LARGE SYNOPTIC SURVEY TELESCOPE

Large Synoptic Survey Telescope (LSST)
Data Management

Data Management Organization and Management

William O'Mullane, John Swinbank, Mario Juric, Leanne Guy and DMLT

LDM-294

Latest Revision: 2020-03-08

Abstract

This management plan covers the organization and management of the Data Management (DM) subsystem during the development, construction, and commissioning of LSST. It sets out DM goals and lays out the management organization roles and responsibilities to achieve them. It provides a high level overview of DM architecture, products and processes. It provides a structured starting point for understanding DM and pointers to further documentation.

Change Record

Version	Date	Description	Owner name
1.1	2004-06-23	Initial version (Document-139).	J. Kantor
1.2	2011-07-12	Updated for PDR.	J. Kantor
1.3	2014-03-07	Updated for construction phase.	J. Kantor
1.4	2014-10-21	SQuaRE section added.	J. Kantor
1.5	2014-10-30	Added LDM-294 handle.	J. Kantor
2.0	2015-03-11	Updated with new RFC process, realignment of TCT, SAT, DMLT.	J. Kantor
3.0	2017-06-30	Complete overhaul of content, with all new authors. Rewritten in LaTeX. Approved for release by W. O'Mullane.	W. O'Mullane
3.1	2017-07-04	Minor cleanups for review. Approved in RFC-358.	W. O'Mullane
3.2	2017-07-19	Editorial fixes and refresh schedule and component diagrams	W. O'Mullane
3.3	2017-08-21	Update CCB and SE groups. Add Science Platform Scientist. Add section on design reviews. Approved in RFC-373.	W. O'Mullane
3.4	2017-12-21	Org chart refresh - rules for review of epics DM-7501	W. O'Mullane
3.5	2018-06-18	New DM product tree and revised org chart. Add deputy subsystem scientist. Approved in RFC-493	J. Swinbank
3.6	2019-01-29	Review product tree. Add release management subsection. Update DMCCB and DMSE team. Approved in RFC-561	G. Comoretto
3.7	2019-02-06	Add text for LSP and Middleware mangers. Time allocation policy for institutional scientists, add admin names to org chart. Approved in RFC-572	W. O'Mullane, L. Guy
3.8	2019-07-29	Updates to Org charts, glossary, third party software, risk management, milestones. Approved in RFC-621	W. O'Mullane, L. Guy
	2019-12-21	SST org charts, middleware lead, builds and fixes milestones. DM-22393	W. O'Mullane

Document source location: `https://github.com/lsst/LDM-294`

Contents

Data Management Organization and Management

1 Introduction

1.1 Purpose

This document defines the mission, goals and objectives, organization and responsibilities of the LSST Data Management subsystem ("DM"). The document is currently scoped to define these elements for the LSST Design, Construction, and Commissioning phases. It does not address any ongoing mission for DM during LSST Operations.

1.2 Mission Statement

Stand up operable, maintainable, quality services to deliver high-quality LSST data products for science and education, all on time and within reasonable cost.

1.3 Goals and Objectives

LSST Data Management will:

- Define the data products, data access mechanisms, and data management and curation requirements for LSST (with approval by others).
- Assess current and operations-era technologies for use in providing engineered solutions to the requirements.
- Define a secure computing, communications, and storage infrastructure and services architecture underlying DM.
- Select, implement, construct, test, document, and deploy the data management infrastructure, middleware, applications, and external interfaces.
- Adopt appropriate cybersecurity measures throughout the DM subsystem and especially on external facing services.
- Document the operational procedures associated with using and maintaining DM capabilities.

- Evaluate, select, recruit, hire/contract and direct permanent staff, contract, and in-kind resources in LSST and from partner organizations participating in LSST DM initiatives.

The DM goals in selecting and, where necessary, developing LSST software solutions are:

- Acquire and/or develop solutions: To achieve its mission, LSST DM prefers to acquire and configure existing, off-the-shelf, solutions. Where no satisfactory off-the-shelf solutions are available, DM develops the software and hardware systems necessary to:
  - Enable the generation of LSST data products at the LSST Archive and Satellite processing center, and
  - Enable the serving of LSST data products from the two LSST DACs (one in the U.S., and one in Chile).
- Maintain coherent architecture: DM software architecture is actively managed at the subsystem level. A well engineered and cleanly designed codebase is less buggy, more maintainable, and makes developers who work on it more productive. Where there is no significant impact on capabilities, budget, or schedule, LSST DM prefers to acquire and/or develop reusable, open source, solutions.
- Support reproducibility and insight into algorithms: Other than when prohibited by licensing, security, or other similar considerations, DM makes all newly developed source code, and in particular that pertaining to scientific algorithms, public. Our primary goals in publicizing the code are to simplify reproducibility of LSST data products and to provide insight into algorithms used. Achieving these goals requires that the software must be properly documented.
- Opportunities beyond LSST: LSST DM codes may be of interest and (re)used beyond the LSST project (e.g., by other survey projects, or by individual LSST end-users). While enabling or supporting such applications goes beyond LSST's construction requirements, cost and schedule-neutral technical and programmatic options that do not preclude them and allow for future generalization should be strongly preferred.

Background decision material on choices made in DM will be documented in technical notes which will be lodged in DocuShare (see Section 3.4) with "DMTN" series handles..

2 Data Management Conceptual Architecture

The DM Subsystem Architecture is detailed in LDM-148. A few of the higher level diagrams are reproduced here to orient the reader within DM.

During Operations, components of the DM Subsystem will be installed and run in multiple locations. These include:

- The Commissioning Cluster in the Base Facility in La Serena, Chile
- The main compute facility at NCSA in Urbana-Champaign
- The United States (US) Data Access Center (Data Access Center (DAC)), also at NCSA in Urbana-Champaign
- The Chilean DAC in the Base Facility
- The Satellite Processing Center at Change Control (CC)-IN2P3 in Lyon, France

Figure 1 shows the various DM components which will be used in operations and the physical compute environments in which they will be deployed. Bulk data storage and transport between components is provided by the Data Backbone. This complex piece of infrastructure is displayed in Figure 3.

Science users will access the data products produced by Large Synoptic Survey Telescope (LSST) through the Science Platform, as shown in Figure 2.

Figure 4 shows the common infrastructure and services layer which underlies the compute environments. This does not list specific technologies for management/monitoring, provisioning/deployment, or workload/workflow — these are still being selected — but under consideration are industry-standard tools such as Nagios, Puppet/vSphere/OpenStack/Kubernetes, and Pegasus.

2.1 External Interfaces & Auxiliary Data

The DM external interfaces are controlled by the ICDs listed in Table 1.

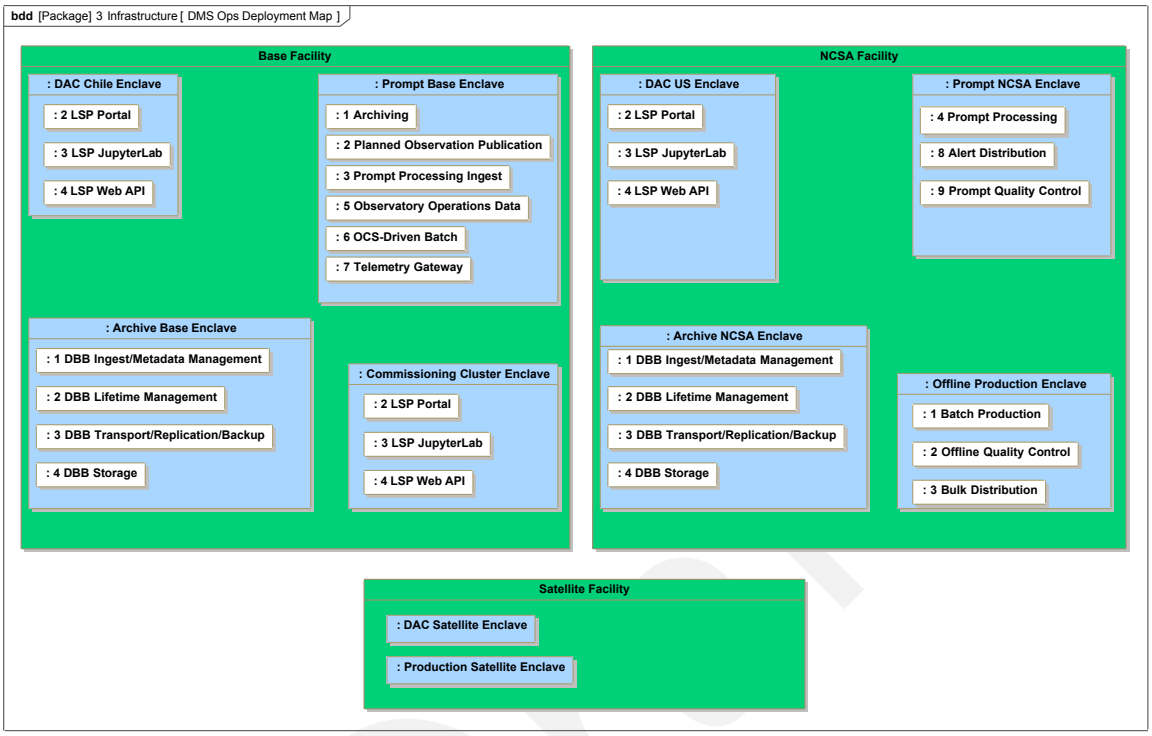

FIGURE 1: DM components as deployed during Operations. Refer to LDM-148 for details of each component.

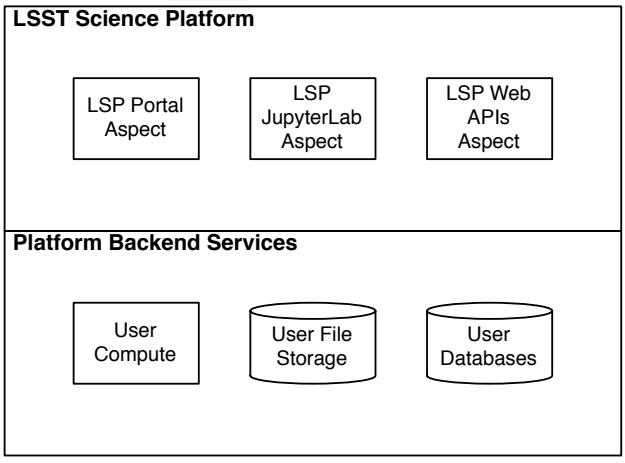

FIGURE 2: The sub-components of the Science Platform.

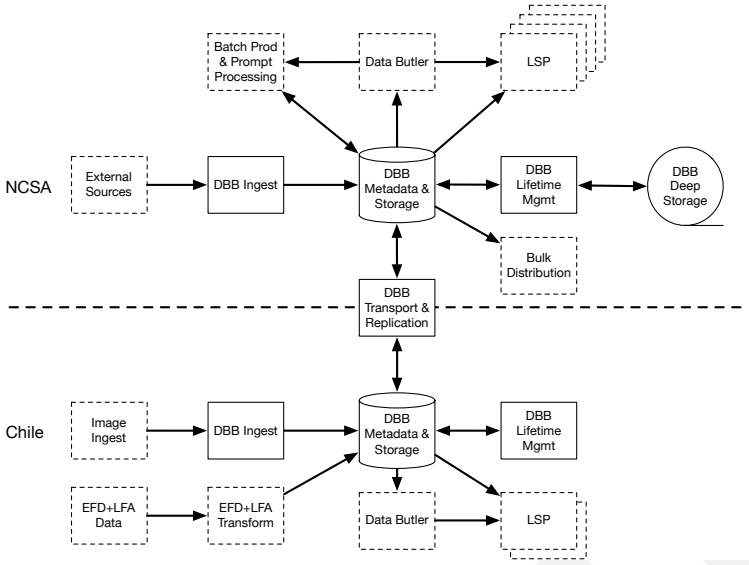

FIGURE 3: The Data Backbone links all the physical components of DM.

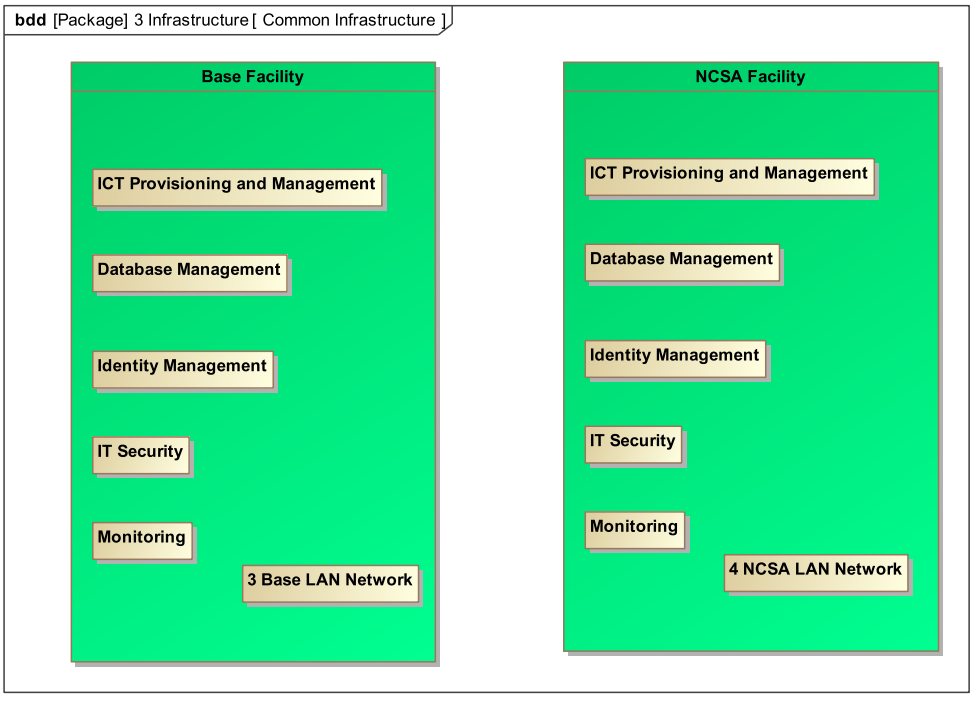

FIGURE 4: Common infrastructure services available at DM locations.

Table 1: DM Interface Control Documents

LSE-68	Data Acquisition Interface between Data Management and Camera
LSE-69	Interface between the Camera and Data Management
LSE-72	Observatory Control System (OCS) Command Dictionary for Data Management
LSE-75	Control System Interfaces between the Telescope and Data Management
LSE-76	Infrastructure Interfaces between Summit Facility and Data Management
LSE-77	Infrastructure Interfaces between Base Facility and Data Management
LSE-130	List of Data Items to be Exchanged Between the Camera and Data Management
LSE-131	Data Management Interface Requirements to Support Education and Public Outreach
LSE-140	Auxiliary Instrumentation Interface between Data Management and Telescope

In addition, certain tasks in DM rely on external catalogs and other information. The current design requires:

- Gaia catalog (Release 2) as a photometry baseline.

3 Data Management Organizational Structure

This section defines the organizational structure during the period in which the DM Subsystem is developed and commissioned, up to the start of LSST Observatory operations.

The DM Project Manager (William O'Mullane), Deputy Project Manager (John Swinbank) and DM Subsystem Scientist (Leanne Guy), who are known collectively as DM Management, lead the DM Subsystem. The Project Manager has direct responsibility for coordination with the overall LSST Project Office, the LSST Change Control Board, the LSST Corporation, and LSST partner organizations on all budgetary, schedule, and resource matters. The Subsystem Scientist has primary scientific and technical responsibility within the subsystem and responsibility for ensuring that the scientific requirements of the LSST are supported and is a member of the LSST Project Science Team (Project Science Team (PST)).

DM views its deliverables as hierarchical tree of *products*, as described in Section 5. The subsystem organization is based around groups which are responsible for the highest levels of that product tree (corresponding to Work Breakdown Structure elements at the third level, i.e. *1.02C.n*; refer to Section 4.2). This is illustrated in Figure 5.

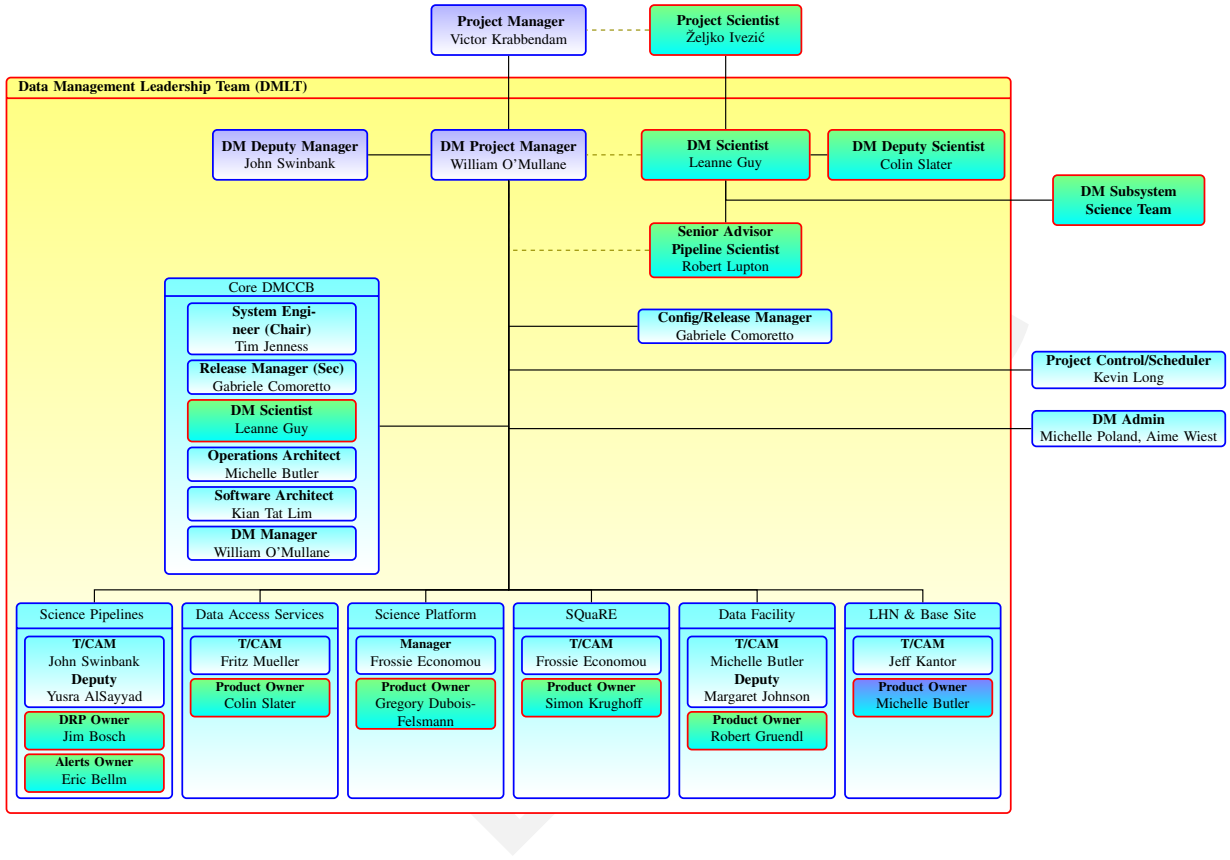

FIGURE 5: DM organization.

3.1 Meetings

As a diverse and distributed organization DM staff will participate in a considerable number of meetings. NSF and Aura have many rules on meeting attendance and LSST keep policies updated accordingly in LPM-191 and Document-13760. This includes the travel summary report template [Document-13762] every traveler must fill after attending a meeting.

The DMLT (Section 7.3) may, on occasion, require that travelers to a specific meeting of direct interest provide a detailed debriefing note or presentation.

3.2 Working Groups

The regular decision making process within DM is based on individual empowerment and a mechanism to develop consensus. This "RFC" process is described in Appendix C.

However, some issues in development of a system like Data Management require more effort to resolve than can be reasonably addressed through an Request For Comment (RFC). When required, the DM Project Manager (PM) will address these issues through the creation of a short-lived "working group". The working group will be given a specific narrow charge, it will be a small group (of perhaps around seven people), its activities will be bounded in time, and it will have a clear deliverable. Members of the group will be agreed by the DMLT (Section 7.3) to provide the best technical input from the perspective of all stakeholders. Since most members of DM have their time scheduled in advance (following the procedure described in Section 4.3), it is important to consider the impact of Working Group (WG) activities on the overall DM schedule. In particular, the consent of the relevant T/CAM should be obtained before a member of their teams is added to a working group. Members of the working group should discuss in their local organizations and socialize recommendations ahead of adoption.

The working group charge will be "RFC"ed in the usual manner to reach an agreed version and to broadly communicate the formation of the WG. The RFCs for working groups are considered automatically flagged (i.e., not subject to self-adoption); typically, the DM PM will adopt them by executive decision after consulting the DMLT. The adopted version of the charge will be issued as an LDM document.

3.3 External Studies

The DM PM may initiate or request studies by external parties to investigate or report on technological or other choices facing the DM subsystem.

3.4 Document Management

DM documents will follow the Systems Engineering Guidelines of LSST. Probability Density Function (PDF) versions of released documents shall be deposited in DocuShare in accordance with the Project's Document Management Plan [LPM-51].

An "LDM-" prefix on a document handle indicates that the document is change-controlled at the subsystem level; i.e., it may be released or modified only with the agreement of the DMCCB (Section 7.4). Uncontrolled documents, such as technical notes (prefix "DMTN-"), may be released whenever the author decides it is appropriate (or when a release is requested by the Project Manager).

The document tree for DM is shown in Figure 6. This is not exhaustive, but serves to give a high level overview of the main documents in DM and the relationships between them.

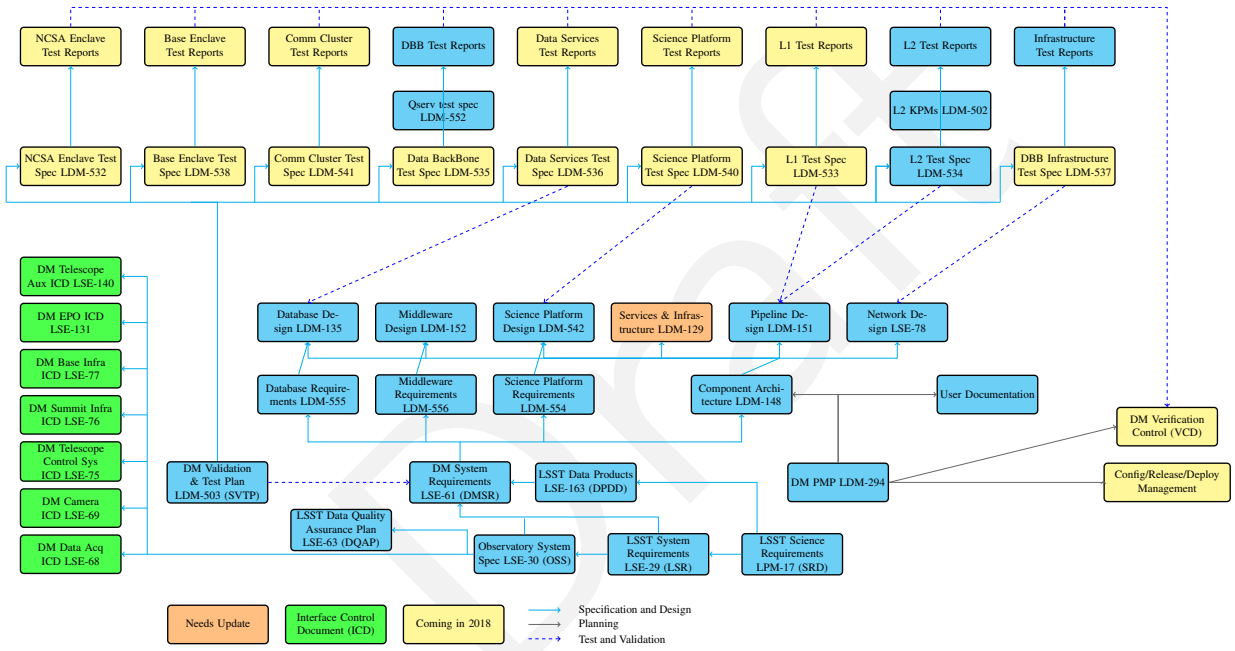

FIGURE 6: The document tree for the Data Management subsystem.

3.4.1 Draft Documents

Draft DM documents will be kept in GitHub. A single repository per document will be maintained with the head revision containing the *released* version which should match the version on DocuShare.

Use of Google Docs or Confluence is tolerated but final delivered documents must conform to the standard LSST format, and hence either produced with LaTeX, using the lsst-texmf pack-

age[1], or Word, using the appropriate LSST template (Document-9224, Document-11920). The precursor document should then be erased with a pointer to the baseline document, stored in GitHub.

3.4.2 End-User Documentation

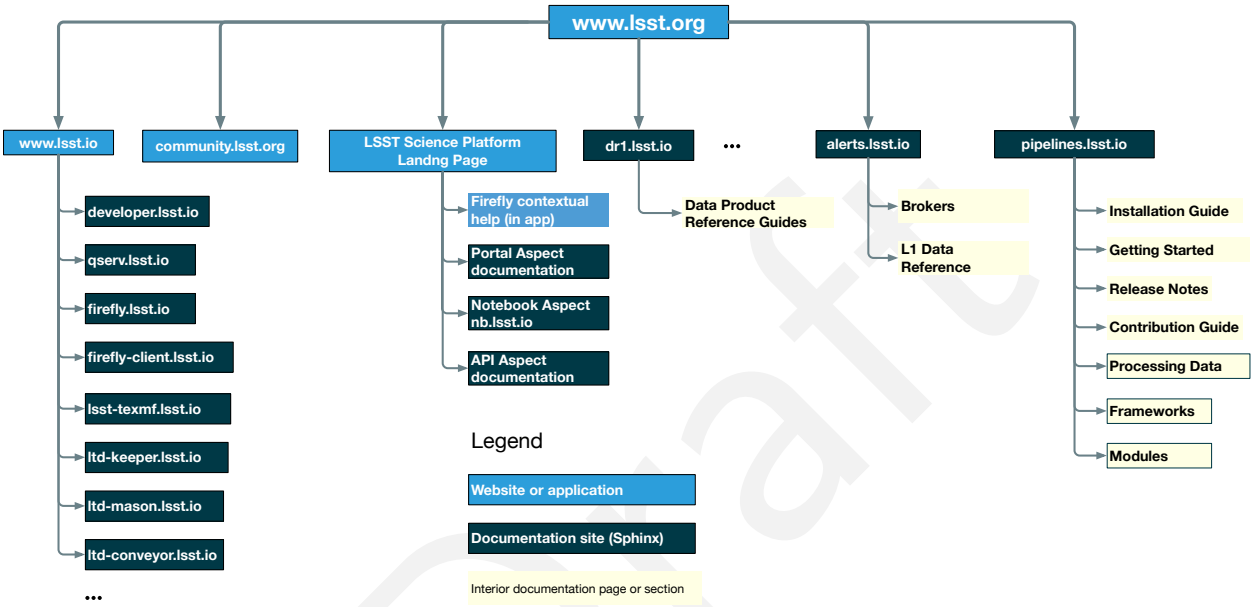

FIGURE 7: Outline of the web hierarchy for the DM end user documentation.

Figure 6 has a single box for "end user documentation". However, appropriate web-based, user-focused documentation is regarded as a major DM deliverable. End user documentation will be web-based, and will follow the hierarchy shown in Figure 7.

3.4.3 Data Facility Documentation

Service-level documentation follows the layered service architecture of the LSST Data Facility (see Figure 8).

3.4.3.1 Cross-cutting Aspects of LSST Data Facility (LDF) Services The cross-cutting aspects of the LSST Data Facility, *security* and operational *manageability*, are represented by the

[1] https://lsst-texmf.lsst.io

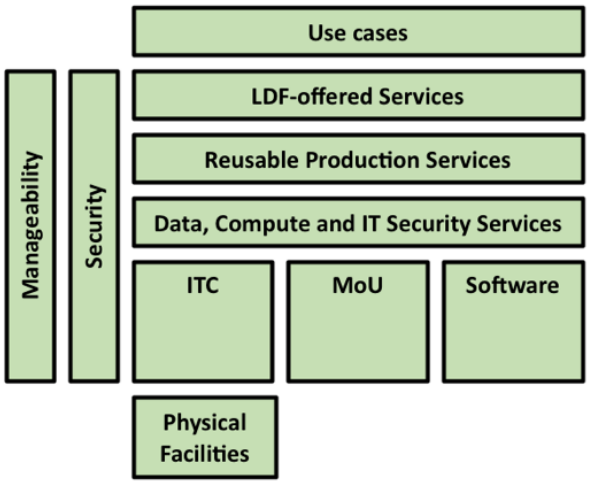

FIGURE 8: Outline of layered service architecture of the Data Facility.

vertical boxes in Figure 8. Documentation of these aspects describes policies, procedures, and supporting management frameworks, including:

1. LDF service management framework: service catalog, service-level agreements (SLAs), configuration management database (CMDB), service monitoring.
2. LDF service management processes and context in the overall project: incident response, request response, issue tracking, problem management and the problem management database, change management and change control authority, release management.
3. Overview of the security enclave structure
4. Security controls and incident response procedures
5. Disaster recovery and continuity policies

3.4.4 Documentation of Service Layers

The box at the top of Figure 8, *use cases*, represents subsystem-level and project-level operational use cases. The next layer, *LDF-offered services*, represents specific services offered by the Data Facility which satisfy those use cases. Documentation of this layer includes:

1. For each service, a concept of operations (ConOps) which summarizes how a service operates to satisfy a use case. The ConOps describes the operational characteristics of the production system, context within overall LSST operations, and representative scenarios.

2. For each service, a theory of operations, which provides a mental model of a constructed system. The theory of operations explains how the constructed service both fulfills the ConOps and integrates with the cross-cutting aspects of the facility. The document describes the overall architecture of the service and dependency on supporting service layers; integration into aspects of computer security, information security and business continuity; and integration into incident reporting and response, availability and capacity management, and change management.

The next two layers, *reusable production services* and *data, compute, and Information Technology (IT) security services*, represent tiers of supporting service. Documentation of these layers includes a theory of operations, as described above, explaining the dependencies on supporting service and Information Technology Center (ITC) layers, and integration with cross-cutting aspects of the facility.

The *ITC* box represents hardware components supporting all LDF services. Documentation of ITC describes the system elements at all facility sites, administration within each security enclave and integration with security operations, the overall provisioning plan, ITC system monitoring and integration into the service monitoring framework, and integration into service management processes including configuration management and change management.

The *software* box represents service software components being developed by the Data Facility. Documentation of software elements follows the standards of the LSST software stack.

Documents are managed as configuration items in the LSST Data Facility CMDB.

3.5 Configuration Control

Configuration control of documents is addressed in Section 3.4. In this section, we consider instead how configuration control is applied to operational systems and software development.

3.5.1 Software Configuration Control

DM follows a git based versioning system based on public git repositories. The approach is covered in the Developer Guide[2] and is consistent with the Project-level Systems Engineering Management Plan LSE-17. The `master` branch is the stable code with development done in *ticket* branches (named with the id of the corresponding Jira Ticket describing the work). Once reviewed a branch is merged to `master`, which should always be functional and releasable. Releases are recorded by tagging the `master` branch; release branches can be created if patches are required.

As we approach commissioning and operations DM will have much stricter configuration control. At this point there will be a version of the software which may need urgent patching, a next candidate release version of the software, and the `master`. A patch to the operational version will require the same fix to be made in the two other versions. The role of the DM Change Control Board (DMCCB; Section 7.4) becomes very important at this point to ensure only essential fixes make it to the live system as patches and that required features are included in planned releases.

We cannot escape the fact that we will have multiple code branches to maintain in operations which will lead to an increase in work load. Hence one should consider that perhaps more manpower may be needed in commissioning to cope with urgent software fixes while continuing development. The other consideration would be that features to be developed post commissioning will probably be delayed more than one may think, as maintenance will take priority.[3]

3.5.2 Hardware Configuration Control

On the hardware side we have multiple configurable items; we need to control which versions of software are on which machines. These days tooling like Puppet make this reasonably painless. Still the configuration must be carefully controlled to ensure reproducible deployments providing correct and reproducible results. The exact set of released software and other tools on each system should be held in a configuration management database. Changes to the configuration should be endorsed by the DMCCB.

[2] `https://developer.lsst.io/processes/workflow.html`
[3] WOM identifies this as the maintenance surge.

The sizing model for compute hardware purchasing is detailed in LDM-144, LDM-141, and LDM-138.

3.6 Release Management

Three key documents describe DM's approach to software releases:

- LDM-672 defines the policies around making releases, in terms of versioning, licensing, etc;
- LDM-564 provides a schedule for major releases expected throughout the construction period;
- DMTN-106 specifies the procedures to be followed while carrying out a software release.

The DMCCB is responsible for synchronizing the release plan with project-wide milestones. [4]

All releases will be identified by a release issue.

Any unscheduled release, major, minor or patch, needs to be requested by the end user to the DMCCB using a RFC Jira issue. The RFC shall contain:

- The justification for the release.
- The date the release is requested to be available.
- A list of proposed functionalities or fixes (Jira issues) which are requested to be implemented in the release.

The DMCCB will assess the release request within one week. If the release is urgent, DMCCB will assess it within 24 hours. The DMCCB will approve or reject the proposed release and add a comment to the RFC with the reason of rejection or, in case of approval, with the following information:

[4] As of January 2019 the release plan needs to be reviewed and the release milestones listed therein need to be made consistent with the scope of the document. Issue DM-17001 is tracking this activity.

- The release identifier (version number NN.nn).
- The estimated release date.
- The list of Jira issues that will be included.

3.7 Risk Management

Risks will be dealt with within the LSST Project framework as defined in LPM-20. Risks in DM may be sent to the DM Project Manager or Deputy Project Manager at any time for consideration to be included in the formal risk register (appropriately costed and weighted). All risks are reviewed regularly by the DM Project Manager and Systems Engineer, who will consider at least three risks per month, and are discussed monthly at the regular DMLT meetings.

3.8 Quality Assurance

In accordance with the project Quality Assurance (QA) plan [LPM-55] we will perform QA on the software products. This work will mainly be carried out by SQuaRE (Section 8.1.1). Quality assurance here means compliance with project guidelines for production, in our case for software production. A part of this is to have a verification/validation plan(s) which in and of itself is a major task (see Section 3.10).

3.9 Action Items

Actions in DM are tracked as Jira issues and periodically reviewed at DMLT meetings.

3.10 Verification and Validation

We intend to verify and validate as much of DM as we can before commissioning and operations. This will be achieved through testing and operations rehearsals/data challenges. The verification and validation approach is detailed in LDM-503, which includes a detailed discussion of the test schedule summarized in Figure 9.

4 Project controls

DM follows the LSST project controls system, as described in LPM-98. Considerations specific to DM are outlined in Section 4.3.

The DM Project Controller is responsible for the PMCS and, in particular, for ensuring that DM properly complies with our earned value management requirements. The Controller is the first point of contact for all questions about the PMCS.

4.1 Schedule

The entire LSST project schedule is held in Primavera. Tied to major project milestones we have a series of DM tests which need to be performed to show readiness for the different project phases. This is depicted in Figure 9.

4.2 Work breakdown structure

While the original DM WBS is laid out in LPM-43 with definitions provided in LPM-44, the new WBS is currently described in Appendix B, which is expected to replace the contents of LPM-43 upon approval by the LSST CCB.

The WBS provides a hierarchical index of all hardware, software, services, and other deliverables which are required to complete the LSST Project. It consists of alphanumeric strings separated by periods. The first component is always “1”, referring to the LSST Construction Project. “02C” in the second component corresponds to Data Management Construction. Subdivisions thereof are indicated by further digits. These subdivisions correspond to teams within the DM project. The top level WBS elements are mapped to the lead institutes in Table 2; the lead institutions roles are outlined in Section 8. The various groups involved in the WBS are briefly described in Section 7.

4.3 Planning Process

Milestones have been defined to describe the major goals of the DM subsystem throughout the construction project. Each milestone has a description, a due date, and a level. Four levels are defined:

FIGURE 9: DM major milestones—designated as LDM-503-*x*—in the LSST schedule. These milestones are defined at level 2 according to the scheme described in Section 4.3.

TABLE 2: DM top level Work Breakdown Structure

WBS	Description	Lead Institution
1.02C.01	System Management	LSST Tucson
1.02C.02	Systems Engineering	LSST Tucson
1.02C.03	Alert Production	University of Washington
1.02C.04	Data Release Production	Princeton University
1.02C.05	Science User Interface and Tools	IPAC
1.02C.06	Science Data Archive	SLAC
1.02C.07	LSST Data Facility	NCSA
1.02C.08	International Communications & Base Site	LSST Tucson
1.02C.09	System Level Testing & Science Validation	LSST Tucson
1.02C.10	Science Quality & Reliability Engineering	LSST Tucson

Level 1 The most important milestones exposed at the NSF level.

Level 2 Cross-subsystem milestones (for example, DM milestones that affect the Camera Subsystem).

Level 3 Cross-team milestones within DM (for example, Middleware milestones that affect the DRP Team).

Level 4 Internal milestones within a team.

The major DM subsystem tests described in Section 4.1 are defined as level 2 milestones. Teams plan their work towards each test by defining a series of level 3 milestones. Teams may define level 4 milestones for their own use.

Resources to achieve the milestones throughout the duration of construction have been allocated by means of *planning packages* loaded into the PMCS. Each top level WBS within DM (per Table 2) is divided into some tens of planning packages, each of which addresses some part of the DM baseline design with a clearly defined scope, deliverable, resource cost, and end date.

As the due date for work approaches, the actions required to complete each planning package—and hence meet the associated milestones—must be defined in detail. The DM team divides the year into two six month long *cycles*, running from November through May (the "spring cycle") and from June through October (the "fall cycle"). At the start of each cycle, the DM Leadership Team (Section 7.3) agrees on the detailed plan of work for the cycle, and this is loaded in to Jira as a series of "epics", corresponding to projects of a few person-months duration, each with defined start and end dates and resource loading. The DM team records work and tracks progress against epics using Jira; the Project Controller (Section 6.5) arranges for this information to be ingested to and made available within the PMCS. When epics are closed the T/CAM should ensure the deliverables are mentioned/linked in the associated comments in Jira. The DMPM shall verify all closed epics have the defined deliverables associated with them.

This process is described in detail in DMTN-020.

5 Products

The products of DM are not the data products defined in LSE-163, but rather the artifacts, systems, and services which will be used by the operational LSST system to generate those data products.

In Section 2, we briefly described the high level approach being taken to the design of the DM products, while Appendix A provides a complete list of products, including the technical manager, WBS element, and product owner for each. That information is summarized in the product tree shown in Figure 10.

Each DM product is being developed to satisfy one or more of the requirements placed upon the DM subsystem. LDM-148 provides a tracing from each product to and from the relevant requirements. These requirements are drawn from LSE-61, the DM System Requirments document. The requirements LSE-61 are themselves traced to higher level requirements in the LSST System Requirements (LSR; LSE-29) and/or the Observatory System Specifications (OSS; LSE-30). Appendix D traces DM requirements to higher level requirements, and Appendix E traces relevant higher-level requirements to DM.

Every code repository used by DM must be associated with a product, and hence will have an associated technical manager and product owner.

6 Roles in Data Management

This section describes the responsibilities associated with the roles shown in Figure 5.

6.1 Data Management Project Manager

The Data Management Project Manager (DMPM) is responsible for the efficient coordination of all LSST activities and responsibilities assigned to the Data Management Subsystem. The DMPM has the responsibility of establishing the organization, resources, and work assignments to provide DM solutions. The DMPM serves as the DM representative in the LSST Project Office and in that role is responsible for presenting DM initiative status and submitting new DM initiatives to be considered for approval. Ultimately, the DMPM, in conjunction

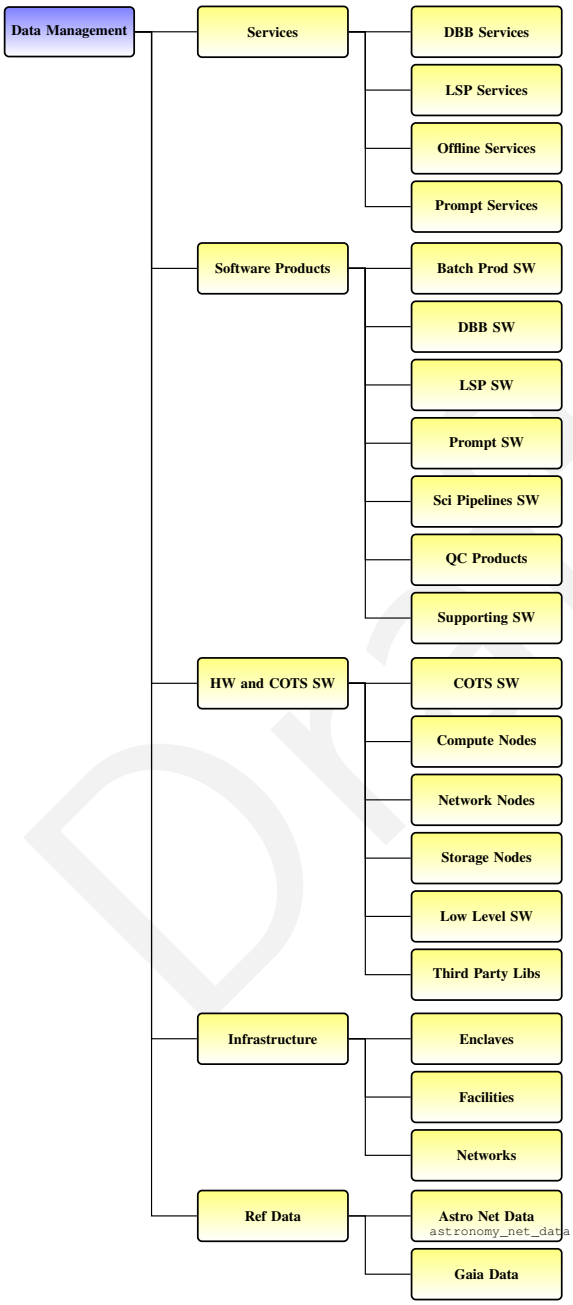

FIGURE 10: An overview of the DM product tree. This provides just a summary of the highest level items: refer to Appendix A for the full list.

with his/her peer Project Managers (Telescope, Camera), is responsible for delivering an integrated LSST system. The DMPM reports to the LSST Project Manager. Specific responsibilities include:

- Manage the overall DM System
- Define scope and request funding for DM System
- Develop and implement the DM project management and control process, including earned value management
- Approve the DM Work Breakdown Structure (Work Breakdown Structure (WBS)), budgets and resource estimates
- Approve or execute as appropriate all DM outsourcing contracts
- Convene and/or participate in all DM reviews
- Co-chair the DM Leadership Team (Section 7.3)

6.2 Deputy Data Management Project Manager

The Data Management Deputy Project Manager (DDMPM) will work together with the DMPM on the general management of DM and any specific PM tasks may be delegated to the deputy as needed and agreed. In the absence of the PM the deputy carries full authority and decision making powers of the PM. The DMPM will keep the Deputy informed of all DM situations such that the deputy may effectively act in place of the Project Manager when absent.

6.3 Data Management Subsystem Scientist

The DMSS has the ultimate responsibility for ensuring DM initiatives provide solutions that meet the overall LSST science goals. As such, this person leads the definition and understanding of the science goals and deliverables of the LSST Data Management System and is accountable for communicating these to the DM engineering team.

The DMSS reports to the LSST Project Scientist. The DMSS is a member of the LSST Change Control Board and the Project Science Team. He/she chairs and directs the work of the DM System Science Team (Section 7.1).

Specific responsibilities and authorities include:

- Communicates with DM science stakeholders (LSST Project Scientist and Team, advisory bodies, the science community) to understand their needs and identifies aspects to be satisfied by the DM Subsystem.
- Develops, maintains, and articulates the vision of DM products and services responsive to stakeholder needs.
- Works with the LSST Project Scientist to communicate the DM System vision to DM stakeholders. Works with the DMPM to communicate and articulate the DM System vision and requirements to the DM construction team.
- Regularly monitors DM construction team progress and provides feedback to the DMPM to ensure the continual understanding of and adherence to the DM vision, requirements, and priorities.
- Develops and/or evaluates proposed changes to DM deliverables driven by schedule, budget, or other constraints.
- Provides advice to the DMPM on science-driven prioritization of construction activities.
- Validates the science quality of DM deliverables and the capability of all elements of the DM System to achieve LSST science goals.
- Serves as Data Management Liaison as requested by LSST Science Collaborations
- Provides safe, effective, efficient operations in a respectful work environment.

Specific authorities include:

- Defines the vision and high-level requirements of the DM products and services required to deliver on LSST science goals.
- Defines the science acceptance criteria for DM deliverables (both final and intermediate) and validates that they have been met (Science Validation).
- Hires or appoints DM System Science Team staff and other direct reports and defines their responsibilities.

- Advises and consents to the appointments of institutional DM Science Leads.
- Delegates authority and responsibility as appropriate to institutional Science Leads and other members of the DM System Science Team.
- Represents and speaks for the LSST Data Management.
- Convenes and/or participates in all DM reviews.
- Co-Chairs the DM Leadership Team

6.4 Deputy Data Management Subsystem Scientist

The relationship the DMSS and deputy is equivalent to that between the DMPM and deputy (see Section 6.2).

6.5 Project Controller/Scheduler

The DM Project Controller is responsible for integrating DM's agile planning process with the LSST Project Management and Control System (Project Management Controls System (PMCS)). Specific responsibilities include:

- Assist T/CAMs in developing the DM plan
- Synchronize the DM plan, managed as per Section 4.3, with the LSST PMCS
- Ensure that the plan is kept up-to-date and milestones are properly tracked
- Create reports, Gantt charts and figures as requested by the DMPM

6.6 Product Owner

A product owner is responsible for the quality and acceptance of a particular product. The product owner shall sign off on the requirements to be fulfilled in every delivery and therefore also on any descopes or enhancements. The product owner shall define tests which can be run to prove a delivery meets the requirements due for that product.

6.7 Senior Advisor / Pipelines Scientist

The LSST Science Pipelines are composed of multiple lower-level products. The Pipelines Scientist serves as product owner for the overall Science Pipelines system, working in close conjunction with the Science Leads for Alert Production and Data Release Production systems (§6.14.2).

- Provide guidance and test criteria for the full pipeline including how QA is done on the products
- Keep the big picture of where the codes are going in view, predominantly with respect to the algorithms, but also the implementation and architecture (as part of the Systems Engineering Team Section 7.2).
- Advise on how we should attack algorithmic problems, providing continuing advice to subsystem product owners as we try new things.
- Advise on calibration issues, provide understanding of the detectors from a DM point of view
- Advise on the overall (scientific) performance of the system, and how we'll test it, thinking about all the small things that we have to get right to make the overall system good.

In addition, the Pipelines Scientist serves as Senior Advisor to the DMPM.

6.8 Science Platform Scientist

The Science Platform is composed of three aspects. Each aspect is produced in a different institution. Each aspect has its own science lead/product owner. The product owner for the Platform is the DMSS Section 6.3; who has final say on requirements and features; however since this is a vital tool for LSST science we feel it is also important to have a scientist considering the platform as a whole. Hence this role is to be the scientific guardian of the science platform as a whole, to make sure all of the aspects work together in a useful manner allowing scientific exploitation of the LSST data. The Science Platform Scientist works in close collaboration with the DMSS.

6.9 Systems Engineer

With the Systems Engineering Team (Section 7.2) the Systems Engineer owns the DM entries in the risk register and is generally in charge of the *process* of building DM products.

As such, the Systems Engineer is responsible for managing requirements as they pertain to DM. This includes:

- Update and ensure traceability of the high level design & requirements documents: DM System Requirements; LSE-61 (DMSR) (LSE-61), OSS (LSE-30), and LSR (LSE-29)
- Oversee work on lower level requirements documents
- Ensure that the system is appropriately modeled in terms of e.g. drawings, design documentation, etc
- Ensure that solid verification plans and standards are established within DM

In addition, the Systems Engineer is responsible for the process to define & maintain DM interfaces (internal and external)

- Define and enforce standards for internal interfaces
- Direct the Interface Scientist's (Section 6.10) work on external ICDs

The Systems Engineer shall chair the DM Change Control Board (Section 7.4)

- Organize DMCCB processes so that the change control process runs smoothly
- Identify RFCs requiring DMCCB attention
- Shepherd RFCs through change control
- Call and chair DMCCB meetings, ensuring that decisions are made and recorded

Finally, the Systems Engineer represents DM on the LSST Change Control Board (CCB).

6.10 Data Management Interface Scientist

The DMIS is is responsible for all external interfaces to the DM Subsystem. This includes ensuring that appropriate tests for those interfaces are defined. This is a responsibility delegated from the DM Systems Engineer (Section 6.9).

As we begin to implement these interfaces this role will diminish as implementers take up the ownership of the interfaces.

6.11 Software Architect

The Software Architect is responsible for the overall design of the DM *software* system. Specific responsibilities include:

- Define the overall architecture of the system and ensuring that all products integrate to form a coherent whole
- Select and advocate appropriate software engineering techniques
- Choose the technologies which are used within the codebase
- Minimize the exposure of DM to volatile external dependencies

The Software Architect will work closely with the Systems Engineer (Section 6.9) to ensure that processes are in place for tracing requirements to the codebase and providing hooks to ensure that requirement verification is possible.

6.12 Operations Architect

The DM Operations Architect is responsible for ensuring that all elements of the DM Subsystem, including operations teams, infrastructure, middleware, applications, and interfaces, come together to form an operable system.

Specific responsibilities include:

- Set up and coordinate operations rehearsals

- Ensure readiness of procedures and personnel for Operations
- Set standards for operations e.g. procedure handling and operator logging
- Participate in stakeholder and end user coordination and approval processes and reviews
- Serve as a member of the LSST Systems Engineering Team

6.13 Release Manager

The Release Manager (RM) is responsible for maintaining and applying the release policy. Specifically, the RM will:

- Develop and maintain the DM Release Policy as a change controlled document;
- Manage the software release process and its compliance with documented policy;
- Define the contents of releases, in conjunction with the product owners, the DMSS, and the technical managers;
- Ensure that each release is accompanied by an appropriate documentation pack, including user manuals, test specifications and reports, and release notes;
- Ensure the release is delivered to NCSA for acceptance;
- Work with technical managers to coordinate bug fixes and maintenance of long-term support releases;
- Serve as a member of the DMCCB (Section 7.4).

6.14 Lead Institution Senior Positions

Each Lead Institution (as defined in Section 8; see also Table 2) has a T/CAM and Scientific or Engineering Lead, who jointly have overall responsibility for a broad area of DM work, typically a Work Breakdown Structure (WBS) Level 2 element. They are supervisors of the team at their institution, with roles broadly analogous to those of the DMPM and Subsystem Scientist.

6.14.1 Technical/Control Account Manager

T/CAMs have managerial and financial responsibility for the engineering teams within DM. Each T/CAM is responsible for a specific set of WBS elements. Their detailed responsibilities include:

- Develop, resource load, and maintain the plan for executing the DM construction project within the scope of their WBS
- Synchronize the construction schedule with development in WBS elements managed by other T/CAMs
- Maintain the budget for their WBS and ensuring that all work undertaken is charged to the correct accounts
- Work with the relevant Science Leads and Product Owners (Section 6.6) to develop the detailed plan for each cycle and sprint as required
- Work with the DM Project Controller (Section 6.5) to ensure that all plans and milestones are captured in the LSST Project Controls system
- Perform day-to-day management of staff within their WBS
- Perform the role of “scrum-master” during agile development
- Report activities as required, including providing input for monthly status reports.

6.14.2 Institutional Science/Engineering Lead

The Institutional Science/Engineering Leads serve as product owners (Section 6.6) for the major components of the DM System (Alert Production, Data Release Production, Science User Interface etc).

In addition, they provide scientific and technical expertise to their local engineering teams.

They work with the T/CAM who has managerial responsibility for their product to define the overall construction plan and the detailed cycle plans for DM.

Institutional science leads are members of the DM System Science Team (Section 7.1) and, as such, report to the DMSS (Section 6.3).

6.15 DM Science Validation Scientist

The DM Science Validation Scientist leads the Science Validation team (Section 7.5). This individual has primary responsibility for planning, executing and analyzing the results of science validation activities, as defined in LDM-503; typically, this includes large-scale data challenges. The Science Validation Scientist is responsible for End to End Science validation and reports to the DMSS.

6.16 Cross-Cutting Roles

There are at least two roles which involve managing work across institute and WBS boundaries. These individuals act as coordinators for the cross-cutting activity, including organizing "standup" (or other) meetings and resolving technical difficulties. They should develop a master schedule for activities within their area of responsibility and synchronize it with the T/CAMs who are managing individual teams. Day-to-day management of staff resides with the T/CAM of the appropriate WBS; it follows that stories can only be assigned to individuals with the agreement of that T/CAM. Though this is more of a coordination-oriented role, these managers have authority to prioritize stories in the relevant area.

6.16.1 Science Platform Manager

The LSST Science Platform spans multiple WBS elements bringing together authentication, front-end services, database access, and notebook execution. At time of writing, Frossie Economou is the Science Platform Manager. See also Section 7.7.

6.16.2 Middleware Manager

Middleware covers several WBS elements and requires multiple parts of the system to work in unison. This includes task execution, workflow management, data access abstractions (the "Data Butler"), and provenance. At time of writing Tim Jenness is the Middleware Manager. See also Section 7.6.

7 Teams within Data Management

Since the DM team is distributed in terms of geography and responsibility across the LSST partner and lead institutions, mechanisms are needed to ensure that the project remains on track at all times. There are five primary coordinating bodies to ensure the management, technical, and quality integrity of the DM Subsystem.

7.1 System Science Team

Members of the DM System Science Team (SST) work together to define, maintain, and communicate to the DM Systems Engineering team a coherent vision of the LSST DM system responsive to the overall LSST Project goals, as well as scientifically validate the as-built system (LDM-503, Section 9.).

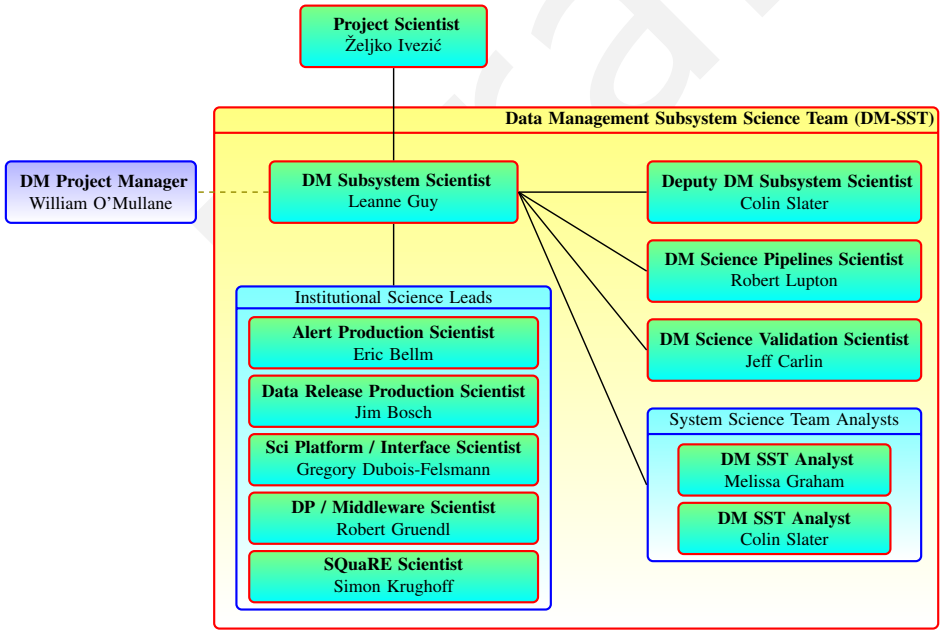

FIGURE 11: DM System Science Team organisation.

7.1.1 Organization and Goals

The System Science Team includes:

- DMSS (chair)
- DM Science Validation Scientist
- DM Institutional Science Leads
- DM System Science Analysts
- DM Science Pipelines Scientist

The System Science Team has been chartered to:

- Support the DMSS (as the overall DM Product Owner) in ensuring that Data Management Subsystem's initiatives provide solutions that meet the overall LSST science goals.
- Support the Institutional Science Leads in their roles as Product Owners for elements of the DM system their respective institutions have been tasked to deliver.
- Support the DM Science Validation Scientist, who organizes and coordinates the science validation efforts (LDM-503).
- Guide the work of System Science Analysts, who generally lead and/or execute studies needed to support SST work.
- Provide a venue for communication with the Science Pipelines Scientist, who broadly advises on topics related to the impact of science pipelines on delivered science and vice versa (Section 6.7).

The members of the System Science Team report to the DMSS and share the following responsibilities:

- Communicate with the science community and internal stakeholders to understand their needs, identifying the aspects to be satisfied by the DM Subsystem.
- Liaise with the science collaborations to understand and coordinate any concurrent science investigations relevant to the DM Subsystem.
- Develop, maintain, and articulate the vision of DM-delivered LSST data products and services that is responsive to stakeholder needs, balanced across science areas, well motivated, and scientifically and technologically current.

- Work with the DMPM and DM T/CAMs to communicate and articulate the DM System vision and requirements to the DM engineering team.
- Identify, develop, and champion new scientific opportunities for the LSST DM System, as well as identify risks where possible.
- Develop change proposals and/or evaluate the scientific impact of proposed changes to DM deliverables driven by schedule, budget, or other constraints.
- Lead the Science Verification of the deliverables of the DM subsystem.

7.1.2 Regression Monitoring of KPMs and other Metrics

All KPMs and other regression monitoring metrics will be calculated on a regular cadence (daily if possible). They are monitored by the SQuaRE scientist, with status periodically reported to the System Science Team (SST). The SQuaRE scientist brings up any major regressions to the attention of the SST, along with an initial assessment of the problem. The SST has the responsibility of monitoring the overall system for whether it meets its key performance metrics as well as understanding any significant performance regressions in performance. The SST may recommend further actions to the DMPM and/or DMSS, if necessary. These include performing additional testing, broader root cause analysis, documenting the regression, or recommendations on the priority of fixing the regression relative to presently scheduled work.

7.1.3 Communications

DM System Science Team communication mechanisms are described on the SST Confluence page at `http://ls.st/sst`. The list of current DM liaisons to the LSST Science Collaborations and international partners is maintained in `https://www.lsstcorporation.org/science-collaborations`

7.1.4 Time Allocation for Institutional Science Leads

The Institutional Science Leads fulfill the role of *Product Owner* for elements of the DM system that their respective institutions have been tasked to deliver; institutional T/CAMs rely on their Scientist to provide *Product Owner* services. In addition, as members of the DM System Science Team, they have responsibilities as described in 7.1.1, which result in work that is more

emergent in nature. To balance these two roles, the DMSS is entitled to allocate up to 50% of the Institutional Science Leads' time to Science Team work. If any Science Team study should require a greater commitment, additional time must be negotiated and agreed with the institutional T/CAMss. This arrangement is intended to ensure both a good working relationship between the T/CAMs and scientists, and that the DMSS maintains sufficient support from the Science Team to deliver a system that meets the overall LSST science goals.

7.2 DM Systems Engineering Team

The Systems Engineering Team is led by the DMPM (Section 6.1) and looks after all aspects of systems engineering. It is comprised of not only the Systems Engineer (Section 6.9), but also the Software Architect (Section 6.11), Operations Architect (Section 6.12), DMSS (Section 6.3), Pipeline Scientist (Section 6.7), Interface Scientist (Section 6.10), and the DDMPM (Section 6.2).

While the product owners (Section 6.6) help DM to create products which are fit for purpose, the Systems Engineering Team must ensure we do it correctly. This group concerns itself with (sub)system wide decisions on architecture and software engineering.

The specific tasks of this group include:

- Formalize the product list for DM[5]
- Formalize the documentation tree for DM, defining which documents need to be produced for each product
- Agree the process for tracing the baseline requirements verification and validation status.
- Agree the formal versions of documents and software which form the technical baseline, individual items will go through the CCB for formal approval. This includes upload to docushare.
- Perform releases of software products — including, but not limited to, the Science Pipelines — as needed, using tooling provided by SQuaRE (Section 8.1.1).

[5] In this sense, "products" are the software and systems which produce data products, rather than the data products themselves. See also 5.

- Debug build problems related tot he build infrastructure for any product being released — pass off product specific problems to the relevant product time.

Some of these tasks are will be delegated to individual group members. These individuals also are the conduit to/from the rest of the DM team to raise ideas/issues with the engineering approach.

7.2.1 Communications

The Systems Engineering Team will only physically meet to discuss specific topics: there will not be a regular meeting of the group outside of the one to one meetings with the DM project manager for the individuals in the group. Discussions will be held via email until in person talks are required.

7.3 DM Leadership Team

The purpose of the DM Leadership Team (DMLT) is to assist the DMPM establish the scope of work and resource allocation across DM and ensure overall project management integrity across DM. The following mandate established the DMLT:

- Charter/purpose
  - Maintain scope of work and keep within resource allocation across DM
  - Ensure overall project management integrity across DM
  - Ensure Earned Value management requirements are met
- Membership
  - Co-chaired by the DMPM (Section 6.1) and DMSS (Section 6.3)
  - Lead Institution Technical/Control Account Managers (T/CAMs; Section 6.14.1)
  - Institutional Science or Engineering Leads (Section 6.14.2)
  - Members of the DM Systems Engineering Team (Section 7.2)
- Responsibilities
  - Prepares all budgets, schedules, plans

- Meets every week to track progress, address issues/risks, adjust work assignments and schedules, and disseminate/discuss general PM communications

The DM Leadership Team and the DM Systems Engineering Team (Section 7.2) work in synchrony. The DMLT makes sure the requirements and architecture/design are estimated and scheduled in accordance with LSST Project required budgets and schedules.

7.3.1 Communications

A mailing list[6] exists for DMLT related messages. On Mondays the DMLT hold a brief (30 to 45 minutes) telecon. This serves to:

- Allow the Project manager and DM Scientist to pass on important project level information and general guidance.
- Raise any blocking or priority issues across DM — this may result in calling a splinter meeting to further discuss with relevant parties.
- Inform all team members of any change requests (LCRs) in process at LSST level which may be of interest to or have an impact on DM
- Check on outstanding actions on DMLT members

Face to Face meetings of DM are held twice a year; these are opportunities to:

- Discuss detailed planning for the next cycle
- Discuss technical topics in a face to face environment
- Work together on critical issues
- Help make DM function as a team

[6] lsst-dmlt@listserv.lsstcorp.org

7.4 DM Change Control Board

The DMCCB has responsibility for issues similar to those of the LSST Change Control Board, but focused on the DM Subsystem. The DMCCB reviews and approves changes to all baselines in the Subsystem, including proposed changes to the DM System Requirements (DMSR), reference design, sizing model, i.e. any LDM-series document. The Technical Baseline, including software/hardware and documentation, is produced by DM and controlled by the DMCCB. DMCCB validates that the form and content of the Technical Baseline is consistent with LSST project standards such as the Systems Engineering Management Plan (SEMP) LSE-17.

- Responsibilities:
  - Determine when deliverables (controlled documents and software) are ready to be baselined (placed under configuration controlled status) or released. This include LDM series documents.
  - Review and approve/reject proposed changes to baselined items - any LCR must go through the DMCCB before being submitted to the project CCB.
  - Review all RFCs and approves *flagged* RFCs prior to 'Adoption'
  - Monitor and approve DM software releases
  - Monitor the status of issues in the DM project on Jira
  - Ensure that the DM Technical Baseline (LDM-xxx) follows LSST and DM configuration control processes.
- Membership:
  - Core members:
    * DMPM
    * DMSS
    * Systems Engineer, Chair (Section 6.9).
    * Operations Architect
    * Software Architect
    * Release Manager, Secretary
  - Optional members (required when topics to discuss are relevant to their areas of expertise):
    * DDMPM, when DMPM is not available

    * Deputy DMSS, when DMSS is not available
    * Pipeline Scientist
    * Science Pipelines / Interface Scientist
    * T/CAMs, who can delegate to their deputies
  - For on-line virtual meetings, if a consensus or quorum is not reached within one week, the DMPM will make a unilateral decision
  - DMPM can also make unilateral decisions in cases of urgency. In that case DMCCB will assess the change *a posteriori*.

The DMCCB will meet, physically or virtually, every week for 30 minutes. Agenda will be available beforehand. Urgent decisions can be taken offline, outside the weekly meeting, in a modality to be defined by the DMCCB itself (email or slack channel).

All RFCs that implies one of the following changes:

- Changes to controlled documents
- API changes to the codebase, including deprecation
- Data model changes

need to be *flagged* and therefore approved by the DMCCB, as detailed in the Developer Guide.

7.5 DM Science Validation Team

The DM Science Validation Team guides the definition of, and receives the products of, science validation and dress rehearsal activities, following the long-term roadmap described in LDM-503. Decisions on the strategic goals of these activities are made in conjunction with the DMSS and DMPM.

The DM Science Validation Team is chaired by the DM Science Validation Scientist (Section 6.15). Its membership includes the DM Pipelines Scientist (Section 6.7) and the various Institutional Science/Engineering Leads (Section 6.14.2). Depending on the activities currently being executed, other members of the System Science Team (Section 7.1), the wider DM Construction Project, and/or external experts may be temporarily added to the team.

7.6 Middleware Team

The Middleware Team is responsible for delivering the Data Butler and pipe_base task framework, including supporting infrastructure to make it possible to deploy them at-scale in the Data Facility in support of Alert and Data Release Production pipeline execution.

The Middleware Team has a Product Owner (Robert Gruendl, NCSA at time of writing) and Manager (Section 6.16.2). However, it does not have a permanent staff; rather it draws on effort from across the Alert Production (Section 8.3.1), Data Release Production (Section 8.2.1), Data Access Services (Section 8.5.1), and Data Facility (Section 8.6.1) groups, as well as other members of the subsystem as necessary. Effort allocation is agreed between the Middleware Manager and the T/CAMs of the various institutes.

7.7 Science Platform Team

The Science Platform Team is responsible for delivering the three aspects of the LSST Science Platform, as described in LDM-542.

The Product Owner for the Science Platform is the DMSS, supported by the Science Platform Scientist (Section 6.8). The team is managed by the Middleware Manager (Section 6.16.2). They coordinate effort across the subsystem, drawing primarily on the Data Access Services (Section 8.5.1), Data Facility (Section 8.6.1) and SQuaRE (Section 8.1.1) teams.

8 Lead institutions in DM

8.1 LSST Tucson

The LSST Project Office in Tucson hosts the DMPM (Section 6.1), the DMSS (Section 6.3), and the Systems Engineer (Section 6.9). In addition, it is home to the Science Quality and Reliability Engineering (SQuaRE) group and LSST International Communications and Base Site (ICBS) groups, described below.

8.1.1 Science Quality and Reliability Engineering

The SQuaRE group is primarily charged with providing technical feedback to the DMPM that demonstrates that DM is fulfilling its responsibilities with regard to quality — of both scientific data products and software — software performance, and reliability. As such, areas of activity include:

- Development of algorithms to detect and analyze quality issues with data[7]
- Infrastructure development to support the generation, collection, and analysis of data quality and performance metrics
- DM developer support services to ensure DM is using appropriate tools to aid software quality
- DM documentation support, to include defining standards and providing tooling for documentation as well as some document writing
- Development and support of the build infrastructure (e.g. Jenkins) and release tools (e.g. container creation) for all DM software products
- Provide repositories of release artifacts, such as private Conda repositories, to support releases as needed and agreed with the Systems Engineering Team (Section 7.2)

In the event that SQuaRE identifies issues with the performance or future maintainability of the DM codebase, it will bring them to the attention of the DM Software Architect. In the event that SQuaRE identifies issues with the quality of the data or algorithmic performance, it will bring them to the attention of the DMSS.

8.1.2 LSST International Communications and Base Site

The ICBS group spans both Tucson and La Serena, and is responsible for the design, procurement, installation, deployment, verification, and operating support during construction and commissioning of all data communications networks at the Summit and Base sites, as well as links between all the LSST Sites, with two exceptions: the Summit Network (WBS 1.04C.12.5)

[7] This may overlap with work carried out by the Science Pipelines groups (§§8.3.1 & 8.2.1). In some instances this will involve sharing code; in others, it may merit duplicating a metric to ensure that it is correct.

and the Archive External Network (1.02C.07.04.06). In the case of the exceptions, there are technical and managerial interfaces between the ICBS and the responsible parties, as well as overlaps of staff. The LSST Network Engineering Team (Network Engineering Team (NET)) spans all of these networking assignees and is chaired by the ICBS staff.

The ICBS group is also jointly responsible with the Data Facility Team at NCSA for procurement, installation, deployment, verification, and operating support during construction and commissioning of the computing and storage infrastructure at the Base Site.

Since a large majority of the ICBS work involves procurement and contracted services, the group works in close cooperation with AURA procurement and contracts, as well as with the following major sub-awardees and their subcontractors:

- REUNA: Chilean National Networks
- Florida International University/AmLight: International Networks connecting Chile and the United States, and US National Networks.

8.2 Princeton University

Princeton University hosts the Pipelines Scientist (Section 6.7) and the Data Release Production (DRP) group, described below.

8.2.1 Data Release Production

The DRP group has three major areas of activity within DM.

- Definition and implementation of the scientific algorithms and pipelines which will be used to generate LSST's annual data releases;
- Definition and implementation of the algorithms and pipelines which will be used to produce the "calibration products" (for example, flat fields, characterization of detector effects, etc) which will be used as inputs to the photometric calibration procedure in both nightly and annual data processing. This includes the development of the spectrophotometric data reduction pipeline for the Auxiliary Telescope;

- Development, in conjunction with the Alert Production team (Alert Production (AP); Section 8.3.1), of a library of re-usable software libraries and components which form the basis of both the AP and DRP pipelines and which are made available to science users within the LSST Science Platform.

Development of software in support of annual data releases and of reusable software components are carried out under the direction of the DRP Science Lead, who acts as product owner for this part of the system. The DRP Science Lead is ultimately responsible to both the Pipelines Scientist (Section 6.7) and DMSS (Section 6.3).

The product owner for the calibration products is the LSST Calibration Scientist (who doubles as the Pipelines Scientist, Section 6.7). The Calibration Scientist liaises with other LSST subsystems and with the products owners of the annual and nightly data processing pipelines to ensure that appropriate calibration products are available to those pipelines to enable them to meet specifications.

Management of the group is the responsibility of the Deputy Science Pipelines T/CAM, reporting to the Science Pipelines T/CAM and ultimately to the DMPM (Section 6.1).

The DRP group is responsible for delivering software which adheres to the architectural and testing standard defined by the Software Architect (Section 6.11). In addition, the DRP group is responsible for testing each major product delivered to demonstrate its fitness for purpose, and working with the DMSS and DM System Science Team (Section 7.1) to define, run and analyze "data challenges" and other large scale tests to validate the performance of the data release production system.

8.3 The University of Washington

Princeton University hosts the DDMPM and Deputy DMSS as well as the AP group, described below.

8.3.1 Alert Production

The AP group has 4 major areas of activity within DM.

- Definition and implementation of the scientific algorithms and pipelines which will be used to generate alerts from LSST's image stream. This will serve as the alert generation pipeline;
- Definition and implementation a scalable and reliable system for transmitting the alerts generated by the alert generation pipeline including a mechanism for applying simple filters to the stream. This is the alert distribution and filtering system;
- Definition and implementation of a system for identifying moving objects in our solar system and fitting their physical properties. This is the Moving Objects Processing System (MOPS);
- Development, in conjunction with the Data Release Production team (DRP; Section 8.2.1), of a library of re-usable software libraries and components which form the basis of both the AP and DRP pipelines and which are made available to science users within the LSST Science Platform.

Development of software in support of the alert generation pipeline, alert distribution system, MOPS and of reusable software components are carried out under the direction of the AP Science Lead, who acts as product owner for this part of the system. The AP Science Lead is ultimately responsible to both the Pipelines Scientist (Section 6.7) and DMSS (Section 6.3).

Management of the group is the responsibility of the Science Pipelines T/CAM, reporting to the DMPM (Section 6.1).

The AP group is responsible for delivering software which adheres to the architectural and testing standard defined by the Software Architect (Section 6.11). In addition, the AP group is responsible for testing each major product delivered to demonstrate its fitness for purpose, and working with the DMSS and DM System Science Team (Section 7.1) to define, run and analyze "data challenges" and other large scale tests to validate the performance of the data release production system.

8.4 California Institute of Technology/IPAC

IPAC hosts the LSST Science Platform Scientist (Section 6.8), the DM Interface Scientist (Section 6.10), and the Science User Interface and Tools (SUIT) group described below.

8.4.1 Science User Interface and Tools

The Science User Interface and Tools (SUIT) group has four major areas of activity within DM:

Design and develop the Firefly Web-based visualization and data exploration framework, based upon the the same software already in operations in other NASA archive services (i.e. IRSA's WISE Image Service) . The Firefly framework provides three basic components – image display and manipulation, tabular table display and manipulation, and 2D plotting – all of which work together to provide different views into the same data. Firefly also provides JavaScript and Python APIs to enable developers to easily use the components in their own Web pages or Jupyter notebooks.

Develop the interfaces needed to connect Firefly to the other LSST Science Platform components, e.g., connect to authentication and authorization, DAX services, user workspace, flexible compute system. Develop visualizations of the objects in the LSST Data Products data model, and support their metadata; e.g., Footprint, HeavyFootprint, WCS models. Provide basic access to Firefly from the LSST stack via afw.display.

Design and implement the Portal Aspect of the LSST Science Platform for Data Access Center, based on Firefly, providing scientists an easy to use interface to search, visualize, and explore LSST data. The portal will enable users to do as much data discovery and exploration as possible through complex searches and facilitate data assessment through visualization and interaction. The Portal will assist users in understanding the semantic linkages between the various LSST data products. The Portal will guide users to documentation on the Science Platform itself, the LSST data products, and the processing that generated them. Support linkage between the Portal and Notebook aspects of the Science Platform, enabling users to switch between the aspects easily by providing tools to make data selected in the Portal readily available for further analysis in user notebooks.

Design and develop the LSST Alert Subscription web portal to enable scientists to access the alert system. The subscription service will enable users to register filters and destinations for alerts matching their interests. The Alert portal will also provide basic capabilities for searching alerts history and for exploring linkage between alerts and other data products.

8.5 SLAC

SLAC hosts the DM Software Architect (Section 6.11) and the Science Data Archive and Data Access Services group described below.

8.5.1 Science Data Archive and Data Access Services

The Science Data Archive and Data Access Services (Data Access Services (DAX)) group has the following major areas of activity within DM:

- Provides software to support ingestion, indexing, query, and administration of DM catalog and image data products, data provenance, and other associated metadata within the LSST Data Access Centers;
- Provides implementations of data access services (including IVOA services), as well as associated client libraries, to be hosted within the LSST Data Access Centers, which facilitate interaction between LSST data products and tools provided by both other parts of the LSST project and by the astronomical research community at large;
- Provides a Python framework (the "Data Butler"), used by the LSST science pipelines, to facilitate abstract persistence/retrieval of in-memory Python objects to/from generic archives of those objects;
- Provides a Python framework ("SuperTask") which serves as an interface layer between pipeline orchestration and algorithmic code, and which allows pipelines to be constructed, configured, and run at the level of a single node or a group of tightly-synchronized nodes;
- Provides support for various middleware and infrastructure toolkits used by DM which would otherwise have no authoritative home institution within DM (e.g. logging support library, spherical geometry support library).

Management of the group is the responsibility of the DAX T/CAM, reporting to the DMPM (Section 6.1).

The DAX group is responsible for delivering software which adheres to the architectural and testing standard defined by the Software Architect (Section 6.11). In addition, the DAX group

is responsible for testing each major product delivered to demonstrate its fitness for purpose, and running and analyzing large scale tests to validate the performance of the science data archive and data access systems.

8.6 NCSA

NCSA hosts the LSST Computer Security group, as well as the DM group responsible for construction and integration of the LSST Data Facility (LDF), described below.

8.6.1 LSST Data Facility

The LDF group has the following major areas of activity within DM:

- Construction of services, including software and operational methods, supporting observatory operations and nightly data production (Level 1 Services). Level 1 Services ingest raw data from all Observatory cameras and the Engineering and Facilities Database (EFD) into the central archive; provide a dedicated computing service controllable by the Observatory Control System (OCS) for prompt generation of nightly calibration assessments, science image parameters, and transient alerts; and provide computing services, data access, and a QA portal for Observatory staff.
- Construction of services, including software and operational methods, for bulk batch data production. Batch Production Services execute processing campaigns, using resources at NCSA and satellite computing centers, to produce data release products, generate templates and calibrations, and perform scaled testing of science pipelines to assess production readiness.
- Construction of services, including software and operational methods, for hosting and operating data access services for community users. These services host the SUIT portal, manage the JupyterLab environment, provide computing and data storage for the Data Access Centers, enable bulk data export, and host the LSST limited alert-filtering service and feeds to community-provided brokers.
- Construction of services, including software and operational methods, for the Data Backbone. Data Backbone Services provide ingestion, management, distribution, access, integrity checking, and backup and disaster recovery for files and catalog data in the LSST central data archive.

- Construction and operation of services for LSST staff. Staff Services provide specific testing and integration platforms (e.g., a Prototype Data Access Center) and general computing and data services for LSST developers.
- Provisioning and management of hardware infrastructure at NCSA and the Chilean Base Center for all services described above, as well as infrastructure for project-wide network-based computer security services and authentication and authorization services.
- Construction and operation of a service management framework and methods to monitor operations of service elements in accordance with service level agreements, track issues, manage service availability, and support change management.
- Operation of services and IT systems during construction to support on-going development, integration, and commissioning activities.

The LDF group is responsible for delivering instantiated production services, which integrate software and hardware components developed across DM. The LDF group performs large-scale tests to integrate and verify production readiness of all components.

9 Development Process

In many respects, DM is effectively a large software project — in particular, we are developing scientific software, and must face all the uncertainties implied by that. An agile process [29] is particularly suited to scientific software development of this sort.

DM has adopted a cyclical approach to software development, with a period of six months. At the beginning of each development cycle, we define a set of "epics", which correspond to major pieces of work to be undertaken during the cycle.

During the development cycle, all code is kept under continuous integration[8] (Continuous Integration (CI)). Code is managed on GitHub`https://github.com`, and is made available using an open source license.

Releases follow the six-month cadence, but the CI system ensures that code on the `master` branch is always deployeable.

[8] Currently using the Jenkins tool; `https://jenkins.io`

DMTN-020 describes in detail the intgration of DM's agile approach to software development with the Earned Value Managenent system used by the LSST construction project.

9.1 Communications

The epics for each six-month development cycle are agreed at the DMLT face-to-face meeting near the beginning of the period (see Section 7.3).

The T/CAMs of each of the institutions meet via video on Tuesdays and Fridays for a short "standup" meeting to ensure that any cross-team issues are surfaced and resolved expeditiously. This meeting is chaired by the Deputy Project Manager. Each T/CAM notes any significant progress of interest to other teams and any problems or potential problems that may arise.

9.2 Conventions

Coding guidelines and conventions are documented online in `https://developer.lsst.io`

9.3 Reviews

The DM Project Manager and Subsystem Scientist will periodically convene internal reviews (following LSE-159) of major DM components as necessary to assess progress and maintain the integrity of the overall system. Planned DM reviews will be listed at the LSST Project Review Hub (`https://project.lsst.org/reviews/hub/`).

In addition, smaller components of the system will undergo DM-internal design reviews. The DMPM decides what will be reviewed (with input from all DM members) and is the Decision Making Authority for approving review recommendations. Participants in the design review will normally include all members of the DMCCB and other experts as appropriate (e.g. the LSST Information Security Officer or designated substitute if there are any security implications). The design review will check that the design:

- meets the requirements and satisfies the use cases, and an implementation can be verified as doing so

- conforms to the LSST DM architecture and has well-defined interfaces
- is expected to be efficient in terms of labor cost, non-labor cost, and schedule
- is expected to be reliable, maintainable, supportable, usable, and secure
- conforms to good engineering practices

Design review presentations should include:

- the identification of the components under review in terms of where they fit within the overall architecture
- use cases and requirements applicable to the components under review that show how they will be used and how they respond/support all usage
- an Application Programming Interface (API) or other description of the public interfaces to the components under review
- a description of the internal patterns and algorithms to be used in the design, known limitations to those, and justification why the limitations are acceptable for this development
- a description of the technological approach to implementation, including use of any third-party components, and reuse of existing elements (e.g. this will be a specialization of the XYZ framework classes)
- a description of how the function and performance of the component(s) under review will be tested

10 Data Management Problem/Conflict Resolution

The above organizational structure allocates significant responsibility to lead institutions. As such, when problems arise that cannot be solved with the responsibility and scope allocated to an institution, the path of escalation and resolution of such problems must be clear.

Any inter-institutional issues should be brought as early as possible to the DMPM, who will attempt to mediate a resolution. The DMPM may consult with the DMLT, DM System Science

Team and DM Systems Engineering Team if there are scientific or technical impacts to be considered.

Should an issue need to be escalated the PM will bring it up in the weekly LSST Project Managers Meeting. In that forum a way forward will be agreed with the LSST Project Manager and other subsystem managers.

A DM Product List

Refer to LDM-148 for a detailed description of the meaning of each product referred to below.

WBS Element	Product	Manager	Owner	Packages
1.02C	Data Management	Wil O'Mullane	Leanne Guy	
Services			Leanne Guy	
DBB Services			Michelle Butler	
1.02C.07.07	DBB Lifetime	Margaret Johnson	Michelle Butler	
1.02C.07.07	DBB Metadata	Margaret Johnson	Michelle Butler	
1.02C.07.07	DBB Storage	Margaret Johnson	Michelle Butler	
1.02C.07.07	DBB Transport	Margaret Johnson	Michelle Butler	
LSP Services			Gregory Dubois-Felsmann	
1.02C.10.02.02	LSP JupyterLab	Frossie Economou	Simon Krughoff	
1.02C.05.07, 1.02C.05.08, 1.02C.05.09	LSP Portal	Xiuqin Wu	Gregory Dubois-Felsmann	
1.02C.06.02	LSP Web API	Fritz Mueller	Colin Slater	
Offline Services			Multiple	
1.02C.07.06.02	Bulk Distrib	Margaret Johnson	Michelle Butler	
1.02C.04.07	Offline QC	Yusra AlSayyad	Jim Bosch	
1.02C.07.06.02	Batch Production	Margaret Johnson	Michelle Butler	
Prompt Services			Multiple	
1.02C.03.03	Alert Distrib	John Swinbank	Eric Bellm	
1.02C.07.06.02	Archiving	Margaret Johnson	Felipe Menanteau	
1.02C.07.06.02	OCS Batch	Margaret Johnson	Felipe Menanteau	
1.02C.07.06.02	Obs Ops Data	Margaret Johnson	Felipe Menanteau	
1.02C.07.06.02	Planned Obs Pub	Margaret Johnson	Felipe Menanteau	
1.02C.07.06.02	Prompt Proc Ing	Margaret Johnson	Felipe Menanteau	
Prmpt Processing				
1.02C.03.08	Prompt QC	John Swinbank	Eric Bellm	
1.02C.07.06.02	Telem Gateway	Margaret Johnson	Felipe Menanteau	
Software Products			Multiple	
Batch Prod SW			Michelle Butler	
1.02C.07.08	Campaign Mgmt	Margaret Johnson	Michelle Butler	
1.02C.07.08	Workload/ flow	Margaret Johnson	Michelle Butler	
DBB SW			Michelle Butler	
1.02C.07.08	DBB Lifetime SW	Margaret Johnson	Michelle Butler	
1.02C.07.08	DBB Meta SW	Margaret Johnson	Michelle Butler	dbb_gateway, dbb_gwclient
1.02C.07.08	DBB Transport SW	Margaret Johnson	Michelle Butler	
LSP SW			Gregory Dubois-Felsmann	
1.02C.10.02.02	LSP JL SW	Frossie Economou	Simon Krughoff	jupyterlab*
1.02C.06.02	LSP Web SW	Fritz Mueller	Colin Slater	dax_webserv
1.02C.05.07, 1.02C.05.08, 1.02C.05.09	SUIT	Xiuqin Wu	Gregory Dubois-Felsmann	suit
SUIT OnlineHelp		Xiuqin Wu	Gregory Dubois-Felsmann	
Prompt SW			Multiple	

1.02C.03.03	Alert Distrib SW	John Swinbank	Eric Bellm	alert_stream
1.02C.07.08	EFD Transform	Margaret Johnson	Simon Krughoff	
1.02C.07.08	Header Srv SW	Margaret Johnson	Felipe Menanteau	HeaderService
1.02C.07.08	Image Ingest SW	Margaret Johnson	Felipe Menanteau	ctrl_iip
1.02C.07.08	Plan Obs Pub SW	Margaret Johnson	Felipe Menanteau	
1.02C.07.08	OCS Batch SW	Margaret Johnson	Felipe Menanteau	
1.02C.07.08	Obs Ops Data SW	Margaret Johnson	Michelle Butler	
Sci Pipelines SW			Robert Lupton	
1.02C.03	Alert Prod SW	John Swinbank	Eric Bellm	spl_ap
1.02C.04.02	Calibration SW	John Swinbank	Robert Lupton	spl_calibration
1.02C.04	DR Prod SW	Yusra AlSayyad	Jim Bosch	spl_drp
1.02C.03.06	MOPS SW	John Swinbank	Eric Bellm	mops_daymops
1.02C.03, 1.02C.04	Spec Prog SW	John Swinbank	Melissa Graham	
1.02C.04.02	Science P. Dist.	John Swinbank	Robert Lupton	lsst_distrib
1.02C.04.02	Science Plugins	John Swinbank	Robert Lupton	spl_plugins
1.02C.04.04	Tmpl Gen SW	Yusra AlSayyad	Jim Bosch	
QC Products			Simon Krughoff	
1.02C.10.02.01	Quality Ctrl SW	Frossie Economou	Simon Krughoff	squash-*, verify, verify_metrics, validate_base, validate_drp
Supporting SW			Multiple	
1.02C.06.02.05	ADQL Translator	Fritz Mueller	Colin Slater	albuquery
1.02C.06.02.01	Data Butler	Fritz Mueller	Jim Bosch	daf_butler
1.02C.06.02.04	Image Server	Fritz Mueller	Colin Slater	dax_imgserv
1.02C.06.02.03	Distrib Database	Fritz Mueller	Colin Slater	qserv, partition, scisql, daf_ingest
1.02C.03, 1.02C.04	Sci Pipelines Libs	John Swinbank	Jim Bosch	lsst_apps
1.02C.06.03	Task Framework	Fritz Mueller	Jim Bosch	pipe_supertask
HW and COTS SW			Multiple	
COTS SW			Multiple	
CILogon				
Docker				
GPFS				
Grafana				
HTCondor				
Kubernetes				
Oracle				
Puppet				
IT Security				
vSphere				
Compute Nodes			Michelle Butler	
1.02C.07.09	Blade (e.g.)	Margaret Johnson	Michelle Butler	
Network Nodes			Multiple	
1.02C.07.09	Router (e.g.)	Margaret Johnson	Michelle Butler	
Storage Nodes			Michelle Butler	
1.02C.07.09	Disk (e.g.)	Margaret Johnson	Michelle Butler	
Low Level SW			Multiple	
OS (e.g.)				
Third Party Libs				

Boost				
Firefly API A.		Xiuqin Wu	Gregory Dubois-Felsmann	
1.02C.05.06	Firefly	Xiuqin Wu	Gregory Dubois-Felsmann	Caltech-IPAC/ firefly
Python				
Infrastructure			Multiple	
Enclaves			Multiple	
1.02C.08.01	Arch Base Encl	Margaret Johnson	Michelle Butler	
1.02C.07.09	Arch NCSA Encl	Margaret Johnson	Michelle Butler	
1.02C.08.01	Comm Clust Encl	Margaret Johnson	Simon Krughoff	
1.02C.08.02	DAC Chile Encl	Margaret Johnson	Michelle Butler	
1.02C.07.09	DAC US Encl	Margaret Johnson	Michelle Butler	
1.02C.07.09	Offline Prod Encl	Margaret Johnson	Michelle Butler	
1.02C.08.01	Prmpt Base Encl	Margaret Johnson	Michelle Butler	
1.02C.07.09	Prmpt NCSA Encl	Margaret Johnson	Michelle Butler	
Facilities			Multiple	
1.02C.08.01, 1.02C.08.02	Base Facility	Jeff Kantor	Jeff Kantor	
1.02C.07.09	NCSA Facility	Margaret Johnson	Michelle Butler	
Networks			Multiple	
1.02C.08.03	Base/ Arch Net	Jeff Kantor	Jeff Kantor	
1.02C.07.08	Base LAN	Margaret Johnson	Michelle Butler	
1.02C.08.03	Net Mgmt	Jeff Kantor	Jeff Kantor	
1.02C.07.09	NCSA LAN	Margaret Johnson	Michelle Butler	
1.02C.08.03	Sum/ Base Net	Jeff Kantor	Jeff Kantor	
Ref Data				
Astro Net Data				
Gaia Data				

B WBS (FY18 onwards) — 1.02C: Data Management Construction

This WBS element provides the complete LSST Data Management System (DMS). The DMS has these main responsibilities in the LSST system:

- Process the incoming stream of images generated by the Camera Subsystem during observing to generate and archive the LSST nightly data products.
- Provide real-time information on data quality to the Observatory Control System (OCS) during observing.
- Process the entire survey data each year to produce deep catalogs of objects and precise measurements of those objects.
- Capture and process calibration images from the Camera Subsystem. Incorporate pipeline improvements and correct errors.
- Provide a VO-compliant interface that makes publicly available all generated data products.

The following products (per Section 5) are defined at this level of WBS:

- Data Management

1.02C.01: System Management

This WBS element provides all activities related to the management and administration of the Data Management WBS elements. This includes all activities and support to maintain a core team responsible for the execution of all Data Management Tasks. Effort in this task insures compliance with Project level controls, documentation, and reporting. This also includes overseeing the management of DMS physical assets (hardware, software, facilities, documents) and support for travel and communications during the Construction Phase, as well as preparing for the same activities during the Operations Phase. This includes:

- Project management of resources, schedules, tasks, and deliverables.

- Quality assurance of the DM project, including Science Data Quality Assessment.
- Configuration control of all DMS elements and asset management for all DMS physical assets.

No products are defined at this level of the WBS.

1.02C.01.01: Project Management

This WBS element includes Project Management staff and supporting tools for the project. The primary deliverables are the Data Management sections of overall LSST PMCS-based project plans, schedules, budgets, and reports. Communications and collaboration tools for team management and coordination are also within this WBS element.

No products are defined at this level of the WBS.

1.02C.01.02: [Legacy] Science Data Quality Integration and Test

This WBS element was used early in construction, and is maintained only for archival accounting purposes. No work is scheduled here; all budget has be been transferred to 1.02C.10.

No products are defined at this level of the WBS.

1.02C.02: Systems Engineering

This WBS element includes all systems engineering activities for the LSST Data Management subsystem, including all subsystem level modeling and simulation development as well as subsystem and system level technical reviews of deliverables.

No products are defined at this level of the WBS.

1.02C.02.01: Data Management Science

This WBS element provides for the scientific leadership of the Data Management Subsystem. Specifically, the activities covered by this WBS element include:

- Ultimate ownership of all science-related DM products (per §5);
- Coordination of the Institutional Science Leads;
- Communication with the external scientific community and internal stakeholders to understand their needs, and, where applicable, ensure they are satisfied with by the DM Subsystem;
- Liaison with science collaborations;
- Resources to identify, develop and champion new scientific opportunities for the LSST DM System, as well as identify risks where possible;
- Leadership of the DM Science Validation effort (day to day responsibility for this is delegated to the DM Science Validation Scientist (1.02C.09).

No products are defined at this level of the WBS.

1.02C.02.02: DM System Architecture

The Architecture Team is a subset of the DM Systems Engineering Team that implements decisions of that team by creating, maintaining, disseminating, and ensuring adherence to a common, consistent system architecture for the Data Management System.

The Architecture Team monitors construction activities to ensure consistency with the defined architecture and performs investigations needed to support its core responsibilities.

No products are defined at this level of the WBS.

1.02C.02.02.01: System Architecture Definition This WBS element includes all activities related to documenting the high-level architecture of the LSST Data Management System. This includes writing and maintaining documents that define and describe the DMS's high-level components and their interfaces, both internal and external, as well as how they work together and are operated to meet the DM System Requirements. This work is performed in conjunction with the technical leadership of the DM teams as well as that of other LSST subsystems.

No products are defined at this level of the WBS.

1.02C.02.02.02: System Architecture Oversight This WBS element includes all activities related to ensuring that the constructed LSST Data Management System, including the computing and storage systems, the processing systems, and the science pipelines, adheres to its architectural principles and standards and that the Data Management development processes are followed. It involves tracking software development; leading, advising, and educating during design, code, sprint, and other reviews; contributing to the completeness of verification testing; maintaining the DM Risk Register; and communicating the DMS architecture internally and externally. This WBS element also involves making decisions on design and process changes to ensure emergent properties of the system such as usability, reliability, understandability, and maintainability. The Architecture Team provides input to decision-making personnel and bodies but does not supervise, directly control, or exercise a veto over development work except where explicitly delegated that role. One such delegation is the Release Manager role which oversees and coordinates the preparation for each software release. Architecture Team input about low-level code is conveyed to individual developers during reviews. Input about refinement of designs is conveyed to technical leads and the NCSA Steering Committee. Input about revisions to designs or plans is conveyed to technical managers and the NCSA Steering Committee for incorporation into prioritization. Interactions with LSST System Engineering, Operations Planning, Risk Management, and Change Control are contained within this WBS, as is architectural representation in the DM Systems Engineering Team and Change Control Board.

No products are defined at this level of the WBS.

1.02C.02.02.03: Architecture Investigation This WBS element includes all activities related to obtaining the data necessary to make architectural decisions, including literature research, prototyping, and model-building.

No products are defined at this level of the WBS.

1.02C.03: Alert Production

This WBS element covers three broad areas of work:

- The development of scientific algorithms and pipelines which will be used to process the LSST image stream to identify transients, variables and moving objects;
- The rapid production and dissemination of alerts describing sources detected by LSST in the difference image;
- The development of a system for identifying moving solar system objects and fitting their physical properties;
- The development of reusable algorithmic and software primitives which will be used in the construction of both nightly and annual data processing pipelines.

The following products (per Section 5) are defined at this level of WBS:

- Alert Prod SW
- Spec Prog SW
- Sci Pipelines Libs

1.02C.03.00: Management, Leadership & Other Costs

This WBS element covers project management and scientific leadership of the Alert Production group. It includes effort to develop the overall plan for the work of the group, to schedule that work, to perform day-to-day technical and control account management of the team, to coordinate development with other parts of the LSST WBS, and to contribute to the operation of the DM Subsystem Science Team. It also includes effort from all team members which does not directly contribute to a specific deliverable (for example, attendance at team meetings).

No products are defined at this level of the WBS.

1.02C.03.01: Single Frame Processing

This WBS element covers the construction of the software, together with its associated configuration files, test suites and documentation, used to produce the single frame processing pipeline This pipeline produces calibrated images from raw images. The focus is on a pipeline

that produces science frames ready for image differencing, but is expected to result in many pieces that can be re-used in the data release production system.

No products are defined at this level of the WBS.

1.02C.03.02: Catalog Association for Alert Production

This WBS element covers the construction of the software, together with its associated configuration files, test suites and documentation, which is used to associate DIASources with other entities required for alert packet construction. Specifically, this will include association with solar system objects and previously constructed DIAObjects.

This will also cover the work necessary to carry out the updating of DIAObjects with the addition of another DIASource.

No products are defined at this level of the WBS.

1.02C.03.03: Alert Distribution System

This WBS element covers the construction of the software, together with its associated configuration files, test suites and documentation, which will make up the alert distribution system. DIAObjects and ancillary data necessary for alert packet assembly will be delivered to this system. There are three parts to the alert distribution system:

- Robust, redundant message queue – DIAObjects and ancillary data will be delivered to the message queue by the alert generation pipeline.
- Flexible stream filtering system – Will operate on the packaged alert stream. This will provide the interface to both community broker and to the minimal LSST provided filtering system.
- Alert database – All alerts will be dumped (possibly verbatim) to a database that can be replayed later from any point in the stream.

The following products (per Section 5) are defined at this level of WBS:

- Alert Distrib
- Alert Distrib SW

1.02C.03.04: Alert Generation Pipeline

This WBS element covers the construction of the software, together with its associated configuration files, test suites and documentation, which is used to produce all information necessary to build the LSST alert stream. This will include work in the areas of:

- Template optimization – An example area of optimization is that of reducing false positives due to the presence of differential chromatic refraction in the data used to build the templates.
- Image differencing – Production of algorithms needed to produce optimal image differences in all contexts LSST expects to operate in (i.e. both low and high galactic latitude).
- Difference image measurement – Dipole, point source (positive and negative), and trailed source measurement are all needed.

No products are defined at this level of the WBS.

1.02C.03.05: Tools for Science Pipelines

This WBS element covers the construction of the software, together with its associated configuration files, test suites and documentation, which are used to provide tooling, software primitives, and software upkeep necessary to execute the science pipelines successfully.

No products are defined at this level of the WBS.

1.02C.03.06: Moving Object Processing System (MOPS)

This WBS element covers the construction of the software, together with its associated configuration files, test suites and documentation, which are used to produce the moving object

processing system. This system is responsible for producing high quality orbital properties for solar system objects observed by LSST.

The following products (per Section 5) are defined at this level of WBS:

- MOPS SW

1.02C.03.07: Transform fitting on stacks of images

This WBS element covers the construction of the software, together with its associated configuration files, test suites and documentation, which will allow for high precision photometric and astrometric calibration of objects using multiple apparitions of each object.

Major features of this work will be:

- Photometric zeropoint fitting on scales larger than a chip.
- Support photometric zeropoints which vary on scales smaller than a chip.
- Support fitting composeable astrometric models that can represent distortions on a variety of scales from multiple different sources.
- The above will allow the distortions from the optical system to be separated from the distortions imprinted by the atmosphere.

No products are defined at this level of the WBS.

1.02C.03.08: Integration

This WBS element covers the construction of the software, together with its associated configuration files, test suites and documentation, necessary for the integration of the alert production system and MOPS. This includes pipeline assembly, integration with the workflow system, definition and implementation of interfaces with other subsystems, and documentation of the system to a level where it can be operated by non-AP team members.

The following products (per Section 5) are defined at this level of WBS:

- Prompt QC

1.02C.04: Data Release Production

This WBS element covers three broad areas of work:

- The development of scientific algorithms and pipelines which will be used to generate LSST's annual data releases;
- The development of algorithms and pipelines which will be used to generate the calibration products required in both nightly and annual data processing;
- The development of reusable algorithmic and software primitives which will be used in the construction of both nightly and annual data processing pipelines.

The following products (per Section 5) are defined at this level of WBS:

- DR Prod SW

1.02C.04.00: Management, Leadership & Other Costs

This WBS element covers project management and scientific leadership of the Data Release Production group. It includes effort to develop the overall plan for the work of the group, to schedule that work, to perform day-to-day technical and control account management of the team, to coordinate development with other parts of the LSST WBS, and to contribute to the operation of the DM Subsystem Science Team. It also includes effort from all team members which does not directly contribute to a specific deliverable (for example, attendance at team meetings).

No products are defined at this level of the WBS.

1.02C.04.01: Software Primitives

This WBS element covers the construction of low-level, re-usable software primitives which form the core libraries underlying the LSST Science Pipelines. It includes the production of

test suites demonstrating the correct operation of these primitives and technical, developer-focused documentation describing their use.

No products are defined at this level of the WBS.

1.02C.04.02: Calibration Products

This WBS element covers the construction of the software, together with its associated configuration files, test suites and documentation, which is used to produce the LSST calibration products. Calibration products are used in the LSST Science Pipelines (both Alert Production and Data Release Production) to:

- Characterize detector anomalies;
- Correct for sensor cross-talk;
- Perform photometric calibration through understanding the throughput of the LSST system and the transmissivity of the atmosphere.

The following products (per Section 5) are defined at this level of WBS:

- Calibration SW
- Science Plugins
- Science P. Dist.

1.02C.04.03: Image Characterization

This WBS element covers the construction of the software, together with its associated configuration files, test suites and documentation, which is used to characterize and calibrate each exposure as part of the Data Release Production processing. This will include:

- Estimation of the point spread function;

- Modeling the background;
- Developing astrometric and photometric calibration solutions.

No products are defined at this level of the WBS.

1.02C.04.04: Coaddition

This WBS element covers the construction of the software, together with its associated configuration files, test suites and documentation, which are used to generate co-added and differenced images as part of the Data Release Production processing.

The following products (per Section 5) are defined at this level of WBS:

- Tmpl Gen SW

1.02C.04.05: Detection & Deblending

This WBS element covers the construction of the software, together with its associated configuration files, test suites and documentation, which are used to detect sources on astronomical images, and to decompose detections which consist of multiple overlapping astronomical objects into their constituent parts ("deblending"). It also includes functionality to merge redundant processing carried out in the overlapping regions of the LSST sky tessellation.

No products are defined at this level of the WBS.

1.02C.04.06: Characterization & Measurement

This WBS element covers the construction of the software, together with its associated configuration files, test suites and documentation, which are used to characterize objects detected in LSST images. This includes:

- Application of fundamental measurement algorithms;

- Fitting of source models to data;
- Multi-epoch measurement;
- Forced measurement;
- Star/galaxy classification.

No products are defined at this level of the WBS.

1.02C.04.07: Maintenance, Quality & Documentation

This WBS element covers holistic documentation, verification and maintenance tasks that pertain to the pipelines and algorithms developed in the other 02C.04 WBS elements and elsewhere in the project. It includes work to construct and maintain an end-to-end Data Release Production test system and ongoing maintenance to adapt the pipelines to changes elsewhere in the system. It also includes providing high-level, scientist and operator facing documentation describing the the system as delivered. Finally, it includes the construction of QC measurement generators which will be used to verify that pipelines are functioning correctly during operations.

The following products (per Section 5) are defined at this level of WBS:

- Offline QC

1.02C.05: Science User Interface and Tools

This WBS element covers the work performed by the Science User Interface and Tools group. It includes the following:

- The Firefly framework to support infrastructure and common functionalities for all SUIT applications, including low-level Python API and JavaScript API;
- Components to provide connection between the core data search/visualization components and the rest of the “LSST Science Platform”;

- The web portal aspect of the LSST Science Platform, to enable the science user community to access, discover, explore, analyze, and download LSST data;
- A web-based user interface to alert subscription and searches.

No products are defined at this level of the WBS.

1.02C.05.00: Management, Leadership, & Other Costs

This WBS element covers Project Management, Control Account Management, and Scientific Leadership of the Science User Interface and Tools group. It includes effort to develop the overall schedule and cost for the work, perform day-to-day technical management of the team, coordinate with other parts of the WBS, provide support for invoices, and contribute to the operation of the DM Subsystem Science Team. It also includes effort from all team members which does not directly contribute to a specific deliverable (for example, attendance at team meetings).

No products are defined at this level of the WBS.

1.02C.05.06: Client-server Query & Visualization Framework

This WBS element covers the construction of low-level, re-usable software components which form the core libraries (Firefly) underlying both the client and server sides of the LSST Science User Interface Portal. It includes software packaging, releases, and deployment, the production of test suites demonstrating the correct operation of the components, and the development of technical, developer-focused documentation describing their use.

Firefly comprises a variety of capabilities, including the following:

- Libraries for data display and visualization for tabular data and astronomical images, including various 2D charts, and a shared data model supporting data overlays on images, and brushing and linking among related displays;
- Abstract search processor interface;

- Libraries for data query, retrieval, and export, including an abstract search processor interface as well as implementations providing common astronomical archive search forms and interfaces to standard (including VO) data query APIs;
- Support for various common formats for astronomical tabular and image data;
- JavaScript and low-level Python APIs, used internally as well as providing for user control and customization;
- Identity and preferences management;
- Load balancing.

The following products (per Section 5) are defined at this level of WBS:

- Firefly

1.02C.05.07: LSST Science Platform Interfaces

This WBS element covers the construction of software components that provide the connection between the core data search/visualization components and the rest of the "LSST Science Platform": supporting the LSST data model, data-access services, and compute and storage resource access. It includes the development of associated documentation and test suites.

It incorporates the following:

- Interface to LSST-specific user identity and management services;
- Access to LSST user workspace;
- Search processors matching the DAX interfaces;
- Search processors for the Engineering and Facilities Database;
- Interface for invoking LSST stack Python code to perform services needed by the Portal;
- Support for reading and displaying LSST-specific data formats (such as afw.table-format files) and data objects (e.g., masks, Footprints, PSF models);

- Support for the afw.display interface to Firefly.

The following products (per Section 5) are defined at this level of WBS:

- LSP Portal
- SUIT

1.02C.05.08: Applications

This WBS element covers the construction of the Portal Aspect of the LSST Science Platform software, including online help, deployment instructions, and other documents. The Portal uses the core Firefly components and the LSST-specific software interfaces in 1.02C.05.07, relying on infrastructure and data access services provided under other WBS elements, to deliver a portal for the science community to access, discover, explore, analyze, and download the LSST data. It covers the following:

- The overall user interface layout and structure;
- Basic access to all LSST catalog and image data (Level 1, Level 2, user/Level 3, calibration, and Engineering and Facilities Database);
- Scientifically motivated workflows guiding users to the available data and illuminating connections among tables and between tables and images;
- All-sky displays allowing exploration of the image data and of maps of the properties of the LSST survey across the sky;
- Access to the user workspace, supporting data sharing and and collaboration;
- Deployment packaging and configuration management.

No products are defined at this level of the WBS.

1.02C.05.09: Alert Interfaces

This WBS element covers the construction of a Web-based user interface for alert subscription and searches. It is based on the core Firefly package and uses interfaces provided by SUIT, DAX, and AP. It covers:

- Alert subscription, setting filters and alert stream destination;
- Access to user management system;
- Alert searches and filtering.

No products are defined at this level of the WBS.

1.02C.05.10: Integration & Test

This WBS element covers the integration and higher-level testing of all the deliverables from the 02C.05 sub-WBSs, including manual UI tests, tracking and reporting bugs in the software from other teams, possible automated UI test setup and instructions, and deployment of the software at the LSST Data Access Centers in collaboration with NCSA.

No products are defined at this level of the WBS.

1.02C.06: Science Data Archive and Application Services

The Science Data Archive and Data Access Services provides the ability to ingest, index, federate, query, and administer DM data products on distributed, heterogeneous storage systems and data servers. All services will be implemented to provide reasonable fault-tolerance and autonomous recovery in the event of software and hardware failures.

No products are defined at this level of the WBS.

1.02C.06.00: Management, Leadership, & Other Costs

This WBS element covers Project Management, Control Account Management, and technical leadership of the Science Data Archive and Data Access Services group. It includes effort to develop the overall schedule and cost for the work, perform day-to-day technical management of the team, coordinate with other parts of the WBS, and provide support for invoices. It also includes effort from all team members which does not directly contribute to a specific deliverable (for example, attendance at team meetings).

No products are defined at this level of the WBS.

1.02C.06.01: Science Data Archive

This WBS element is a summary element that includes software programs, database tables, configuration files, unit tests, component integration tests, and documentation that implement structures and tools to manage the LSST Data Products in databases and files, including defining schemas and ingesting tables and files and their metadata and provenance into the archive.

No products are defined at this level of the WBS.

1.02C.06.01.01: Database Catalogs, Alerts, and Metadata This WBS element includes software programs, database tables, configuration files, unit tests, component integration tests, and documentation that implement Database Catalogs, Alerts, and Metadata capabilities.

It implements all database catalogs: L1 Alert Production and User Database, L2 Internal DRP, L2 Data Release Catalogs, Level 3 Catalogs, Calibration Database, Restructured Engineering Facilities Database, and Deep Drilling Database. It includes schemas and structures (partitioning, replication, distribution models, L1 production/user, L2 swap/release), and tools for manipulating the catalogs, such as managing ingest, replication, hot swap, recovery and import/export.

It implements data-product-specific metadata and provenance for all LSST data product cat-

alogs and images. It includes schemas and structures (partitioning, replication, distribution models), and tools for manipulating the metadata, such as managing ingest, replication, hot swap, recovery and import/export. Global metadata that spans multiple data products is handled through 02C.06.02.05.

It implements structure for alerts, as well as tools for persisting and efficiently retrieving them.

No products are defined at this level of the WBS.

1.02C.06.01.02: Image and File Archive This WBS element includes software programs, database tables, configuration files, unit tests, component integration tests, and documentation that implement the Image and File Archive, including tools for managing image and files (ingestion, import/export).

No products are defined at this level of the WBS.

1.02C.06.02: Data Access Services

This WBS element is a summary element that includes software programs, database tables, configuration files, unit tests, component integration tests, and documentation that implement Data Access Service capabilities.

The following products (per Section 5) are defined at this level of WBS:

- LSP Web API
- LSP Web SW

1.02C.06.02.01: Data Access Client Framework This WBS element includes software programs, database tables, configuration files, unit tests, component integration tests, and documentation that implement overall Client Framework for Data Access Services.

It implements capability to store and retrieve LSST Data Products in terms of their application

level “astronomical” semantics, mapping those semantics to physical, persistent versions of those data products in databases and files.

It provide capabilities to run user data analysis close to the data.

The following products (per Section 5) are defined at this level of WBS:

- Data Butler

1.02C.06.02.02: Web Services Framework This WBS element includes software programs, database tables, configuration files, unit tests, component integration tests, and documentation that implement an overall framework for running database, metadata and image cutout services.

The work involves providing IVOA standard service interfaces where applicable.

No products are defined at this level of the WBS.

1.02C.06.02.03: Query Services This WBS element includes work needed to come up with a DBMS that meets LSST user query analysis needs. Such DBMS should include standard off-the-shelf DBMS capabilities including advanced features such as scalability to petabytes, incremental scaling, parallel queries, shared scans, fault tolerance, resource management, as well as LSST-specific features such as efficient support for spatial and temporal data at scale.

The work involves customizing, optimizing, improving and gluing together relevant components, building missing features, configuration files, unit tests, integration tests, and documentation. It also includes building tools for maintaining, configuring, and administering such system.

The following products (per Section 5) are defined at this level of WBS:

- Distrib Database

1.02C.06.02.04: Image and File Services This WBS element includes software programs, database tables, configuration files, unit tests, component integration tests, and documentation that implement image and file services. Image and File Services provide the capability to access and manipulate image and file-based data, manage file caches, and recreate images on demand.

The following products (per Section 5) are defined at this level of WBS:

- Image Server

1.02C.06.02.05: Catalog Services This WBS element includes software programs, database tables, configuration files, unit tests, component integration tests, and documentation needed to build web services on top of all LSST database products (all levels, all metadata).

It includes work on global metadata structures for all LSST data products, including all data releases, L3 user data and all images. Data-product-specific metadata is handled through 02C.06.01.01.

The following products (per Section 5) are defined at this level of WBS:

- ADQL Translator

1.02C.06.03: Task Framework

This WBS element includes software programs, database tables, configuration files, unit tests, component integration tests, and documentation needed to build the Task Framework.

The Task Framework is a Python class library that provides a structure (standardized class entry points and conventions) to organize low-level algorithms into potentially-reusable algorithmic components (Tasks; e.g. dark frame subtraction, object detection, object measurement), and to organize tasks into basic pipelines (SuperTasks; e.g., process a single visit, build a coadd, difference a visit). The Task Framework allows the pipelines to be constructed, configured, and run at the level of a single node or a group of tightly-synchronized nodes. In addition to multi-node Tasks, it also allows for sub-node parallelization across multiple cores.

Pipeline configuration includes configuring parameters for scientific algorithms, allowing overrides of defaults based on camera/survey, computing environment, or user choice. It also includes configuration of debugging capabilities used during pipeline development.

The Task Framework serves as an interface layer between orchestration and the algorithmic code. It exposes a standard interface to "activators" (command-line runners as well as the orchestration layer and QA systems), which use it to execute the code wrapped in tasks. The Task Framework exposes to the orchestration system needs and capabilities of the underlying algorithmic code (e.g., the number of cores needed, expected memory-per-core, expected need for data). It may also receive from the orchestration layer the information on how to optimally run the particular task (i.e., which level of intra-node parallelization is be desired).

This WBS includes construction of basic implementations for these components. More complex (or custom) implementations and alternative backends for the APIs and components above (e.g., a special backend to retrieve a configuration from a central database, or a backend to send logs to a database instead of files, or a MultiCore API backend that's better aware of local machine architecture) are out of scope.

The following products (per Section 5) are defined at this level of WBS:

- Task Framework

1.02C.06.04: Middleware, Infrastructure, and Toolkits

This WBS element is a summary element that includes software programs, database tables, configuration files, unit tests, component integration tests, and documentation that implement basic middleware infrastructure primitives.

No products are defined at this level of the WBS.

1.02C.06.04.01: Logging This WBS element includes software programs, database tables, configuration files, unit tests, component integration tests, and documentation that implement a set of classes/functions enabling tasks to log diagnostic messages about their execution.

No products are defined at this level of the WBS.

1.02C.06.04.02: Daf_base and Utilities This WBS element is a summary element that includes software programs, database tables, configuration files, unit tests, component integration tests, and documentation that implement small common utility classes for memory management, key/value storage, dates and times, RA/declination formatting, etc.

No products are defined at this level of the WBS.

1.02C.06.04.03: Sphgeom This WBS element is a summary element that includes software programs, database tables, configuration files, unit tests, component integration tests, and documentation pertaining to the sphgeom spherical geometry library.

No products are defined at this level of the WBS.

1.02C.07: LSST Data Facility

This WBS element primarily supports the construction of the LSST data facility, a distributed facility centered at NCSA, with a goal of providing services in Construction to Observing Operations and Science Operations. Services range from acquisition of pixels from the LSST instruments, faithful retention of LSST data, batch production (including executing data release processing, and providing data access centers). Construction responsibilities include providing computing resources, integration of the center, and providingservices to the construction project. The LSST data facility uses resources at the base center, NCSA, CC-IN2P3, and commercial providers.

No products are defined at this level of the WBS.

1.02C.07.05: LSST Data Facility Management, Service Architecture, and Project Controls

This element of the WBS contains the work to oversee and manage the LSST Data Facility's performance and strategy, design and interface controls, and project controls and reporting.

The work includes all cross-cutting elements of the Data Facility: line management, governance and oversight, overall engineering and design, planning for operations, service management, and project reporting.

1. Management and Oversight
2. Service Architecture and Management
3. Project Controls and Reporting

No products are defined at this level of the WBS.

1.02C.07.06.01: LDF-offered Services

This element of the WBS contains the work to instantiate and run LSST Data Facility (LDF) production services, which each satisfy a specific use case, in order to achieve LSST science requirements.

The work includes integration of all service components, development of verification and validation tests, readiness testing, service-level documentation, integration into service management and service monitoring systems (including feeding status and quality metrics for display), integration with security controls, configuration of components and integration with reliant services, deployment into production, early life support, and operation for construction and commissioning use cases (including management, configuration, upgrading, monitoring, request response, problem management, and first-order quality assurance of data products and scientific and technical aspects of the production services).

1. Services for Observatory Operations
2. Services for Designated Offline Campaign Processing
3. Data Access Services for Authorized Users
4. Services for General Staff
5. Data Facility Service Desk

No products are defined at this level of the WBS.

1.02C.07.06.02: Reusable Production Services

This element of the WBS contains the work to instantiate and run project-oriented production services that are reused to support many development, integration and production use cases. These services understand the operational relationships of the service dependencies and components and are aware of representative use cases of the service.

The work includes integration of all service components, readiness testing, service-level documentation, integration into service management and service monitoring systems, integration with security controls, configurations of components and integration with reliant services, deployment into production, early life support, and operation for construction and commissioning user cases (including management, configuration, upgrading, monitoring, request response, problem management, and first-order quality assurance of scientific and technical aspects of production services).

1. Prompt Processing Service
2. Internal Transient Event Handling Service
3. Telemetry Gatewaying Service
4. Master Batch Job Scheduling Service
5. QA Portal Hosting Service
6. Implementation of File Management Policies and High-level Data Movement Workflows
7. Management of End-user Data Rights
8. Central Elements of Workflows, Reports, and Interactive Informative Displays based on IdM Service Endpoints

The following products (per Section 5) are defined at this level of WBS:

- Archiving
- Planned Obs Pub
- Prompt Proc Ing

- Obs Ops Data
- OCS Batch
- Telem Gateway
- Batch Production
- Bulk Distrib

1.02C.07.07: Data, Compute and IT Security Services

This element of the WBS contains the work to instantiate and run general IT services that support all project-facing services described in the preceding WBS elements. This layer achieves the functionality of storing files and data within the Data Backbone and providing access at all service endpoints with the required quality of service.

The work includes integration of all software and hardware components into a service, readiness testing, service-level documentation, integration into service management and service monitoring systems, integration with security controls, configurations of components, deployment into production, early life support, and operation for construction and commissioning user cases (including management, configuration, upgrading, monitoring, request response, problem management, and first-order quality assurance of scientific and technical aspects of production services).

1. File-oriented Services within the Data Backbone
2. Managed Database Services
3. Backup and Disaster Recovery Services
4. Batch Computing and Data Staging Environment Services
5. Containerized Application Management Services
6. IT Service Management and Monitoring Support Services

The following products (per Section 5) are defined at this level of WBS:

- DBB Metadata
- DBB Lifetime
- DBB Transport
- DBB Storage

1.02C.07.08: LDF Service Software

This element of the WBS contains the work to construct, test, and maintain software for LSST Data Facility Services.

1. Level 1 Services Software
2. Batch Production Services Software
3. Data Backbone Services Software
4. Miscellaneous Facility Services Software

The following products (per Section 5) are defined at this level of WBS:

- EFD Transform
- Header Srv SW
- Image Ingest SW
- Obs Ops Data SW
- OCS Batch SW
- Plan Obs Pub SW
- Campaign Mgmt
- Workload/flow
- DBB Meta SW

- DBB Lifetime SW
- DBB Transport SW
- Base LAN

1.02C.07.09: ITC and Facilities

This element of the WBS contains the work to provide ITC and supporting facility elements for the US Archive Center and the Chilean Base Center. ITC includes local and wide-area networking, file storage resources and file systems, disaster recovery resources, database hardware, compute systems, and ITC management infrastructure.

The work includes planning, provisioning, operation, and decommissioning of physical resources at Chile and NCSA, as well as the work to construct and operate ITC configuration management tools (e.g., Puppet), coordination tools (e.g., ticket systems), and ITC processes (e.g., incident response). ITC is organized by security enclave, each with specific administrative controls.

1. Master Provisioning Enclaves ITC
2. Networking
3. Development and Integration Enclave ITC
4. L1 Enclave ITC
5. General Production Enclave ITC
6. General Base Enclave ITC
7. US DAC Enclave ITC
8. Chilean DAC Production Enclave ITC
9. Data Backbone Enclave ITC

The following products (per Section 5) are defined at this level of WBS:

- NCSA LAN
- NCSA Facility
- Arch NCSA Encl
- DAC US Encl
- Offline Prod Encl
- Prmpt NCSA Encl
- Blade (e.g.)
- Disk (e.g.)
- Router (e.g.)

1.02C.08: International Communications and Base Site

This WBS element is a summary element that includes the infrastructure for the Base Center and the national and international networks connecting the Mountain Summit, Base, Archive, and Headquarters sites.

No products are defined at this level of the WBS.

1.02C.08.01: Base Center

This WBS element is a summary element that includes the infrastructure that receives data from the camera DAQ subsystem and the Observatory Control System, store a copy of that data, and forwards the data on to the Archive Center for processing. It also includes a cluster dedicated to Commissioning activities. The Base Center is hosted in the Base Facility, which is provided by the Telescope and Site WBS.

The following products (per Section 5) are defined at this level of WBS:

- Base Facility
- Arch Base Encl

- Comm Clust Encl
- Prmpt Base Encl

1.02C.08.02: Chilean Data Access Center

This WBS element is a summary element that includes the infrastructure for the Chilean Data Access Center. The Chilean Data Access Center provides a community access point for all LSST data, including computing and storage resources dedicated to end user processing to create Level 3 data products enabling the LSST science.

The following products (per Section 5) are defined at this level of WBS:

- DAC Chile Encl

1.02C.08.03: Long Haul Networks

The LSST high-speed network plan consists of two principle segments and several sub-segments:

1. Chilean National WAN
    - La Serena–Santiago (principal and secondary paths)
    - La Serena–AURA Gatehouse
    - AURA Gatehouse–Summit
2. International Chile–US WAN
    - Santiago–U.S (100 Gbps Ring)
    - Santiago–US (Spectrum)
    - US National

Implementation of these two primary segments were assigned to REUNA (Chilean) and FIU/AmLight (International). Subsequently, it was determined that the AURA Gatehouse–Summit

subsegment would be a direct contract from AURA to Telefonica for installation, and operated by AURA/REUNA.

The Chilean network implementation involves the execution of five separate contracts. These contracts are embedded in the Work Breakdown Structure and details are provided for each one[9].

Similarly, the International network implementation involves the execution of four separate contracts. These contracts are embedded in the Work Breakdown Structure, and details are provided for each one[10].

The following products (per Section 5) are defined at this level of WBS:

- Sum/Base Net
- Base/Arch Net
- Net Mgmt

1.02C.09: System Level Testing & Science Validation

This WBS element covers oversight and management of integration and test activities. Each WBS has its own elements of the integration and test for specific items. It includes:

- Support for the activities of the DM Validation Scientist and the management of the Science Validation team.
- Maintenance of the overall subsystem testing plan (LDM-503).
- Participation in large scale tests, with specific responsibility for gathering of test results.
- Curation of fixed data sets and associated tests assembled to provide a rich set of test data for the Software & Science Quality Control Service (1.02C.10.02.01) and, where necessary, for validation activities.

No products are defined at this level of the WBS.

[9] Contractual details have been elided from the summary in this document.
[10] Ditto.

1.02C.10: Science Quality and Reliability Engineering

Science Quality and Reliability Engineering (SQuaRE) delivers services that ensure the quality of DM software, data products and reliability of services.

This WBS element covers three broad areas of work:

- Automated Software and Science Quality Control (Verification) Services;
- Science Platform Notebook Environment for QA, Commissioning & User Science;
- Developer Infrastructure, Software Distribution, Documentation Tooling, Communication Tooling.

No products are defined at this level of the WBS.

1.02C.10.01: Management, Leadership, & Other Costs

This WBS element consists of function associated with the project, technical and scientific management of the 1.02C.10 WBS, including planning, reporting, presentations, meetings, staffing and other functions associated with organizing delivery of the WBS. It also includes SQuaRE staff participation in meetings and events requiring their presence, such as the regular LSST Joint Technical Meetings and Project & Community Workshops.

No products are defined at this level of the WBS.

1.02C.10.02: Quality Control, Dataspace Services, and Developer Infrastructure

This WBS element consists of software, services, unit tests, integration tests, configuration and deployment automation, availability monitoring and documentation for: quality analysis, enabling of science analysis, automated quality control, verification and developer services.

No products are defined at this level of the WBS.

1.02C.10.02.01: Automated Software and Science Quality Control Service This WBS element consists of software and services that support the implementation of Data Management's plan to ensure the quality of the DM Pipelines.

1.02C.10.02.01.01: SQuaSH A harness for executing prepared tests automatically and continuously to characterize the algorithmic performance of the code, key aspects of the performance of the facility that are apparent in the data, its verification status, and uncover regressions to aid development.

1.02C.10.02.01.02: Monitoring A system for notifying when values for SQuaSH metrics exceed notifiable limits.

1.02C.10.02.01.03: Verification Reports Tooling Using data produced by SQuaSH to create verification reports and software release characterizations.

1.02C.10.02.01.04: Alert QA harness A harness to perform QA tests on the alert stream.

The following products (per Section 5) are defined at this level of WBS:

- Quality Ctrl SW

1.02C.10.02.02: Science Platform Notebook Environment for QA, Commissioning & User Science

1.02C.10.02.02.01: Jupyter Notebook & Templates A set of notebooks, and templates for making them, that demonstrate key features of the capabilities of the system.

1.02C.10.02.02.02: JupyterLab Deployment Architecture, orchestration and deployment configuration for the Science Platform Notebook service for commissioning.

1.02C.10.02.02.03: Custom Portals/Notebooks This WBS element covers supporting the portals delivered by the SUIT team (1.02C.05.07) post-delivery where they relate to QA and commissioning activities as necessary.

1.02C.10.02.02.04: Notebook Software Environments Production of environments (e.g. containers) suitable for the execution of custom portals/notebooks.

1.02C.10.02.02.05: Notebook Execution The process to scale notebook execution so they can execute over a large dataset. This involves an interface to the batch workflow system.

1.02C.10.02.02.06: Dataspace packaging The packaging and configuration required to deploy the dataspace on a platform that is design-matched to the compute and filespace elements of the Archive Center dataspace (e.g. if the DAC compute is based on an OpenStack architecture, the deliverable of this WBS are the packages, configuration, automation deployment and instructions that would allow a Data Access Center at an international partner to deploy a Dataspace service on top of their open OpenStack compute for their own users).

The following products (per Section 5) are defined at this level of WBS:

- LSP JupyterLab
- LSP JL SW

1.02C.10.02.03: Developer Infrastructure, Software Distribution, Documentation Tooling, Communication Tooling This WBS element consists of services that support a large distributed software team and its product. It includes systems that support current best practices in software engineering such as continuous integration, release management, software packaging and distribution, documentation standards, and infrastructure and communication tooling supporting development and team culture. All these services are oriented towards developers, and some are also oriented towards users of the DM software outside DM. While these are EVM deliverables, work is planned in such a way to reserve effort for ad-hoc developer-driven requests, since these are customer-oriented services that benefit from continuous improvement.

1.02C.10.02.03.01: Software Development Services Continuous Integration service(s), repository management, code linters, software development environments.

1.02C.10.02.03.02: Release Engineering Work with the Release Manager (1.02C.02.02.02) to provide portability testing, binary and containerized distribution, build tooling.

1.02C.10.02.03.03: Documentation Tooling Documentation standards, documentation linters, software and technical documentation production and publication, developer guide, user guide, tutorials, document discovery services.

1.02C.10.02.03.04: Communication Tooling Community forum, ChatOps.

1.02C.10.02.03.05: Bug/Tracking Helpdesk Bug Tracking, Helpdesk, Community Management

No products are defined at this level of the WBS.

C DM Discussion and Decision Making Process

DM has adopted a multi-layered approach to making decisions. In general, decisions are made at the lowest level possible within the team — at the level of the individual developer where practical. When this is not possible, decision making is escalated through the hierarchy described below.

C.1 Empowerment

All DM team members are empowered by the DM Project Manager (PM) and DM Subsystem Scientist (SS) to make decisions on any DM-internal matter, including technical/algorithm issues, process improvements, tool choices, etc., when:

1. they are willing and able to do the work to implement the decision or with people who agree with the team member,
2. they (collectively) are willing and able to fix any problems if it goes wrong, and
3. they believe that all affected parties (including your immediate manager) would not seriously object to your decision and implementation.

C.2 RFC Process

If the above three criteria are not met, perhaps because the team member doesn't know all the affected parties or because they don't know their positions, the team member should publish the proposed decision and implementation as a Jira issue in the Request For Comments (RFC) project with a component of "DM."

It is usually difficult to determine all the affected parties for published package interfaces. Changes to interfaces should thus typically go through this process.

It's a good idea to contact any known affected parties before starting this process to check that the resolution is sensible. The institutional technical manager is always affected, as she or he is responsible for tracking the work schedule. If work for others is being proposed, they are obviously affected. The institutional scientist, the DM Software Architect (SA), the

DM Interface Scientist (IS), and the DM Subsystem Scientist (SS) are also valuable resources for determining affected parties.

The purpose of an RFC is to inform others about the existence and content of the proposed decision and implementation in order to allow them to evaluate its impact, comment on it, refine it if necessary, and agree (implicitly or explicitly) or object (explicitly) to its execution.

The discussion of the RFC takes place in the medium of the requestor's choosing (e.g., a specific mailing list, the RFC Jira issue itself, a Slack Channel, a convened videocon, some combination of those, etc.), but the requestor should be open to private communications as well.

In the RFC process, the opinions of those who will be doing the work (and fixing any problems if something goes wrong) are given more weight. In some cases, this may mean that the RFC issue's Assignee passes to someone else. The opinions of more senior people or people more experienced in the area should also be given more weight and may also result in the Assignee changing.

The Assignee is responsible for determining when no serious objections remain. In particular, there is no need to call for a formal vote on the (refined) resolution. If no explicit objections have been raised within, typically, 72 hours for "ordinary" issues and 1 week for "major" issues, the Assignee should assume that there are none. This is known as "lazy consensus." When this state has been reached, the Assignee is responsible for ensuring that the final consensus has been recorded in the RFC issue before closing it and proceeding with implementation of the decision.

The requestor must be especially careful about not making irreversible changes in the "lazy consensus" time period unless they are absolutely certain there's a general agreement on the stated course of action. If something is broken, the requestor must be be ready to fix it. It is critical to apply sound reasoning and good judgment about what may be acceptable and what might be not. Mistakes will happen; accept that occasionally there will be a requirement to revert an action for which it was thought agreement existed.

C.3 Exceptions and Appeals

Some proposed resolutions may require changes to one or more of the baselined, change-controlled documents describing the Data Management system (those in DocuShare with an

LDM- handle or marked as change-controlled in Confluence). Note that major changes to budget or scope will almost certainly affect one or more LDM- documents. In this case only, the DM Configuration Control Board (DMCCB; Section 7.4) may empanel an ad hoc committee including the lead author of the document and other relevant experts. This committee or the CCB itself must *explicitly* approve the change.

Change-controlled documents with other handles, such as LSE- or LPM-, including inter-subsystem interfaces, have project-wide change control processes. Please consult the DM PM, SA, or IS for more information. At least one member of the DM CCB will read each RFC to determine if it might affect a change-controlled document.

If the DM team can't converge on a resolution to an RFC that has no serious objections but the requestor still feel that something must be done, the request will be escalated. In most non-trivial cases, they will, with the advice of the SA, empanel a group of experts to which they will delegate the right to make the decision, by voting if need be.

C.4 Formalities

For project management purposes, RFCs are formally proposals made to the DM PM and SS who by default are responsible for everything in DM (they "own" all problems). As owners, they have the final word in accepting or rejecting all proposals. Functionally, they delegate that ownership, the right and responsibility to make decisions – to others within the team (e.g. the SA, IS, group leads, etc.) who are expected to delegate it even further. Notifying the institutional technical manager about an RFC serves to inform the DM PM.

D Traceability matrix of DMSR requirements to OSS Requirements

DMS	OSS
DMS-REQ-0002 Transient Alert Distribution	OSS-REQ-0127 Level 1 Data Product Availability OSS-REQ-0184 Transient Alert Publication
DMS-REQ-0004 Nightly Data Accessible Within 24 hrs	OSS-REQ-0127 Level 1 Data Product Availability
DMS-REQ-0006 Timely Publication of Level 2 Data Releases	OSS-REQ-0134 Level 2 Data Product Availability
DMS-REQ-0008 Pipeline Availability	
DMS-REQ-0009 Simulated Data	OSS-REQ-0351 Difference Source Spurious Probability Metric OSS-REQ-0353 Difference Source Spuriousness Threshold - Transients OSS-REQ-0354 Difference Source Spuriousness Threshold - MOPS
DMS-REQ-0010 Difference Exposures	OSS-REQ-0129 Exposures (Level 1)
DMS-REQ-0018 Raw Science Image Data Acquisition	OSS-REQ-0114 Acquisition of Science Sensor data
DMS-REQ-0020 Wavefront Sensor Data Acquisition	OSS-REQ-0316 Wavefront Sensor Data
DMS-REQ-0022 Crosstalk Corrected Science Image Data Acquisition	OSS-REQ-0114 Acquisition of Science Sensor data OSS-REQ-0127 Level 1 Data Product Availability
DMS-REQ-0024 Raw Image Assembly	OSS-REQ-0114 Acquisition of Science Sensor data OSS-REQ-0129 Exposures (Level 1)
DMS-REQ-0029 Generate Photometric Zeropoint for Visit Image	OSS-REQ-0056 System Monitoring & Diagnostics OSS-REQ-0152 Level 1 Photometric Zero Point Error
DMS-REQ-0030 Generate WCS for Visit Images	OSS-REQ-0162 Level 2 Catalog Accuracy OSS-REQ-0149 Level 1 Catalog Precision
DMS-REQ-0032 Image Differencing	OSS-REQ-0121 Open Source, Open Configuration OSS-REQ-0129 Exposures (Level 1)
DMS-REQ-0033 Provide Source Detection Software	OSS-REQ-0121 Open Source, Open Configuration OSS-REQ-0130 Catalogs (Level 1) OSS-REQ-0137 Catalogs (Level 2)

Continued on next page

DMS	OSS
DMS-REQ-0034 Associate Sources to Objects	OSS-REQ-0339 Level 2 Source-Object Association Quality
DMS-REQ-0042 Provide Astrometric Model	OSS-REQ-0149 Level 1 Catalog Precision OSS-REQ-0153 World Coordinate System Accuracy OSS-REQ-0160 Level 1 Difference Source - Difference Object Association Quality OSS-REQ-0162 Level 2 Catalog Accuracy
DMS-REQ-0043 Provide Calibrated Photometry	OSS-REQ-0137 Catalogs (Level 2) OSS-REQ-0130 Catalogs (Level 1) OSS-REQ-0275 Calibration Processing Performance Allocations
DMS-REQ-0046 Provide Photometric Redshifts of Galaxies	
DMS-REQ-0047 Provide PSF for Coadded Images	OSS-REQ-0153 World Coordinate System Accuracy OSS-REQ-0316 Wavefront Sensor Data OSS-REQ-0136 Co-added Exposures
DMS-REQ-0052 Enable a Range of Shape Measurement Approaches	OSS-REQ-0137 Catalogs (Level 2)
DMS-REQ-0059 Bad Pixel Map	OSS-REQ-0129 Exposures (Level 1) OSS-REQ-0271 Supported Image Types
DMS-REQ-0060 Bias Residual Image	OSS-REQ-0271 Supported Image Types OSS-REQ-0046 Calibration
DMS-REQ-0061 Crosstalk Correction Matrix	OSS-REQ-0349 Data Release Production Crosstalk Correction
DMS-REQ-0062 Illumination Correction Frame	OSS-REQ-0271 Supported Image Types OSS-REQ-0046 Calibration
DMS-REQ-0063 Monochromatic Flatfield Data Cube	OSS-REQ-0271 Supported Image Types OSS-REQ-0046 Calibration
DMS-REQ-0065 Provide Image Access Services	OSS-REQ-0180 Data Products Query and Download Availability OSS-REQ-0181 Data Products Query and Download Infrastructure OSS-REQ-0176 Data Access

Continued on next page

DMS	OSS
DMS-REQ-0068 Raw Science Image Metadata	OSS-REQ-0122 Provenance OSS-REQ-0171 Engineering and Facilities Data
DMS-REQ-0069 Processed Visit Images	OSS-REQ-0129 Exposures (Level 1)
DMS-REQ-0070 Generate PSF for Visit Images	OSS-REQ-0056 System Monitoring & Diagnostics
DMS-REQ-0072 Processed Visit Image Content	OSS-REQ-0129 Exposures (Level 1)
DMS-REQ-0074 Difference Exposure Attributes	OSS-REQ-0122 Provenance
DMS-REQ-0075 Catalog Queries	OSS-REQ-0176 Data Access
DMS-REQ-0077 Maintain Archive Publicly Accessible	OSS-REQ-0186 Access to Previous Data Releases
DMS-REQ-0078 Catalog Export Formats	OSS-REQ-0176 Data Access
DMS-REQ-0089 Solar System Objects Available Within Specified Time	OSS-REQ-0127 Level 1 Data Product Availability
DMS-REQ-0094 Keep Historical Alert Archive	OSS-REQ-0128 Alerts
DMS-REQ-0096 Generate Data Quality Report Within Specified Time	OSS-REQ-0131 Nightly Summary Products
DMS-REQ-0097 Level 1 Data Quality Report Definition	OSS-REQ-0131 Nightly Summary Products
DMS-REQ-0098 Generate DMS Performance Report Within Specified Time	OSS-REQ-0131 Nightly Summary Products
DMS-REQ-0099 Level 1 Performance Report Definition	OSS-REQ-0131 Nightly Summary Products
DMS-REQ-0100 Generate Calibration Report Within Specified Time	OSS-REQ-0131 Nightly Summary Products
DMS-REQ-0101 Level 1 Calibration Report Definition	OSS-REQ-0131 Nightly Summary Products
DMS-REQ-0102 Provide Engineering & Facility Database Archive	OSS-REQ-0132 Engineering and Facility Database Archive
DMS-REQ-0103 Produce Images for EPO	OSS-REQ-0136 Co-added Exposures
DMS-REQ-0106 Coadded Image Provenance	OSS-REQ-0122 Provenance
DMS-REQ-0119 DAC resource allocation for Level 3 processing	OSS-REQ-0143 Resource Allocation
DMS-REQ-0120 Level 3 Data Product Self Consistency	OSS-REQ-0120 Consistency

Continued on next page

DMS	OSS
	OSS-REQ-0118 Consistency and Completeness
DMS-REQ-0121 Provenance for Level 3 processing at DACs	OSS-REQ-0122 Provenance
DMS-REQ-0122 Access to catalogs for external Level 3 processing	OSS-REQ-0140 Production OSS-REQ-0180 Data Products Query and Download Availability
DMS-REQ-0123 Access to input catalogs for DAC-based Level 3 processing	OSS-REQ-0140 Production
DMS-REQ-0124 Federation with external catalogs	OSS-REQ-0140 Production
DMS-REQ-0125 Software framework for Level 3 catalog processing	OSS-REQ-0121 Open Source, Open Configuration OSS-REQ-0122 Provenance
DMS-REQ-0126 Access to images for external Level 3 processing	OSS-REQ-0140 Production OSS-REQ-0180 Data Products Query and Download Availability
DMS-REQ-0127 Access to input images for DAC-based Level 3 processing	OSS-REQ-0140 Production
DMS-REQ-0128 Software framework for Level 3 image processing	OSS-REQ-0121 Open Source, Open Configuration OSS-REQ-0122 Provenance
DMS-REQ-0130 Calibration Data Products	OSS-REQ-0129 Exposures (Level 1) OSS-REQ-0194 Calibration Exposures Per Day OSS-REQ-0271 Supported Image Types
DMS-REQ-0131 Calibration Images Available Within Specified Time	OSS-REQ-0021 Base Site OSS-REQ-0046 Calibration OSS-REQ-0194 Calibration Exposures Per Day
DMS-REQ-0132 Calibration Image Provenance	OSS-REQ-0122 Provenance OSS-REQ-0123 Reproducibility
DMS-REQ-0155 Provide Data Access Services	OSS-REQ-0176 Data Access
DMS-REQ-0156 Provide Pipeline Execution Services	OSS-REQ-0037 Observatory Control System Definition

Continued on next page

DMS	OSS
	OSS-REQ-0117 Automated Production
DMS-REQ-0158 Provide Pipeline Construction Services	
DMS-REQ-0160 Provide User Interface Services	OSS-REQ-0057 Image Visualization
DMS-REQ-0161 Optimization of Cost, Reliability and Availability in Order	
DMS-REQ-0162 Pipeline Throughput	OSS-REQ-0127 Level 1 Data Product Availability OSS-REQ-0020 Usable Observing Time
DMS-REQ-0163 Re-processing Capacity	OSS-REQ-0134 Level 2 Data Product Availability
DMS-REQ-0164 Temporary Storage for Communications Links	
DMS-REQ-0165 Infrastructure Sizing for ”catching up”	OSS-REQ-0050 Summit Power Grid Loss OSS-REQ-0051 Summit-Base Connectivity Loss OSS-REQ-0052 Summit Data Buffer
DMS-REQ-0166 Incorporate Fault-Tolerance	
DMS-REQ-0167 Incorporate Autonomics	
DMS-REQ-0168 Summit Facility Data Communications	OSS-REQ-0002 The Summit Facility
DMS-REQ-0170 Prefer Computing and Storage Down	
DMS-REQ-0171 Summit to Base Network	OSS-REQ-0003 The Base Facility OSS-REQ-0127 Level 1 Data Product Availability
DMS-REQ-0172 Summit to Base Network Availability	OSS-REQ-0373 Unscheduled Downtime Subsystem Allocations
DMS-REQ-0173 Summit to Base Network Reliability	OSS-REQ-0373 Unscheduled Downtime Subsystem Allocations
DMS-REQ-0174 Summit to Base Network Secondary Link	OSS-REQ-0049 Degraded Operational States
DMS-REQ-0175 Summit to Base Network Ownership and Operation	OSS-REQ-0036 Local Autonomous Administration of System Sites
DMS-REQ-0176 Base Facility Infrastructure	OSS-REQ-0003 The Base Facility
DMS-REQ-0177 Base Facility Temporary Storage	OSS-REQ-0053 Base-Archive Connectivity Loss OSS-REQ-0054 Base Data Buffer

Continued on next page

DMS	OSS
DMS-REQ-0178 Base Facility Co-Location with Existing Facility	OSS-REQ-0006 Sites
DMS-REQ-0180 Base to Archive Network	OSS-REQ-0053 Base-Archive Connectivity Loss OSS-REQ-0055 Base Updating from Archive
DMS-REQ-0181 Base to Archive Network Availability	OSS-REQ-0053 Base-Archive Connectivity Loss
DMS-REQ-0182 Base to Archive Network Reliability	OSS-REQ-0053 Base-Archive Connectivity Loss
DMS-REQ-0183 Base to Archive Network Secondary Link	OSS-REQ-0049 Degraded Operational States
DMS-REQ-0185 Archive Center	OSS-REQ-0004 The Archive Facility
DMS-REQ-0186 Archive Center Disaster Recovery	OSS-REQ-0176 Data Access
DMS-REQ-0187 Archive Center Co-Location with Existing Facility	OSS-REQ-0022 Archive Site
DMS-REQ-0188 Archive to Data Access Center Network	
DMS-REQ-0189 Archive to Data Access Center Network Availability	
DMS-REQ-0190 Archive to Data Access Center Network Reliability	
DMS-REQ-0191 Archive to Data Access Center Network Secondary Link	
DMS-REQ-0193 Data Access Centers	OSS-REQ-0004 The Archive Facility
DMS-REQ-0194 Data Access Center Simultaneous Connections	
DMS-REQ-0196 Data Access Center Geographical Distribution	OSS-REQ-0021 Base Site OSS-REQ-0022 Archive Site
DMS-REQ-0197 No Limit on Data Access Centers	OSS-REQ-0021 Base Site OSS-REQ-0022 Archive Site
DMS-REQ-0265 Guider Calibration Data Acquisition	OSS-REQ-0194 Calibration Exposures Per Day
DMS-REQ-0266 Exposure Catalog	OSS-REQ-0130 Catalogs (Level 1)
DMS-REQ-0267 Source Catalog	OSS-REQ-0137 Catalogs (Level 2)
DMS-REQ-0268 Forced-Source Catalog	OSS-REQ-0137 Catalogs (Level 2)
DMS-REQ-0269 DIASource Catalog	OSS-REQ-0130 Catalogs (Level 1)

Continued on next page

DMS	OSS
DMS-REQ-0270 Faint DIASource Measurements	OSS-REQ-0166 Alert Completeness and Purity
DMS-REQ-0271 DIAObject Catalog	OSS-REQ-0130 Catalogs (Level 1)
DMS-REQ-0272 DIAObject Attributes	OSS-REQ-0130 Catalogs (Level 1)
DMS-REQ-0273 SSObject Catalog	OSS-REQ-0130 Catalogs (Level 1)
DMS-REQ-0274 Alert Content	OSS-REQ-0128 Alerts
DMS-REQ-0275 Object Catalog	OSS-REQ-0137 Catalogs (Level 2)
DMS-REQ-0276 Object Characterization	OSS-REQ-0137 Catalogs (Level 2)
DMS-REQ-0277 Coadd Source Catalog	OSS-REQ-0137 Catalogs (Level 2)
DMS-REQ-0278 Coadd Image Method Constraints	OSS-REQ-0136 Co-added Exposures
DMS-REQ-0279 Deep Detection Coadds	OSS-REQ-0136 Co-added Exposures
DMS-REQ-0280 Template Coadds	OSS-REQ-0136 Co-added Exposures
DMS-REQ-0281 Multi-band Coadds	OSS-REQ-0136 Co-added Exposures
DMS-REQ-0282 Dark Current Correction Frame	OSS-REQ-0271 Supported Image Types OSS-REQ-0046 Calibration
DMS-REQ-0283 Fringe Correction Frame	OSS-REQ-0271 Supported Image Types OSS-REQ-0046 Calibration
DMS-REQ-0284 Level-1 Production Completeness	OSS-REQ-0052 Summit Data Buffer
DMS-REQ-0285 Level 1 Source Association	OSS-REQ-0159 Level 1 Moving Object Quality OSS-REQ-0160 Level 1 Difference Source - Difference Object Association Quality OSS-REQ-0130 Catalogs (Level 1)
DMS-REQ-0286 SSObject Precovery	OSS-REQ-0159 Level 1 Moving Object Quality
DMS-REQ-0287 DIASource Precovery	OSS-REQ-0130 Catalogs (Level 1)
DMS-REQ-0288 Use of External Orbit Catalogs	OSS-REQ-0159 Level 1 Moving Object Quality
DMS-REQ-0289 Calibration Production Processing	OSS-REQ-0170 Calibration Data OSS-REQ-0004 The Archive Facility
DMS-REQ-0290 Level 3 Data Import	OSS-REQ-0140 Production
DMS-REQ-0291 Query Repeatability	OSS-REQ-0181 Data Products Query and Download Infrastructure
DMS-REQ-0292 Uniqueness of IDs Across Data Releases	OSS-REQ-0137 Catalogs (Level 2)

Continued on next page

DMS	OSS
	OSS-REQ-0130 Catalogs (Level 1)
DMS-REQ-0293 Selection of Datasets	OSS-REQ-0118 Consistency and Completeness OSS-REQ-0176 Data Access
DMS-REQ-0294 Processing of Datasets	OSS-REQ-0117 Automated Production OSS-REQ-0118 Consistency and Completeness OSS-REQ-0119 Completeness OSS-REQ-0120 Consistency
DMS-REQ-0295 Transparent Data Access	OSS-REQ-0176 Data Access
DMS-REQ-0296 Pre-cursor, and Real Data	
DMS-REQ-0297 DMS Initialization Component	OSS-REQ-0041 Subsystem Activation OSS-REQ-0307 Subsystem Initialization OSS-REQ-0121 Open Source, Open Configuration OSS-REQ-0122 Provenance
DMS-REQ-0298 Data Product and Raw Data Access	OSS-REQ-0176 Data Access
DMS-REQ-0299 Data Product Ingest	OSS-REQ-0141 Storage OSS-REQ-0004 The Archive Facility
DMS-REQ-0300 Bulk Download Service	OSS-REQ-0178 Data Distribution
DMS-REQ-0301 Control of Level-1 Production	OSS-REQ-0044 Standard Operating States
DMS-REQ-0302 Production Orchestration	OSS-REQ-0004 The Archive Facility OSS-REQ-0038 Scope of Control OSS-REQ-0117 Automated Production
DMS-REQ-0303 Production Monitoring	OSS-REQ-0004 The Archive Facility OSS-REQ-0038 Scope of Control OSS-REQ-0034 System Control
DMS-REQ-0304 Production Fault Tolerance	OSS-REQ-0117 Automated Production
DMS-REQ-0305 Task Specification	OSS-REQ-0121 Open Source, Open Configuration OSS-REQ-0122 Provenance
DMS-REQ-0306 Task Configuration	OSS-REQ-0121 Open Source, Open Configuration OSS-REQ-0122 Provenance
DMS-REQ-0307 Unique Processing Coverage	OSS-REQ-0120 Consistency OSS-REQ-0118 Consistency and Completeness

Continued on next page

DMS	OSS
DMS-REQ-0308 Software Architecture to Enable Community Re-Use	OSS-REQ-0121 Open Source, Open Configuration
DMS-REQ-0309 Raw Data Archiving Reliability	OSS-REQ-0111 Science Image Archiving Reliability
DMS-REQ-0310 Un-Archived Data Product Cache	OSS-REQ-0130 Catalogs (Level 1)
DMS-REQ-0311 Regenerate Un-archived Data Products	OSS-REQ-0129 Exposures (Level 1)
DMS-REQ-0312 Level 1 Data Product Access	OSS-REQ-0127 Level 1 Data Product Availability OSS-REQ-0185 Transient Alert Query
DMS-REQ-0313 Level 1 & 2 Catalog Access	OSS-REQ-0186 Access to Previous Data Releases
DMS-REQ-0314 Compute Platform Heterogeneity	OSS-REQ-0177 Data Access Environment OSS-REQ-0124 Software Development Standards
DMS-REQ-0315 DMS Communication with OCS	OSS-REQ-0003 The Base Facility
DMS-REQ-0316 Commissioning Cluster	
DMS-REQ-0317 DIAForcedSource Catalog	OSS-REQ-0130 Catalogs (Level 1)
DMS-REQ-0318 Data Management Unscheduled Downtime	OSS-REQ-0373 Unscheduled Downtime Subsystem Allocations
DMS-REQ-0319 Characterizing Variability	OSS-REQ-0126 Level 1 Data Products
DMS-REQ-0320 Processing of Data From Special Programs	LSR-REQ-0075 Survey Time Allocation OSS-REQ-0392 Data Products Handling for Special Programs
DMS-REQ-0321 Level 1 Processing of Special Programs Data	OSS-REQ-0392 Data Products Handling for Special Programs
DMS-REQ-0322 Special Programs Database	OSS-REQ-0392 Data Products Handling for Special Programs
DMS-REQ-0323 Calculating SSObject Parameters	OSS-REQ-0126 Level 1 Data Products
DMS-REQ-0324 Matching DIASources to Objects	OSS-REQ-0126 Level 1 Data Products
DMS-REQ-0325 Regenerating L1 Data Products During Data Release Processing	OSS-REQ-0135 Uniformly calibrated and processed versions of Level 1 Data Products

Continued on next page

DMS	OSS
DMS-REQ-0326 Storing Approximations of Per-pixel Metadata	OSS-REQ-0391 Data Product Conventions
DMS-REQ-0327 Background Model Calculation	OSS-REQ-0056 System Monitoring & Diagnostics
DMS-REQ-0328 Documenting Image Characterization	OSS-REQ-0391 Data Product Conventions
DMS-REQ-0329 All-Sky Visualization of Data Releases	OSS-REQ-0136 Co-added Exposures
DMS-REQ-0330 Best Seeing Coadds	OSS-REQ-0136 Co-added Exposures
DMS-REQ-0331 Computing Derived Quantities	OSS-REQ-0391 Data Product Conventions
DMS-REQ-0332 Denormalizing Database Tables	OSS-REQ-0133 Level 2 Data Products
DMS-REQ-0333 Maximum Likelihood Values and Covariances	OSS-REQ-0391 Data Product Conventions
DMS-REQ-0334 Persisting Data Products	OSS-REQ-0136 Co-added Exposures
DMS-REQ-0335 PSF-Matched Coadds	OSS-REQ-0133 Level 2 Data Products
DMS-REQ-0336 Regenerating Data Products from Previous Data Releases	LSR-REQ-0049 Data Product Archiving
DMS-REQ-0337 Detecting faint variable objects	OSS-REQ-0136 Co-added Exposures
DMS-REQ-0338 Targeted Coadds	OSS-REQ-0136 Co-added Exposures LSR-REQ-0040 Data Quality Monitoring
DMS-REQ-0339 Tracking Characterization Changes Between Data Releases	LSR-REQ-0040 Data Quality Monitoring
DMS-REQ-0340 Access Controls of Level 3 Data Products	OSS-REQ-0142 Access OSS-REQ-0176 Data Access OSS-REQ-0187 Information Security
DMS-REQ-0341 Providing a Precovery Service	OSS-REQ-0126 Level 1 Data Products
DMS-REQ-0342 Alert Filtering Service	LSR-REQ-0025 Transient Filtering
DMS-REQ-0343 Performance Requirements for LSST Alert Filtering Service	OSS-REQ-0184 Transient Alert Publication OSS-REQ-0193 Alerts per Visit
DMS-REQ-0344 Constraints on Level 1 Special Program Products Generation	OSS-REQ-0392 Data Products Handling for Special Programs

Continued on next page

DMS	OSS
DMS-REQ-0345 Logging of catalog queries	OSS-REQ-0134 Level 2 Data Product Availability
DMS-REQ-0346 Data Availability	OSS-REQ-0004 The Archive Facility OSS-REQ-0167 Data Archiving OSS-REQ-0313 Telemetry Database Retention
DMS-REQ-0347 Measurements in catalogs	OSS-REQ-0391 Data Product Conventions
DMS-REQ-0348 Pre-defined alert filters	LSR-REQ-0026 Predefined Transient Filters
DMS-REQ-0349 Detecting extended low surface brightness objects	OSS-REQ-0133 Level 2 Data Products
DMS-REQ-0350 Associating Objects across data releases	
DMS-REQ-0351 Provide Beam Projector Coordinate Calculation Software	OSS-REQ-0383 Beam Projector Coordinate Relationship
DMS-REQ-0352 Base Wireless LAN (WiFi)	OSS-REQ-0003 The Base Facility
DMS-REQ-0353 Publishing predicted visit schedule	OSS-REQ-0378 Advanced Publishing of Scheduler Sequence
DMS-REQ-0354 EFD Query Performance	
DMS-REQ-0363 Access to Previous Data Releases	OSS-REQ-0186 Access to Previous Data Releases
DMS-REQ-0364 Data Access Services	OSS-REQ-0396 Data Access Services
DMS-REQ-0365 Operations Subsets	OSS-REQ-0398 Operations Subsets
DMS-REQ-0366 Subsets Support	OSS-REQ-0400 Subsets Support
DMS-REQ-0367 Access Services Performance	OSS-REQ-0394 Access Services Performance
DMS-REQ-0368 Implementation Provisions	OSS-REQ-0399 Implementation Provisions
DMS-REQ-0369 Evolution	OSS-REQ-0395 Evolution
DMS-REQ-0370 Older Release Behavior	OSS-REQ-0397 Older Release Behavior
DMS-REQ-0371 Query Availability	OSS-REQ-0401 Query Availability

E Traceability matrix of OSS requirements to DMSR requirements

OSS	DMS
LSR-REQ-0025 Transient Filtering	DMS-REQ-0342 Alert Filtering Service
LSR-REQ-0026 Predefined Transient Filters	DMS-REQ-0348 Pre-defined alert filters
LSR-REQ-0040 Data Quality Monitoring	DMS-REQ-0338 Targeted Coadds DMS-REQ-0339 Tracking Characterization Changes Between Data Releases
LSR-REQ-0049 Data Product Archiving	DMS-REQ-0336 Regenerating Data Products from Previous Data Releases
LSR-REQ-0075 Survey Time Allocation	DMS-REQ-0320 Processing of Data From Special Programs
OSS-REQ-0002 The Summit Facility	DMS-REQ-0168 Summit Facility Data Communications
OSS-REQ-0003 The Base Facility	DMS-REQ-0315 DMS Communication with OCS DMS-REQ-0171 Summit to Base Network DMS-REQ-0176 Base Facility Infrastructure DMS-REQ-0352 Base Wireless LAN (WiFi)
OSS-REQ-0004 The Archive Facility	DMS-REQ-0299 Data Product Ingest DMS-REQ-0302 Production Orchestration DMS-REQ-0303 Production Monitoring DMS-REQ-0185 Archive Center DMS-REQ-0193 Data Access Centers DMS-REQ-0289 Calibration Production Processing DMS-REQ-0346 Data Availability
OSS-REQ-0006 Sites	DMS-REQ-0178 Base Facility Co-Location with Existing Facility
OSS-REQ-0020 Usable Observing Time	DMS-REQ-0162 Pipeline Throughput
OSS-REQ-0021 Base Site	DMS-REQ-0196 Data Access Center Geographical Distribution DMS-REQ-0197 No Limit on Data Access Centers DMS-REQ-0131 Calibration Images Available Within Specified Time
OSS-REQ-0022 Archive Site	DMS-REQ-0187 Archive Center Co-Location with Existing Facility DMS-REQ-0196 Data Access Center Geographical Distribution DMS-REQ-0197 No Limit on Data Access Centers
OSS-REQ-0034 System Control	DMS-REQ-0303 Production Monitoring
OSS-REQ-0036 Local Autonomous Administration of System Sites	DMS-REQ-0175 Summit to Base Network Ownership and Operation

Continued on next page

OSS	DMS
OSS-REQ-0037 Observatory Control System Definition	DMS-REQ-0156 Provide Pipeline Execution Services
OSS-REQ-0038 Scope of Control	DMS-REQ-0302 Production Orchestration DMS-REQ-0303 Production Monitoring
OSS-REQ-0041 Subsystem Activation	DMS-REQ-0297 DMS Initialization Component
OSS-REQ-0044 Standard Operating States	DMS-REQ-0301 Control of Level-1 Production
OSS-REQ-0046 Calibration	DMS-REQ-0131 Calibration Images Available Within Specified Time DMS-REQ-0060 Bias Residual Image DMS-REQ-0282 Dark Current Correction Frame DMS-REQ-0063 Monochromatic Flatfield Data Cube DMS-REQ-0062 Illumination Correction Frame DMS-REQ-0283 Fringe Correction Frame
OSS-REQ-0049 Degraded Operational States	DMS-REQ-0174 Summit to Base Network Secondary Link DMS-REQ-0183 Base to Archive Network Secondary Link
OSS-REQ-0050 Summit Power Grid Loss	DMS-REQ-0165 Infrastructure Sizing for ”catching up”
OSS-REQ-0051 Summit-Base Connectivity Loss	DMS-REQ-0165 Infrastructure Sizing for ”catching up”
OSS-REQ-0052 Summit Data Buffer	DMS-REQ-0165 Infrastructure Sizing for ”catching up” DMS-REQ-0284 Level-1 Production Completeness
OSS-REQ-0053 Base-Archive Connectivity Loss	DMS-REQ-0180 Base to Archive Network DMS-REQ-0181 Base to Archive Network Availability DMS-REQ-0182 Base to Archive Network Reliability DMS-REQ-0177 Base Facility Temporary Storage
OSS-REQ-0054 Base Data Buffer	DMS-REQ-0177 Base Facility Temporary Storage
OSS-REQ-0055 Base Updating from Archive	DMS-REQ-0180 Base to Archive Network
OSS-REQ-0056 System Monitoring & Diagnostics	DMS-REQ-0327 Background Model Calculation DMS-REQ-0029 Generate Photometric Zeropoint for Visit Image DMS-REQ-0070 Generate PSF for Visit Images
OSS-REQ-0057 Image Visualization	DMS-REQ-0160 Provide User Interface Services
OSS-REQ-0111 Science Image Archiving Reliability	DMS-REQ-0309 Raw Data Archiving Reliability

Continued on next page

OSS	DMS
OSS-REQ-0114 Acquisition of Science Sensor data	DMS-REQ-0024 Raw Image Assembly DMS-REQ-0018 Raw Science Image Data Acquisition DMS-REQ-0022 Crosstalk Corrected Science Image Data Acquisition
OSS-REQ-0117 Automated Production	DMS-REQ-0156 Provide Pipeline Execution Services DMS-REQ-0302 Production Orchestration DMS-REQ-0304 Production Fault Tolerance DMS-REQ-0294 Processing of Datasets
OSS-REQ-0118 Consistency and Completeness	DMS-REQ-0307 Unique Processing Coverage DMS-REQ-0120 Level 3 Data Product Self Consistency DMS-REQ-0294 Processing of Datasets DMS-REQ-0293 Selection of Datasets
OSS-REQ-0119 Completeness	DMS-REQ-0294 Processing of Datasets
OSS-REQ-0120 Consistency	DMS-REQ-0307 Unique Processing Coverage DMS-REQ-0120 Level 3 Data Product Self Consistency DMS-REQ-0294 Processing of Datasets
OSS-REQ-0121 Open Source, Open Configuration	DMS-REQ-0032 Image Differencing DMS-REQ-0033 Provide Source Detection Software DMS-REQ-0297 DMS Initialization Component DMS-REQ-0306 Task Configuration DMS-REQ-0305 Task Specification DMS-REQ-0308 Software Architecture to Enable Community Re-Use DMS-REQ-0125 Software framework for Level 3 catalog processing DMS-REQ-0128 Software framework for Level 3 image processing
OSS-REQ-0122 Provenance	DMS-REQ-0297 DMS Initialization Component DMS-REQ-0306 Task Configuration DMS-REQ-0305 Task Specification DMS-REQ-0121 Provenance for Level 3 processing at DACs DMS-REQ-0125 Software framework for Level 3 catalog processing DMS-REQ-0128 Software framework for Level 3 image processing DMS-REQ-0068 Raw Science Image Metadata

Continued on next page

OSS	DMS
	DMS-REQ-0074 Difference Exposure Attributes DMS-REQ-0106 Coadded Image Provenance DMS-REQ-0132 Calibration Image Provenance
OSS-REQ-0123 Reproducibility	DMS-REQ-0132 Calibration Image Provenance
OSS-REQ-0124 Software Development Standards	DMS-REQ-0314 Compute Platform Heterogeneity
OSS-REQ-0126 Level 1 Data Products	DMS-REQ-0341 Providing a Precovery Service DMS-REQ-0319 Characterizing Variability DMS-REQ-0323 Calculating SSObject Parameters DMS-REQ-0324 Matching DIASources to Objects
OSS-REQ-0127 Level 1 Data Product Availability	DMS-REQ-0312 Level 1 Data Product Access DMS-REQ-0162 Pipeline Throughput DMS-REQ-0171 Summit to Base Network DMS-REQ-0002 Transient Alert Distribution DMS-REQ-0089 Solar System Objects Available Within Specified Time DMS-REQ-0022 Crosstalk Corrected Science Image Data Acquisition DMS-REQ-0004 Nightly Data Accessible Within 24 hrs
OSS-REQ-0128 Alerts	DMS-REQ-0094 Keep Historical Alert Archive DMS-REQ-0274 Alert Content
OSS-REQ-0129 Exposures (Level 1)	DMS-REQ-0032 Image Differencing DMS-REQ-0311 Regenerate Un-archived Data Products DMS-REQ-0024 Raw Image Assembly DMS-REQ-0069 Processed Visit Images DMS-REQ-0072 Processed Visit Image Content DMS-REQ-0010 Difference Exposures DMS-REQ-0130 Calibration Data Products DMS-REQ-0059 Bad Pixel Map
OSS-REQ-0130 Catalogs (Level 1)	DMS-REQ-0033 Provide Source Detection Software DMS-REQ-0043 Provide Calibrated Photometry DMS-REQ-0310 Un-Archived Data Product Cache DMS-REQ-0285 Level 1 Source Association DMS-REQ-0287 DIASource Precovery DMS-REQ-0292 Uniqueness of IDs Across Data Releases DMS-REQ-0266 Exposure Catalog DMS-REQ-0269 DIASource Catalog DMS-REQ-0271 DIAObject Catalog

Continued on next page

OSS	DMS
	DMS-REQ-0272 DIAObject Attributes DMS-REQ-0273 SSObject Catalog DMS-REQ-0317 DIAForcedSource Catalog
OSS-REQ-0131 Nightly Summary Products	DMS-REQ-0096 Generate Data Quality Report Within Specified Time DMS-REQ-0098 Generate DMS Performance Report Within Specified Time DMS-REQ-0100 Generate Calibration Report Within Specified Time DMS-REQ-0097 Level 1 Data Quality Report Definition DMS-REQ-0099 Level 1 Performance Report Definition DMS-REQ-0101 Level 1 Calibration Report Definition
OSS-REQ-0132 Engineering and Facility Database Archive	DMS-REQ-0102 Provide Engineering & Facility Database Archive
OSS-REQ-0133 Level 2 Data Products	DMS-REQ-0332 Denormalizing Database Tables DMS-REQ-0335 PSF-Matched Coadds DMS-REQ-0349 Detecting extended low surface brightness objects
OSS-REQ-0134 Level 2 Data Product Availability	DMS-REQ-0345 Logging of catalog queries DMS-REQ-0163 Re-processing Capacity DMS-REQ-0006 Timely Publication of Level 2 Data Releases
OSS-REQ-0135 Uniformly calibrated and processed versions of Level 1 Data Products	DMS-REQ-0325 Regenerating L1 Data Products During Data Release Processing
OSS-REQ-0136 Co-added Exposures	DMS-REQ-0334 Persisting Data Products DMS-REQ-0279 Deep Detection Coadds DMS-REQ-0280 Template Coadds DMS-REQ-0281 Multi-band Coadds DMS-REQ-0330 Best Seeing Coadds DMS-REQ-0337 Detecting faint variable objects DMS-REQ-0338 Targeted Coadds DMS-REQ-0278 Coadd Image Method Constraints DMS-REQ-0047 Provide PSF for Coadded Images DMS-REQ-0103 Produce Images for EPO DMS-REQ-0329 All-Sky Visualization of Data Releases
OSS-REQ-0137 Catalogs (Level 2)	DMS-REQ-0033 Provide Source Detection Software DMS-REQ-0043 Provide Calibrated Photometry

Continued on next page

OSS	DMS
	DMS-REQ-0052 Enable a Range of Shape Measurement Approaches DMS-REQ-0292 Uniqueness of IDs Across Data Releases DMS-REQ-0267 Source Catalog DMS-REQ-0275 Object Catalog DMS-REQ-0276 Object Characterization DMS-REQ-0277 Coadd Source Catalog DMS-REQ-0268 Forced-Source Catalog
OSS-REQ-0140 Production	DMS-REQ-0122 Access to catalogs for external Level 3 processing DMS-REQ-0126 Access to images for external Level 3 processing DMS-REQ-0123 Access to input catalogs for DAC-based Level 3 processing DMS-REQ-0127 Access to input images for DAC-based Level 3 processing DMS-REQ-0124 Federation with external catalogs DMS-REQ-0290 Level 3 Data Import
OSS-REQ-0141 Storage	DMS-REQ-0299 Data Product Ingest
OSS-REQ-0142 Access	DMS-REQ-0340 Access Controls of Level 3 Data Products
OSS-REQ-0143 Resource Allocation	DMS-REQ-0119 DAC resource allocation for Level 3 processing
OSS-REQ-0149 Level 1 Catalog Precision	DMS-REQ-0042 Provide Astrometric Model DMS-REQ-0030 Generate WCS for Visit Images
OSS-REQ-0152 Level 1 Photometric Zero Point Error	DMS-REQ-0029 Generate Photometric Zeropoint for Visit Image
OSS-REQ-0153 World Coordinate System Accuracy	DMS-REQ-0042 Provide Astrometric Model DMS-REQ-0047 Provide PSF for Coadded Images
OSS-REQ-0159 Level 1 Moving Object Quality	DMS-REQ-0285 Level 1 Source Association DMS-REQ-0286 SSObject Precovery DMS-REQ-0288 Use of External Orbit Catalogs
OSS-REQ-0160 Level 1 Difference Source - Difference Object Association Quality	DMS-REQ-0042 Provide Astrometric Model DMS-REQ-0285 Level 1 Source Association
OSS-REQ-0162 Level 2 Catalog Accuracy	DMS-REQ-0042 Provide Astrometric Model DMS-REQ-0030 Generate WCS for Visit Images

Continued on next page

OSS	DMS
OSS-REQ-0166 Alert Completeness and Purity	DMS-REQ-0270 Faint DIASource Measurements
OSS-REQ-0167 Data Archiving	DMS-REQ-0346 Data Availability
OSS-REQ-0170 Calibration Data	DMS-REQ-0289 Calibration Production Processing
OSS-REQ-0171 Engineering and Facilities Data	DMS-REQ-0068 Raw Science Image Metadata
OSS-REQ-0176 Data Access	DMS-REQ-0155 Provide Data Access Services DMS-REQ-0298 Data Product and Raw Data Access DMS-REQ-0065 Provide Image Access Services DMS-REQ-0075 Catalog Queries DMS-REQ-0078 Catalog Export Formats DMS-REQ-0186 Archive Center Disaster Recovery DMS-REQ-0340 Access Controls of Level 3 Data Products DMS-REQ-0293 Selection of Datasets DMS-REQ-0295 Transparent Data Access
OSS-REQ-0177 Data Access Environment	DMS-REQ-0314 Compute Platform Heterogeneity
OSS-REQ-0178 Data Distribution	DMS-REQ-0300 Bulk Download Service
OSS-REQ-0180 Data Products Query and Download Availability	DMS-REQ-0065 Provide Image Access Services DMS-REQ-0122 Access to catalogs for external Level 3 processing DMS-REQ-0126 Access to images for external Level 3 processing
OSS-REQ-0181 Data Products Query and Download Infrastructure	DMS-REQ-0065 Provide Image Access Services DMS-REQ-0291 Query Repeatability
OSS-REQ-0184 Transient Alert Publication	DMS-REQ-0002 Transient Alert Distribution DMS-REQ-0343 Performance Requirements for LSST Alert Filtering Service
OSS-REQ-0185 Transient Alert Query	DMS-REQ-0312 Level 1 Data Product Access
OSS-REQ-0186 Access to Previous Data Releases	DMS-REQ-0313 Level 1 & 2 Catalog Access DMS-REQ-0077 Maintain Archive Publicly Accessible DMS-REQ-0363 Access to Previous Data Releases
OSS-REQ-0187 Information Security	DMS-REQ-0340 Access Controls of Level 3 Data Products
OSS-REQ-0193 Alerts per Visit	DMS-REQ-0343 Performance Requirements for LSST Alert Filtering Service

Continued on next page

OSS	DMS
OSS-REQ-0194 Calibration Exposures Per Day	DMS-REQ-0131 Calibration Images Available Within Specified Time DMS-REQ-0265 Guider Calibration Data Acquisition DMS-REQ-0130 Calibration Data Products
OSS-REQ-0271 Supported Image Types	DMS-REQ-0130 Calibration Data Products DMS-REQ-0059 Bad Pixel Map DMS-REQ-0060 Bias Residual Image DMS-REQ-0282 Dark Current Correction Frame DMS-REQ-0063 Monochromatic Flatfield Data Cube DMS-REQ-0062 Illumination Correction Frame DMS-REQ-0283 Fringe Correction Frame
OSS-REQ-0275 Calibration Processing Performance Allocations	DMS-REQ-0043 Provide Calibrated Photometry
OSS-REQ-0307 Subsystem Initialization	DMS-REQ-0297 DMS Initialization Component
OSS-REQ-0313 Telemetry Database Retention	DMS-REQ-0346 Data Availability
OSS-REQ-0316 Wavefront Sensor Data	DMS-REQ-0020 Wavefront Sensor Data Acquisition DMS-REQ-0047 Provide PSF for Coadded Images
OSS-REQ-0339 Level 2 Source-Object Association Quality	DMS-REQ-0034 Associate Sources to Objects
OSS-REQ-0349 Data Release Production Crosstalk Correction	DMS-REQ-0061 Crosstalk Correction Matrix
OSS-REQ-0351 Difference Source Spurious Probability Metric	DMS-REQ-0009 Simulated Data
OSS-REQ-0353 Difference Source Spuriousness Threshold - Transients	DMS-REQ-0009 Simulated Data
OSS-REQ-0354 Difference Source Spuriousness Threshold - MOPS	DMS-REQ-0009 Simulated Data
OSS-REQ-0373 Unscheduled Downtime Subsystem Allocations	DMS-REQ-0318 Data Management Unscheduled Downtime DMS-REQ-0172 Summit to Base Network Availability DMS-REQ-0173 Summit to Base Network Reliability
OSS-REQ-0378 Advanced Publishing of Scheduler Sequence	DMS-REQ-0353 Publishing predicted visit schedule
OSS-REQ-0383 Beam Projector Coordinate Relationship	DMS-REQ-0351 Provide Beam Projector Coordinate Calculation Software
OSS-REQ-0391 Data Product Conventions	DMS-REQ-0347 Measurements in catalogs DMS-REQ-0331 Computing Derived Quantities

Continued on next page

OSS	DMS
	DMS-REQ-0333 Maximum Likelihood Values and Covariances DMS-REQ-0326 Storing Approximations of Per-pixel Metadata DMS-REQ-0328 Documenting Image Characterization
OSS-REQ-0392 Data Products Handling for Special Programs	DMS-REQ-0320 Processing of Data From Special Programs DMS-REQ-0321 Level 1 Processing of Special Programs Data DMS-REQ-0344 Constraints on Level 1 Special Program Products Generation DMS-REQ-0322 Special Programs Database
OSS-REQ-0394 Access Services Performance	DMS-REQ-0367 Access Services Performance
OSS-REQ-0395 Evolution	DMS-REQ-0369 Evolution
OSS-REQ-0396 Data Access Services	DMS-REQ-0364 Data Access Services
OSS-REQ-0397 Older Release Behavior	DMS-REQ-0370 Older Release Behavior
OSS-REQ-0398 Operations Subsets	DMS-REQ-0365 Operations Subsets
OSS-REQ-0399 Implementation Provisions	DMS-REQ-0368 Implementation Provisions
OSS-REQ-0400 Subsets Support	DMS-REQ-0366 Subsets Support
OSS-REQ-0401 Query Availability	DMS-REQ-0371 Query Availability

F References

[1] **[LSE-159]**, Angeli, G., 2013, *Reviews Definitions, Guidelines, and Procedures*, LSE-159, URL https://ls.st/LSE-159

[2] **[Document-11920]**, Angeli, G., McKercher, R., 2013, *Document Cover Page and Style Guide*, Document-11920, URL https://ls.st/Document-11920

[3] **[Document-9224]**, Angeli, G., McKercher, R., 2013, *Change Controlled Document Cover Page and Style Guide*, Document-9224, URL https://ls.st/Document-9224

[4] **[LDM-141]**, Becla, J., Lim, K.T., 2013, *Data Management Storage Sizing and I/O Model*, LDM-141, URL https://ls.st/LDM-141

[5] **[DMTN-020]**, Becla, J., Economou, F., Gelman, M., et al., 2016, *Project Management Guide*, DMTN-020, URL https://dmtn-020.lsst.io/

[6] **[LPM-191]**, Calabrese, D., 2017, *Travel Policy*, LPM-191, URL https://ls.st/LPM-191

[7] **[Document-13760]**, Carlson, E., 2017, *Travel Request Instructions for AURA Employees*, Document-13760, URL https://ls.st/Document-13760

[8] **[Document-13762]**, Carlson, E., 2017, *LSST Travel Summary Report Template*, Document-13762, URL https://ls.st/Document-13762

[9] **[LSE-17]**, Claver, C., Angeli, G., Selvy, B., 2016, *Systems Engineering Management Plan*, LSE-17, URL https://ls.st/LSE-17

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

[11] **[LSE-30]**, Claver, C.F., The LSST Systems Engineering Integrated Project Team, 2018, *Observatory System Specifications (OSS)*, LSE-30, URL https://ls.st/LSE-30

[12] **[DMTN-106]**, Comoretto, G., 2019, *DM Release Process*, DMTN-106, URL http://DMTN-106.lsst.io

[13] **[LDM-672]**, Comoretto, G., Guy, L., 2019, *LSST Software Release Management Policy*, LDM-672, URL http://LDM-672.lsst.io

[14] **[LSE-75]**, Dubois-Felsmann, G., 2011, *Control System Interfaces between the Telescope and Data Management*, LSE-75, URL https://ls.st/LSE-75

[15] **[LSE-76]**, Dubois-Felsmann, G., 2011, *Infrastructure Interfaces between Summit Facility and Data Management*, LSE-76, URL https://ls.st/LSE-76

[16] **[LSE-77]**, Dubois-Felsmann, G., 2013, *Infrastructure Interfaces between Base Facility and Data Management*, LSE-77, URL https://ls.st/LSE-77

[17] **[LSE-69]**, Dubois-Felsmann, G., 2014, *Interface between the Camera and Data Management*, LSE-69, URL https://ls.st/LSE-69

[18] **[LSE-130]**, Dubois-Felsmann, G., 2015, *Support-Data Exchanges between Data Management and Camera*, LSE-130, URL https://ls.st/LSE-130

[19] **[LSE-68]**, Dubois-Felsmann, G., 2015, *Camera Data Acquisition Interface*, LSE-68, URL https://ls.st/LSE-68

[20] **[LSE-140]**, Dubois-Felsmann, G., 2016, *Auxiliary Instrumentation Interface between Data Management and Telescope*, LSE-140, URL https://ls.st/LSE-140

[21] **[LSE-61]**, Dubois-Felsmann, G., Jenness, T., 2018, *LSST Data Management Subsystem Requirements*, LSE-61, URL https://ls.st/LSE-61

[22] **[LSE-72]**, Dubois-Felsmann, G., Schumacher, G., Selvy, B., 2014, *OCS Command Dictionary for Data Management*, LSE-72, URL https://ls.st/LSE-72

[23] **[LDM-542]**, Dubois-Felsmann, G., Lim, K.T., Wu, X., et al., 2017, *LSST Science Platform Design*, LDM-542, URL https://ls.st/LDM-542

[24] **[LDM-144]**, Freemon, M., Pietrowicz, S., Alt, J., 2016, *Site Specific Infrastructure Estimation Model*, LDM-144, URL https://ls.st/LDM-144

[25] **[LSE-131]**, Jacoby, S., Emmons, B., Selvy, B., 2017, *Interface between Data Management and Education and Public Outreach*, LSE-131, URL https://ls.st/LSE-131

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

[27] **[LDM-138]**, Kantor, J., Axelrod, T., Lim, K.T., 2013, *Data Management Compute Sizing Model*, LDM-138, URL https://ls.st/LDM-138

[28] **[LPM-20]**, Krabbendam, V., Selvy, B., 2015, *Risk & Opportunity Management Plan*, LPM-20, URL https://ls.st/LPM-20

[29] Larman, C., Basili, V.R., 2003, Computer, 36, 47, doi:10.1109/MC.2003.1204375

[30] **[LDM-148]**, Lim, K.T., Bosch, J., Dubois-Felsmann, G., et al., 2018, *Data Management System Design*, LDM-148, URL https://ls.st/LDM-148

[31] **[LPM-98]**, Long, K.E., 2016, *LSST Project Controls System Description*, LPM-98, URL https://ls.st/LPM-98

[32] **[LPM-51]**, McKercher, R., 2013, *Document Management Plan*, LPM-51, URL https://ls.st/LPM-51

[33] **[LPM-43]**, McKercher, R., 2016, *WBS Structure*, LPM-43, URL https://ls.st/LPM-43

[34] **[LPM-44]**, McKercher, R., 2016, *WBS Dictionary*, LPM-44, URL https://ls.st/LPM-44

[35] **[LDM-564]**, O'Mullane, W., Economou, F., Jenness, T., Loftus, A., 2018, *Data Management Software Releases for Verification/Integration*, LDM-564, URL https://ls.st/LDM-564

[36] **[LDM-503]**, O'Mullane, W., Swinbank, J., Jurić, M., Economou, F., 2018, *Data Management Test Plan*, LDM-503, URL https://ls.st/LDM-503

[37] **[LPM-55]**, Sweeney, D., McKercher, R., 2013, *Project Quality Assurance Plan*, LPM-55, URL https://ls.st/LPM-55

G Glossary

2D Two-dimensional.

Alert A packet of information for each source detected with signal-to-noise ratio > 5 in a difference image during Prompt Processing, containing measurement and characterization parameters based on the past 12 months of LSST observations plus small cutouts of the single-visit, template, and difference images, distributed via the internet.

Alert Production The principal component of Prompt Processing that processes and calibrates incoming images, performs Difference Image Analysis to identify DIASources and DIAObjects, packages and distributes the resulting Alerts, and runs Solar System Processing..

AP Alert Production.

API Application Programming Interface.

Archive The repository for documents required by the NSF to be kept. These include documents related to design and development, construction, integration, test, and operations of the LSST observatory system. The archive is maintained using the enterprise content management system DocuShare, which is accessible through a link on the project website www.project.lsst.org.

Association of Universities for Research in Astronomy consortium of US institutions and international affiliates that operates world-class astronomical observatories, AURA is the legal entity responsible for managing what it calls independent operating Centers, including LSST, under respective cooperative agreements with the National Science Foundation. AURA assumes fiducial responsibility for the funds provided through those cooperative agreements. AURA also is the legal owner of the AURA Observatory properties in Chile.

AURA Association of Universities for Research in Astronomy.

Base Facility The data center located at the Base Site in La Serena, Chile. The Base Facility is composed of the Base portion of the Prompt Enclave directly supporting Observatory operations, the Commissioning Cluster, an Archive Enclave holding data products, and the Chilean Data Access Center.

Batch Production Computational processing that is executed as inputs become available, in a distributed way across multiple enclaves when needed, while tracking status and outputs. Examples of Batch Production include offline processing for Prompt data products, calibration products, template images, and Special Programs data products. Prioritization protocols for the various types of batch production are given in LDM-148.

Butler A middleware component for persisting and retrieving image datasets (raw or processed), calibration reference data, and catalogs.

calibration The process of translating signals produced by a measuring instrument such as a telescope and camera into physical units such as flux, which are used for scientific analysis. Calibration removes most of the contributions to the signal from environmental and instrumental factors, such that only the astronomical component remains.

Calibration Scientist The person responsible for the system calibration plan who establishes the requirements for the constituent elements of the calibration hardware, software, and operational data. The Calibration Scientist works under the direction of the Systems Engineering group.

Camera The LSST subsystem responsible for the 3.2-gigapixel LSST camera, which will take more than 800 panoramic images of the sky every night. SLAC leads a consortium

of Department of Energy laboratories to design and build the camera sensors, optics, electronics, cryostat, filters and filter exchange mechanism, and camera control system.

CC Change Control.

CCB Change Control Board.

Center An entity managed by AURA that is responsible for execution of a federally funded project.

Change Control Board Advisory board to the Project Manager; composed of technical and management representatives who recommend approval or disapproval of proposed changes to, deviations from, and waivers to a configuration item's current approved configuration documentation.

CI Continuous Integration.

CMDB Configuration Management Database.

Commissioning A two-year phase at the end of the Construction project during which a technical team a) integrates the various technical components of the three subsystems; b) shows their compliance with ICDs and system-level requirements as detailed in the LSST Observatory System Specifications document (OSS, LSE-30); and c) performs science verification to show compliance with the survey performance specifications as detailed in the LSST Science Requirements Document (SRD, LPM-17).

configuration A task-specific set of configuration parameters, also called a 'config'. The config is read-only; once a task is constructed, the same configuration will be used to process all data. This makes the data processing more predictable: it does not depend on the order in which items of data are processed. This is distinct from arguments or options, which are allowed to vary from one task invocation to the next.

Construction The period during which LSST observatory facilities, components, hardware, and software are built, tested, integrated, and commissioned. Construction follows design and development and precedes operations. The LSST construction phase is funded through the National Science Foundation (NSF) MREFC account.

DAC Data Access Center.

Data Access Center Part of the LSST Data Management System, the US and Chilean DACs will provide authorized access to the released LSST data products, software such as the Science Platform, and computational resources for data analysis. The US DAC also includes a service for distributing bulk data on daily and annual (Data Release) timescales to partner institutions, collaborations, and LSST Education and Public Outreach (EPO)..

Data Backbone The software that provides for data registration, retrieval, storage, transport,

replication, and provenance capabilities that are compatible with the Data Butler. It allows data products to move between Facilities, Enclaves, and DACs by managing caches of files at each endpoint, including persistence to long-term archival storage (e.g. tape).

Data Management The LSST Subsystem responsible for the Data Management System (DMS), which will capture, store, catalog, and serve the LSST dataset to the scientific community and public. The DM team is responsible for the DMS architecture, applications, middleware, infrastructure, algorithms, and Observatory Network Design. DM is a distributed team working at LSST and partner institutions, with the DM Subsystem Manager located at LSST headquarters in Tucson.

DAX Data Access Services.

DDMPM Data Management Deputy Project Manager.

DM Data Management.

DMCCB DM Change Control Board.

DMIS DM Interface Scientist.

DMLT DM Leadership Team.

DMPM Data Management Project Manager.

DMSR DM System Requirements; LSE-61.

DMSS DM Subsystem Scientist.

Document Any object (in any application supported by DocuShare or design archives such as PDMWorks or GIT) that supports project management or records milestones and deliverables of the LSST Project.

DocuShare The trade name for the enterprise management software used by LSST to archive and manage documents.

DRP Data Release Production.

Earned Value A measurement of how much work has been completed compared to how much was expected to have been completed at a given point in the project.

EFD Engineering and Facility Database.

Firefly A framework of software components written by IPAC for building web-based user interfaces to astronomical archives, through which data may be searched and retrieved, and viewed as Flexible Image Transport System (FITS) images, catalogs, and/or plots. Firefly tools will be integrated into the Science Platform.

FITS Flexible Image Transport System.

Flexible Image Transport System an international standard in astronomy for storing images, tables, and metadata in disk files. See the IAU FITS Standard for details.

git A distributed revision control system, often used for software source code. See the Git

User Manual for details. Not developed by LSST DM.

ICBS International Communications and Base Site.

IRSA Infrared Science Archive.

IT Information Technology.

ITC Information Technology Center.

IVOA International Virtual-Observatory Alliance.

LaTeX (Leslie) Lamport TeX (document markup language and document preparation system).

LDF LSST Data Facility.

LDM LSST Data Management (Document Handle).

LSR LSST System Requirements; LSE-29.

LSST Large Synoptic Survey Telescope.

metadata General term for data about data, e.g., attributes of astronomical objects (e.g. images, sources, astroObjects, etc.) that are characteristics of the objects themselves, and facilitate the organization, preservation, and query of data sets. (E.g., a FITS header contains metadata).

metric A measurable quantity which may be tracked. A metric has a name, description, unit, references, and tags (which are used for grouping). A metric is a scalar by definition. See also: aggregate metric, model metric, point metric.

monitoring In DM QA, this refers to the process of collecting, storing, aggregating and visualizing metrics.

MOPS Moving Object Processing System (deprecated; see SSP).

MREFC Major Research Equipment and Facility Construction.

NASA National Aeronautics and Space Administration.

National Science Foundation primary federal agency supporting research in all fields of fundamental science and engineering; NSF selects and funds projects through competitive, merit-based review.

NCSA National Center for Supercomputing Applications.

NET Network Engineering Team.

NSF National Science Foundation.

OCS Observatory Control System.

Operations The 10-year period following construction and commissioning during which the LSST Observatory conducts its survey.

OSS Observatory System Specifications; LSE-30.

patch An quadrilateral sub-region of a sky tract, with a size in pixels chosen to fit easily into memory on desktop computers.

PDF Probability Density Function.

pipeline A configured sequence of software tasks (Stages) to process data and generate data products. Example: Association Pipeline.

PM Project Manager.

PMCS Project Management Controls System.

Project Management Controls System suite of tools used to organize and manage a project, including cost and schedule databases, a qualified accounting system, and change control.

Project Manager The person responsible for exercising leadership and oversight over the entire LSST project; he or she controls schedule, budget, and all contingency funds.

Project Science Team an operational unit within LSST that carries out specific scientific performance investigations as prioritized by the Director, the Project Manager, and the Project Scientist. Its membership includes key scientists on the Project who provide specific necessary expertise. The Project Science Team provides required scientific input on critical technical decisions as the project construction proceeds.

Project Scientist The principal scientific advisor to the LSST Project Manager to ensure that LSST system specifications are appropriate for achieving the scientific goals of the project; the Project Scientist also works closely with the Systems Engineering group and chairs the LSST Science Council.

provenance Information about how LSST images, Sources, and Objects were created (e.g., versions of pipelines, algorithmic components, or templates) and how to recreate them.

PST Project Science Team.

QA Quality Assurance.

Release Publication of a new version of a document, software, or data product. Depending on context, releases may require approval from Project- or DM-level change control boards, and then form part of the formal project baseline.

REUNA Red Universitaria Nacional.

Review Hub An LSST website that acts as a clearinghouse for information about external reviews of all LSST components planned to occur in the next six months. The site links to review-specific websites for both planned reviews and reviews that have been conducted already.

RFC Request For Comment.

RM Release Manager.

Science Pipelines The library of software components and the algorithms and processing pipelines assembled from them that are being developed by DM to generate science-ready data products from LSST images. The Pipelines may be executed at scale as part

of LSST Prompt or Data Release processing, or pieces of them may be used in a standalone mode or executed through the LSST Science Platform. The Science Pipelines are one component of the LSST Software Stack.

Science Platform A set of integrated web applications and services deployed at the LSST Data Access Centers (DACs) through which the scientific community will access, visualize, and perform next-to-the-data analysis of the LSST data products.

SQuaRE Science Quality and Reliability Engineering.

stack a grouping, usually in layers (hence stack), of software packages and services to achieve a common goal. Often providing a higher level set of end user oriented services and tools.

Subsystem A set of elements comprising a system within the larger LSST system that is responsible for a key technical deliverable of the project.

Subsystem Scientist The principal science advisor to a Subsystem Manager; he or she ensures that the subsystem specifications are appropriated for achieving the project's goals.

SUIT Science User Interface and Tools.

Summit The site on the Cerro Pachón, Chile mountaintop where the LSST observatory, support facilities, and infrastructure will be built.

Summit Facility The main Observatory and Auxiliary Telescope buildings at the Summit Site on Cerro Pachon, Chile.

Systems Engineer A member of the Systems Engineering group who works closely with the Systems Engineering Manager and the Systems Scientist on the integrated LSST system's various technical issues spanning the full life cycle of the entire project.

Systems Engineering an interdisciplinary field of engineering that focuses on how to design and manage complex engineering systems over their life cycles. Issues such as requirements engineering, reliability, logistics, coordination of different teams, testing and evaluation, maintainability and many other disciplines necessary for successful system development, design, implementation, and ultimate decommission become more difficult when dealing with large or complex projects. Systems engineering deals with work-processes, optimization methods, and risk management tools in such projects. It overlaps technical and human-centered disciplines such as industrial engineering, control engineering, software engineering, organizational studies, and project management. Systems engineering ensures that all likely aspects of a project or system are considered, and integrated into a whole.

T/CAM Technical/Control (or Cost) Account Manager.

transient A transient source is one that has been detected on a difference image, but has not

been associated with either an astronomical object or a solar system body.

US United States.

Validation A process of confirming that the delivered system will provide its desired functionality; overall, a validation process includes the evaluation, integration, and test activities carried out at the system level to ensure that the final developed system satisfies the intent and performance of that system in operations.

WBS Work Breakdown Structure.

WG Working Group.

WISE Wide-field Survey Explorer.

Work Breakdown Structure a tool that defines and organizes the LSST project's total work scope through the enumeration and grouping of the project's discrete work elements.