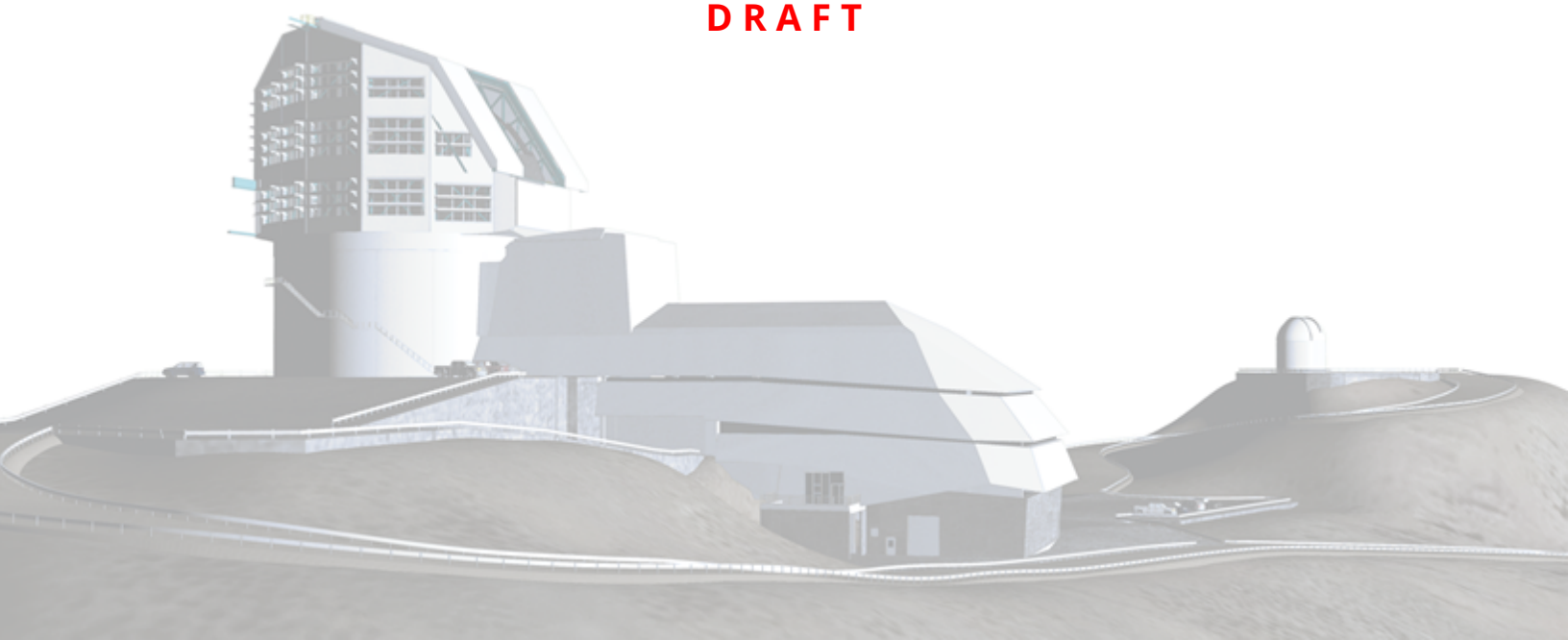

Vera C. Rubin Observatory
Data Management

Characterization Metric Report: Science Pipelines Version 22.0.0

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DMTR-311

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DRAFT

Abstract

This brief report describes measurements of data quality metrics that were carried out for release v22.0.0 of the LSST Science Pipelines. The report for the previous version can be found in [DMTR-281].

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Characterization Metric Report: Science Pipelines Version 22.0.0

In this Report, we characterize the performance of the Rubin Observatory Science Pipelines Version 22.0.0. 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.

The data release production pipeline using Gen3 middleware for HSC was not fully featured for this release, so the metrics presented here were computed on a run that used the Gen2 middleware, which will be deprecated after this release.

Beginning in March 2021, the metrics calculation package `validate_drp` was deprecated and replaced with `faro`, a new package built to use the Gen3 butler, and that is part of the standard science pipeline builds. Henceforth `faro` will be the tool we use to measure data quality metrics for Rubin Observatory. Before adopting `faro`, detailed verification was performed to confirm that, given the same input datasets and configuration parameters, `faro` and `validate_drp` produce identical results. Once this parity was demonstrated, `faro` was adopted and will now evolve (i.e., it will no longer be expected to produce identical results to those from `validate_drp`). Nonetheless, many of the algorithms from `validate_drp` were either ported directly to `faro` or have been modified slightly after porting. Our focus has now turned to implementing new metrics in `faro`.

The metric calculation pipelines from `faro` were run on the RC2 tracts to derive the photometric, astrometric, and shape metrics that are reported here. We exclude the two astrometry metrics (AM3 and AF3) that concern residuals on 200-arcminute scales, since neither the handful of CCDs in the validation_data_hsc dataset nor the individual tracts of RC2 span large enough spatial scales to enable these measurements.

For comparison, we provide the SRD required "design" value of each metric as defined in the Science Requirements Document [LPM-17]. For context, the SRD does not place any constraints on *y*-band for these Key Performance Metrics (KPMs). For the photometric metrics, there are only specifications for *g*, *r*, and *i*'. In the case of the ellipticity correlation metrics,

there are specs only for *r* and *i'*. The *y*-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.

1 Updated algorithms

Since the previous (v21.0.0) Science Pipelines release, we have engaged in detailed review of the science quality metrics and algorithms to calculate them. In response to this review, we have updated some of the metric calculation algorithms to reflect our current understanding of their intent.

The metric PA1 assesses the photometric repeatability. Its implementation in `validate_drp` involved selecting pairs of visits for each object at random and calculating their magnitude difference. This was turned into a root mean square (RMS) about the (unknown) mean magnitude by dividing by $\sqrt{2}$, and then the interquartile range of these RMS magnitude differences was calculated. This process was repeated for 50 random shuffles, and the mean value of the interquartile range of RMS differences reported as the PA1 "repeatability" (in mmag). With larger datasets now available containing multiple visits in the same patch of sky, we have implemented a much simpler definition of photometric repeatability. Specifically, for all objects meeting the quality criteria for selection, the RMS of the magnitude measurements about the mean is calculated. The metric PA1 is simply the median value (in mmag) of this RMS value per tract. This conceptually simpler definition is more reflective of the SRD's intent, and will allow for extensions such as subtracting the expected contribution from statistical noise to isolate the systematic photometric repeatability floor. The magnitude differences used to calculate PA1 are also used to measure PF1, the percentage of measurements that deviate by more than some threshold (in mmag) from the mean.

The metrics assessing ellipticity residuals (TE1 and TE2) have also been updated in response to our recent review. The previous implementation measured TE1 and TE2 from matched catalogs (i.e., sources matched between multiple visits), while the SRD definition specifies quantities that should be measured from objects in coadded images. We have rewritten the algorithm to calculate ellipticity residuals from coadd Objects rather than matched catalogs

of sources. Another change we made was to calculate the average of the *absolute value* of the correlation function instead of the straight average of the correlation function – because the correlation function value can be negative, taking a mean value artificially skews the value toward zero, rather than reflecting the magnitude of the effect. Additional investigation of the proper set of sources to select for measuring ellipticity residuals is ongoing (e.g., Jira ticket DM-30256), as the current selection is likely including sources whose PSF flux has been altered by the deblending process. Thus the values of metrics TE1 and TE2 in the tables below are not fully reflective of the capabilities of the science pipelines.

An additional metric reported here that has not been included in previous versions of this Report is AB1 – the residuals from comparison of a source's measured position in any band other than *r*, as compared the the same source's position in *r*-band. The RMS of these offsets in milliarcseconds is AB1.

Finally, we note the removal of some metrics that have been reported with previous Science Pipelines releases. Specifically, we no longer report PA2, AD1, and AD2, which are named quantities in the SRD that correspond to thresholds used in calculating related metrics (e.g., PA2 defines the threshold for outliers in measuring PF1), and not meant to define metrics themselves.

2 Summary of performance metrics

Other than the changes in how metrics are calculated (i.e., new algorithms and the adoption of the Gen3 Butler-native package `faro` for metric calculation), none of the major changes since Pipelines Version 21.0.0 should have dramatic effects on the performance metrics presented here. One of the biggest changes implemented in Version 22.0.0 is the adoption of the `scarlet` deblender for coadd measurement. While this will affect measurements of deblended objects from coadd images, none of the metrics in this report use measurements of deblended objects. The ellipticity residuals (Section 5) are measured on coadds, but specifically select isolated sources whose measurements were not altered by deblending. All other metrics are calculated based on single-visit data.

3 Photometric Performance

These photometric performance metrics are defined in LSS-REQ-0093 (LSE-29) and Table 14 of LPM-17. Values are presented for both the legacy `validate_drp` calculations (for comparison to Version 21), and for the updated algorithms implemented in `faro`. The `validate_drp` algorithms will be deprecated after this release. *Note that the change in values between the* `validate_drp` *and* `faro` *metrics is due to adoption of a new algorithm for calculating the metrics, as outlined in Section 1.*

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 21 Value (RC2)	Release 22 Value (RC2)	Release 22 Value (RC2-`faro`)	Comments
PA1: *u*	mmag	≤ 7.5	—	—	—	No data
PA1: *g*	mmag	≤ 5.0	13.8	13.7	7.6	
PA1: *r*	mmag	≤ 5.0	14.7	14.4	8.5	
PA1: *i*	mmag	≤ 5.0	14.7	14.5	9.2	
PA1: *z*	mmag	≤ 7.5	11.8	12.0	7.0	
PA1: *y*	mmag	≤ 7.5	14.3	14.2	8.0	
PF1: *u*	%	≤ 20	—	—	—	No data
PF1: *g*	%	≤ 20	31.1	30.4	12.0	
PF1: *r*	%	≤ 10	33.0	32.0	14.5	
PF1: *i*	%	≤ 10	33.7	32.9	16.0	
PF1: *z*	%	≤ 20	14.1	14.0	8.7	
PF1: *y*	%	≤ 10	17.6	16.9	12.0	

4 Astrometric Performance

The following metrics are defined following LSR-REQ-0094 [LSE-29] and Table 18 of LPM-17.

Metric	Unit	SRD Requirement – Design	Release 21 Value (RC2)	Release 22 Value (RC2)	Comments
AM1: *u*	mas	≤ 10	—	—	No data
AM1: *g*	mas	≤ 10	4.8	5.3	
AM1: *r*	mas	≤ 10	5.2	5.0	
AM1: *i*	mas	≤ 10	4.4	4.3	
AM1: *z*	mas	≤ 10	4.9	5.1	
AM1: *y*	mas	≤ 10	6.6	6.7	
AF1: *u*	%	≤ 10	—	—	No data
AF1: *g*	%	≤ 10	0.5	0.8	
AF1: *r*	%	≤ 10	1.3	1.6	
AF1: *i*	%	≤ 10	0.5	0.6	
AF1: *z*	%	≤ 10	0.4	0.9	
AF1: *y*	%	≤ 10	3.1	2.7	
AD1: *u*	mas	≤ 20	—	—	No data
AD1: *g*	mas	≤ 20	6.0	7.6	
AD1: *r*	mas	≤ 20	7.4	7.6	
AD1: *i*	mas	≤ 20	5.8	6.4	
AD1: *z*	mas	≤ 20	6.6	7.8	
AD1: *y*	mas	≤ 20	10.8	10.1	
AM2: *u*	mas	≤ 10	—	—	No data
AM2: *g*	mas	≤ 10	5.0	5.2	
AM2: *r*	mas	≤ 10	5.0	4.8	
AM2: *i*	mas	≤ 10	4.4	4.3	
AM2: *z*	mas	≤ 10	5.0	5.2	
AM2: *y*	mas	≤ 10	6.8	6.5	
AF2: *u*	%	≤ 10	—	—	No data
AF2: *g*	%	≤ 10	0.6	0.9	
AF2: *r*	%	≤ 10	1.1	1.2	
AF2: *i*	%	≤ 10	0.6	0.7	
AF2: *z*	%	≤ 10	0.4	0.9	
AF2: *y*	%	≤ 10	2.8	3.5	
AD2: *u*	mas	≤ 20	—	—	No data
AD2: *g*	mas	≤ 20	6.0	7.7	

Metric	Unit	SRD Requirement – Design	Release 21 Value (RC2)	Release 22 Value (RC2)	Comments
AD2: *r*	mas	≤ 20	6.9	7.4	
AD2: *i*	mas	≤ 20	5.8	6.4	
AD2: *z*	mas	≤ 20	5.9	7.9	
AD2: *y*	mas	≤ 20	10.5	11.0	
AB1: *u*	mas	≤ 10	—	—	No data
AB1: *g*	mas	≤ 10	—	8.4	
AB1: *r*	mas	≤ 10	—	4.6	
AB1: *i*	mas	≤ 10	—	5.2	
AB1: *z*	mas	≤ 10	—	4.4	
AB1: *y*	mas	≤ 10	—	6.1	

5 Ellipticity Correlations

The following metrics are defined following LSR-REQ-0097 [LSE-29] and Table 27 of LPM-17. *Note that, as detailed in Section 1, we adopted new algorithms for calculating these metrics between pipelines releases 21 and 22.*

Metric	Unit	SRD Requirement – Design	Release 21 Value (RC2)	Release 22 Value (RC2)	Comments
TE1: *u*	—	$\leq 2 \times 10^{-5}$	—	—	No data
TE1: *g*	—	$\leq 2 \times 10^{-5}$	1.4×10^{-5}	1.5×10^{-5}	
TE1: *r*	—	$\leq 2 \times 10^{-5}$	2.0×10^{-5}	2.6×10^{-4}	
TE1: *i*	—	$\leq 2 \times 10^{-5}$	1.1×10^{-5}	1.9×10^{-5}	
TE1: *z*	—	$\leq 2 \times 10^{-5}$	1.6×10^{-5}	9.4×10^{-6}	
TE1: *y*	—	$\leq 2 \times 10^{-5}$	9.3×10^{-6}	4.8×10^{-5}	
TE2: *u*	—	$\leq 1 \times 10^{-7}$	—	—	No data
TE2: *g*	—	$\leq 1 \times 10^{-7}$	3.7×10^{-7}	1.1×10^{-6}	
TE2: *r*	—	$\leq 1 \times 10^{-7}$	1.0×10^{-6}	2.0×10^{-6}	
TE2: *i*	—	$\leq 1 \times 10^{-7}$	2.5×10^{-6}	1.5×10^{-6}	
TE2: *z*	—	$\leq 1 \times 10^{-7}$	5.0×10^{-7}	8.4×10^{-7}	

Metric	Unit	SRD Requirement – Design	Release 21 Value (RC2)	Release 22 Value (RC2)	Comments
TE2: y	—	$\leq 1 \times 10^{-7}$	1.2×10^{-6}	1.4×10^{-6}	

6 Computational Performance

Computational performance metrics were not measured for this release.

A References

[1] **[DMTR-281]**, Carlin, J., 2020, *Characterization Metric Report: Science Pipelines Version 21.0.0*, DMTR-281, URL https://ls.st/DMTR-281

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

[3] **[LPM-17]**, Ivezić, Ž., The LSST Science Collaboration, 2018, *LSST Science Requirements Document*, LPM-17, URL https://ls.st/LPM-17

B Acronyms

Acronym	Description
DM	Data Management
DMTR	DM Test Report
HSC	Hyper Suprime-Cam
LPM	LSST Project Management (Document Handle)
LSE	LSST Systems Engineering (Document Handle)
LSR	LSST System Requirements; LSE-29

LSST	Legacy Survey of Space and Time (formerly Large Synoptic Survey Telescope)
PSF	Point Spread Function
RMS	Root-Mean-Square
SRD	LSST Science Requirements; LPM-17