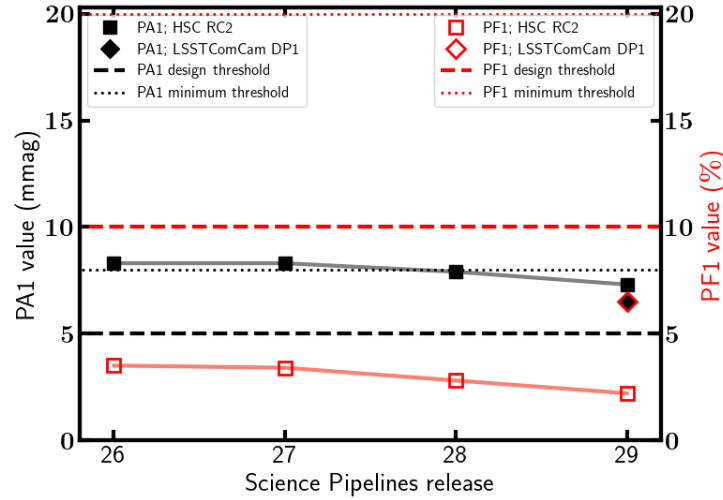
FIGURE 1: Photometry metrics PA1 (photometric repeatability) and PF1 (percentage of measurements exceeding the outlier threshold) measured in the *r*-band. The figure shows the values of these metrics as measured with `analysis_tools` in versions 26-29 of the LSST Science Pipelines as squares, compared against the SRD requirements (for both the "design" and "minimum" thresholds). The measured values of both metrics show minor improvements between the two most recent releases (v28 8and v29); this is likely due to the refactoring of calibration tasks. Measurements of PA1 and PF1 on LSSTComCam data in tract 5063 from DP1 are shown as diamonds, demonstrating that even at the early stage of commissioning when these data were obtained, the data quality meets the design requirement for PF1 (outlier fraction), and is well beneath the minimum threshold (and near the design specification) for PA1 (repeatability).

1 Summary of performance metrics

In spite of the extensive refactoring of the calibration process between versions 28 and 29 of the pipelines, the data quality metrics are only slightly different between the two versions. Both the photometry metrics (Section 2) and the astrometry metrics (Section 3) show slight improvements.

2 Photometric Performance

These photometric performance metrics are defined in LSS-REQ-0093 (LSE-29) and Table 14 of LPM-17. Values in this table represent the mean of the results reported by `analysis_tools` for the three tracts in RC2. An additional column has been added in this version to report the results measured from tract 5063 of DP1 LSSTComCam on-sky data.

Any entries left blank are those for which we do not have data in the given filter for that dataset.

Metric	Unit	SRD Requirement – Design	Release 28 Value (RC2)	Release 29 Value (RC2)	Release dp1_v29 Value (LSSTComCam)	Comments
PA1: u	mmag	≤ 7.5	-	-	7.1	
PA1: g	mmag	≤ 5.0	7.8	7.1	8.9	
PA1: r	mmag	≤ 5.0	7.9	7.3	6.5	
PA1: i	mmag	≤ 5.0	8.1	7.5	6.2	
PA1: z	mmag	≤ 7.5	6.5	6.1	7.3	
PA1: y	mmag	≤ 7.5	6.9	6.3	6.0	
PF1: u	%	≤ 10.0	-	-	2.2	
PF1: g	%	≤ 10.0	4.2	2.7	3.4	
PF1: r	%	≤ 10.0	2.8	2.2	6.5	
PF1: i	%	≤ 10.0	1.9	1.6	0.2	
PF1: z	%	≤ 10.0	1.1	0.9	1.0	
PF1: y	%	≤ 10.0	1.7	1.1	0.0	

3 Astrometric Performance

The following metrics are defined following LSR-REQ-0094 [LSE-29] and Table 18 of LPM-17. Values in this table represent the mean of the results reported by `analysis_tools` for the three tracts in RC2. An additional column has been added in this version to report the results measured from tract 5063 of DP1 LSSTComCam on-sky data.

Any entries left blank are those for which we do not have data in the given filter for that dataset.
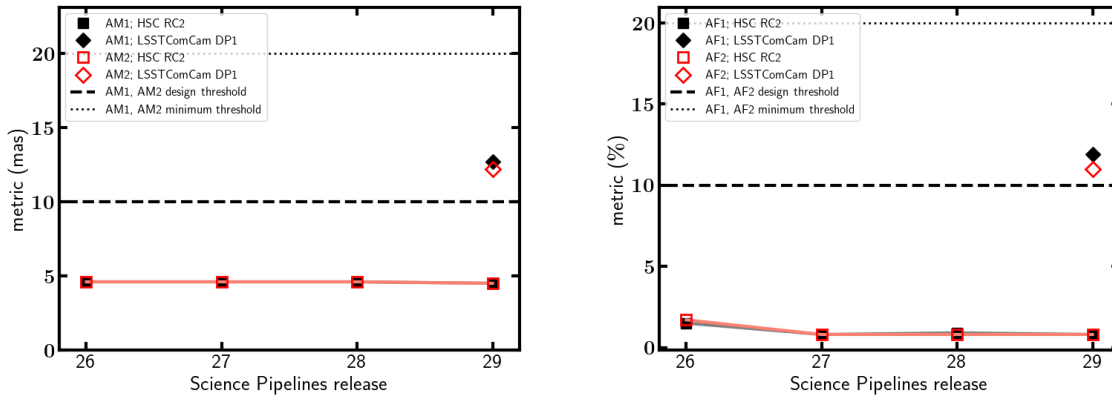
FIGURE 2: Astrometry metrics measured on *r*-band images compared over the past few major pipelines releases. The figure shows the values of these metrics as measured with `analysis_tools` in versions 26-29 of the Science Pipelines as squares. *Left:* Median astrometric measurement error on 5-arcminute scales (AM1) and 20-arcminute scales (AM2), compared against the SRD requirements (for the "design" and "minimum" thresholds; note that the thresholds for AM1 and AM2 are the same, and thus indistinguishable on the figure). *Right:* Fraction of astrometric measurements exceeding the outlier threshold on 5-arcminute (AF1) and 20-arcminute (AF2) scales, compared against the SRD requirements (for the "design" and "minimum" thresholds; note that the thresholds for AF1 and AF2 are the same, and thus indistinguishable on the figure). The measured values of the astrometric scatter metrics AM1 and AM2 and the outlier fractions AF1 and AF2 all show slight improvements between pipelines versions 28 and v29. Measurements of these metrics on LSSTComCam data in tract 5063 from DP1 are shown as diamonds, demonstrating that even at the early stage of commissioning when these data were obtained, the data quality nearly meets the design requirements for AM1, AM2, AF1, and AF2, and is well beneath the minimum thresholds (and near the design specification) for all of them.

Metric	Unit	SRD Requirement – Design	Release 28 Value (RC2)	Release 29 Value (RC2)	Release dp1_v29 Value (LSSTCom-Cam)	Comments
AM1: *u*	mas	≤ 10.0	-	-	18.1	
AM1: *g*	mas	≤ 10.0	5.2	5.0	15.4	
AM1: *r*	mas	≤ 10.0	4.6	4.5	12.7	
AM1: *i*	mas	≤ 10.0	4.1	3.9	11.4	
AM1: *z*	mas	≤ 10.0	5.1	5.0	11.4	
AM1: *y*	mas	≤ 10.0	6.9	6.8	12.4	
AF1: *u*	%	≤ 10.0	-	-	24.7	

Metric	Unit	SRD Requirement – Design	Release 28 Value (RC2)	Release 29 Value (RC2)	Release dp1_v29 Value (LSSTComCam)	Comments
AF1: g	%	≤ 10.0	0.9	0.8	24.1	
AF1: r	%	≤ 10.0	0.9	0.8	11.9	
AF1: i	%	≤ 10.0	0.6	0.6	8.7	
AF1: z	%	≤ 10.0	0.6	0.6	9.6	
AF1: y	%	≤ 10.0	2.9	2.8	12.0	
AD1: u	mas	≤ 20.0	-	-	30.4	
AD1: g	mas	≤ 20.0	9.7	9.6	30.8	
AD1: r	mas	≤ 20.0	9.2	9.0	21.3	
AD1: i	mas	≤ 20.0	7.9	7.7	19.1	
AD1: z	mas	≤ 20.0	9.6	9.6	19.7	
AD1: y	mas	≤ 20.0	12.6	12.5	21.4	
AM2: u	mas	≤ 10.0	-	-	17.0	
AM2: g	mas	≤ 10.0	5.3	5.2	15.4	
AM2: r	mas	≤ 10.0	4.6	4.5	12.2	
AM2: i	mas	≤ 10.0	4.0	3.9	11.0	
AM2: z	mas	≤ 10.0	5.2	5.1	10.8	
AM2: y	mas	≤ 10.0	7.1	6.9	11.6	
AF2: u	%	≤ 10.0	-	-	24.1	
AF2: g	%	≤ 10.0	0.9	0.9	24.7	
AF2: r	%	≤ 10.0	0.8	0.8	11.0	
AF2: i	%	≤ 10.0	0.6	0.5	8.1	
AF2: z	%	≤ 10.0	0.7	0.7	8.4	
AF2: y	%	≤ 10.0	3.2	3.2	10.7	
AD2: u	mas	≤ 20.0	-	-	30.0	
AD2: g	mas	≤ 20.0	10.0	9.8	31.5	
AD2: r	mas	≤ 20.0	9.3	9.2	20.7	
AD2: i	mas	≤ 20.0	7.9	7.6	18.6	
AD2: z	mas	≤ 20.0	9.9	9.8	18.8	
AD2: y	mas	≤ 20.0	12.9	12.8	20.4	

A   References

[1] **[DMTR-451]**, Carlin, J., 2025, *Characterization Metric Report: Science Pipelines Version 28.0.0*, Data Management Test Report DMTR-451, NSF-DOE Vera C. Rubin Observatory, URL `https://dmtr-451.lsst.io/`

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

[3] **[DMTN-277]**, Ferguson, P., Rykoff, E., Carlin, J., Saunders, C., Parejko, J., 2025, *The Monster: A reference catalog with synthetic ugrizy-band fluxes for the Vera C. Rubin observatory*, Data Management Technical Note DMTN-277, NSF-DOE Vera C. Rubin Observatory, URL `https://dmtn-277.lsst.io/`

[4] **[DMTN-211]**, Guy, L.P., 2022, *Faro: A framework for measuring the scientific performance of petascale Rubin Observatory data products*, Data Management Technical Note DMTN-211, NSF-DOE Vera C. Rubin Observatory, URL `https://dmtn-211.lsst.io/`

[5] **[LPM-17]**, Ivezić, Ž., The LSST Science Collaboration, 2018, *LSST Science Requirements Document*, Project Controlled Document LPM-17, Vera C. Rubin Observatory, URL `https://ls.st/LPM-17`

[6] **[RTN-095]**, Vera C. Rubin Observatory, 2025, *The Vera C. Rubin Observatory Data Preview 1*, Technical Note RTN-095, NSF-DOE Vera C. Rubin Observatory, URL `https://rtn-095.lsst.io/`, doi:10.71929/rubin/2570536

[7] **[SITCOMTN-149]**, Vera C. Rubin Observatory, 2025, *An Interim Report on the ComCam On-Sky Campaign*, Commissioning Technical Note SITCOMTN-149, NSF-DOE Vera C. Rubin Observatory, URL `https://sitcomtn-149.lsst.io/`

B   Acronyms

Acronym	Description
DM	Data Management

DMTN	DM Technical Note
DMTR	DM Test Report
DP1	Data Preview 1
ECDFS	Extended Chandra Deep Field-South Survey
HSC	Hyper Suprime-Cam
KPM	Key Performance Metric
LPM	LSST Project Management (Document Handle)
LSE	LSST Systems Engineering (Document Handle)
LSR	LSST System Requirements; LSE-29
LSS	Large Scale Structure
LSST	Legacy Survey of Space and Time (formerly Large Synoptic Survey Telescope)
LSSTCam	LSST Science Camera
LSSTComCam	Rubin Commissioning Camera
PSF	Point Spread Function
RTN	Rubin Technical Note
SRD	LSST Science Requirements; LPM-17
SSP	Solar System Processing