LARGE SYNOPTIC SURVEY TELESCOPE

Large Synoptic Survey Telescope (LSST)

LSST Level 1 System Test Specification
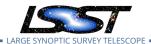
Eric C. Bellm, John D. Swinbank

LDM-533

Latest Revision: 2018-01-11

Abstract

This document describes the detailed test specification for the LSST Level 1 System.

Change Record

Version	Date	Description	Owner name
1.0	2018-01-11	Initial release of draft version.	Bellm, Swinbank
1.1	2018-01-11	Implementation of RFC-429	T. Jenness

Document curator: Eric C. Bellm

Document source location: `https://github.com/lsst/ldm-533`

Version from source repository: 9705d8d

Contents

The contents of this document are subject to configuration control by the LSST DM Change Control Board.

LSST Level 1 System Test Specification

1   Introduction

This document specifies the test procedure for the LSST Level 1 System.

The LSST Level 1 System is the component of the LSST system which is responsible for scientific processing leading to:

- Single frame processing and measurement;

- Alert generation from difference image analysis;

- Alert distribution to community brokers;

- Simple filtering of alerts;

- Precovery and forced photometry measurements on new and previously-known sources found in difference imaging;

- Identification of moving objects.

- Generating QC metrics based on pipeline execution and post-processing of scientific data products.

A full description of this product is provided in §6 (which describes the Data Facility-provided execution services) and §13.1 (the science payloads) of LDM-148.

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 1 System as 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.

1.2 Scope

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

- Services provided by the LSST Data Facility:

  - Prompt Processing Execution
  - Batch and Offline Processing Execution
  - Level 1 Quality Control
  - Alert Distribution Execution
  - Alert Filtering Execution

- Science payloads:

  - Single frame processing Payload
  - Alert Generation Payload
  - Precovery and Forced Photometry Payload
  - MOPS Payload

1.3 Applicable Documents

LDM-148   LSST DM System Architecture
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

1.4 References

[1] **[LSE-61]**, Dubois-Felsmann, G., Jenness, T., 2017, *LSST Data Management Subsystem Requirements*, LSE-61, URL `https://ls.st/LSE-61`

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

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

[4] **[LDM-148]**, Lim, K.T., Bosch, J., Dubois-Felsmann, G., et al., 2017, *Data Management System Design*, LDM-148, URL `https://ls.st/LDM-148`

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

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

[7] **[LDM-294]**, O'Mullane, W., Swinbank, J., Jurić, M., DMLT, 2017, *Data Management Organization and Management*, LDM-294, URL `https://ls.st/LDM-294`

[8] **[LDM-151]**, Swinbank, J.D., et al., 2017, *Data Management Science Pipelines Design*, LDM-151, URL `https://ls.st/LDM-151`

[9] **[LSE-63]**, Tyson, T., DQA Team, Science Collaboration, 2017, *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 Alert 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 AP payload design are correctly produced and persisted appropriately to the LSST Data Backbone, Alert Distribution System, and/or Alert Filtering service as appropriate.

- Ensure that all data products required by the Precovery and Forced Photometry payload are correctly produced and persisted appropriately to the LSST Data Backbone.

- Ensure that all data products required by the MOPS system are correctly produced and persisted appropriately to the LSST Data Backbone.

- Demonstrate that QC metrics are properly calculated and transmitted during the execution all L1 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 following are the major items under test:

- The science payload capable of prompt processing of single visit images;

- The Alert Generation payload that detects variable sources through difference image analysis;

- The Alert Distribution System that packages alerts and forwards them to community brokers;

- The filtering system that allows science users to apply simple filters to the alert stream;

- The Precovery and Forced Photometry payloads that measure flux levels for new and previously-known sources found in difference images;

- The Moving Object Processing System payload that identifies solar system bodies from difference image sources;

- Services capable of scheduling and managing the execution of all of the above payloads, marshalling their results, and making them available to other parts of the system for analysis or further distribution.

2.2   Features to be tested

- Execution of payloads described in §2.1;

- Persistence of all required data products;

- Scientific fidelity of those data products: do they satisfy the requirements described in LSE-61?

2.3   Features not to be tested

This document does not describe facilities for periodically generating or collecting key performance metrics (KPMs), except insofar as those KPMs are incidentally measured as part of executing the documented testcases. The KPMs and the system being used to track KPMs and to ensure compliance with documented 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.

Note that, when executing pipelines, tasks or individual algorithms, any unexplained or unexpected errors or warnings appearing in the associated log or on screen output must be described in the documentation for the system under test. Any warning or error for which this is not the case must be filed as a software problem report and filed with the DMCCB.

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-XX-YY where:

PROD The product under test. Relevant entries for this document are:

AG The Alert Generation payload and associated service

AD The Alert Distribution payload and associated service

AF The Alert Filtering service

PFP The Precovery and Forced Photometry payload and associated service

MOPS The MOPS payload and associated service

XX Test specification number (in increments of 10)

YY Test case number (in increments of 5)

3   Test Specification Design

3.1   AG-00: Small Scale Alert Generation Processing

3.1.1   Objective

This test specification demonstrates the successful execution of an Alert Generation payload on a relatively small scale based on data from precursor surveys.

It will demonstrate that:

- Science payload code can be made available on systems managed by the LSST Data Facility;

- The science payload can be executed under the control of the Offline Processing Execution service;

- All required science data products can be collected by the execution service and made available for subsequent analysis;

- The Alert Generation payload generates results broadly equivalent to "native" reductions of precursor survey data.

Note that this test specification does not extend to demonstrating the detailed compliance of LSST data products with all Science Requirements Document level requirements: such a demonstration would require carefully curated LSST-like datasets (or simulated data), a detailed understanding of the LSST system, LSST-like calibration products, etc, which are assumed not to be available for this test.

3.1.2   Approach refinements

The general approach defined in LDM-503 is used.

3.1.3   Test case identification

Test Case	Description
AG-00-00	Tests that the Alert Generation science payload can be installed on LSST Data Facility-managed systems.
AG-00-05	Tests that required data products are produced by executing the Alert Generation payload.

AG-00-10	Tests that the delivered processed visit images meet scientific requirements.
AG-00-15	Tests that the delivered difference images meet scientific requirements.
AG-00-20	Tests that the delivered DIASource catalogs meet scientific requirements.
AG-00-25	Tests that the delivered DIAObject catalog meets scientific requirements.

4 Test Case Specification

4.1 AG-00-00: Installation of the Alert Generation science payload.

4.1.1 Requirements

DMS-REQ-0308.

4.1.2 Test items

This test will check:

- That the Alert Generation science payload is available for distribution from documented channels;

- That the Alert Generation science payload can be installed on LSST Data Facility-managed systems.

4.1.3 Intercase dependencies

None.

4.1.4 Environmental needs

4.1.4.1 Hardware This test case shall be executed on a developer system at NCSA which serves as the "head node" or otherwise provides access to filesystems shared by the LSST Ver-

The contents of this document are subject to configuration control by the LSST DM Change Control Board.

7

ification Cluster (LSST-VC). We assume that this system will be `lsst-dev01.ncsa.illinois.edu` and the filesystem will be a GPFS-based system mounted at `/software`.

The test also requires access to one LSST-VC compute node.

4.1.4.2 Software All prerequisite packages listed at `https://pipelines.lsst.io/install/prereqs/centos.html` must be available on the test system and on the LSST-VC compute node.

4.1.5 Input specification

No input data is required for this test case.

4.1.6 Output specification

The Alert Generation science payload will be made available on a shared filesystem accessible from LSST-VC compute notes.

4.1.7 Procedure

1. Release 14.0 of the LSST Science Pipelines will be installed into the GPFS filesystem accessible at `/software` on `lsst-dev01` following the instructions at `https://pipelines.lsst.io/install/newinstall.html`.

2. The lsst_distrib top level package will be enabled:

   ```
   source /software/lsstsw/stack3/loadLSST.bash
   setup lsst_distrib
   ```

3. The "LSST Stack Demo" package will be downloaded onto the test system from `https://github.com/lsst/lsst_dm_stack_demo/releases/tag/14.0` and uncompressed.

4. The demo package will be executed by following the instructions in its "README" file. The string "Ok." should be returned. Specifically, we execute:

   ```
   setup obs_sdss
   ./bin/demo.sh
   python bin/compare expected/Linux64/detected-sources.txt
   ```

The contents of this document are subject to configuration control by the LSST DM Change Control Board.

5. A shell on an LSST-VC compute node will now be obtained by executing:

```
$ srun -I --pty bash
```

6. The demo package will be executed on the compute node and the same result obtained.

7. The Alert Production datasets and packages are not yet part of lsst_distrib and so must be installed separately. They will be installed as follows on the GPFS filesystem:

```
setup git_lfs
git clone https://github.com/lsst/ap_verify_hits2015.git

export AP_VERIFY_HITS2015_DIR=$PWD/ap_verify_hits2015
cd $AP_VERIFY_HITS2015_DIR
setup -r .
cd -

setup obs_decam

git clone https://github.com/lsst-dm/ap_association
cd ap_association
setup -k -r .
scons
cd -

git clone https://github.com/lsst-dm/ap_pipe
cd ap_pipe
setup -k -r .
scons
cd -

git clone https://github.com/lsst-dm/ap_verify
cd ap_verify
setup -k -r .
scons
cd -
```

and any errors or failures reported.

4.2   AG-00-05: Alert Generation Produces Required Data Products

4.2.1   Requirements

DMS-REQ-0069, DMS-REQ-0010, DMS-REQ-0269, DMS-REQ-0271

4.2.2   Test items

This test will check that the basic data products produced by Alert Generation are generated by execution of the science payload.

These products will include:

- Processed visit images (PVIs; DMS-REQ-0069);
- Difference Exposures (DMS-REQ-0010);
- DIASource catalogs (DMS-REQ-0269);
- DIAObject catalogs (DMS-REQ-0271);

4.2.3   Intercase dependencies

- AG-00-00

4.2.4   Environmental needs

4.2.4.1   Hardware   The test shall be carried out on a machine with at least 16 GB of RAM and multiple CPU cores which has access to the `/datasets` shared (GPFS) filesystem at the LSST Data Facility.

4.2.4.2   Software   Release 14.0 of the DM Software Stack will be pre-installed (following the procedure described in AG-00-00).

4.2.5   Input specification

A complete processing of the DECam "HiTS" dataset, as defined at `https://dmtn-039.lsst.io/` and `https://github.com/lsst/ap_verify_hits2015`, through the Alert Generation science payload.

This dataset shall be made available in a standard LSST data repository, accessible via the "Data Butler".

It is not required that all combinations of visit and CCD have been processed successfully: a number of failures are expected. However, documentation to describe processing failures should be provided.

4.2.6   Output specification

None.

4.2.7   Procedure

- The DM Stack and Alert Processing packaged shall be initialized as described in AG-00-00.

- The alert generation processing will be executed using the verification cluster:

```
python ap_verify/bin/prepare_demo_slurm_files.py

# At present we must run a single ccd+visit to handle ingestion before
# parallel processing can begin
./ap_verify/bin/exec_demo_run_1ccd.sh 410915 25

ln -s ap_verify/bin/demo_run.sl
ln -s ap_verify/bin/demo_cmds.conf
sbatch demo_run.sl
```
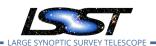
and any errors or failures reported.

- A "Data Butler" will be initialized to access the repository.

- For each of the expected data products types (listed in §4.2.2) and each of the expected units (PVIs, catalogs, etc.), the data product will be retrieved from the Butler and verified to be non-empty.

- `DIAObjects` are currently only stored in a database, without shims to the Butler, so the existence of the database table and its non-empty contents will be verified by directly accessing it using `sqlite3` and executing appropriate SQL queries.

4.3   AG-00-10: Scientific Verification of Processed Visit Images

4.3.1   Requirements

DMS-REQ-0069, DMS-REQ-0327, DMS-REQ-0029, DMS-REQ-0070, DMS-REQ-0030, DMS-REQ-0072.

4.3.2   Test items

This test will check that the Processed Visit Images (PVIs) delivered by the alert generation science payload meet the requirements laid down by LSE-61.

Specifically, this will demonstrate that:

- Processed visit images have been generated and persisted during payload execution;

- Each PVI includes a science pixel array, a mask array, and a variance array. (DMS-REQ-0072).

- Each PVI includes a background model (DMS-REQ-0327), photometric zero-point (DMS-REQ-0029), spatially-varying PSF (DMS-REQ-0070) and WCS (DMS-REQ-0030).

- Saturated pixels are correctly masked.

- Pixels affected by cosmic rays are correctly masked.

- The background is not oversubtracted around bright objects.

This test does not include quantitative targets for the science quality criteria.

4.3.3   Intercase dependencies

- AG-00-00

- AG-00-05

4.3.4   Environmental needs

4.3.4.1   Hardware   The test shall be carried out on a machine with at least 16 GB of RAM and multiple CPU cores which has access to the `/datasets` shared (GPFS) filesystem at the LSST Data Facility.

4.3.4.2   Software   Release 14.0 of the DM Software Stack will be pre-installed (following the procedure described in AG-00-00).

4.3.5   Input specification

A complete processing of the DECam "HiTS" dataset, as defined at `https://dmtn-039.lsst.io/` and `https://github.com/lsst/ap_verify_hits2015`, through the Alert Generation science payload.

This dataset shall be made available in a standard LSST data repository, accessible via the "Data Butler".

It is not required that all combinations of visit and CCD have been processed successfully: a number of failures are expected. However, documentation to describe processing failures should be provided.

4.3.6   Output specification

None.

4.3.7   Procedure

- The DM Stack shall be initialized using the `loadLSST` script (as described in AG-00-00).

- A "Data Butler" will be initialized to access the repository.

- For each processed CCD, the PVI will be retrieved from the Butler, and the existence of all components described in §4.3.2 will be verified.

- Five sensors will be chosen at random from each of two visits and inspected by eye for unmasked artifacts.

4.4 AG-00-15: Scientific Verification of Difference Images

4.4.1 Requirements

DMS-REQ-0010, DMS-REQ-0074,

4.4.2 Test items

This test will check that the difference images delivered by the Alert Generation science payload meet the requirements laid down by LSE-61.

Specifically, this will demonstrate that:

- Difference images have been generated and persisted during payload execution;

- Each difference image includes information about the identity of the input exposures, and metadata such as a representation of the PSF matching kernel (DMS-REQ-0074);

- Masks are correctly propagated from the input images.

This test does not include quantitative targets for the science quality criteria.

4.4.3 Intercase dependencies

- AG-00-00

- AG-00-05

4.4.4 Environmental needs

4.4.4.1 Hardware The test shall be carried out on a machine with at least 16 GB of RAM and multiple CPU cores which has access to the `/datasets` shared (GPFS) filesystem at the LSST Data Facility.

4.4.4.2 Software   Release 14.0 of the DM Software Stack will be pre-installed (following the procedure described in AG-00-00).

4.4.5 Input specification

A complete processing of the DECam "HiTS" dataset, as defined at `https://dmtn-039.lsst.io/` and `https://github.com/lsst/ap_verify_hits2015`, through the Alert Generation science payload.

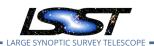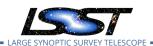This dataset shall be made available in a standard LSST data repository, accessible via the "Data Butler".

It is not required that all combinations of visit and CCD have been processed successfully: a number of failures are expected. However, documentation to describe processing failures should be provided.

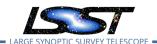### 4.4.6 Output specification

None.

4.4.7 Procedure

- The DM Stack shall be initialized using the `loadLSST` script (as described in AG-00-00).

- A "Data Butler" will be initialized to access the repository.

- For each processed CCD, the difference image will be retrieved from the Butler, and the existence of all components described in §4.4.2 will be verified.

- Five sensors will be chosen at random from each of two visits and the masks of the input and difference images compared by eye.

4.5 AG-00-20: Scientific Verification of DIASource Catalog

4.5.1 Requirements

DMS-REQ-0269, DMS-REQ-0270, DMS-REQ-0347, DMS-REQ-0331.

4.5.2   Test items

This test will check that the difference image source catalogs delivered by the Alert Generation science payload meet the requirements laid down by LSE-61.

Specifically, this will demonstrate that:

- Measurements in the catalog are presented in flux units (DMS-REQ-0347);

- Each DIASource record contains an appropriate subset of the attributes required by DMS-REQ-0269. In particular, the LDM-503-3-era pipeline is expected to provide DIA-Source positions (sky and focal plane), fluxes, and flags indicative of issues encountered during processing.

- Faint DIASources satisfying additional criteria are stored (DMS-REQ-0270).

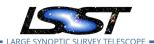- Derived quantities are provided in pre-computed columns (DMS-REQ-0331);

This test does not include quantitative targets for the science quality criteria.

4.5.3   Intercase dependencies

- AG-00-00

- AG-00-05

4.5.4   Environmental needs

4.5.4.1   Hardware   The test shall be carried out on a machine with at least 16 GB of RAM and multiple CPU cores which has access to the `/datasets` shared (GPFS) filesystem at the LSST Data Facility.

4.5.4.2   Software   Release 14.0 of the DM Software Stack will be pre-installed (following the procedure described in AG-00-00).

4.5.5   Input specification

A complete processing of the DECam "HiTS" dataset, as defined at `https://dmtn-039.lsst.io/` and `https://github.com/lsst/ap_verify_hits2015`, through the Alert Generation science payload.

This dataset shall be made available in a standard LSST data repository, accessible via the "Data Butler".

It is not required that all combinations of visit and CCD have been processed successfully: a number of failures are expected. However, documentation to describe processing failures should be provided.

4.5.6   Output specification

None.

4.5.7   Procedure

- The DM Stack shall be initialized using the `loadLSST` script (as described in AG-00-00).

- A "Data Butler" will be initialized to access the repository.

- DIASource records will be accessed by querying the Butler, then examined interactively at a Python prompt.

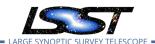## 4.6   AG-00-25: Scientific Verification of DIAObject Catalog

4.6.1   Requirements

DMS-REQ-0285, DMS-REQ-0271, DMS-REQ-0272, DMS-REQ-0347, DMS-REQ-0331

4.6.2   Test items

This test will check that the DIAObject catalogs delivered by the Alert Generation science payload meet the requirements laid down by LSE-61.

Specifically, this will demonstrate that:

- DIAObjects are recorded with unique identifiers (DMS-REQ-0271);

- Measurements in the catalog are presented in flux units (DMS-REQ-0347);

- Each DIAObject record contains contains an appropriate set of summary attributes (DMS-REQ-0271 and DMS-REQ-0272). Note:

  - This test is executed independently of the Data Release Production system. Hence, DIAObjects are not associated to Objects, and the association metadata specified by DMS-REQ-0271 is not expected to be available.

  - The LDM-503-3 era pipeline is not expected to calculate or persist all attributes specified by DMS-REQ-0272 requirement.

- Relevant derived quantities are provided in pre-computed columns (DMS-REQ-0331);

This test does not include quantitative targets for the science quality criteria.
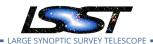
4.6.3   Intercase dependencies

- AG-00-00

- AG-00-05

4.6.4   Environmental needs

4.6.4.1   Hardware   The test shall be carried out on a machine with at least 16 GB of RAM and multiple CPU cores which has access to the `/datasets` shared (GPFS) filesystem at the LSST Data Facility.

4.6.4.2   Software   Release 14.0 of the DM Software Stack will be pre-installed (following the procedure described in AG-00-00).

4.6.5   Input specification

A complete processing of the DECam "HiTS" dataset, as defined at `https://dmtn-039.lsst.io/` and `https://github.com/lsst/ap_verify_hits2015`, through the Alert Generation science payload.

This dataset shall be made available in a standard LSST data repository, accessible via the "Data Butler".

It is not required that all combinations of visit and CCD have been processed successfully: a number of failures are expected. However, documentation to describe processing failures should be provided.

4.6.6   Output specification

None.

4.6.7   Procedure

- The DM Stack shall be initialized using the `loadLSST` script (as described in AG-00-00).

- `sqlite3` or Python's `sqlalchemy` module will be used to access the Level 1 database.

A   The DECam '"HiTS" dataset

We use a subset of the DECam hits dataset, contained in the repository `https://github.com/lsst/ap_verify_hits2015.git`. As described in `https://dmtn-039.lsst.io/`, we select HiTS fields `Blind15A_26`, `Blind15A_40`, and `Blind15A_42`. We construct templates from the best-seeing observations of same region of sky using the previous year's observations, labelled `Blind14A_04`, `Blind14A_10`, and `Blind14A_09`.

The specific visits we use are:

410915, 410929, 410931, 410971, 410985, 410987, 411021, 411035, 411037, 411055, 411069, 411071, 411255, 411269, 411271 , 411305, 411319, 411321, 411355, 411369, 411371, 411406, 411420, 411422 , 411456, 411470, 411472, 411657, 411671, 411673, 411707, 411721, 411724, 411758, 411772, 411774, 411808, 411822, 411824, 411858, 411872, 411874 , 412060, 412074, 412076, 412250, 412264, 412266, 412307, 412321, 412324, 412504, 412518, 412520, 412554, 412568, 412570, 412604, 412618, 412620, 412654, 412668, 412670, 412704, 412718, 412720, 413635, 413649, 413651, 413680, 413694, 413696, 415314, 415328, 415330, 415364, 415378, 415380, 419791, 419802, 419804, 421590, 421604, 421606.

For each visit we exclude CCDs 1, 2, and 61, leaving CCDs 3-60 and 62. We use g-band only for these tests due to the need to build templates.