



LARGE SYNOPTIC SURVEY TELESCOPE

Large Synoptic Survey Telescope (LSST) Data Management Test Plan

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LDM-503

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Abstract

This is the Test Plan for Data Management. In it we define terms associated with testing and further test specifications for specific items.

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Data Management Test Plan

1 Introduction

In this document we lay out the verification and validation approach for LSST Data Management. In addition we outline some of the high level test milestones in Section 6 and our planned schedule for demonstrating interim verification status.

1.1 Objectives

We describe the test and verification approach for DM and describe various constraints and limitations in the testing to be performed. We also describe the validation tests to be performed on the partially and fully integrated system. We do not describe all tests in details; those are described in dedicated test specifications for major components of Data Management. Here we outline the required elements for those specifications as well as the tools we use to for continuous verification.

1.2 Scope

This provides the approach and plan for all of Data Management. It covers interfaces between Data Management and components from other LSST subsystems but nothing outside of Data Management. This document is change-controlled by the DMCCB and will be updated in response to any requirements updates or changes of approach.

1.3 Assumptions

We will run large scale Science Validations in order to demonstrate the system's end-to-end capability against its design specifications. A large amount of informal science validation will be done in the the teams and documented in technical notes; in this test plan we are looking for validation of the broader system and specifically *operability* i.e. whether we can run this system every day for the 10 year planned survey with a reasonable level of operational support.

1.4 Applicable Documents

When applicable documents change a change may be required in this document.

LPM-55 LSST Quality Assurance Plan
LDM-294 DM Project Management Plan
LDM-148 DM Architecture

1.5 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-81]**, Dubois-Felsmann, G., 2013, *LSST Science and Project Sizing Inputs*, LSE-81, URL <https://ls.st/LSE-81>
- [4] **[LSE-61]**, Dubois-Felsmann, G., 2016, *LSST Data Management Subsystem Requirements*, LSE-61, URL <https://ls.st/LSE-61>
- [5] **[LSE-82]**, Dubois-Felsmann, G., Lim, K.T., 2013, *Science and Project Sizing Inputs Explanation*, LSE-82, URL <https://ls.st/LSE-82>
- [6] **[LPM-17]**, Ivezić, Ž., The LSST Science Collaboration, 2011, *LSST Science Requirements Document*, LPM-17, URL <https://ls.st/LPM-17>
- [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-240]**, Kantor, J., Juric, M., Lim, K.T., 2016, *Data Management Releases*, LDM-240, URL <https://ls.st/LDM-240>

- [10] **[LDM-502]**, Nidever, D., Economou, F., 2016, *The Measurement and Verification of DM Key Performance Metrics*, LDM-502, URL <https://ls.st/LDM-502>
- [11] **[LDM-294]**, O'Mullane, W., DMLT, 2017, *Data Management Project Management Plan*, LDM-294, URL <https://ls.st/LDM-294>
- [12] **[LPM-55]**, Sweeney, D., McKercher, R., 2013, *Project Quality Assurance Plan*, LPM-55, URL <https://ls.st/LPM-55>
- [13] **[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>

1.6 Definitions, acronyms, and abbreviations

The following table has been manually generated pending automatic generation from the on-line LSST acronym list:

Acronym	Description
AP	Alerts Production
API	Application Programming Interface
CAM	CAMera
CI	Configuration Item
DAC	Data Access Center
DAQ	Data AcQuisition (system)
DAX	Data Access Services
DBB	Data BackBone
DM	Data Management
DMCCB	DM Change Control Board
DMLT	DM Leadership Team
DPC	Data Processing Centre
DRP	Data Release Production
EFD	Engineering Facilities Database
HSC	Hyper Suprime-Cam
ICD	Interface Control Document

JIRA	issue tracking product (not an acronym, but a truncation of Gojira, the Japanese name for Godzilla)
KPM	Key Performance Metric
LCR	LSST Change Request
LSST	Large-aperture Synoptic Survey Telescope
NCSA	National Center for Supercomputing Applications
OCS	Observatory Control System
OPS	OPerations
PDAC	Prototype Data Access Center
QA	Quality Assurance
QC	Quality Control
QSERV	In-house LSST Database system
SP	Software Product
SPR	Software Problem Report
SUIT	Science User Interface Team
SV	System Verification
TBD	To Be Defined (Determined)
TCT	Technical Control Team (Obsolete – now DMCCB)
UX	User InterFace widget
WBS	Work Breakdown Structure
WISE	Wide-field Survey Explorer

2 Roles and Reporting

Each test specification must make clear who the *tester* is.

Testers report issues (SPRs) through the Data Management ticketing system (e.g. Jira at the time of this document revision) and also write a test report (and/or provide any necessary configuration for automatic report generation).

The test reports will be used to populate the verification control document (see Section 3). We are monitoring the LSST Systems Engineer's approach to plan commissioning tests for LSST system-wide verification and will evaluate the merits of using the same toolchain for Data

Management verification.

Operations rehearsals require an *ops rehearsal co-ordinator* to oversee the process rather than tests. The rehearsal may not be directed by the Operations Manager since that person has a major role in the rehearsal. An individual not involved in the rehearsal itself will be identified to perform this function.

Tests and procedures will sometimes fail – a test specification may be rerun several times until it passes but the report must include an explanation that indicates that any failures were understood (e.g. they were due to a fault that was fixed) or repeated sufficient times to ensure that passing the test was not transient success.

For large scale tests and rehearsals the DMCCB, or an individual designated by it, will be tasked to write up the findings as well as decide on timescales for re-running part or all of a test in case of failure or partial success.

Other parties that have a relevant role in Data Management verification are identified in the appropriate sections of the document; these are involved in their primary capacity (e.g. the DM Systems Engineer) and so are not individually listed in this section.

3 DM Verification Approach

Our approach towards verifying the Data Management requirements follows standard engineering practice. Each high level component will have at least one test specification defining a set of tests related to the design requirements for the component. These specifications are represented on the top of Figure 1. Any given requirement may have several tests associated with it in the specification; the tests may be phased to account for incremental delivery depending on the need for certain functionality at a specific time.

The test spec will cover all aspects of the test as outlined in Section 3.3. These high level test specifications may call out individual lower level test specification where it makes sense (either technically or programatically) to test lower-level components in isolation.

3.1 Reports

As we execute tests we will generate test reports on the Pass/Fail of the individual tests related to specific requirements. This Information will allow us to build a Verification Control Document (VCD) (right of Figure 1). The VCD will provide a % verification of each requirement in DM (rolled up to OSS requirements also). Figure 1 currently calls for a report from each test spec – this may be captured directly in e.g. Jira and does not need to originate as a document-format (Word, LaTeX) source.

In cases of reports that are generated via automatic (continuous) verification, the report may be in the format of a Jupyter Notebook that simultaneously can serve as test specification and test report and, in some cases, the test script itself. This is the preferred method provided the notebook-as-report is satisfactorily captured in DocuShare.

The DM components are outlined in LDM-294 and detailed in LDM-148. At a high level these components are represented in Figure 2. Based on those components we can see the set of Test Specifications needed in Table 2. That table does not contain all of the document numbers yet for cases for second-level components (and in some cases they may be rolled up into their parent).

3.2 Test Items

The test items covered in this test plan are:

- Data Management and its primary components for testing and integration purposes. These are listed in Table 2. All components listed in orange and yellow have specifications in the corresponding documents listed. Major sub-components in white may have individual test specifications or be addressed in the component they are under depending on applicable factors such as whether they are scheduled for testing at the same time and/or whether they share architectural components or are largely distinct.
- The external interfaces between Data Management and other sub-systems. These are described in DocuShare collection 5201.
- Operational procedures like Data Release Process, the Software Release Process and the Security Plan.

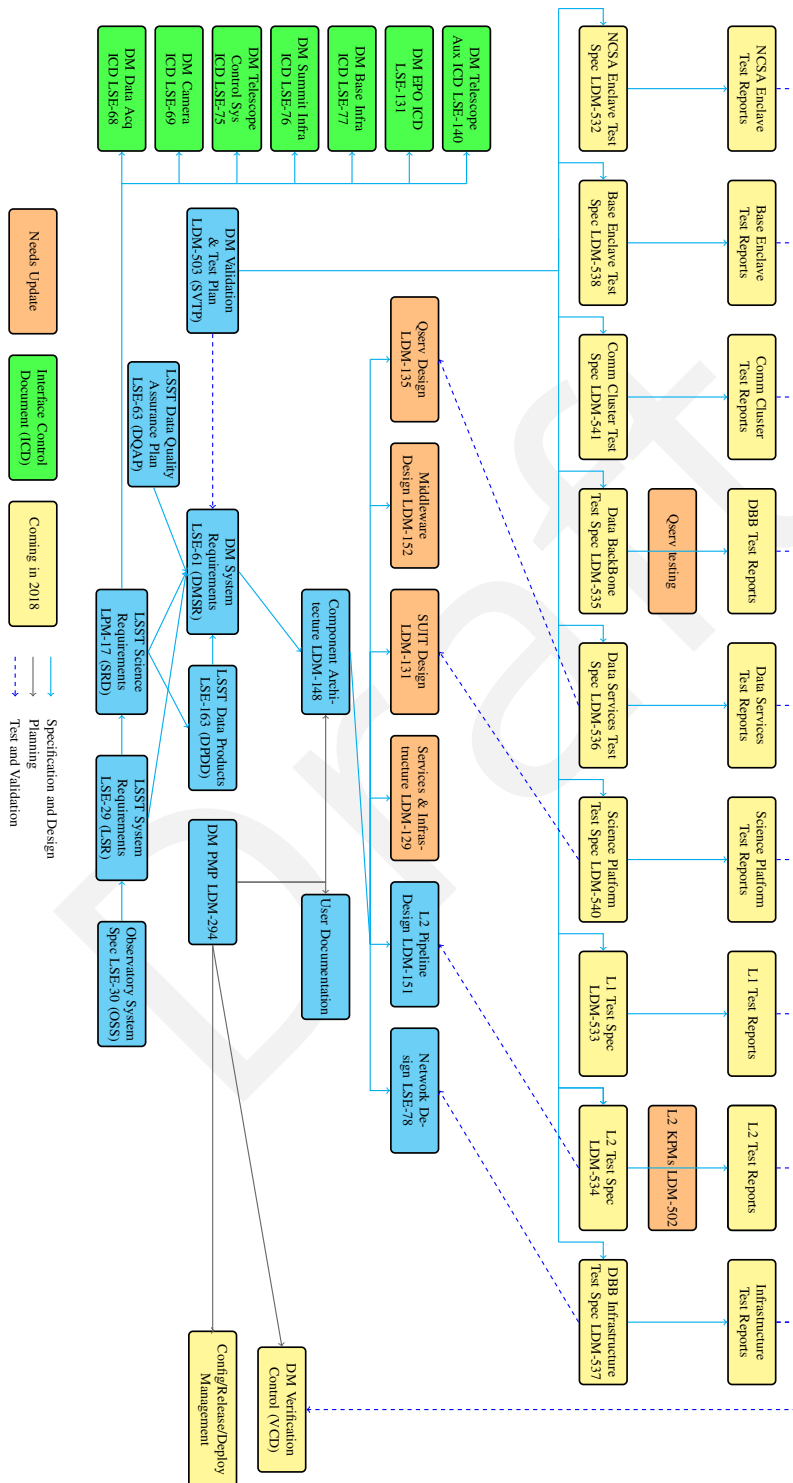


FIGURE 1: Documentation tree for DM software relating the high level documents to each other. (from LDM-294)

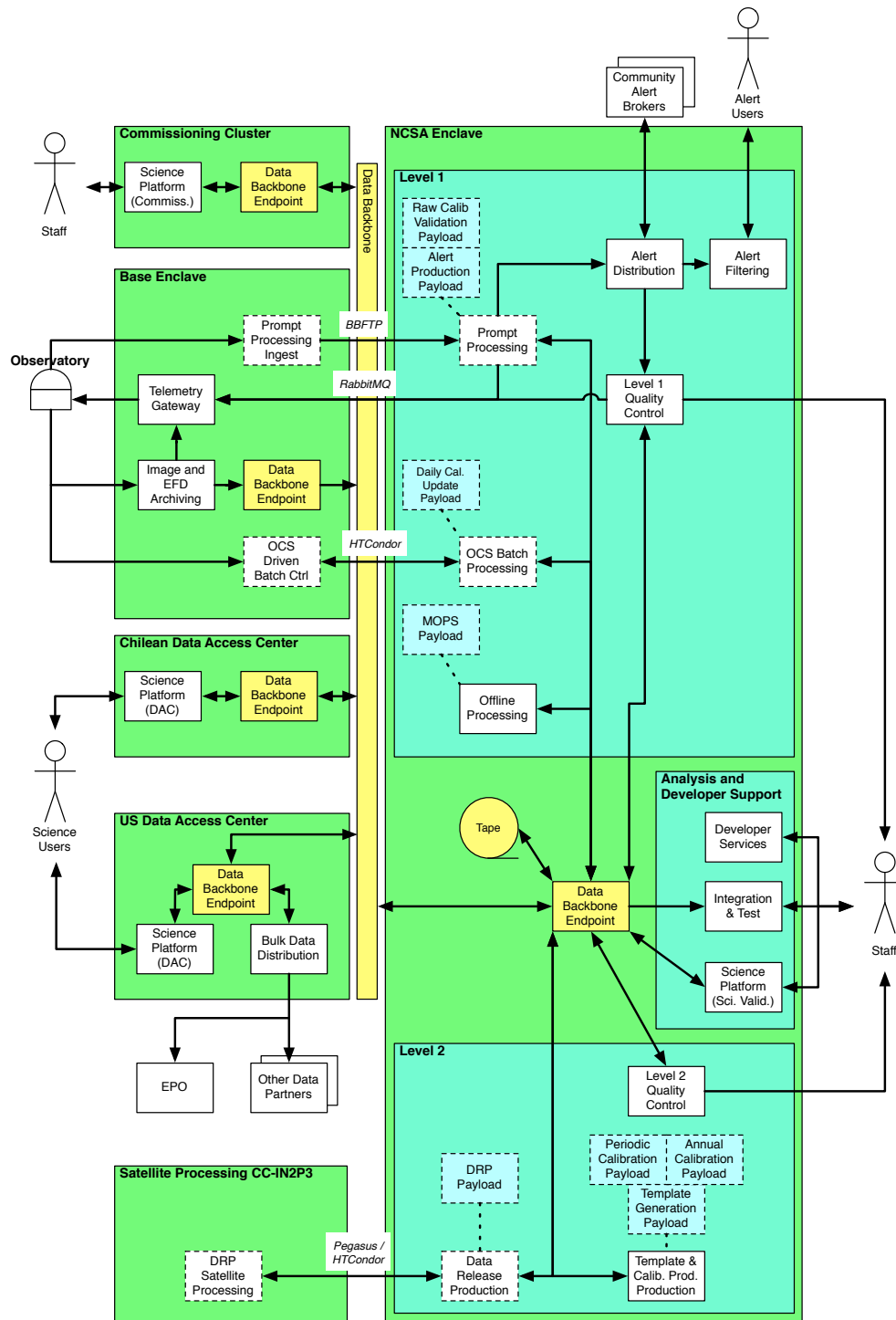


FIGURE 2: DM components as deployed during Operations. Where components are deployed in multiple locations, the connections between them are labeled with the relevant communication protocols. Science payloads are shown in blue. (from LDM-148)

TABLE 2: Components from LDM-148 with the test specifications to verify them.

Component	Testing Spec
NCSA Enclave	LDM-532
- L1 System	LDM-533
-- L1 Prompt Processing	TBD
-- L1 Alert Distribution	TBD
-- L1 Alert Filtering (mini Broker)	TBD
-- L1 Quality Control	TBD
-- L1 OCS Batch Processing	TBD
-- L1 Offline Processing	TBD
- L2 System	LDM-534
-- L2 QC	TBD
-- L2 Data Release	TBD
-- L2 Calibration Products	TBD
Data Backbone	LDM-535
- DBB Data Services	LDM-536
-- DBB QSERV	TBD
-- DBB Databases	TBD
- - DBB Image Database/Metadata Prov	TBD
-- DBB Data Butler Client	TBD
- DBB infrastructure	LDM-537
-- DBB Tape Archive	TBD
-- DBB Cache	TBD
-- DBB Data Endpoint	TBD
-- DBB Data Transport	TBD
-- Networks	TBD
Base Enclave	LDM-538
-- Prompt Processing Ingest	TBD
-- Telemetry Gateway	TBD
-- Image and EFD Archiving	TBD
-- OCS Driven Batch Control	TBD
Data Access Center Enclave	LDM-539
-- Bulk Data Distribution	TBD
-- Science Platform	LDM-540
-- Science Platform JupyterLab	TBD
-- Science Platform Portal	TBD
-- DAX VO+ Services	TBD
Commisioning Cluster Enclave	LDM-541
-- SuperTask ..	

3.3 Testing Specification document format

The Testing Specification documents will be drawn in conjunction with the LSST Systems Engineer. In all cases they will include:

- A list of components being tested within the scope of the Test Specification Document.
- A list of features in those components that are being explicitly tested.
- How those features related to identified requirements for that component.
- A description of the environment in which the tests are carried out (e.g. hardware platform) and a description of how they differ from the operational system in tests prior to final integration (e.g. interfaces that may be mocked without affecting that component's testing).
- The inputs (such as data, API load, etc.) that are to be used in the test.
- Pass-fail criteria on any metrics to be done.
- How any outputs that are used to determine pass/fail (e.g. data or metrics) are published (made available).
- A Software Quality Assurance manifest listing (as relevant) code repositories, configuration information, release/distribution methods and applicable documentation (such as installation instructions, developer guide, user guide etc.)

4 Pass/Fail Criteria

A Test Case will be considered "Passed" when:

- All of the test steps of the Test Case are completed and
- All open SPRs from this Test Case are considered noncritical by DMCCB.

A Test Case will be considered "Partially Passed" when:

- Only a subset of all of the test steps in the Test Case are completed but the overall purpose of the test has been met and
- Any critical SPRs from this Test Case agreed in Software Review Board are still not closed.

A Test Case will be considered “Failed” when:

- Only a subset of all of the test steps in the Test Case are completed and the overall purpose of the test has not been met and
- Any critical SPRs from this Test Case agreed in Software Review Board are still not closed.

Note that in LPM-17 science requirements are described as having a minimum specification, a design specification and a stretch goal. We preserve these distinctions where they have been made in, for example, the verification framework and automated metric harness. However for the purposes of Pass/Fail criteria, it is the design specification that is verified as having been met for a test to pass without intervention of the Software Review Board.

In the event that a requirement is failing its design specification and the minimum specification is invoked, this is an LSST project level issue and is escalated beyond the scope of this plan.

5 Constraints and Limitations

- Verification is being done on the basis of precursor data sets such as HSC (see for example LDM-502), and eventually with engineering data from the LSST arrays. These are just a proxy for full-focal-plane on-site LSST data.
- Metric measurements and operational rehearsals during construction may not involve critical operational systems that are still in development. For example, while computational performance is being measured, computationally dominant algorithmic steps such as deblending and multi-fit are only modeled, since they have not yet been implemented; operational rehearsals are done without the factory LSST workflow system; etc.

5.1 Requirements Traceability Constraints

This section outlines the traceability of requirements through key LSST and Data Management documentation. In principle all DM requirements should be flowed to LSE-61 which forms the basis of DM work. We are working to make that the reality, meanwhile the current situation is outlined here.

5.1.1 Scientific

Some science requirements are captured in LSE-29 (aka [LSR](#)) and flow down to LSE-30 (aka [OSS](#)); some also exist in LSE-163 (aka [DPDD](#)) and will flow down in LSE-61 (aka [DMSR](#)).

5.1.2 Computational

There are requirements in LSE-61 (aka [DMSR](#)) which captures the LSE-30 ([OSS](#)) requirements that DM is responsible for. *In practice LSE-63 (the QA document) has not been flowed down to LSE-61.* These are:

- The primary computational performance flown down from LSE-29 ([LSR](#)) is OTT1 which is the requirement to issue an alert within 60 seconds of exposure end. DMS-REQ-0004
LSR-REQ-0101
- Another requirement flown down from LSE-29 is calculation of orbits within 24 hours of the end of the observing night. DMS-REQ-0004
LSR-REQ-0104
L1PublicT
- There is a new (not yet baselined?) requirement for the calibration pipeline to reduce calibration observations within 1200 seconds. calProcTime
- A nightly report on data quality, data management system performance and a calibration report have to be generated with 4 hours of the end of the night. DMS-REQ-0096
dqReportComplTime

Note that there are no computational requirements on individual technical components e.g.. data processing cluster availability, database data retrieval speeds, etc. There is an upper limit on acceptable data loss, and there is a network availability requirement.

5.1.3 KPMs

As a proxy for validating the DM system, LDM-240 (aka “the spreadsheet”) defined a set of Key Performance Metrics that the system could be verified against. KPMs were not formally flowed down from LSE-29 ([LSR](#)) through LSE-30 ([OSS](#)) although there is some overlap with LSE-29 requirements. In particular, the non-science KPMs only exist in LDM-240 (*spreadsheet/old plan*), although they are implicitly assumed in the sizing model presented in LSE-81 and LSE-82.

5.2 Interfaces

We will verify external interfaces to other subsystems and selected major internal interfaces. The ICDs describing external interfaces are curated in Docushare Collection 5201.

6 Master Schedule

The schedule for testing the system until operations commences (currently 2022) is outlined in Table 4. These tests mark the major milestones of DM, they are shown in the Gantt chart in Figure 3.

Table 4: List of High Level integration tests for DM

ID	Date/Freq	Location	Title, Description
LDM-503-NLY	Nightly	Amazon	Nightly Tests Run all automated tests on all DM packages automatically.
LDM-503-WLY	Weekly	Amazon	Integration tests Basic Sanity check to make sure code compiles at no regressions have occurred and also pushing though a basic data set.
LDM-503-	TBP	NCSA	Interface tests The interface tests have to be planned and documented in a separate test plan that should include tests for each two parties on an interface (2by2 tests) as well as tests for all parties. Some of these will be covered again in E2E tests but before that we should be confident they work. This includes internal and external interfaces.
LDM-503-	TBP	NCSA + IN2P3	End to End Tests ?? Freeze software for Ops .. https://confluence.lsstcorp.org/display/DM/Data+Processing+End+to+End+Testing What is the status of these ?
LDM-503-2	2017-11-30	NCSA	HSC reprocessing • Validate the data products with the LSST stack match or improve upon HSC products.

LDM-503-3	2017-11-30	NCSA	Alert generation validation • Validate the alert generation stack performance on several DECam and HSC datasets.
LDM-503-4	2018-02-28	NCSA	Camera DAQ integration functionality test • The data acquisition hardware should be available to DM on 2018-02-30. We should prepare by testing that adjacent archive systems.
LDM-503-4b	2018-03-31	NCSA	Test Report: Camera DAQ interface Integration Verification • The data acquisition hardware should be available to DM on 2018-02-30. We should test integration with the adjacent archive systems.
LDM-503-5	2018-05-31	NCSA	Alert distribution validation • Validate alert distribution system and mini-broker fed by live or simulated live data.
LDM-503-6	2018-06-30	NCSA	DM ComCam interface verification readiness • ComCam will be in Tucson on 2018-07-24. The DM system must be ready to deal with it.
LDM-503-7	2018-08-31	NCSA	Camera data processing • Partial camera data should be available to DM July 31st. We plan to test DM stack with it.
LDM-503-8	2018-11-30	NCSA	Spectrograph data acquisition • Demonstrate that we can acquire (and process?) data from the spectrograph.
LDM-503-9	2018-11-30	NCSA	Verification tests in advance of pre-ops rehearsal for commissioning #1 • Test how the system will run during commissioning.
LDM-503-10	2019-02-28	NCSA	DAQ validation • There is a project Milestone that DAQ/DM/Networks are available March 15th. We need to run tests in Feb to show this is ready.
LDM-503-11a	2019-10-20	NCSA	DM ComCam operations readiness • ComCam will be in use in Nov . The DM system must be ready to deal with it.

LDM-503-11	2019-10-31	NCSA	Verification tests in advance of pre-ops rehearsal for commissioning #2 • More complete commissioning rehearsal: how do the scientists look at data? How do they provide feedback to the telescope? How do we create/update calibrations?
LDM-503-12	2020-01-31	NCSA	Verification tests in advance of pre-ops rehearsal for commissioning #3 • Dress rehearsal: commissioning starts in April, so by this stage we should be ready to do everything needed.
LDM-503-13	2020-11-30	NCSA	Ops rehearsal DRP (ComCam data) • ComCam data will now be available. Demonstrate its use in producing a data release.
LDM-503-14	2021-03-31	NCSA	DM Software for Science Verification • Science Verification starts in April. Demonstrate that all required DM software is available.
LDM-503-15	2021-11-30	NCSA	Ops rehearsal DRP (SV data) • Science Verification data will now be available. Demonstate its use in producing a data release.
LDM-503-16	2022-02-28	NCSA	Verification tests in advance of full scale ops rehearsal #1 • Test readiness for operations.
LDM-503-17	2022-09-30	NCSA	Verification tests in advance of full scale ops rehearsal #2 • Confirm readiness for operations.

7 Verification Tests

7.1 HSC reprocessing(LDM-503-2)

- Validate the data products with the LSST stack match or improve upon HSC products.
- From the pipelines perspective, I think there's no new work involved here beyond the v13.0 release (at which point the HSC merge is complete and QA has been performed). Suggest we'd run this with the latest release as of the date of the test (so this is 14.N, where 14.0 is the end-of-S17 release).

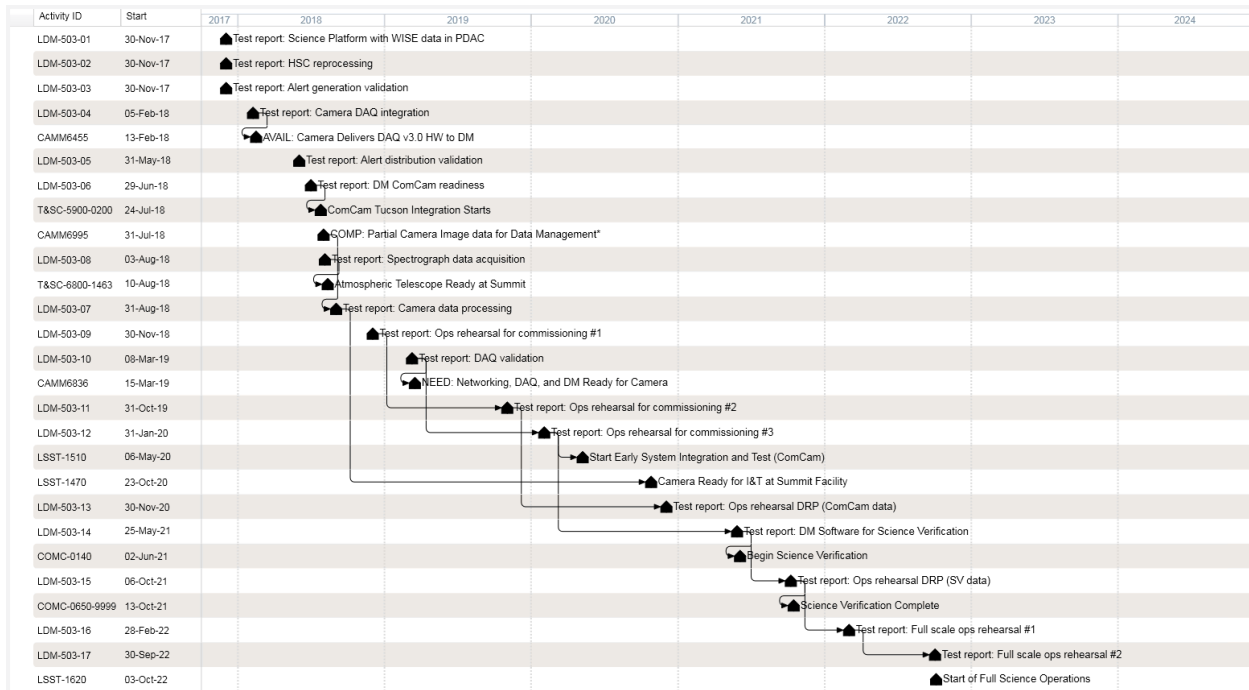


FIGURE 3: DM major milestones(LDM-503-x) in the LSST schedule.

7.2 Alert generation validation(LDM-503-3)

- Validate the alert generation stack performance on several DECam and HSC datasets.
- "Stack" is probably ill-defined here — is this simply testing science logic, or are we going after a wider integration exercise?

7.3 Camera DAQ integration functionality test(LDM-503-4)

- The data acquisition hardware should be available to DM on 2018-02-30. We should prepare by testing that adjacent archive systems.
- A minimal DM-only system that can archive mocked-up images and demonstrate that they can be retrieved, with provenance and metadata.

7.4 Test Report: Camera DAQ interface Integration Verification (LDM-503-4b)

- The data acquisition hardware should be available to DM on 2018-02-30. We should test integration with the adjacent archive systems.
- A minimal system that can archive simulated images from the DAQ Test Stand and demonstrate that they can be retrieved.

7.5 Alert distribution validation(LDM-503-5)

- Validate alert distribution system and mini-broker fed by live or simulated live data.
- Can we test a SUIT interface to the broker at this point? I believe it's not scheduled until later in construction.

7.6 DM ComCam interface verification readiness(LDM-503-6)

- ComCam will be in Tucson on 2018-07-24. The DM system must be ready to deal with it.
- "The DM system" should use some further definition: what do we want to test here? Data flow from ComCam to the Data Backbone, or science processing of ComCam data?

7.7 Camera data processing(LDM-503-7)

- Partial camera data should be available to DM July 31st. We plan to test DM stack with it.

7.8 Spectrograph data acquisition(LDM-503-8)

- Demonstrate that we can acquire (and process?) data from the spectrograph.
- Per LSE-79, AuxTel delivery in Nov 2017 (ie, a year before this milestone) includes: → EFD ETL service → Aux Telescope Archiving Service → Data backbone in support of Aux Telescope archiving Do we need to schedule another test to cover that?

7.9 Verification tests in advance of pre-ops rehearsal for commissioning #1(LDM-503-9)

- Test how the system will run during commissioning.
- "Focus on ISR" — we should test whatever we have available. See LSE-79 for a list of requirements.

7.10 DAQ validation(LDM-503-10)

- There is a project Milestone that DAQ/DM/Networks are available March 15th. We need to run tests in Feb to show this is ready.

7.11 DM ComCam operations readiness (LDM-503-11a)

- ComCam will be in use in Nov . The DM system must be ready to deal with it.
- "The DM system" should use some further definition: what do we want to test here? Data flow from ComCam to the Data Backbone, or science processing of ComCam data?

7.12 Verification tests in advance of pre-ops rehearsal for commissioning #2(LDM-503-11)

- More complete commissioning rehearsal: how do the scientists look at data? How do they provide feedback to the telescope? How do we create/update calibrations?

7.13 Verification tests in advance of pre-ops rehearsal for commissioning #3(LDM-503-12)

- Dress rehearsal: commissioning starts in April, so by this stage we should be ready to do everything needed.

7.14 Ops rehearsal DRP (ComCam data)(LDM-503-13)

- ComCam data will now be available. Demonstrate its use in producing a data release.
- Note that LSE-79 requires a suite of DM services in support of the full camera in May 2020. It seems inappropriate to test them as part of a commissioning ops rehearsal, but they are well before this data. Do we need another test milestone?

7.15 DM Software for Science Verification(LDM-503-14)

- Science Verification starts in April. Demonstrate that all required DM software is available.
- SV will include calculating all KPMs to demonstrate that we are reaching the science requirements. That obviously means we'll need code which is both capable of reaching those requirements, and calculating the KPMs.

7.16 Ops rehearsal DRP (SV data)(LDM-503-15)

- Science Verification data will now be available. Demonstate its use in producing a data release.

7.17 Verification tests in advance of full scale ops rehearsal #1(LDM-503-16)

- Test readiness for operations.

7.18 Verification tests in advance of full scale ops rehearsal #2(LDM-503-17)

- Confirm readiness for operations.

8 Software Tools

A number of tools and development practices are in use in Data Management to ensure software quality and to verify requirements are met. These tools are used continuously (e.g. to measure key performance metrics routinely) or periodically (e.g. software release characterizations) and so will be well understood by the time the formal verification phase begins.

8.1 Continuous Integration and Unit Testing

Code is checked via a continuous integration (CI) service both for on-demand developer use and for verifying the quality of the master branch. Irrespective of supported platforms, we have a practice of verifying that the stack can run on at least 2 distinct operating systems/platforms as portability is often a good indicator of maintainability. The CI service also permits verification that the codebase runs with different third party dependencies; for example we test that the python code runs both under (legacy) Python 2.7 and (trailing edge versions of) Python 3. This reduces the foreseeable technical debt of porting to Python 3 for operations.

Unit testing policy is described in the DM Developer guide under Unit Test Policy.

Roles and responsibilities in this area include:

- The DM Systems Engineering Team team is responsible for approving dependencies and setting strategy such as the Python 3 portability.
- The DM Systems Engineering Team is responsible for setting the Unit Test policy.
- The SQuaRE team is responsible for developing, operating and supporting Continuous Integration Services.
- The SQuaRE team determines platform release practice ICW the other teams and Architecture.

At the time of this revision we do not have unit test coverage tooling for Python; this is coming with the planned switch to the pytest framework.

8.2 Code Reviews

DM's process requires that every story resulting in code changes to the stack is reviewed prior to being merged to master. This is both as code quality verification and also to ensure that at least one other team-member has some familiarity with a particular part of the codebase. DM's Code Review process is described in the DM Developer guide under the section DM Code Review and Merging Process.

Roles and responsibilities in this area include:

- The DM Systems Engineering Team defines the development process and style guide including the code review standard.
- SQuaRE is responsible for supporting tooling to assist code review (e.g. linters, Jira-Github integration, etc).

8.3 Automated Requirements Verification and KPM Measurement

DM uses a harness for continuous metric verification. In the software development context this is used for:

- Calculating KPMs where available and alerting when they exceed specification.
- A regression testing framework for any developer-supplied metric, with optional alerts when excursions occur from past values to verify that performance is not being degraded by new code or environments.
- Visualizing these results and linking them back to build and pull request information.
- Drill-down of those metrics in pre-defined visualization templates geared towards specific verification use-cases.

Roles and responsibilities in this area include:

- The pipeline teams are responsible for providing some of the code and data to calculate the KPMs.

- SQuaRE is responsible for developing and operating the continuous metric verification services.
- Individual developers contribute non-KPM metrics as desired.

9 Operations Validation

Operations Validation of the system is done through Operations Rehearsals (and or end-to-end tests). This may repeat some or all of a science validation exercises but in a more operational setting with a focus on operations. The proposed rehearsal dates are listed in Table 5.

Table 5: Operations rehearsals for Ops validation of DM

Date/Freq	Location	Title, Description
Oct 2018	NCSA	Operations rehearsal for commissioning With TBD weeks commissioning (lets say a week) – pick which parts of plan we could rehearse. Chuck suggests Instrument Signal Removal should be the focus of this (or the next rehearsal).
Oct 2019	NCSA	Operations rehearsal #2 for commissioning More complete rehearsal – where do the scientist look at quality data? How do they feed it back to the Telescope ? How do we create/update calibrations ? Exercises some of the control loops.
Jan 2020	Base	Operations rehearsal #3 for commissioning Dress rehearsal – Just like it will be April for the actual commissioning.
Dec 2020	NCSA	Operations Rehearsal Data Release (Commissioning Data) Dress rehearsal – Just like it will be April for the actual commissioning.
2021	NCSA	Operations Rehearsal Data Release (Regular Data).
Feb 2022	NCSA/Base	Operations Rehearsal(s) Rehearsals for real operations which start Oct 2022
Sept 2022	NCSA/Base	Operations Rehearsal(s) Full Dress rehearsal for real operations which start Oct 2022

10 Science Validation

10.1 Definition

We define **DM Science Validation** as **the process by which we assess the as-built Data Management system meets the needs of the scientific community and other identified stakeholders.**

We assess the projected and realized scientific usability of the system by periodically exercising the integrated system in a way that goes beyond synthetic unit and integration tests and verification of piece-wise requirements as described in previous sections. In other words, we *attempt to use the system in ways we expect it to be used by the ultimate users of the system, scientists.* An example may be performing a mock science study on the results of processing of precursor data, or performing a mock science-like activity (e.g., interactive analysis of time-domain datasets) on a partially stood-up service (e.g., the Notebook aspect of the LSST Science Platform). We record and analyze any issues encountered in such usage, and feed this information back to the DM Science and DM development teams.

Science Validation exercises are designed to close the design-build-verify loop, and enable one to measure the degree to which the requirements, designs, the as-built system, and future development plans continue to satisfy stakeholder needs. They also provide valuable feedback about modifications needed to ensure the delivery of a scientifically capable system. Ultimately, SV activities transfer into commissioning SV activities and provide training to the future members of the Commissioning team.

10.2 Schedule and Execution

10.2.1 Schedule

DM SV activities are planned and prepared in a rolling wave fashion in parallel with development activities (on a 6-month cycle, or perhaps a year). The SV activities will typically be designed so as to exercise the capabilities of the system expected to be delivered at the end of a given development cycle. These follow a long-term roadmap of SV activities, linked to product delivery milestones in the DM's Construction Plan (see the table in Section 6). The Science Validation (SV) team guides the definition of goals of those activities, in close consultation with the DM Project Manager.

By their nature, SV activities will typically lag behind deliveries of the (sub)system being verified – ideally, they will commence immediately upon delivery. Preparatory SV activities (e.g., identification and acquisition of suitable datasets, identification of potential Science Collaboration resources to include on the activity, or development of activity-specific analysis codes) will commence as early as feasible. DM SV Scientist will coordinate the execution of all SV activities.

SV activities should aim to take no longer than two months to conclude, to enable rapid actionable feedback to DM Management and DM Subsystem Science.

10.2.2 Execution

Science Validation activities typically follow the successful execution of unit and integration test activities described in the previous sections, especially the larger “dress rehearsals” and “data challenges” as listed in Section 6 (Master Schedule).

Following successful service stand-up or data challenge execution (at integration and unit test level), the generated data products or integrated services are turned over to the SV team. The SV team performs additional tests and data analyses to exercise the integrated system and assess its quality relative to expectations for the current phase of construction. This assessment is fed back to DM Subsystem Science and Systems Engineering teams to inform them about the status and needed improvements to the system.

Beyond reporting on the results, the SV team examines the tests or procedures developed in this phase and identifies those that are good new metrics of system quality and could be run in an automated fashion. These are fed back to the development teams for productizing and incorporation into the automated QC systems.

10.3 Deliverables

Key deliverables of Science Validation activities are:

- Reports on the assessed capability of the Data Management System to satisfy stakeholder needs. The assessments shall take into account the expected maturity of the system being tested.

- Recommendations for improvements and changes, both in the quality of as-constructed systems (i.e., what needs to be built differently or better, to make it more consistent with the system vision), as well as the overall system vision (i.e., recommendations on where the vision may need to be modified to fully respond to stakeholder needs).
- Measurements of performance metrics that do not lend themselves to easy automation (e.g., science activities requiring human involvement, like visual classification, or UX tests).
- Identification of new performance metrics to be tracked, including potential deliveries of code to the DM Construction and I&T teams for inclusion in automated quality control pipelines.
- Other deliverables as charged when chartering a particular SV exercise.

10.4 Organization and Resources

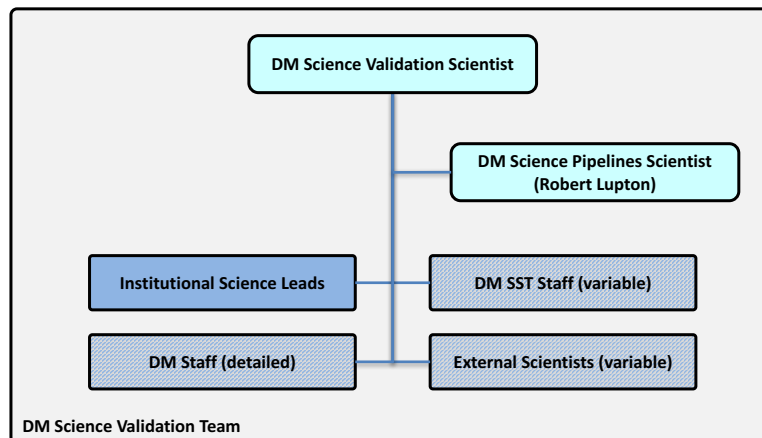


FIGURE 4: Organogram of the Data Management Science Validation Team. The group is chaired by the DM Science Validation Scientist, with the DM Science Pipelines Scientist and Institutional Science Leads making up the permanent membership. Depending on the SV activities being executed at any given time, the group may draw on additional temporary members from DM SST Staff, the broader DM Construction staff, as well as external scientists (e.g., Science Collaboration members committed to assisting SV goals). SV membership is reassessed on a cycle by cycle basis, with estimates incorporated in the long-term plan.

The DM Subsystem Scientist is accountable to the LSST Project Scientist for successful execution of DM Science Validation activities. This responsibility is delegated to the **DM Science Validation Scientist**, who leads the Science Validation (SV) team.

The SV team guides the definition of goals and receives the products of dress rehearsal activities, consistent with the long-term testing roadmap defined in Section 6. Decisions on strategic goals of SV exercises are made in close consultation and coordination with the DM Project Manager and Subsystem Scientist. The results of SV activities are reported to the DM Project Manager and Subsystem Scientist.

SV activities draw on resources of the DM System Science Team, but may also tap into the broader construction team if needed (and as jointly agreed upon with the DM Project Manager), as well as contributors from the LSST Science Collaborations. Additional members may be added as needed, depending on SV activities being considered and based on the recommendation of the DM SV Scientist and resource constraints.

The SV Scientist, the DM Science Pipelines Scientist, and all Institutional Science Leads are ex-officio members of the SV Team. DM Project Scientist and Managers are not formal members, but monitor the work of the group.

10.4.1 Example

An example of a Science Validation activity may be as follows:

- Based on the long-term development roadmap and new capabilities expected to be delivered, at the beginning of a 6-month cycle the SV Team defines the goals of a data challenge to be executed at the end of the cycle. For the purposes of this example, we assume a major new feature to be delivered is astrometric calibration and estimation of proper motions.
- A small data release production using HSC data is defined that should result in a data set sufficient to measure the size and orientation of velocity ellipsoids in the Galactic halo. If such measurements are a success, they would independently validate the newly added global astrometric calibration and proper motion measurement capability.
- At the end of the development cycle, the Science Pipelines team delivers to the proto-Operations team a documented and internally tested set of DRP pipelines with the new capabilities as defined above. The pipelines pass all unit and small-scale integration tests. The proto-Operations team deploys and re-verifies the received pipelines in the I&T environment designed to closely mimic the production environment. They verify

that the pipeline integrates well with the orchestration system and is capable of executing medium-to-large scale processing. The pipelines pass integration tests.

- The data challenge is operationally planned and executed by the proto-Operations team, including the execution of any predefined QA metrics. The data products and test results are turned over to the Science Validation team.
- The Science Validation team performs the analysis needed to achieve SV exercise goals (the measurement of velocity ellipsoids, in this case).
- The results and conclusions derived from the data challenge are fed back to the DRP team, DM Project Management, and DM Subsystem Science; they may be used to assess the overall quality of the product, pass a formal requirement, and/or inform future construction decisions.
- Any newly developed but broadly useful tests are identified as such, and fed to the I&T team for inclusion into the battery of tests that are run on a regular basis.

A Verification Matrix

The DM verification matrix may be found in LSE-61. As subset of the columns from the matrix are displayed here to indicate how we will verify DM requirements.

Requirement	Name	Method
DMS-REQ-0024	Raw Image Assembly	Demonstration
DMS-REQ-0018	Raw Science Image Data Acquisition	Test
DMS-REQ-0068	Raw Science Image Metadata	Test
DMS-REQ-0022	Crosstalk Corrected Science Image Data Acquisition	Test
DMS-REQ-0020	Wavefront Sensor Data Acquisition	Test
DMS-REQ-0265	Guider Calibration Data Acquisition	Demonstration
DMS-REQ-0004	Nightly Data Accessible Within 24 hrs	Test
DMS-REQ-0069	Processed Visit Images	Demonstration
DMS-REQ-0072	Processed Visit Image Content	Demonstration
DMS-REQ-0029	Generate Photometric Zeropoint for Visit Image	Demonstration
DMS-REQ-0030	Generate WCS for Visit Images	Test
DMS-REQ-0070	Generate PSF for Visit Images	Demonstration
DMS-REQ-0010	Difference Exposures	Demonstration
DMS-REQ-0074	Difference Exposure Attributes	Demonstration
DMS-REQ-0266	Exposure Catalog	Inspection

DMS-REQ-0269	DIASource Catalog	Demonstration
DMS-REQ-0270	Faint DIASource Measurements	
DMS-REQ-0271	DIAObject Catalog	Demonstration
DMS-REQ-0272	DIAObject Attributes	Demonstration
DMS-REQ-0273	SSObject Catalog	Demonstration
DMS-REQ-0317	DIAForcedSource Catalog	Demonstration
DMS-REQ-0274	Alert Content	Demonstration
DMS-REQ-0097	Level 1 Data Quality Report Definition	Demonstration
DMS-REQ-0099	Level 1 Performance Report Definition	Demonstration
DMS-REQ-0101	Level 1 Calibration Report Definition	Demonstration
DMS-REQ-0267	Source Catalog	Demonstration
DMS-REQ-0275	Object Catalog	Demonstration
DMS-REQ-0276	Object Characterization	Inspection
DMS-REQ-0046	Provide Photometric Redshifts of Galaxies	Inspection
DMS-REQ-0034	Associate Sources to Objects	Demonstration
DMS-REQ-0279	Deep Detection Coadds	Demonstration
DMS-REQ-0280	Template Coadds	Demonstration
DMS-REQ-0281	Multi-band Coadds	Demonstration
DMS-REQ-0278	Coadd Image Attributes	Demonstration
DMS-REQ-0047	Provide PSF for Coadded Images	Demonstration
DMS-REQ-0106	Coadded Image Provenance	Demonstration
DMS-REQ-0277	Coadd Source Catalog	Demonstration
DMS-REQ-0268	Forced-Source Catalog	Demonstration
DMS-REQ-0103	Produce Images for EPO	Demonstration
DMS-REQ-0130	Calibration Data Products	Demonstration
DMS-REQ-0132	Calibration Image Provenance	Demonstration
DMS-REQ-0059	Bad Pixel Map	Demonstration
DMS-REQ-0060	Bias Residual Image	Demonstration
DMS-REQ-0061	Crosstalk Correction Matrix	Demonstration
DMS-REQ-0282	Dark Current Correction Frame	Demonstration
DMS-REQ-0063	Monochromatic Flatfield Data Cube	Demonstration
DMS-REQ-0062	Illumination Correction Frame	Demonstration
DMS-REQ-0283	Fringe Correction Frame	Demonstration
DMS-REQ-0291	Query Repeatability	Demonstration
DMS-REQ-0292	Uniqueness of IDs Across Data Releases	Demonstration
DMS-REQ-0293	Selection of Datasets	Demonstration
DMS-REQ-0294	Processing of Datasets	Demonstration
DMS-REQ-0295	Transparent Data Access	Demonstration
DMS-REQ-0284	Level-1 Production Completeness	Demonstration

DMS-REQ-0131	Calibration Images Available 1 Hour Before Observing	Demonstration
DMS-REQ-0002	Transient Alert Distribution	Demonstration
DMS-REQ-0285	Level 1 Source Association	Demonstration
DMS-REQ-0286	SSObject Preccovery	Demonstration
DMS-REQ-0287	DIASource Preccovery	Demonstration
DMS-REQ-0288	Use of External Orbit Catalogs	Demonstration
DMS-REQ-0089	Solar System Objects Available within 24 hours	Demonstration
DMS-REQ-0096	Generate Data Quality Report within 4 hours	Demonstration
DMS-REQ-0098	Generate DMS Performance Report within 4 hours	Demonstration
DMS-REQ-0100	Generate Calibration Report within 4 hours	Demonstration
DMS-REQ-0289	Calibration Production Processing	Inspection
DMS-REQ-0006	Timely Publication of Level 2 Data Releases	Inspection
DMS-REQ-0290	Level 3 Data Import	Demonstration
DMS-REQ-0119	DAC resource allocation for Level 3 processing	Demonstration
DMS-REQ-0120	Level 3 Data Product Self Consistency	Inspection
DMS-REQ-0121	Provenance for Level 3 processing at DACs	Inspection
DMS-REQ-0125	Software framework for Level 3 catalog processing	Demonstration
DMS-REQ-0128	Software framework for Level 3 image processing	Demonstration
DMS-REQ-0308	Software Architecture to Enable Community Re-Use	Demonstration
DMS-REQ-0009	Simulated Data	Demonstration
DMS-REQ-0296	Pre-cursor, and Real Data	Demonstration
DMS-REQ-0032	Image Differencing	Demonstration
DMS-REQ-0033	Provide Source Detection Software	Demonstration
DMS-REQ-0043	Provide Calibrated Photometry	Demonstration
DMS-REQ-0042	Provide Astrometric Model	Demonstration
DMS-REQ-0052	Enable a Range of Shape Measurement Approaches	Demonstration
DMS-REQ-0160	Provide User Interface Services	Demonstration
DMS-REQ-0297	DMS Initialization Component	Demonstration
DMS-REQ-0155	Provide Data Access Services	
DMS-REQ-0298	Data Product Access	Demonstration
DMS-REQ-0299	Data Product Ingest	Demonstration
DMS-REQ-0300	Bulk Download Service	Demonstration
DMS-REQ-0065	Provide Image Access Services	Demonstration
DMS-REQ-0301	Control of Level-1 Production	Demonstration
DMS-REQ-0156	Provide Pipeline Execution Services	
DMS-REQ-0302	Production Orchestration	Demonstration
DMS-REQ-0303	Production Monitoring	Demonstration
DMS-REQ-0304	Production Fault Tolerance	Demonstration
DMS-REQ-0158	Provide Pipeline Construction Services	

DMS-REQ-0305	Task Specification	Inspection
DMS-REQ-0306	Task Configuration	Demonstration
DMS-REQ-0307	Unique Processing Coverage	Demonstration
DMS-REQ-0309	Raw Data Archiving Reliability	Demonstration
DMS-REQ-0094	Keep Historical Alert Archive	Demonstration
DMS-REQ-0310	Un-Archived Data Product Cache	Demonstration

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