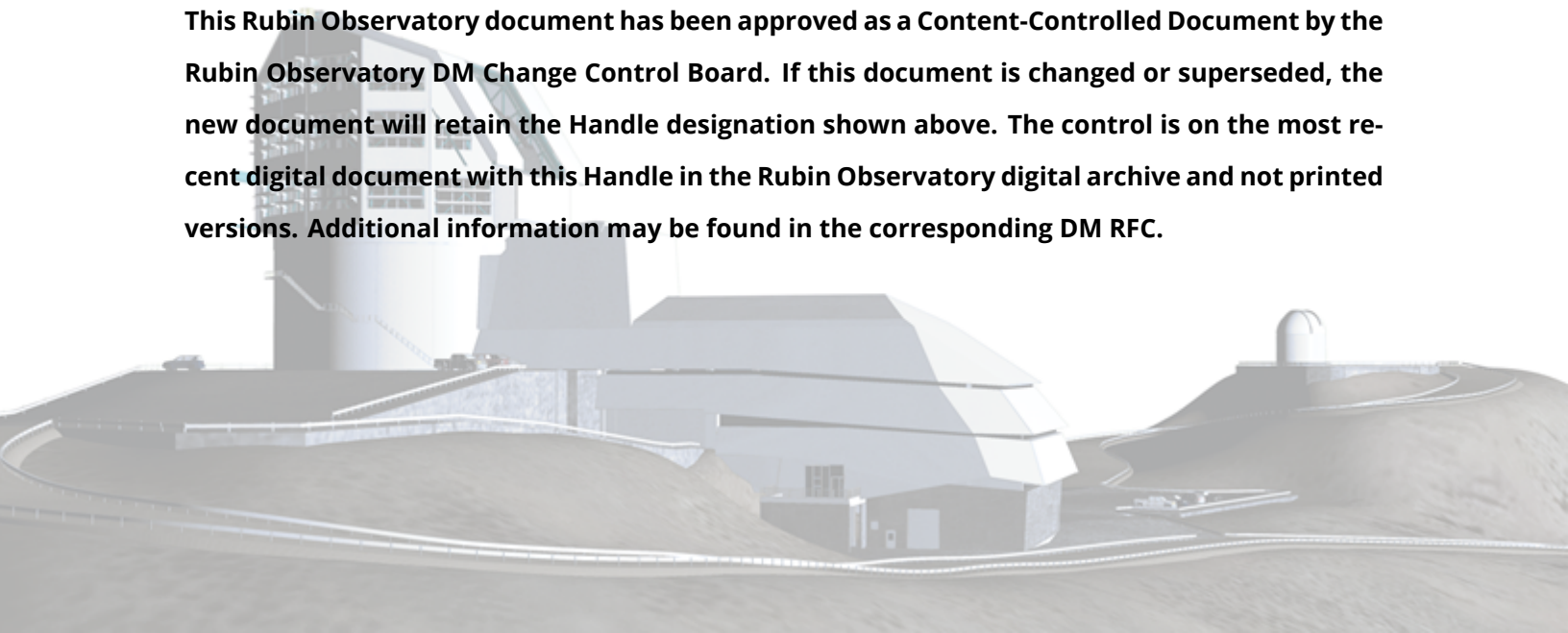
Vera C. Rubin Observatory
Data Management

Data Management Organization and Management

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

LDM-294

Latest Revision: 2023-08-13



Abstract

This management plan covers the organization and management of the Data Management (DM) subsystem during the development, construction, and commissioning of Vera C. Rubin Observatory . 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
3.9	2020-03-07	Update SST org chart, add Middleware and Science Platform teams, provide more details on responsibility for debugging builds and hosting releases. RFC-666, DM-22393	W. O'Mullane

Continued on next page

Version	Date	Description	Owner name
3.10	2020-08-18	Clarify requirements traceability. Refresh org &,doc charts. Refresh text for review. Automatically generate Gantt chart from milestones submodule.RFC-708	J. Swinbank, W. O'Mullane
3.11	2020-10-28	Refresh org chart and Gantt chart , CCB composition, EUPS maintenance RFC-732	W. O'Mullane
3.12	2021-01-06	Should point to dev guide for empowerment and RFC RFC-747	W. O'Mullane
3.13	2021-05-30	Updated Org, inclusion of IT Chile, milestones refresh, USDF mention. Approved with RFC RFC-781	W. O'Mullane
3.14	2022-04-20	Updated Pipelines and Calibration Scientist roles and org charts following project reorganization. Added new T/CAM for the Data Facility. Gantt update DM-34498	L. Guy
3.15	2022-09-11	Update gantt, org chart, make some LSST Rubin, adjust system architecture RFC-877	W. O'Mullane
3.16	2023-08-13	Update charts and schedule with June data RFC-940	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 subsection 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 United States Data Facility (USDF) at SLAC National Accelerator Laboratory (SLAC) in Menlo Park
- The Interim Data Facility (IDF) running on Google
- The United States (US) Data Access Center (DAC), at SLAC in Menlo Park
- The Chilean DAC in the Base Facility
- The French Data Facility (FrDF) at Centre de Calcul de l'IN2P3 (CC-IN2P3) in Lyon, France
- The United Kingdom Data Facility (UKDF) at Royal Observatory Edinburgh (ROE) in Scotland

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 Vera C. Rubin Observatory 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.

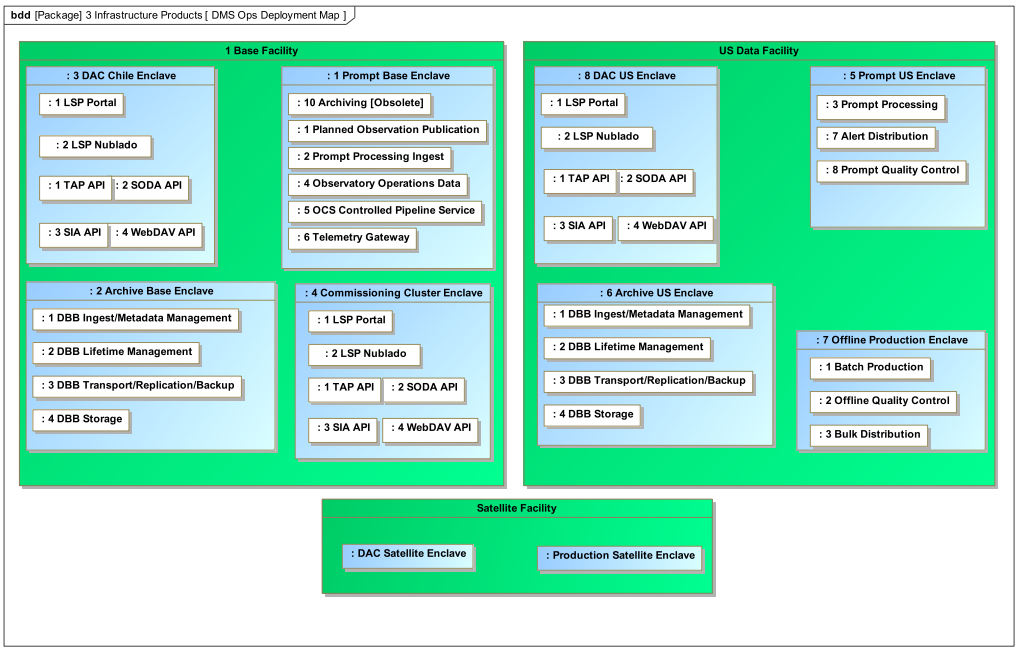


FIGURE 1: DM components as deployed during Operations. Refer to LDM-148 for details of each component.

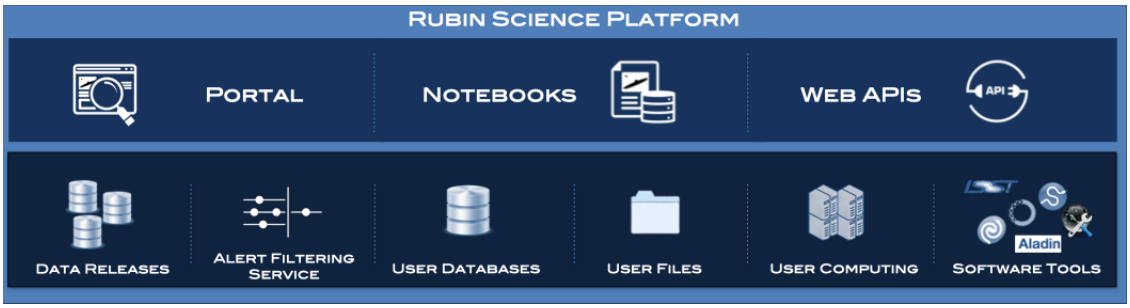


FIGURE 2: The sub-components of the Science Platform.

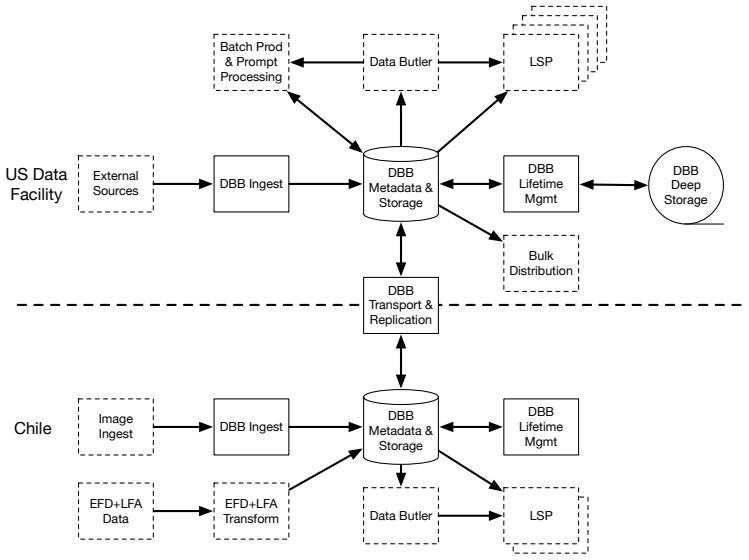


FIGURE 3: The Data Backbone links all the physical components of DM.

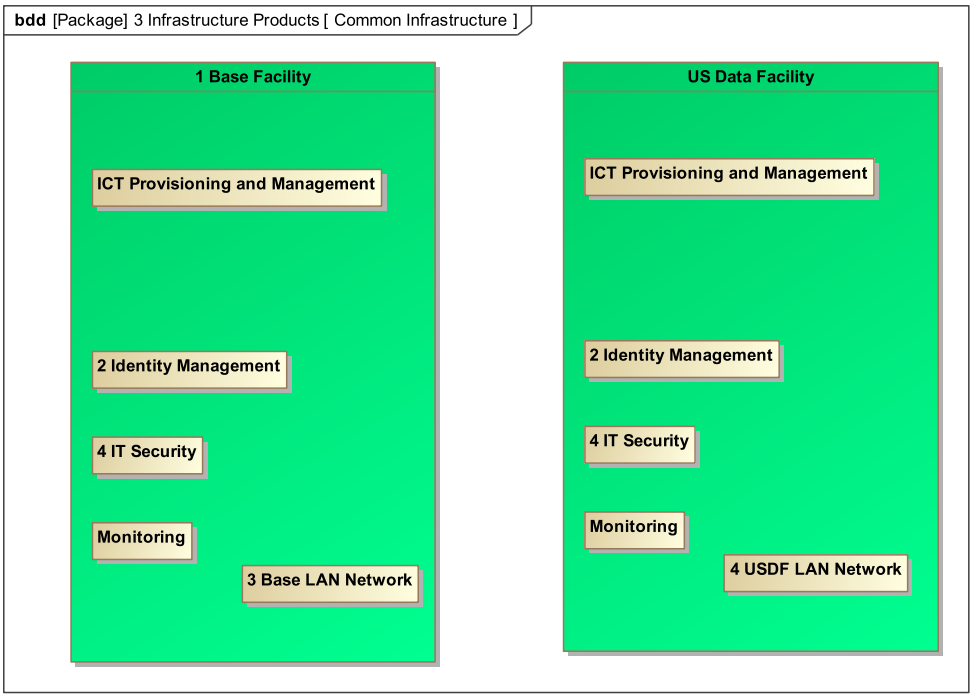


FIGURE 4: Common infrastructure services available at DM locations.

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

2.1 External Interfaces & Auxiliary Data

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

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 Vera C. Rubin Observatory operations.

The DM Project Manager (William O'Mullane), Deputy Project Manager (Frossie Economou) 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 Vera C. Rubin Observatory Project Office, the Vera C. Rubin Observatory Change

Control Board, the LSST Corporation, and Vera C. Rubin Observatory 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 observatory are supported and is a member of the Vera C. Rubin Observatory 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 subsection 4.2). This is illustrated in Figure 5.

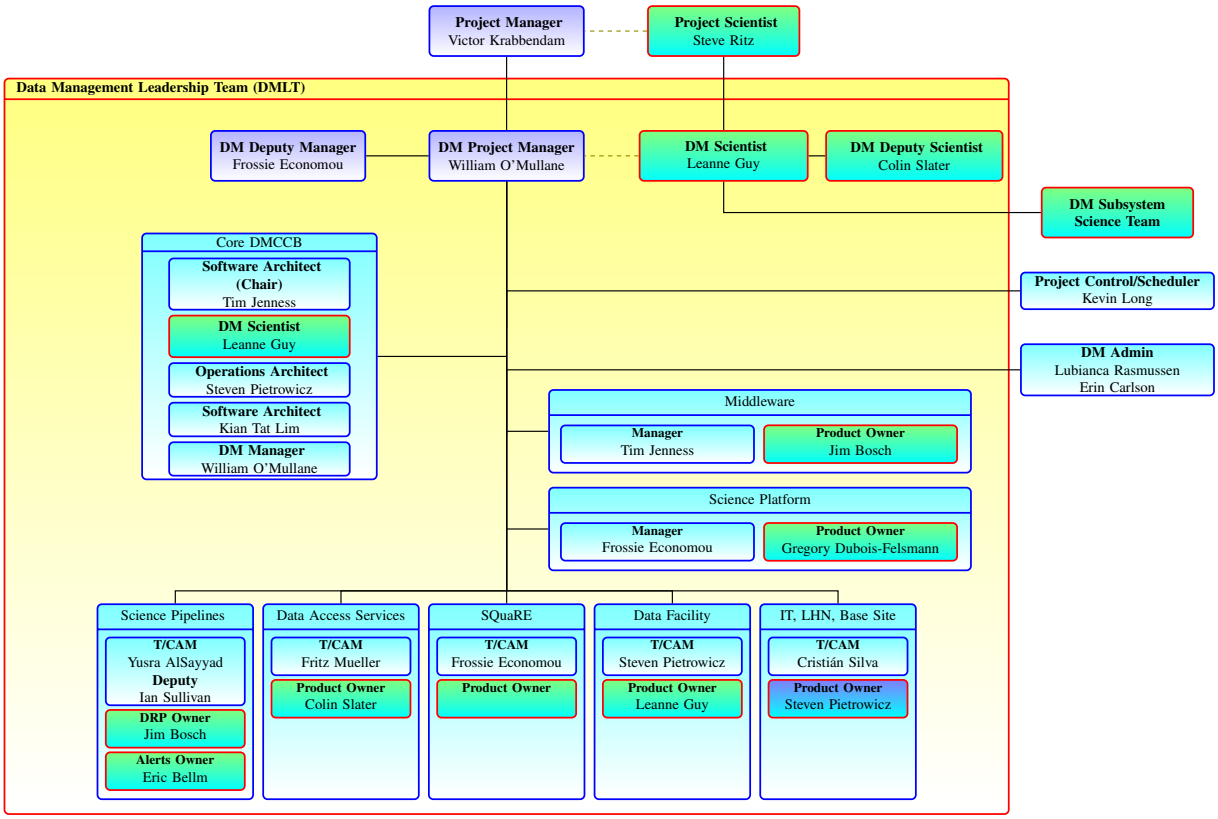


FIGURE 5: DM organization.

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 the project keeps poli-

cies 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 (subsection 7.4) 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 RFC . When required, the DM 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 (subsection 7.4) 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 subsection 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 Technical/Control (or Cost) Account Manager (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 DMPM 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 DMPM 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 Rubin Observatory. 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 (subsection 7.5). 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.

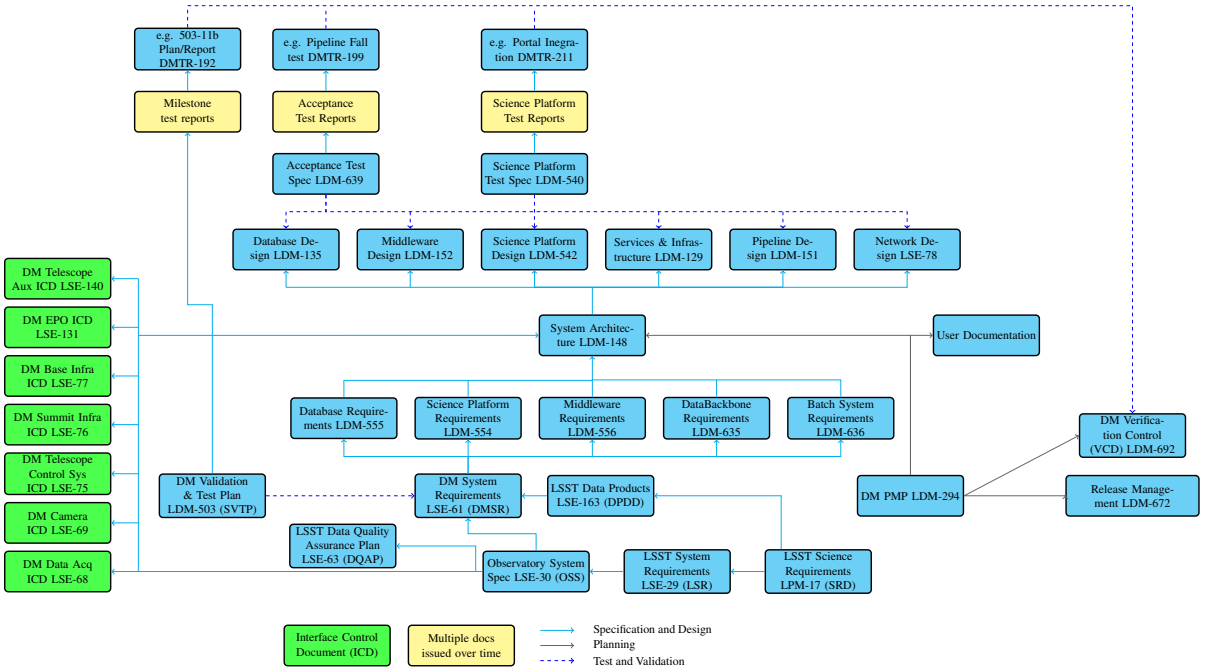


FIGURE 6: The document tree for the Data Management subsystem.

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 Vera C. Rubin Observatory format, and hence either produced with (Leslie) Lamport TeX (document markup language and document preparation system) (LaTeX), using the lsst-texmf package[1], or Word, using the appropriate Rubin 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

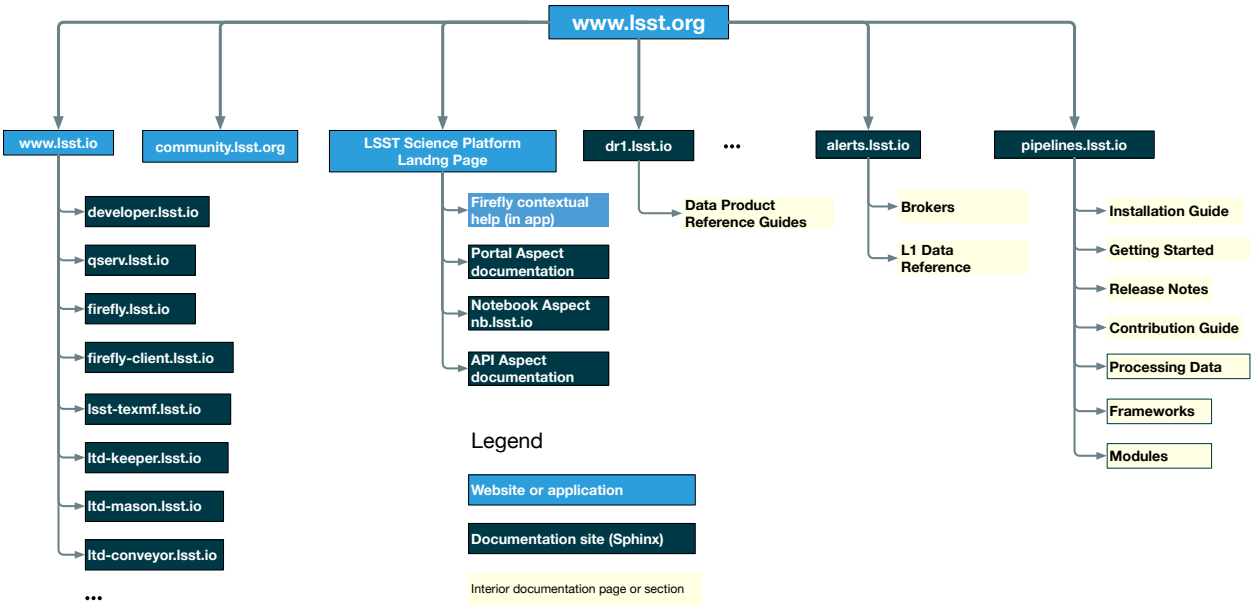


FIGURE 7: Outline of the web hierarchy for the DM end user documentation.

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.

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

3.4.3 Data Facility Documentation

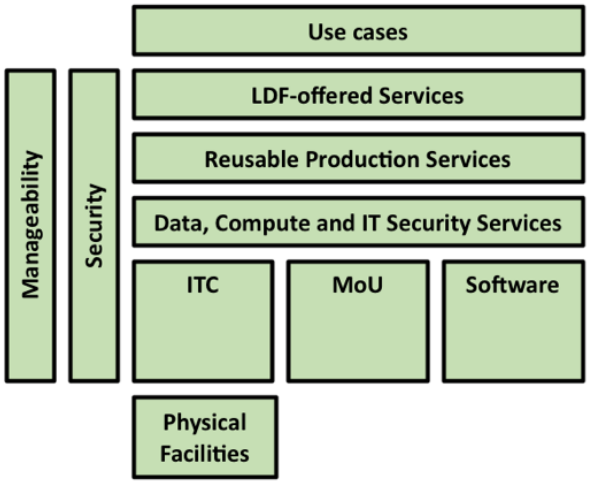


FIGURE 8: Outline of layered service architecture of the Data Facility.

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 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 (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 Vera C. Rubin Observatory 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, a DM 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 Rubin 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 subsection 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 `main` 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 `main`, which should always be functional and releasable. Releases are recorded by tagging the `main` 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 `main`. 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 (DM Change Control Board (DMCCB); subsection 7.5) 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]

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

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.

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 Request For Comment (RFC) Jira issue. The RFC shall contain:

- The justification for the release.
- The date the release is requested to be available.

[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.

- 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:

- 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 Rubin 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 are discussed weekly 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 Science Quality and Reliability Engineering (SQuaRE) (subsubsection 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 subsection 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. The state of verification is given in the Verification Control Document (VCD) LDM-692.

4 Project controls

DM follows the Rubin project controls system, as described in LPM-98. Considerations specific to DM are outlined in subsection 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 Rubin 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 Rubin CCB.

The WBS provides a hierarchical index of all hardware, software, services, and other deliverables which are required to complete the Rubin Project. It consists of alphanumeric strings separated by periods. The first component is always “1”, referring to the Rubin 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:

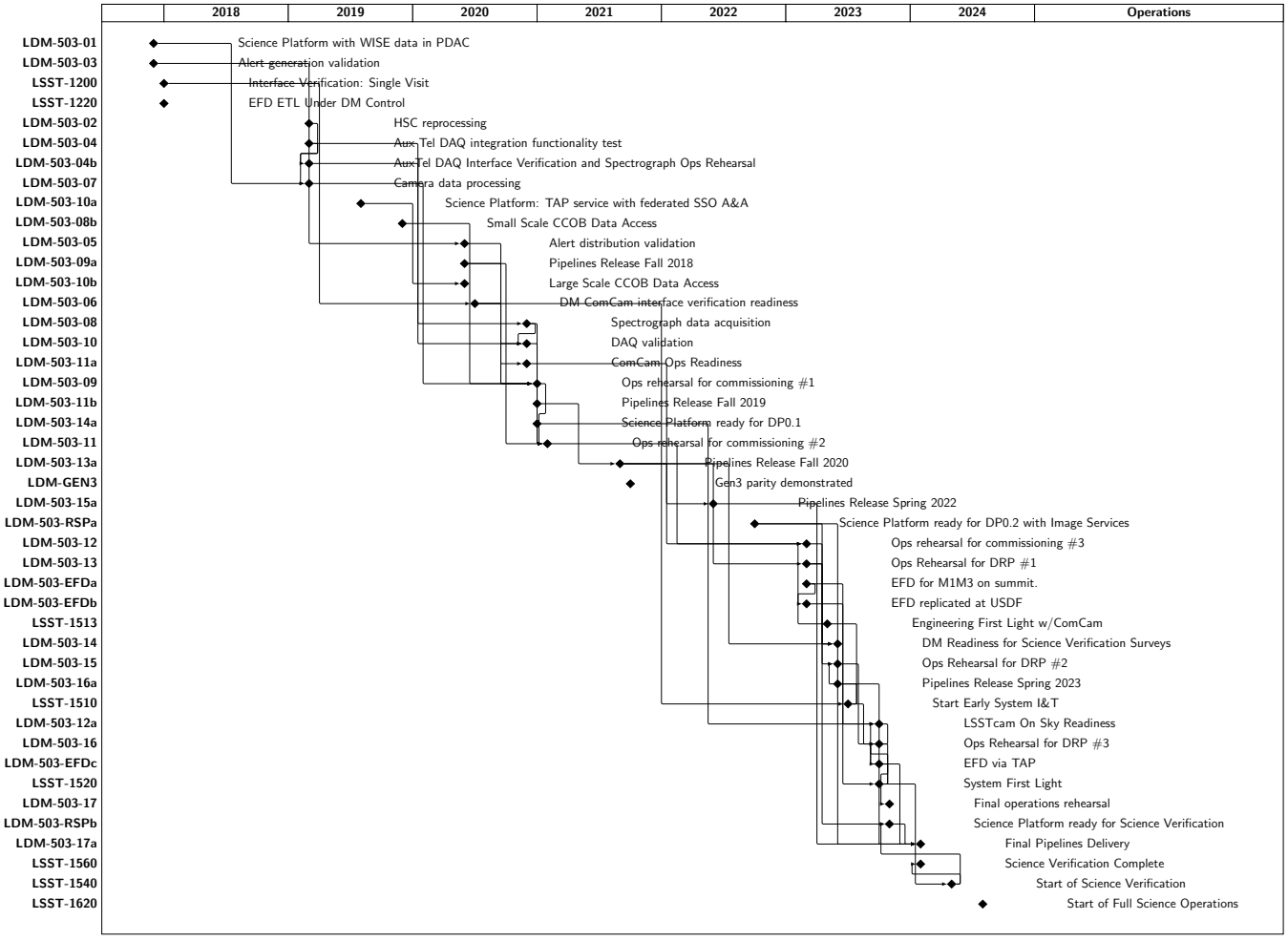


FIGURE 9: DM major milestones—designated as LDM-503-*x*—in the Rubin schedule. These milestones are defined at level 2 according to the scheme described in subsection 4.3. Status in DMTN-158

TABLE 2: DM top level Work Breakdown Structure

WBS	Description	Lead Institution
1.02C.01	System Management	Rubin Tucson
1.02C.02	Systems Engineering	Rubin 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	Rubin Tucson
1.02C.09	System Level Testing & Science Validation	Rubin Tucson
1.02C.10	Science Quality & Reliability Engineering	Rubin 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 subsection 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 (subsection 7.4) 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 (subsection 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.

All milestones status and tracking is provided monthly in DMTN-158.

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 Requirements document. The requirements LSE-61 are themselves traced to higher level requirements in the Observatory System Specifications (OSS; LSE-30) (See also Figure 6). 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.

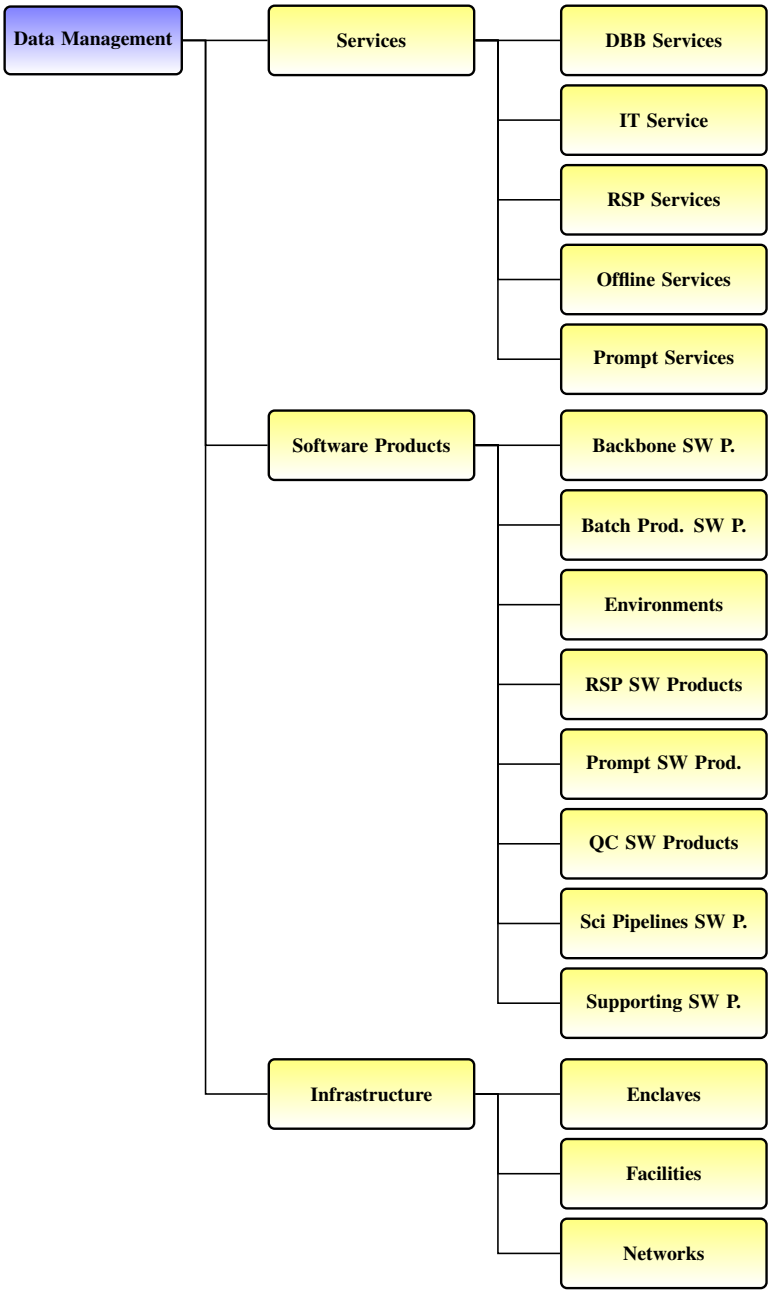


FIGURE 10: An overview of the DM product tree. This provides just a summary of the highest level items: refer to Appendix A for the full list.

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 allLSST 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 theLSST 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 with his/her peer Project Managers (Telescope, Camera), is responsible for delivering an integratedLSST system. The DMPM reports to theLSST 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 (subsection 7.4)

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

The DMSS reports to theLSST Project Scientist. The DMSS is a member of theLSST Change Control Board and the Project Science Team. He/she chairs and directs the work of the DM System Science Team (subsection 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 theLSST 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 achieveLSST science goals.

- Serves as Data Management Liaison as requested byLSST 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 onLSST 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 theLSST 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 subsection 6.2).

6.5 Project Controller/Scheduler

The DM Project Controller is responsible for integrating DM's agile planning process with theLSST 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 subsection 4.3, with theLSST 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 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 (§6.15.2).

- 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 overall DM architecture, working with the DM Systems Engineer and Architecture Team.
- Advise on how we should attack algorithmic problems, providing continuing advice to subsystem product owners as we try new things.
- 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.

6.8 Calibration Scientist

The Calibration Scientist serves as product owner for the final science-ready calibrated data products, working in close conjunction with the Science Leads for Alert Production and Data

Release Production systems (§6.15.2), the Camera Scientist, and the Calibration Hardware Scientist.

- Oversee the end-to-end LSST calibration strategy and plans, and advise on calibration issues
- Provide an understanding of the detectors from a DM point of view, working with the Camera Scientist
- Provide guidance and test criteria at all stages of image processing through final science-ready calibrated data products, including how QA is done
- Ensure that the final calibrated data products meet the SRD requirements

6.9 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 subsection 6.3, who has final say on requirements and features. However, since the Platform 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.

6.10 Systems Engineer

With the Systems Engineering Team (subsection 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; LSST Systems Engineering (Document Handle) (LSE)-61 (DMSR)

(LSE-61), Observatory System Specifications; LSE-30 (OSS) (LSE-30), and LSST System Requirements; LSE-29 (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 (subsection 6.11) work on external ICDs

The Systems Engineer shall chair the DM Change Control Board (subsection 7.5)

- 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 theLSST Change Control Board (CCB).

6.11 Data Management Interface Scientist

The DM Interface Scientist (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 Engineering Team (subsection 7.2).

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

6.12 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 Team (subsection 7.2) to ensure that processes are in place for tracing requirements to the codebase and providing hooks to ensure that requirement verification is possible.

6.13 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 theLSST Systems Engineering Team

6.14 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 National Center for Supercomputing Applications (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 (subsection 7.5).

6.15 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.

6.15.1 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 (subsection 6.6) to develop the detailed plan for each cycle and sprint as required
- Work with the DM Project Controller (subsection 6.5) to ensure that all plans and milestones are captured in theLSST 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.

6.15.2 Institutional Science/Engineering Lead

The Institutional Science/Engineering Leads serve as product owners (subsection 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 (subsection 7.1) and, as such, report to the DMSS (subsection 6.3).

6.16 DM Science Validation Scientist

The DM Science Validation Scientist leads the Science Validation team (subsection 7.6). 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.

6.17 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.

6.17.1 Science Platform Manager

TheLSST 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 subsection 7.8.

6.17.2 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 subsection 7.7.

7 Teams within Data Management

Since the DM team is distributed in terms of geography and responsibility across the Rubin 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 Rubin DM system responsive to the overall Rubin Project goals, as well as scientifically validate the as-built system (LDM-503, Section 9.).

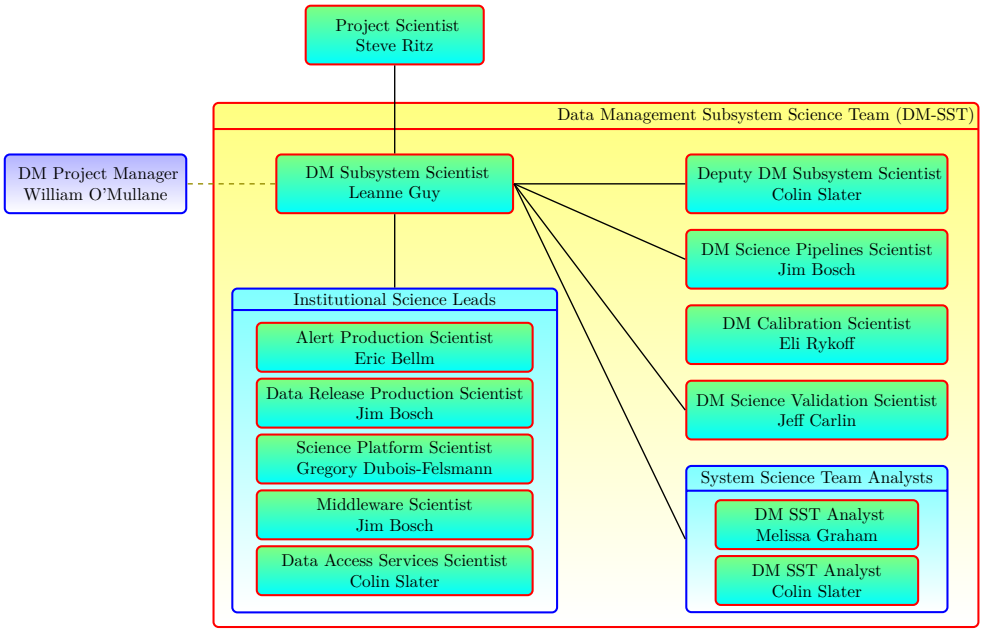


FIGURE 11: DM System Science Team organisation.

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 Rubin 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 (subsection 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 Rubin 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 Rubin science goals.

7.2 DM Systems Engineering Team

The Systems Engineering Team is led by the DMPM (subsection 6.1) and looks after all aspects of systems engineering. It is comprised of not only the Software Architects (subsection 6.12), Operations Architect (subsection 6.13), DMSS (subsection 6.3), Pipeline Scientist (subsection 6.7), Interface Scientist (subsection 6.11), and the DDMPM (subsection 6.2).

While the product owners (subsection 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 (subsubsection 8.1.1).
- Debug unexpected build problems:
  - Resolve issues related to the underlying build infrastructure directly;
  - Pass off product-specific problems to the relevant product team.
- Maintain the build/packaging system e.g. newinstall.sh, lsstsw, lsst_build and EUPS.

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

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 Chile IT Team

The Chile IT lead (Cristían Silva) has responsibility for the IT infrastructure in Chile. This includes the long haul network (LHN). For more details on Chile IT see ITTN-006. A brief set of responsibilities include:

- Provide desktop support for Chile users at the base, Tucson Labs, and summit.
- Handle all IT hardware and software purchases in Chile.
- Handle all IT installations in Chile.
- Handle Long Haul Network contracts and meetings.
- Provide infrastructure as code layer (Puppet/Kubernetes etc.) upon which other teams may deploy services.
- Provide networking for all the components of the observatory.
- Provide monitoring of IT services
- Provide authentication and authorization services for the operational facilities.
- Provide video conferencing support
- Provide backup facilities and ensure backups are made
- Deployment and management of all layer 1 network connections in Rubin scope, including camera fibers, dome network, etc.

7.3.1 Communications

The IT lead must interact with other CAMS to ensure all services are provided as needed and agreed. This means having representation at key telescope and site planning meetings (as well DMLT). Chile IT lead will have a weekly tag up with IT Tucson and the DMPM. Internally the team holds weekly and daily standups.

7.4 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 (subsection 6.1) and DMSS (subsection 6.3)
  - Lead Institution Technical/Control Account Managers (T/CAMs; subsubsection 6.15.1)
  - Institutional Science or Engineering Leads (subsubsection 6.15.2)
  - Members of the DM Systems Engineering Team (subsection 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 (subsection 7.2) work in synchrony. The DMLT makes sure the requirements and architecture/design are estimated and scheduled in accordance with Rubin Project required budgets and schedules.

02C.08 LHN is a bit of an anomaly in the DM WBS and probably should not have been in the WBS. IT have recently been put in charge of this but project do not wish to restructure the WBS. As such 02C.08 remains in DM but the CAM is not considered part of DMLT (though welcome to attend).

7.4.1 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 Rubin 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[7]; 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

7.5 DM Change Control Board

The DMCCB has responsibility for issues similar to those of the Rubin Change Control Board, but focused on the DM Subsystem. The DMCCB reviews and approves changes to all base-

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

[7] One of these has been virtual since late 2018 and with COVID-19 its not obvious we will return soon to in person meetings.

lines 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 Rubin 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 Rubin and DM configuration control processes.
- Membership:
  - Core members:
    * Chair Tim Jenness.
    * DMPM
    * DMSS
    * Operations Architect
    * Software Architect
    * Release Manager, Secretary
  - Optional members (required when topics to discuss are relevant to their areas of expertise):
    * Deputy DMSS, when DMSS is not available
    * Pipeline Scientist
    * Science Pipelines Architect (this aligns with an operational role)
    * T/CAMs, who can delegate as needed

- 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.

7.6 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 (subsection 6.16). Its membership includes the DM Pipelines Scientist (subsection 6.7) and the various Institutional Science/Engineering Leads (subsubsection 6.15.2). Depending on the activities currently being executed, other members of the System Science Team (subsection 7.1), the wider DM Construction Project, and/or external experts may be temporarily added to the team.

7.7 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 (subsubsection 6.17.2). However, it does not have a permanent staff; rather it draws on effort from across the Alert Production (subsubsection 8.3.1), Data Release Production (subsubsection 8.2.1), Data Access Services (subsubsection 8.5.1), and Data Facility (subsubsection 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.

7.8 Science Platform Team

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

The Product Owner for the Science Platform is the DMSS, supported by the Science Platform Scientist (subsection 6.9). The team is managed by the Science Platform Manager (subsubsection 6.17.1). They coordinate effort across the subsystem, drawing primarily on the Data Access Services (subsubsection 8.5.1), Data Facility (subsubsection 8.6.1) and SQuaRE (subsubsection 8.1.1) teams.

8 Lead institutions in DM

8.1 LSST Tucson

The LSST Project Office in Tucson hosts the DMPM (subsection 6.1) and deputy DMPM, the DMSS (subsection 6.3), and the Systems Engineer (subsection 6.10). In addition, it is home to the Science Quality and Reliability Engineering (SQuaRE) group and LSST International Communications and Base Site (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[8]
- 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, groovy and dm-jenkins-jobs) and release tools (e.g. container creation) for all DM software products
- Deploy, host and manage repositories of release artifacts, such as private Conda repositories, to support releases as needed and agreed with the Systems Engineering Team (subsection 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

[8]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.

links between all the LSST Sites, with two exceptions: the Summit Network (WBS 1.04C.12.5) 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 Association of Universities for Research in Astronomy (AURA) procurement and contracts, as well as with the following major sub-awardees and their subcontractors:

- Red Universitaria Nacional (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 (subsection 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); subsubsection 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 (subsection 6.7) and DMSS (subsection 6.3).

The product owner for the calibration products is the LSST Calibration Scientist (who doubles as the Pipelines Scientist, subsection 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 (subsection 6.1).

The DRP group is responsible for delivering software which adheres to the architectural and testing standard defined by the Software Architect (subsection 6.12). 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 (subsection 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

UW hosts the 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 (Moving Object Processing System (deprecated; see SSP) (MOPS));
- Development, in conjunction with the Data Release Production team (DRP; subsubsection 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 (subsection 6.7) and DMSS (subsection 6.3).

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

The AP group is responsible for delivering software which adheres to the architectural and testing standard defined by the Software Architect (subsection 6.12). 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 (subsection 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 (subsection 6.9) and provides some support for Firefly. This is now at the level of 1 FTE total.

Design and develop the Firefly Web-based visualization and data exploration framework, based upon the the same software already in operations in other National Aeronautics and Space Administration (NASA) archive services (i.e. Infrared Science Archive (IRSA)'s Wide-field Survey Explorer (WISE) Image Service) . The Firefly framework provides three basic components – image display and manipulation, tabular table display and manipulation, and Two-dimensional (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.

8.5 SLAC

SLAC hosts the DM Software Architect (subsection 6.12) 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 International Virtual-Observatory Alliance (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 (subsection 6.1).

The DAX group is responsible for delivering software which adheres to the architectural and testing standard defined by the Software Architect (subsection 6.12). 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 (Engineering and Facility 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 Science User Interface and Tools (LSST Data Management WBS element and team, responsible for LSP Portal Aspect) (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 [30] 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[9] (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 `main` branch is always deployable.

DMTN-020 describes in detail the integration of DM's agile approach to software development with the Earned Value Management system used by the Legacy Survey of Space and Time (formerly Large Synoptic Survey Telescope) (LSST) construction project.

9.1 Communications

The epics for each six-month development cycle are agreed at the DM Leadership Team (DMLT) face-to-face meeting near the beginning of the period (see subsection 7.4).

The T/CAMs of each of the institutions meet via video on Thursdays 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. This is facilitated by a slack bot through which each cam answers a few questions and highlights any topic for live discussion. As of June 2022, post DP0, the operations team leads also join this meeting to allow effective linking between construction and operations.

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

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 Project Manager (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				
DBB Services		Steve Pietrowicz		
1.02C.07.07	DBB Lifetime		Michelle Gower	
1.02C.07.07	DBB Metadata		Michelle Gower	
1.02C.07.07	DBB Storage		Michelle Gower	
1.02C.07.07	DBB Transport		Michelle Gower	
IT Service				
Identity Mngt				
IT Chile				
C. Computational Mgmt.		Cristian Silva	Wil O'Mullane	
C. Storage Mgmt.		Cristian Silva	Wil O'Mullane	
IT USDF		Richard Dubois		
Computational Mgmt			Wil O'Mullane	
USDF Identity Mngt				
1.02C.08.03	USDF Net Mgmt		Wil O'Mullane	
USDF Storage Mgmt			Wil O'Mullane	
Issue Tracking				
IT Security				
Databases				
1.02C.06.01.01	APDB	Fritz Mueller	Colin Slater	
EFD Cache		Frossie Economou	Leanne Guy	
RSP Database				
M. Consolidated DB				
1.02C.08.03	Net Mgmt	Cristian Silva	Wil O'Mullane	
RSP Services		Frossie Economou	Gregory Dubois-Felsmann	
RSP Web API		Frossie Economou	Leanne Guy	
SIA API		Frossie Economou	Leanne Guy	
SODA API		Frossie Economou	Leanne Guy	
TAP API		Frossie Economou	Leanne Guy	
WebDAV API		Frossie Economou	Leanne Guy	
1.02C.06.02	RSP Web API			
1.02C.10.02.02	RSP Nublado	Frossie Economou	Leanne Guy	lsst-sqre/ nublado
1.02C.05.07 1.02C.05.08	RSP Portal	Gregory Dubois-Felsmann	Gregory Dubois-Felsmann	
Offline Services				
1.02C.07.06.02	Bulk Distrib	Steve Pietrowicz	Tim Jenness	
1.02C.04.07	Offline QC	Yusra AlSayyad	Jim Bosch	
1.02C.07.06.02	Batch Production	Steve Pietrowicz	Michelle Gower	
Prompt Services				
1.02C.03.03	Alert Distrib	Yusra AlSayyad	Eric Bellm	
Archive Services				
EFD Transf.		Frossie Economou	Leanne Guy	
1.02C.07.06.02	Header Service	Steve Pietrowicz	Tim Jenness	

1.02C.07.06.02	Image Archiver	Steve Pietrowicz	Kian-Tat Lim	
1.02C.07.06.02	Archiving	Steve Pietrowicz	Steve Pietrowicz	
1.02C.02.02	OCS Pipeline	Kian-Tat Lim	Tim Jenness	
1.02C.07.06.02	Obs Ops Data	Steve Pietrowicz	Kian-Tat Lim	
1.02C.07.06.02	Planned Obs Pub	Steve Pietrowicz	Kian-Tat Lim	
1.02C.07.06.02	Prompt Proc Ing	Richard Dubois	Kian-Tat Lim	
Prmpt Processing		Richard Dubois	Eric Bellm	
1.02C.03.08	Prompt QC	Yusra AlSayyad	Eric Bellm	
1.02C.07.06.02	Telem Gateway	Steve Pietrowicz	Kian-Tat Lim	
Software Products		Wil O'Mullane		
Backbone SW P.		Steve Pietrowicz		
1.02C.07.08	DBB Lifetime SW		Michelle Gower	
1.02C.07.08	DBB Meta SW		Michelle Gower	lsst-dm/ dbb_gateway lsst-dm/ dbb_gwclient
1.02C.07.08	DBB Transport SW		Michelle Gower	
Batch Prod. SW P.		Steve Pietrowicz		
1.02C.07.08	Campaign Mgmt		Michelle Gower	
1.02C.07.08	Workload/ flow		Michelle Gower	
Environments		Kian-Tat Lim		
SPL Conda Env			Tim Jenness	
RSP SW Products		Frossie Economou	Gregory Dubois-Felsmann	
1.02C.06.02.04	Image Server SW	Frossie Economou	Colin Slater	dax_imgserv
1.02C.06.02	RSP Web SW			dax_webserv
1.02C.10.02.02	RSP Notebook SW	Frossie Economou	Leanne Guy	lsst-sqre/ jupyterlabutils lsst-sqre/ jupyterhubutils
1.02C.05.08	Portal Online Help	Gregory Dubois-Felsmann	Gregory Dubois-Felsmann	suit-onlinehelp
1.02C.05.07 1.02C.05.08	RSP Portal SW	Gregory Dubois-Felsmann	Gregory Dubois-Felsmann	suit
TAP Software		Frossie Economou	Leanne Guy	
Prompt SW Prod.				
1.02C.03.03	Alert Distrib SW	Yusra AlSayyad	Eric Bellm	lsst-dm/ alert_stream
EFD Transform		Frossie Economou	Leanne Guy	
1.02C.07.08	Header Srv SW	Steve Pietrowicz	Tim Jenness	lsst-dm/ HeaderService
1.02C.07.08	Image Ingest SW	Steve Pietrowicz	Kian-Tat Lim	ctrl_iip
1.02C.07.08	Plan Obs Pub SW	Steve Pietrowicz	Kian-Tat Lim	
1.02C.02.02	OCS Pipeline SW	Kian-Tat Lim	Tim Jenness	
1.02C.07.08	Obs Ops Data SW	Steve Pietrowicz	Kian-Tat Lim	lsst-dm/ ctrl_oods
QC SW Products		Frossie Economou	Leanne Guy	
1.02C.10.02.01	Quality Ctrl SW	Frossie Economou	Leanne Guy	lsst-sqre/ squash
Sci Pipelines SW P.		Yusra AlSayyad	Leanne Guy	
1.02C.03	Alert Prod SW	Yusra AlSayyad	Eric Bellm	ap_pipe
1.02C.04.02	Calibration SW	Yusra AlSayyad	Eli Rykoff	cp_pipe
1.02C.04	DR Prod SW	Yusra AlSayyad	Jim Bosch	
1.02C.03 1.02C.04	Spec Prog SW	Yusra AlSayyad	Leanne Guy	
1.02C.04.02	Science P. Dist.	Yusra AlSayyad	Leanne Guy	lsst_distrib
1.02C.04.02	Science Plugins	Yusra AlSayyad	Leanne Guy	
SPL Workflow				

1.02C.03.06	SSP SW	Yusra AlSayyad	Eric Bellm	mops_daymops
1.02C.04.04	Tmpl Gen SW	Yusra AlSayyad	Jim Bosch	
Supporting SW P.		Yusra AlSayyad		
1.02C.06.02.05	ADQL Translator	Frossie Economou	Leanne Guy	albuquery
1.02C.06.02.01	Data Butler	Tim Jenness	Jim Bosch	daf_butler
1.02C.06.02.03	Distrib Database	Fritz Mueller	Colin Slater	qserv
1.02C.03 1.02C.04	Sci Pipelines Libs	Yusra AlSayyad	Jim Bosch	lsst_apps
1.02C.06.03	Task Framework	Tim Jenness	Tim Jenness	pipe_supertask
Infrastructure		Wil O'Mullane		
Enclaves				
1.02C.08.01	Arch Base Encl	Cristian Silva	Wil O'Mullane	
1.02C.07.09	Arch US Encl	Richard Dubois	Wil O'Mullane	
1.02C.08.01	Comm Clust Encl	Frossie Economou	Leanne Guy	
1.02C.08.02	DAC Chile Encl	Cristian Silva	Wil O'Mullane	
1.02C.07.09	DAC US Encl	Richard Dubois	Wil O'Mullane	
1.02C.07.09	Offline Prod Encl	Richard Dubois	Wil O'Mullane	
1.02C.08.01	Prmpt Base Encl	Cristian Silva	Wil O'Mullane	
1.02C.07.09	Prompt US Encl	Richard Dubois	Wil O'Mullane	
Facilities				
Data Facilities				
France Data Facility				
1.02C.07.09	Interim Data Facility	Frossie Economou	Wil O'Mullane	
1.02C.07.09	US Data Facility	Richard Dubois	Wil O'Mullane	
1.02C.08.01 1.02C.08.02	Base Facility	Cristian Silva	Wil O'Mullane	
1.02C.07.09	US Data Facility	Richard Dubois	Wil O'Mullane	
Networks				
1.02C.08.03	Base/ Arch Net	Cristian Silva	Cristian Silva	
1.02C.07.08	Base LAN	Cristian Silva	Wil O'Mullane	
1.02C.08.03	Sum/ Base Net	Cristian Silva	Cristian Silva	
1.02C.07.09	USDF LAN	Richard Dubois	Wil O'Mullane	

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.

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

- OCS Pipeline
- OCS Pipeline SW

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:

- SSP 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.

No products are defined at this level of the WBS.

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:

- RSP Portal
- RSP Portal SW

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.

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

- Portal Online Help

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 catalogs 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.

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

- APDB

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:

- RSP Web API
- RSP 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 SW

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:

- Planned Obs Pub
- Prompt Proc Ing
- Obs Ops Data
- Telem Gateway
- Image Archiver
- Header Service
- Archiving
- 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:

- Header Srv SW
- Image Ingest SW
- Obs Ops Data 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:

- USDF LAN
- US Data Facility
- US Data Facility
- Prompt US Encl
- Arch US Encl
- Offline Prod Encl
- DAC US Encl
- Interim Data Facility

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
- Prmpt Base Encl
- Arch Base Encl
- Comm Clust 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 FI-U/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[10].

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[11].

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

- Net Mgmt

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

- Sum/Base Net
- Base/Arch Net
- USDF 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.

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:

- RSP Nublado
- RSP Notebook 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.

DM team members are empowered to make decisions as outlined in the Developer Guide : Empowerment

The RFC process is detailed in The developer guide : RFC .

D Traceability matrix of DM requirements to higher-level requirements

Requirements on the DM subsystem, as listed in the DMSR, derive from higher level requirements documents, most notably including the LSR and OSS. This section traces each DM requirement to its higher-level origin. See also Appendix E for the inverse mapping.

DMS	OSS
DMS-REQ-0001 Public Access to Science Data	OSS-REQ-0176 Data Access
DMS-REQ-0003 Create and Maintain Science Data Archive	OSS-REQ-0167 Data Archiving
DMS-REQ-0005 Produce Data Releases	
DMS-REQ-0007 Pipeline Infrastructure	
DMS-REQ-0011 Produce Difference Sources	
DMS-REQ-0012 LPM-REQ-0004 Taking an Inventory of the Solar System	
DMS-REQ-0013 LPM-REQ-0004 Taking an Inventory of the Solar System	
DMS-REQ-0014 Maintain Copy of Object Catalog at Base	
DMS-REQ-0015 Maintain Copy of Recent Difference Sources at Base	
DMS-REQ-0016 Produce and Distribute Transient Alerts	
DMS-REQ-0017 Report WCS to Observatory	
DMS-REQ-0019 Raw Data Archiving	
DMS-REQ-0021 Wavefront Sensor Data Archiving	
DMS-REQ-0023 Provide ISR Pipeline	
DMS-REQ-0025 Provide Linearization Software	
DMS-REQ-0026 Provide Artifact Masking Software	
DMS-REQ-0027 Provide PSF Determination Software	

Continued on next page

DMS	OSS
DMS-REQ-0028 Provide Image Data Quality Assessment Software	
DMS-REQ-0031 Provide Astrometric Calibration Software	
DMS-REQ-0035 LPM-REQ-0005 Exploring the Transient Sky	
DMS-REQ-0036 Moving Object Pipeline Accuracy	
DMS-REQ-0037 LPM-REQ-0004 Taking an Inventory of the Solar System	
DMS-REQ-0038 LPM-REQ-0001 Constraining Dark Energy and Dark Matter	
DMS-REQ-0039 LPM-REQ-0003 Supernovae	
DMS-REQ-0040 LPM-REQ-0001 Constraining Dark Energy and Dark Matter	
DMS-REQ-0041 LPM-REQ-0002 Weak Lensing Studies	
DMS-REQ-0044 LPM-REQ-0003 Supernovae	
DMS-REQ-0045 LPM-REQ-0003 Supernovae	
DMS-REQ-0048 General CoAdd Images Pipeline Requirements	
DMS-REQ-0049 Provide Image Addition Software	
DMS-REQ-0050 LPM-REQ-0002 Weak Lensing Studies	
DMS-REQ-0051 Provide Shape Measurement Software	
DMS-REQ-0053 General Astrometric Calibration Pipeline Requirements	
DMS-REQ-0054 Provide Photometric Calibration Software	
DMS-REQ-0055 Correct for Camera Bias Structure	
DMS-REQ-0056 Correct for Camera Crosstalk	

Continued on next page

DMS	OSS
DMS-REQ-0057 Correct for Detector Fringing	
DMS-REQ-0058 Correct for Instrument Sensitivity Variation	
DMS-REQ-0064 Exposure Archive Publicly Accessible	
DMS-REQ-0066 Keep Exposure Archive	
DMS-REQ-0067 Raw Science Images Available within 24 hours	
DMS-REQ-0071 Calibrated Science Exposures Available witihin 24 hours	
DMS-REQ-0073 Difference Exposures Available within 24 hours	
DMS-REQ-0076 Keep Science Data Archive	
DMS-REQ-0079 Difference Source Attributes	
DMS-REQ-0080 Difference Sources Available within 24 hours	
DMS-REQ-0081 Produce Object Catalog	
DMS-REQ-0082 Source List Updates	
DMS-REQ-0083 Level 1 Object Attributes	
DMS-REQ-0084 Summary Metadata Attributes	
DMS-REQ-0085 Summary Metadata Updates	
DMS-REQ-0086 LPM-REQ-0004 Taking an Inventory of the Solar System	
DMS-REQ-0087 Source Lists Update Frequency	
DMS-REQ-0088 Moving Object Attributes	
DMS-REQ-0090 Generate Alerts	
DMS-REQ-0091 Detect in Two Exposures in Visit	
DMS-REQ-0092 Alert Attributes	
DMS-REQ-0093 LPM-REQ-0005 Exploring the Transient Sky	

Continued on next page

DMS	OSS
DMS-REQ-0095 Archive Alerts within 24 hours	
DMS-REQ-0104 Produce Co-Added Exposures	
DMS-REQ-0105 Co-Added Images Updated at Least Every 6 months	
DMS-REQ-0107 LPM-REQ-0006 Mapping the Milky Way	
DMS-REQ-0108 LPM-REQ-0004 Taking an Inventory of the Solar System	
DMS-REQ-0109 Calibrated Point Source Photometry	
DMS-REQ-0110 LPM-REQ-0006 Mapping the Milky Way	
DMS-REQ-0111 Extended Object Photometry	
DMS-REQ-0112 LPM-REQ-0005 Exploring the Transient Sky	
DMS-REQ-0113 Object Classification	
DMS-REQ-0114 Photomeric Redshift PDF	
DMS-REQ-0115 LPM-REQ-0002 Weak Lensing Studies	
DMS-REQ-0116 LPM-REQ-0002 Weak Lensing Studies	
DMS-REQ-0117 Low SNR Source Attributes	
DMS-REQ-0118 Source Attributes	
DMS-REQ-0129 Crosstalk Correction Matrix Attributes	
DMS-REQ-0133 Access to Engineering and Facilities Database	
DMS-REQ-0134 Access to image Data	
DMS-REQ-0135 Access to image metrics	
DMS-REQ-0136 Account for data collection and transfer	
DMS-REQ-0137 Analyze data and data quality	

Continued on next page

DMS	OSS
DMS-REQ-0138 Analyze data from all databases	
DMS-REQ-0139 Analyze data in sandbox	
DMS-REQ-0140 Assign automated quality status	
DMS-REQ-0141 Characterize trends and correlations in metrics	
DMS-REQ-0142 Compliance with Project Standards	
DMS-REQ-0143 Configurable summary reports	
DMS-REQ-0144 Data to the Enginering and Facilities Database	
DMS-REQ-0145 Examine data at lower levels	
DMS-REQ-0146 Flexibility	
DMS-REQ-0147 Generate alarms	
DMS-REQ-0148 Generate summary reports	
DMS-REQ-0149 Maintain required pacing	
DMS-REQ-0150 Override of automated quality status	
DMS-REQ-0151 Perform automated analysis of metric values	
DMS-REQ-0152 Specify alarms	
DMS-REQ-0153 Statistical analyses provided	
DMS-REQ-0154 Web-Based Interface	
DMS-REQ-0157 Provide Management and Control Services	
DMS-REQ-0159 Provide Data/Catalog Construction Services	
DMS-REQ-0169 Mountaintop Site Temporary Storage	
DMS-REQ-0179 Base Facility Data Quality Assessment	
DMS-REQ-0184 Base to Archive Network Lease	

Continued on next page

DMS	OSS
DMS-REQ-0192 Archive to Data Access Center Network Lease	
DMS-REQ-0195 Data Access Center VO Standards	
DMS-REQ-0198 Data Quality	OSS-REQ-0125 Data Products
DMS-REQ-0199 Instrument Signature Removal Quality	OSS-REQ-0129 Exposures (Level 1)
DMS-REQ-0200 Flattening Error	
DMS-REQ-0201 Bad Pixel Identification Efficiency	
DMS-REQ-0202 Fringe Removal Efficiency	
DMS-REQ-0203 Cosmic Ray Rejection Efficiency	
DMS-REQ-0204 Image Characterization Quality	OSS-REQ-0129 Exposures (Level 1)
DMS-REQ-0205 World Coordinate System Median Error	
DMS-REQ-0206 World Coordinate System Success Rate	
DMS-REQ-0207 Photometric Zero Point Error	
DMS-REQ-0208 Point Spread Function Determination Mean Error	
DMS-REQ-0209 Point Spread Function Determination Success Rate	
DMS-REQ-0210 Background Determination Mean Error	
DMS-REQ-0211 Image Subtraction and Difference Source Quality	OSS-REQ-0130 Catalogs (Level 1) OSS-REQ-0129 Exposures (Level 1)
DMS-REQ-0212 Image Subtraction Success Rate	
DMS-REQ-0213 Image Subtraction Residuals in Object Footprints	
DMS-REQ-0214 Detected Sources in Subtracted Image Completeness	

Continued on next page

DMS	OSS
DMS-REQ-0215 Detected Sources in Subtracted Image False Detection Rate	
DMS-REQ-0216 Coaddition Quality	OSS-REQ-0136 Co-added Exposures
DMS-REQ-0217 Coaddition for Detection Mean Error	
DMS-REQ-0218 Coaddition for Subtraction Template PSF FWHM Width	
DMS-REQ-0219 Deep Detection and Measurement Quality	OSS-REQ-0137 Catalogs (Level 2)
DMS-REQ-0220 Deep Detection and Measurement Completeness	
DMS-REQ-0221 Deep Detection and Measurement Shape Accuracy	
DMS-REQ-0222 Moving Object Quality	OSS-REQ-0130 Catalogs (Level 1) OSS-REQ-0137 Catalogs (Level 2)
DMS-REQ-0223 Moving Object Detection Completeness	
DMS-REQ-0224 Source - Moving Object Match Completeness	
DMS-REQ-0225 Source-Object Association Quality	OSS-REQ-0137 Catalogs (Level 2) OSS-REQ-0130 Catalogs (Level 1)
DMS-REQ-0226 Source-Object Association Accuracy	
DMS-REQ-0227 Source-Object Association Classification Correctness	
DMS-REQ-0228 Photometric Quality	OSS-REQ-0137 Catalogs (Level 2)
DMS-REQ-0229 Photometric Precision - Unconfused Point Sources	
DMS-REQ-0230 Photometric Precision - Extended Sources	
DMS-REQ-0231 Photometric Spatial Uniformity - Point Sources	
DMS-REQ-0232 Photometric Spatial Uniformity - Extended Sources	
DMS-REQ-0233 Astrometric Quality	OSS-REQ-0137 Catalogs (Level 2)
DMS-REQ-0234 Accuracy of mean place	

Continued on next page

DMS	OSS
DMS-REQ-0235 Accuracy of proper motion	
DMS-REQ-0236 Accuracy of parallax	
DMS-REQ-0237 Level of systematic error in positions	
DMS-REQ-0238 Catalog Completeness and Reliability	OSS-REQ-0137 Catalogs (Level 2)
DMS-REQ-0239 Completeness - Point Sources	
DMS-REQ-0240 Completeness - Extended Sources	
DMS-REQ-0241 Reliability - Point Sources	
DMS-REQ-0242 Reliability - Extended Sources	
DMS-REQ-0243 Transient Alert Quality	OSS-REQ-0128 Alerts
DMS-REQ-0244 Alert Completeness	
DMS-REQ-0245 Alert Reliability	
DMS-REQ-0246 Automated Production	
DMS-REQ-0247 Data Products Processing Infrastructure	
DMS-REQ-0248 Data Products Query and Download Availability	
DMS-REQ-0249 Data Products Query and Download Infrastructure	
DMS-REQ-0250 Image Storage Reliability	
DMS-REQ-0251 Consistency and Completeness	
DMS-REQ-0252 Maintain Provenance	
DMS-REQ-0253 Reproducibility	
DMS-REQ-0254 Open Software Interfaces	
DMS-REQ-0255 Re-processing and Provenance	
DMS-REQ-0256 Simulated Data Products	
DMS-REQ-0257 Pseudo-random number usage and management	
DMS-REQ-0258 Data Curation - from science req somewhere?	

Continued on next page

DMS	OSS
DMS-REQ-0259 Major elements of data processing	
DMS-REQ-0260 Calibration Data Product production	
DMS-REQ-0261 Transient Alert Production	
DMS-REQ-0262 Ignore Cosmic Rays	
DMS-REQ-0263 Survey Duration - from science req somewhere?	
DMS-REQ-0264 Re-Calibration of Images	

E Traceability matrix of higher-level requirements to DM requirements

Requirements on the DM subsystem, as listed in the DMSR, derive from higher level requirements documents, most notably including the LSR and OSS. This section shows which DM requirements are derived from each higher-level origin. See also Appendix D for the inverse mapping.

OSS	**DMS**
OSS-REQ-0125 Data Products	DMS-REQ-0198 Data Quality
OSS-REQ-0128 Alerts	DMS-REQ-0243 Transient Alert Quality
OSS-REQ-0129 Exposures (Level 1)	DMS-REQ-0199 Instrument Signature Removal Quality DMS-REQ-0204 Image Characterization Quality DMS-REQ-0211 Image Subtraction and Difference Source Quality
OSS-REQ-0130 Catalogs (Level 1)	DMS-REQ-0211 Image Subtraction and Difference Source Quality DMS-REQ-0222 Moving Object Quality DMS-REQ-0225 Source-Object Association Quality
OSS-REQ-0136 Co-added Exposures	DMS-REQ-0216 Coaddition Quality
OSS-REQ-0137 Catalogs (Level 2)	DMS-REQ-0219 Deep Detection and Measurement Quality DMS-REQ-0222 Moving Object Quality DMS-REQ-0225 Source-Object Association Quality DMS-REQ-0228 Photometric Quality DMS-REQ-0233 Astrometric Quality DMS-REQ-0238 Catalog Completeness and Reliability
OSS-REQ-0167 Data Archiving	DMS-REQ-0003 Create and Maintain Science Data Archive
OSS-REQ-0176 Data Access	DMS-REQ-0001 Public Access to Science Data

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., 2018, *Data Management Project Management Guide*, DMTN-020, URL https://dmtn-020.lsst.io/, Vera C. Rubin Observatory Data Management Technical Note

[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 https://dmtn-106.lsst.io/, Vera C. Rubin Observatory Data Management Technical Note

[13] **[LDM-692]**, Comoretto, G., 2021, *DM Verification Control Document*, LDM-692, URL https://ldm-692.lsst.io/,
Vera C. Rubin Observatory Data Management Controlled Document

[14] **[LDM-672]**, Comoretto, G., Guy, L.P., O'Mullane, W., et al., 2019, *LSST Software Release Management*, LDM-672, URL https://ldm-672.lsst.io/,
Vera C. Rubin Observatory Data Management Controlled Document

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

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

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

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

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

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

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

[22] **[LSE-61]**, Dubois-Felsmann, G., Jenness, T., 2019, *Data Management System (DMS) Requirements*, LSE-61, URL https://lse-61.lsst.io/,
Vera C. Rubin Observatory

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

[24] **[LDM-542]**, Dubois-Felsmann, G., Economou, F., Lim, K.T., et al., 2019, *Science Platform Design*, LDM-542, URL https://ldm-542.lsst.io/,
Vera C. Rubin Observatory Data Management Controlled Document

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

[26] **[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

[27] **[LSE-163]**, Jurić, M., Axelrod, T., Becker, A., et al., 2023, *Data Products Definition Document*, LSE-163, URL https://lse-163.lsst.io/,
Vera C. Rubin Observatory

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

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

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

[31] **[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

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

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

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

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

[36] **[ITTN-006]**, O'Mullane, W., Silva, C., 2020, *Management and Planning of Rubin IT*, ITTN-006, URL https://ittn-006.lsst.io/,
Vera C. Rubin Observatory

[37] **[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

[38] **[LDM-503]**, O'Mullane, W., Swinbank, J., Juric, M., et al., 2022, *Data Management Test Plan*, LDM-503, URL https://ldm-503.lsst.io/,
Vera C. Rubin Observatory Data Management Controlled Document

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

[40] **[DMTN-158]**, Swinbank, J., O'Mullane, W., 2023, *DM Milestone Summary*, DMTN-158, URL https://dmtn-158.lsst.io/,
Vera C. Rubin Observatory Data Management Technical Note

G Glossary

2D Two-dimensional.

Alert Production Executing on the Prompt Processing system, the Alert Production payload processes and calibrates incoming images, performs Difference Image Analysis to identify DIASources and DIAObjects, and then packages the resulting alerts for distribution..

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-IN2P3 Centre de Calcul de l'IN2P3.

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 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.

Data Release Production An episode of (re)processing all of the accumulated LSST images, during which all output DR data products are generated. These episodes are planned to occur annually during the LSST survey, and the processing will be executed at the Archive Center. This includes Difference Imaging Analysis, generating deep Coadd Images, Source detection and association, creating Object and Solar System Object catalogs, and related metadata.

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.

element A node in the hierarchical project WBS.

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 FITS images, catalogs, and/or plots. Firefly tools will be integrated into the Science Platform.

FrDF French Data Facility.

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.

IDF Interim Data Facility.

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.

LHN long haul network.

LSE LSST Systems Engineering (Document Handle).

LSR LSST System Requirements; LSE-29.

LSST Legacy Survey of Space and Time (formerly 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).

NASA National Aeronautics and Space Administration.

NCSA National Center for Supercomputing Applications.

NET Network Engineering Team.

Object In LSST nomenclature this refers to an astronomical object, such as a star, galaxy, or other physical entity. E.g., comets, asteroids are also Objects but typically called a Moving Object or a Solar System Object (SSObject). One of the DRP data products is a table of Objects detected by LSST which can be static, or change brightness or position with time.

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.

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.

QA Quality Assurance.

Quality Assurance All activities, deliverables, services, documents, procedures or artifacts which are designed to ensure the quality of DM deliverables. This may include QC systems, in so far as they are covered in the charge described in LDM-622. Note that contrasts with the LDM-522 definition of "QA" as "Quality Analysis", a manual process which occurs only during commissioning and operations. See also: Quality Control.

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.

ROE Royal Observatory Edinburgh.

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.

SLAC SLAC National Accelerator Laboratory.

SLAC National Accelerator Laboratory A national laboratory funded by the US Department of Energy (DOE); SLAC leads a consortium of DOE laboratories that has assumed responsibility for providing the LSST camera. Although the Camera project manages its own schedule and budget, including contingency, the Camera team's schedule and requirements are integrated with the larger Project. The camera effort is accountable

to the LSSTPO..

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 (LSST Data Management WBS element and team, responsible for LSP Portal Aspect).

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 Pachón, 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.

UKDF United Kingdom Data Facility.

US United States.

USDF United States Data Facility.

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.

VCD Verification Control Document.

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.