LARGE SYNOPTIC SURVEY TELESCOPE

Large Synoptic Survey Telescope (LSST)

LSST Level 2 System Software Test Specification

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Abstract

This document describes the detailed test specification for the LSST Level 2 System.

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LSST Level 2 System Software Test Specification

1 Introduction

This document specifies the test procedure for the LSST Level 2 System.

The LSST Level 2 Systemis the compontent of the LSST system which is responsible for scientific processing leading to:

- Annual data release production;
- Periodic (re-) generation of calibration products;
- Periodic (re-) generation of templates for generating difference images, to be consumed in the L1 system;
- Generating QC metrics based on pipeline execution and post-processing of scientific data products.

1.1 Objectives

This document builds on the description of LSST Data Management's approach to testing as described in LDM-503 to describe the detailed tests that will be performed on the LSST Level 2 Systemas part of the verification of the DM system.

It identifies test designs, test cases and procedures for the tests, and the pass/fail criteria for each test. It identifies pass/fail criteria for each test.

1.2 Scope

This document describes the test procedures for the following components of the LSST system (as described in LDM-148):

Note

This list does not include any of the pipeline execution components, which I take as falling outside this document: should check.
Per mail to KTL, WOM of 2017-06-24, I suggest that we need to add a "QC Payloads" component.
Per the same mail, I suggest that the "Science Algorithms" and "Science Primitives" components should not exist.

- Annual Calibration
- Daily Calibration Update
- Data Release Production
- Periodic Calibration
- Raw Calibration
- Science Algorithms (partial)
- Science Primitives (partial)
- Template Generation

1.3 Applicable Documents

LDM-151	LSST DM Science Pipelines Design
LDM-294	LSST DM Organization & Management
LDM-502	The Measurement and Verification of DM Key Performance Metrics
LDM-503	LSST DM Test Plan
LSE-61	LSST DM Subsystem Requirements
LSE-163	LSST Data Products Definition Document
LSE-180	Level 2 Photometric Calibration for the LSST Survey

1.4 References

[1] **[LSE-29]**, Claver, C.F., The LSST Systems Engineering Integrated Project Team, 2016, *LSST System Requirements*, LSE-29, URL https://ls.st/LSE-29

[2] **[LSE-30]**, Claver, C.F., The LSST Systems Engineering Integrated Project Team, 2016, *LSST System Requirements*, LSE-30, URL https://ls.st/LSE-30

[3] **[LSE-61]**, Dubois-Felsmann, G., 2016, *LSST Data Management Subsystem Requirements*, LSE-61, URL https://ls.st/LSE-61

[4] **[LPM-17]**, Ivezić, Ž., The LSST Science Collaboration, 2011, *LSST Science Requirements Document*, LPM-17, URL https://ls.st/LPM-17

[5] **[LSE-180]**, Jones, L., 2013, *Level 2 Photometric Calibration for the LSST Survey*, LSE-180, URL https://ls.st/LSE-180

[6] **[LDM-151]**, Jurić, M., Lupton, R., et al., T.A., 2013, *Data Management Applications Design*, LDM-151, URL https://ls.st/LDM-151

[7] **[LSE-163]**, Juric, M., et al., 2017, *LSST Data Products Definition Document*, LSE-163, URL https://ls.st/LSE-163

[8] **[LDM-148]**, Kantor, J., Axelrod, T., 2013, *Data Management System Design*, LDM-148, URL https://ls.st/LDM-148

[9] **[LDM-502]**, Nidever, D., Economou, F., 2016, *The Measurement and Verification of DM Key Performance Metrics*, LDM-502, URL https://ls.st/LDM-502

[10] **[LDM-294]**, O'Mullane, W., DMLT, 2017, *Data Management Project Management Plan*, LDM-294, URL https://ls.st/LDM-294

[11] **[LDM-503]**, O'Mullane, W., Jurić, M., Economou, F., 2017, *Data Management Test, Verification and Validation Plan*, LDM-503, URL https://ls.st/LDM-503

[12] **[LSE-63]**, Tyson, T., DQA Team, Science Collaboration, 2011, *Data quality Assurance Plan: Requirements for the LSST Data Quality Assessment Framework*, LSE-63, URL https://ls.st/LSE-63

2 Approach

The major activities to be performed are to:

- Compare the design of the Data Release Production payload as implemented to the requirements on the outputs of the DM Subsystem as defined in LSE-63 and LSE-163 to demonstrate that all data products required by the scientific community will be delivered by the system as built.
- Ensure that all data products included in the DRP payload design are correctly produced and persisted appropriately to the LSST Data Backbone when executing a data release production.
- Compare the design of the Calibration Products payloads as implemented to the requirements laid down in LSE-63, the overall design described in LSE-180 and the inputs of the scientific pipeline payloads as described in LDM-151.
- Ensure that all data products included in the CPP payload design are correctly produced and persisted appropriately to the LSST Data Backbone and/or Calibration Database when executing a calibration products production.
- Compare the implementation of the Template Generation payloads to the inputs required by the Alert Production payload as defined in LDM-151.
- Ensure that all data products required by the L1 system are correctly produced and persisted appropriately to the LSST Data Backbone when executing a template generation production.
- Demonstrate that QC metrics are properly calculated and transmitted during the execution all L2 production types.
- Demonstrate that post-processing QC analysis of data products can be used to identify and report on failures or anomalies in the processing.

2.1 Tasks and criteria

The follwing are the major items under test:

- Science payloads capable of generating all LSST Level 2 data products;

- Calibration products payloads, run at a variety of cadences, to generate all calibration products required in the generation of LSST Level 1 and 2 data products;
- Template generation payloads capable of generating deep teamples required for difference imaging in the context of the LSST Level 1 system.

2.2 Features to be tested

- Execution of payloads described in §2.1;
- Persistence of all required data products.

2.3 Features not to be tested

This version of the LSST Level 2 Systemtest specification addresses only the functional requirements of the systems under test, as derived from the DM System Requirements (LSE-61).

A further set of requirements which describe the scientific fidelity of the output data products are not tested in this version of this test specification pending flow-down to LSE-61.

The progress of the DM system towards satisfying the scientific requirements on LSST's data products is tracked by means of a series of Key Performance Metrics (KPMs) derived from high-level requirements documents (LPM-17, LSE-29, LSE-30). The system being used to track KPMs and to ensure compliance with these requirements is described in LDM-502.

2.4 Pass/fail criteria

The results of all tests will be assessed using the criteria described in LDM-503 §4.

2.5 Suspension criteria and resumption requirements

Refer to individual test cases where applicable.

2.6 Naming convention

All tests are named according to the pattern PROD-SCOPE-XX-YY where:

PROD The product code, per LDM-294. Relevant entries for this document are:

CALDAILY Daily CP payload

CPPSLOW Periodic CPP payload

CPPYEAR Annual CPP payload

TMPLGEN Template generation payload

CPPQC CPP QC measurement generators

DRP Annual mini-DRP and DRP payload

L2QC L2 QC measurement generators

CPPQC CPP QC measurement generators

SCOPE The type of test being described:

ACP concerning acceptance testing

BCK concerning backup and restore testing

FUN concerning functional testing

INS concerning installation testing

INT concerning integration testing

ITF concerning interface testing

MNT concerning maintenance testing

PRF concerning performance testing

REG concerning regression testing

VER concerning verification testing

XX Test design number (in increments of 10)

YY Test case number (in increments of 5)

3 Test Specification Design

3.1 CPPSLOW-VER-00: Calibration Product Verification

3.1.1 Objective

This test design verifies that the calibration products production pipeline as designed and built meets the overall requirements of the DM system. Specifically, we verify that:

- The design of the system is such that all calibration products required by LSE-61 are produced;
- The code as delivered is accompanied by a suite of unit tests;
- The code as delivered is accompanied by appropriate documentation;
- The code complies with all relevant DM coding standards;
- The code makes use of standard DM interfaces to e.g. the data backbone, the logging system, the provenance system;
- The code is built and tested by the DM continuous integration system.

Note that the tests described in this section apply to all perioically executed calibration products production payloads, regardless of cadence (the same codebase will be used for daily updates and annual calibration products production).

3.1.2 Approach refinements

The general approach defined in LDM-503 is used. Methods include:

- Document inspection;
- Code inspection;
- Review of CI system logs.

3.1.3 Test case identification

Test Case	Description
CPPSLOW-VER-00-00	CPP design inspection
CPPSLOW-VER-00-05	CPP code inspection
CPPSLOW-VER-00-10	CPP testing review

3.2 CPPSLOW-FUN-10: Periodic Calibration Product Data Products

3.2.1 Objective

This test design verifies the existence of algorithms for generating of all periodic calibration products required by the DM System Requirements. These include:

- Bad pixel maps;
- Bias residual images;
- Crosstalk correction matrices;
- Illumination correction frames;
- Monochromatic flat fields;
- Dark current correction frames;
- Fringe correction frames.

Note that the tests described in this section apply to all perioically executed calibration products production payloads, regardless of cadence (the same codebase will be used for daily updates and annual calibration products production).

These tests demonstrate the existence of functional algorithms which calculate the required products; they are not intended to demonstrate the operation of an integrated calibration products production system.

3.2.2 Approach refinements

The general approach defined in LDM-503 is used.

The primary test method is to execute the relevant pipeline tasks on some sample input dataset and to demonstrate that an appropriate output dataset is produced.

3.2.3 Test case identification

Test Case	Description
CPPSLOW-FUN-10-00	Bad pixel map generation
CPPSLOW-FUN-10-05	Bias residual image generation

CPPSLOW-FUN-10-10	Crosstalk correction matrix generation
CPPSLOW-FUN-10-15	Illumination correction frame generation
CPPSLOW-FUN-10-20	Monochromatic flat field generation
CPPSLOW-FUN-10-25	Dark current correction frame generation
CPPSLOW-FUN-10-30	Fringe correction frame generation
CPPSLOW-FUN-10-35	Synthetic broadband flat generation

3.3 CPPSLOW-INT-20: Periodic Calibration Product Production Integration

3.3.1 Objective

This test design verifies that all the constituent algorithms of the periodic CPP payload, tested separately in CPPSLOW-FUN-10 (§3.2), can be integrated and controlled by the LSST processing control system.

3.3.2 Approach refinements

The general approach defined in LDM-503 is used.

3.3.3 Test case identification

Test Case	Description
CPPSLOW-INT-20-00	Tests that an end-to-end calibration products pipeline can be run under manual control
CPPSLOW-INT-20-05	Tests that a complete periodic calibration products productionc an be run under the control of the LSST system.

4 Test Case Specification

4.1 Preparation

Before running any test case, the LSST Science Pipelines must be correctly installed. Follow the procedure described in the Pipelines Documentation.

4.2 CPPSLOW-VER-00-00: CPP design inspection

4.2.1 Requirements

DMS-REQ-0059,DMS-REQ-0060,DMS-REQ-0061,DMS-REQ-0062,DMS-REQ-0063,DMS-REQ-0130,DMS-REQ-0132,DMS-REQ-0282,DMS-REQ-0283.

4.2.2 Test items

This test will check:

- That the design of the calibration products production pipelines is adequate to meet the DM subsystem requirements.

4.2.3 Intercase dependencies

None.

4.2.4 Procedure

By reference to LDM-151, the Science Pipelines design document, and LSE-61, the DM subsystem requirements, demonstrate that:

- The calibration products to be produced by the design outlined in LDM-151 satisfy all of the DM requirements;
- All of the calibration products to be produced are required for use by either the L1 or L2 science payloads, or have some other identified purpose.

4.3 CPPSLOW-VER-00-05: CPP code inspection

4.3.1 Requirements

DMS-REQ-0132,DMS-REQ-0158,DMS-REQ-0308.

4.3.2 Test items

This test will check:

- That the code delivered complies with relevant DM software quality standards;
- That the code is accompanied by appropriate documentation;
- That the code makes use of appropriate DM interfaces to the rest of the system where applicable;
- That the code is appropriately tested.

4.3.3 Intercase dependencies

None.

4.3.4 Procedure

- Check for the existence of a suite of unit test cases accompanying the codebase;
- Check the code to demonstrate that it is written in the standard LSST task framework and that it uses only standardized DM interfaces to logging and data access (i.e. it does not print directly to screen or perform filesystem I/O within the algorithmic code);
- Check that the code is accompanied by a user manual describing procedures for its installation and operation.

4.4 CPPSLOW-VER-00-10: CPP testing inspection

4.4.1 Requirements

DMS-REQ-0308.

4.4.2 Test items

This test will check:

- That all automated test suites associated with the product pass;

- That there are no unexpected errors or warnings from the build, test or installation process.

4.4.3 Intercase dependencies

CPPSLOW-VER-00-05.

4.4.4 Procedure

- Check the logs from the LSST CI system which was used to build and package the software under test to ensure:
  - Successful execution of the test suite, with no failures and no tests being skipped without explanatory documentation.
  - That there were no compiler, test, linter or other warnings associated with the software build processing.

4.5 CPPSLOW-FUN-10-00: Bad pixel map generation

4.5.1 Requirements

DMS-REQ-0059,DMS-REQ-0130.

4.5.2 Test items

This test will check:

- That a pipeline task (or equivalent tool) exists which generates a list of “bad” (unusable) pixels for one or more CCDs.

4.5.3 Intercase dependencies

None.

4.5.4 Input specification

Note

Detailed specification of the inputs required to generate an appropriate list of bad pixels will require further thought & input from the Calibration Scientist; this is a work in progress.

- A pre-existing list of known-bad pixels for the CCD under test. This is a Camera Team deliverable from sensor acceptance testing.
- Dark frames corresponding to the CCD under test. (How many? Where from — do they need to be on sky, or can we generated them from the test stand?)
- Flat field frames corresponding to the CCD under test. (How many? Where from — do they need to be on sky, or can we generated them from the test stand?)
- "Pocket pumping" exposures corresponding to the CCD under test. (How many? Where from — do they need to be on sky, or can we generated them from the test stand?)

These products should be available within a Butler repository accessible through the regular LSST data access framework from the system on which the test is being run.

4.5.5 Output specification

- A list of bad pixels in the CCD under test.

These products should be persisted to a Butler repository accessible through the regular LSST data access framework from the system on which the test is being run.

4.5.6 Procedure

The task for generating bad pixel masks will be executed from the command line, with a configuration appropriate for it to fetch required input data from the input Butler repository.

The resulting bad pixel list will be persisted to the output repository. To check for correctness, it should be:

- Compared to the initial list of bad pixels provided by the Camera Team;
- Optionally overplotted on the input data for manual inspection.

4.6 CPPSLOW-FUN-10-05: Bias residual image generation

4.6.1 Requirements

DMS-REQ-0060,DMS-REQ-0130.

4.6.2 Test items

This test will check:

- That a pipeline task (or equivalent tool) exists which generates a master image which can be used to correct for temporally stable bias structure in data from a CCD.

4.6.3 Intercase dependencies

None.

4.6.4 Input specification

Note

Detailed specification of the inputs required will require further thought & input from the Calibration Scientist; this is a work in progress.

- Multiple (how many?) zero-second exposures of the CCD under test.

These products should be available within a Butler repository accessible through the regular LSST data access framework from the system on which the test is being run.

4.6.5 Output specification

- A master bias residual image.

These products should be persisted to a Butler repository accessible through the regular LSST data access framework from the system on which the test is being run.

4.6.6 Procedure

The task for generating the master bias residual image will be executed from the command line, with a configuration appropriate for it to fetch required input data from the input Butler repository.

The resulting master bias will be persisted to the output repository. It should be retrieved from the output repository using the Butler and checked to ensure it contains physically plausible values (TBD by the Calibration Scientist).

4.7 CPPSLOW-FUN-10-10: Crosstalk correction matrix generation

4.7.1 Requirements

DMS-REQ-0061,DMS-REQ-0130.

4.7.2 Test items

This test will check:

- That a pipeline task (or equivalent tool) exists which generates a matrix describing the fraction of the signal detected in any given amplifier on each sensor in the focal plane appears in any other amplifier.

Note that crosstalk is sensitive to the details of the camera configuration (circuit board locations, cable flex, etc), and so the final values of the crosstalk correction matrix cannot be measured until the camera is in situ on the mountain (and even then they may continue to evolve, necessitating periodic re-measurement). However, this test verifies the operation of the algorithm for generating the matrix, not the values used in operation, so this test does not need to be run with the camera in its final configuration.

4.7.3 Intercase dependencies

None.

4.7.4 Input specification

> **Note**
>
> Detailed specification of the inputs required will require further thought & input from the Calibration Scientist; this is a work in progress.

- Dithered Colliated Beam Projector (CBP) observations with the full camera or a representative subset thereof.

These products should be available within a Butler repository accessible through the regular LSST data access framework from the system on which the test is being run.

4.7.5 Output specification

- A crosstalk correction matrix.

These products should be persisted to a Butler repository accessible through the regular LSST data access framework from the system on which the test is being run.

4.7.6 Procedure

The task for generating the crosstalk correction matrix will be executed from the command line, with a configuration appropriate for it to fetch required input data from the input Butler repository.

The resulting crosstalk correction matrix will be persisted to the output repository. It should be retrieved from the output repository using the Butler and checked to ensure it contains physically plausible values (TBD by the Calibration Scientist).

4.8 CPPSLOW-FUN-10-15: Illumination correction frame generation

4.8.1 Requirements

DMS-REQ-0062,DMS-REQ-0130.

4.8.2 Test items

This test will check:

- That a pipeline task (or equivalent tool) exists which generates an image that corrects for the non-uniform illumination of the flat field screen.

4.8.3 Intercase dependencies

None.

4.8.4 Input specification

Note

Detailed specification of the inputs required will require further thought & input from the Calibration Scientist; this is a work in progress.

- Collimated Beam Projector (CBP) images as specified in LDM-151 §4.2.10.

These products should be available within a Butler repository accessible through the regular LSST data access framework from the system on which the test is being run.

4.8.5 Output specification

- An illumination correction image.

These products should be persisted to a Butler repository accessible through the regular LSST data access framework from the system on which the test is being run.

4.8.6 Procedure

The task for generating the illumination correction frame will be executed from the command line, with a configuration appropriate for it to fetch required input data from the input Butler repository.

The resulting illumination correction image will be persisted to the output repository. It should be retrieved from the output repository using the Butler and checked to ensure it contains physically plausible values (TBD by the Calibration Scientist; ultimately, per LSE-61, it will be verified by application to operational data).

4.9 CPPSLOW-FUN-10-20: Monochromatic flat field generation

4.9.1 Requirements

DMS-REQ-0063,DMS-REQ-0130.

4.9.2 Test items

This test will check:

- That a pipeline task (or equivalent tool) exists which generates an set of master pure monochromatic flat field images.

4.9.3 Intercase dependencies

CPPSLOW-FUN-10-05, CPPSLOW-FUN-10-15, CPPSLOW-FUN-10-25.

4.9.4 Input specification

Note

Detailed specification of the inputs required will require further thought & input from the Calibration Scientist; this is a work in progress.

- Monochromatic flat field images;
- Collimated Beam Projector (CBP) images as specified in LDM-151 §4.2.10.

These products should be available within a Butler repository accessible through the regular LSST data access framework from the system on which the test is being run.

4.9.5 Output specification

- A monochromatic flat field data cube.

These products should be persisted to a Butler repository accessible through the regular LSST data access framework from the system on which the test is being run.

4.9.6 Procedure

Tasks for assembling, bias correcting and dark correcting the monochromatic flat field images will be executed from the command line, and the results persisted to a data repository. These serve as inputs to the monochromatic flat field data cube production.

The task for generating the monochromatic flat field data cube will be executed from the command line, and the results persisted to a further data repository.

The Butler will be used to retrieve the flat field data cube from the output repository, and the contents checked to ensure they are physically plausible (values TBD by the Calibration Scientist.)

4.10 CPPSLOW-FUN-10-25: Dark current correction frame generation

4.10.1 Requirements

DMS-REQ-0063,DMS-REQ-0282.

4.10.2 Test items

This test will check:

- That a pipeline task (or equivalent tool) exists which generates a coadded dark current correction image.

4.10.3 Intercase dependencies

Note

LDM-151 notes that we need to perform standard ISR on the darks before combining them, so that likely means a call out to a single frame/ISR test case when it exists.

CPPSLOW-FUN-10-05.

4.10.4 Input specification

Note

Detailed specification of the inputs required will require further thought & input from the Calibration Scientist; this is a work in progress.

- Multiple individual dark exposures of a single CCD with exposure times of 300 s.

These products should be available within a Butler repository accessible through the regular LSST data access framework from the system on which the test is being run.

4.10.5 Output specification

- A coadded dark current correction frame.

These products should be persisted to a Butler repository accessible through the regular LSST data access framework from the system on which the test is being run.

4.10.6 Procedure

The instrument signature removal code will be run on the individual input exposures from the command line, and the results persisted to a data repository.

The task for generating the coadded dark current correction frame will be executed from the command line, and the results persisted to a further data repository.

The Butler will be used to retrieve the flat field data cube from the output repository, and the contents checked to ensure they are physically plausible (values TBD by the Calibration Scientist.)

4.11 CPPSLOW-FUN-10-30: Fringe correction frame generation

4.11.1 Requirements

DMS-REQ-0063,DMS-REQ-0283.

4.11.2 Test items

This test will check:

- That a pipeline task (or equivalent tool) exists which generates an image which corrects for detector fringing.

4.11.3 Intercase dependencies

CPP-SLOW-FUN-10-20.

4.11.4 Input specification

Note

Detailed specification of the inputs required will require further thought & input from the Calibration Scientist; this is a work in progress.

- Monochromatic flat field data cube.

These products should be available within a Butler repository accessible through the regular LSST data access framework from the system on which the test is being run.

4.11.5 Output specification

- An image that corrects for fringing.

These products should be persisted to a Butler repository accessible through the regular LSST data access framework from the system on which the test is being run.

4.11.6 Procedure

The task for generating the fringe correction frame will be executed from the command line, with a configuration appropriate for it to fetch required input data from the input Butler repository.

The resulting fringe correction frame will be persisted to the output repository. It should be retreived from the output repository using the Butler and checked to ensure it contains physically plausible values (TBD by the Calibration Scientist).

4.12 CPPSLOW-FUN-10-35: Synthetic broadband flat generation

4.12.1 Requirements

DMS-REQ-0130.

4.12.2 Test items

This test will check:

- That a pipeline task (or equivalent tool) exists which generates a synthetic broad-band flat for each filter in use with the LSST system.

4.12.3 Intercase dependencies

CPPSLOW-FUN-10-20.

4.12.4 Input specification

Note

Detailed specification of the inputs required will require further thought & input from the Calibration Scientist; this is a work in progress.

- Monochromatic flat field data cube covering all filters.

These products should be available within a Butler repository accessible through the regular LSST data access framework from the system on which the test is being run.

4.12.5 Output specification

- One synthetic broadband flat field image for the CCD being tested for each filter.

These products should be persisted to a Butler repository accessible through the regular LSST data access framework from the system on which the test is being run.

4.12.6 Procedure

The task (or tasks, if one per filter; final design TBD) for generating the broadband synthetic flat field image will be executed from the command line, with a configuration appropriate for it to fetch required input data from the input Butler repository.

The resulting broadband synthetic flats will be persisted to the output repository. They should be retreived from the output repository using the Butler and checked to ensure they contain physically plausible values (TBD by the Calibration Scientist).

4.13 CPPSLOW-INT-20-00: Manual Calibration Products Production Execution

4.14 CPPSLOW-INT-20-05: Calibration Products Production Service