



LARGE SYNOPTIC SURVEY TELESCOPE

# Large Synoptic Survey Telescope (LSST) Data Management Organization and Management

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**LDM-294**

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## Abstract

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

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# Data Management Organization and Management

## 1 Introduction

### 1.1 Purpose

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

### 1.2 Mission Statement

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

### 1.3 Goals and Objectives

LSST Data Management will:

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

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

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

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

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

## 2 Data Management Conceptual Architecture

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

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

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

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

Science users will access the data products produced by LSST through the Science Platform, as shown in Figure 2.

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

### 2.1 External Interfaces & Auxiliary Data

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

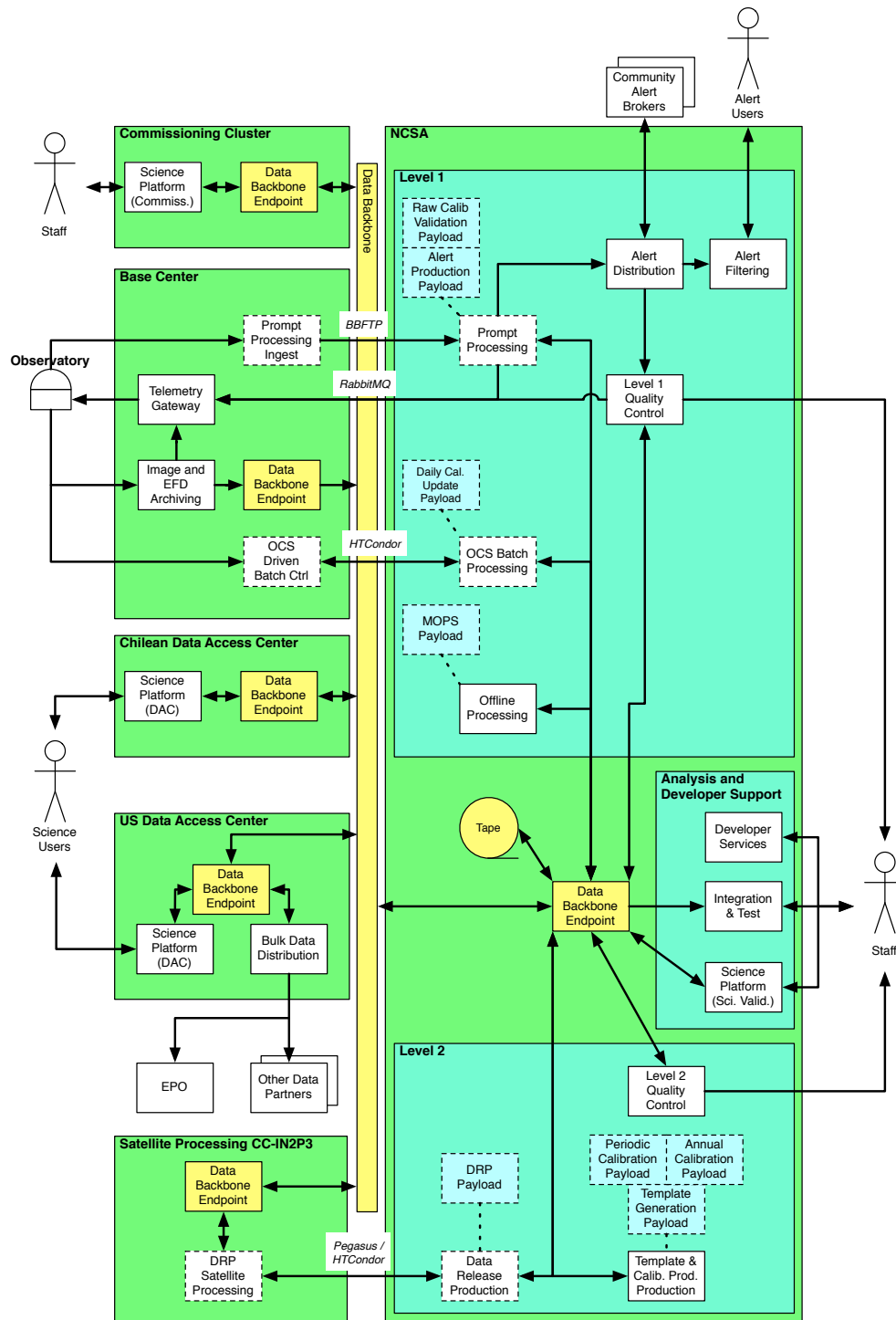


FIGURE 1: DM components as deployed during Operations. Where components are deployed in multiple locations, the connections between them are labeled with the relevant communication protocols. Science payloads are shown in blue.

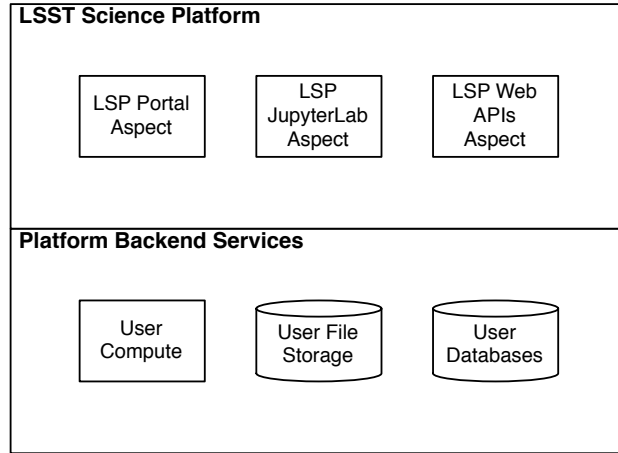


FIGURE 2: The sub-components of the Science Platform.

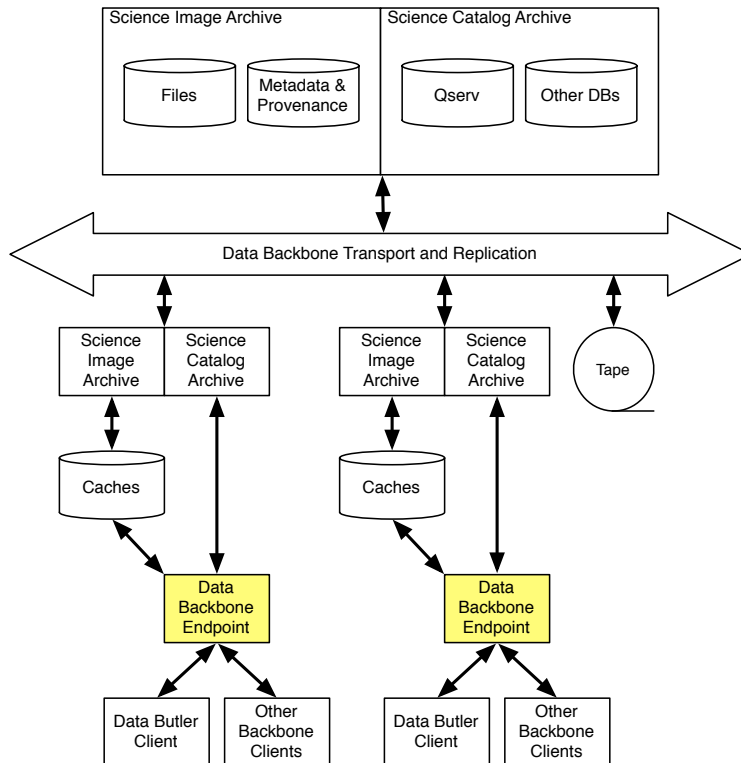


FIGURE 3: The Data Backbone links all the physical components of DM.

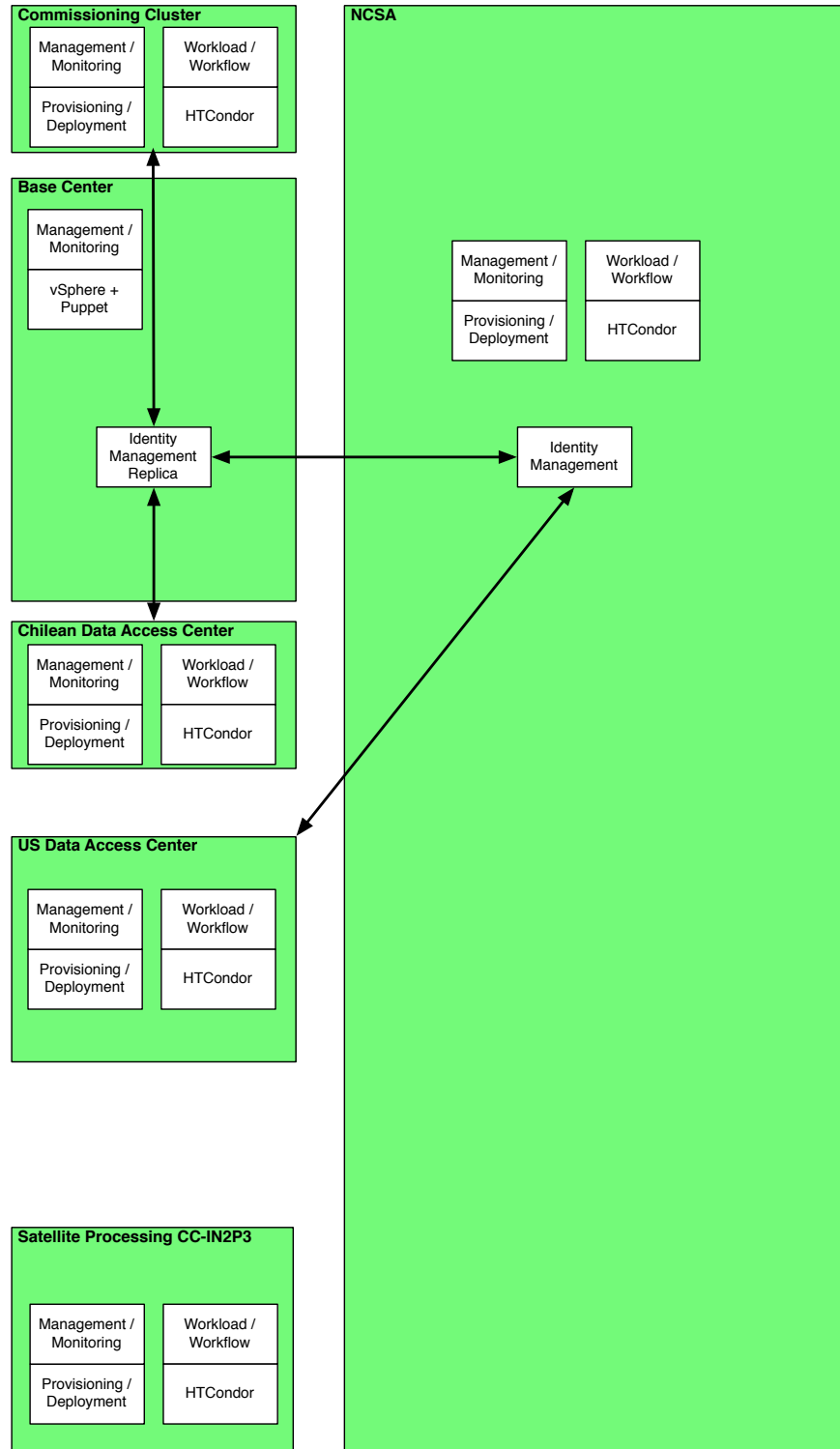


FIGURE 4: Common infrastructure services available at each DM location.

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

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

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

### 3 Data Management Organization Structure

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

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

DM views its deliverables as hierarchical tree of *products*, as described in Section 5. The sub-system 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). This is illustrated in Figure 5.

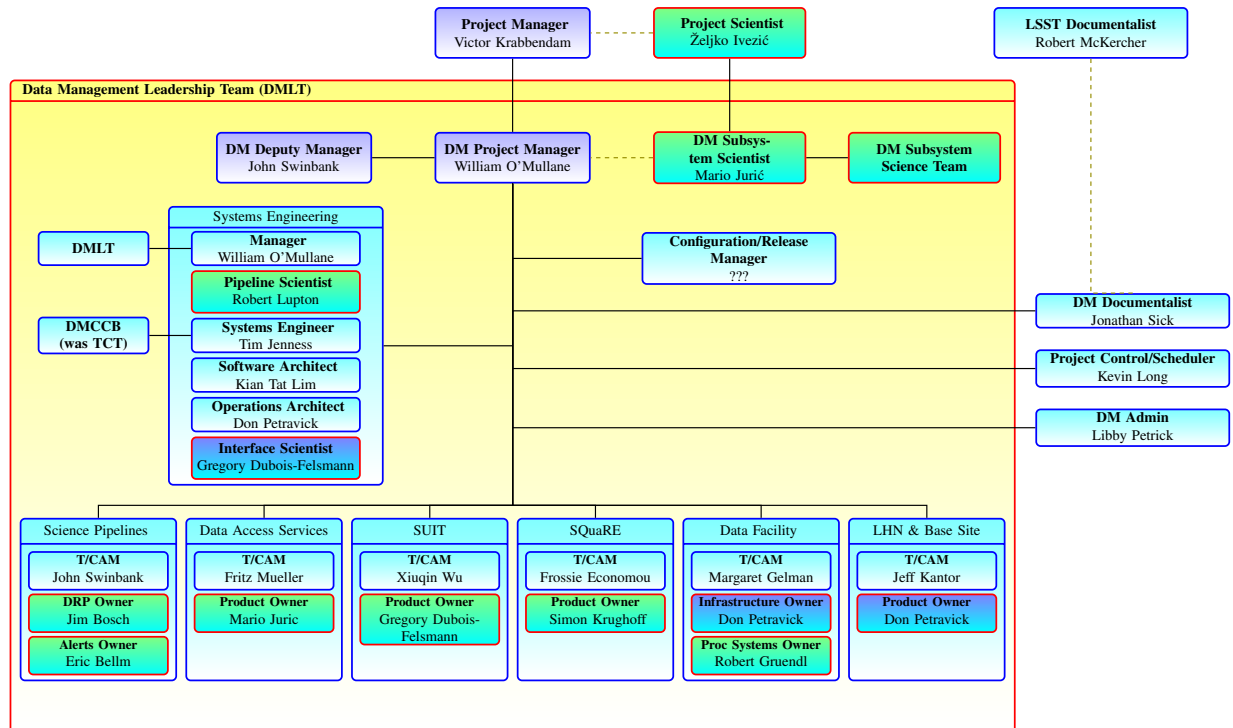


FIGURE 5: DM organization.

### 3.1 Meetings

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

A detailed debrief note or presentation may be asked of travelers to specific meetings of interest by the DMLT (7.3).



## 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 (perhaps 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 (7.3) to provide the best technical input from the perspective of all stakeholders. Members of the working group should discuss in their local organizations and socialize recommendations ahead of adoption.

## 3.3 External Studies

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

## 3.4 Document Management

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

LDM-level documents are change-controlled, and may be released only on agreement of the DMCCB (Section 7.4). Uncontrolled documents, such as technical notes, may be released when the author decides it is appropriate or is asked to release it 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 how they relate to each other. Some documents shown in red are not yet written.

Figure 6 has a single box for “end user documentation”. However, appropriate web-based, user-focused documentation is regarded as a major DM deliverable. Figure 7 shows the in-

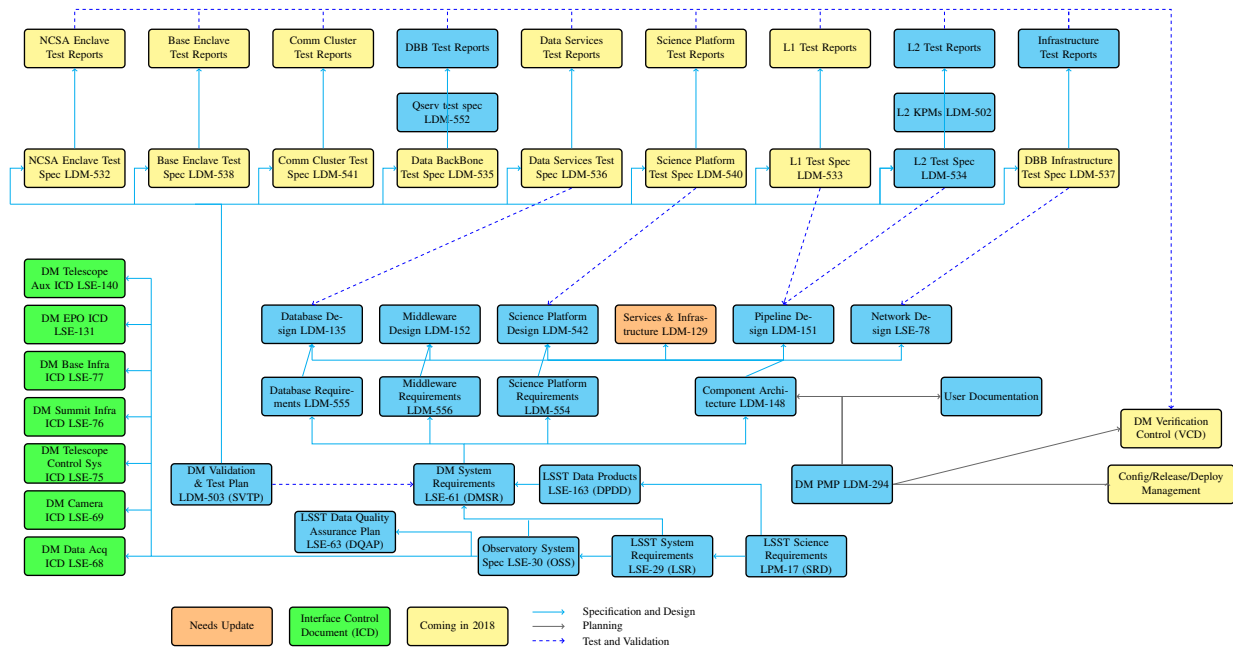


FIGURE 6: Outline of the documentation tree for DM software relating the high level documents to each other.

tended hierarchy for this documentation.

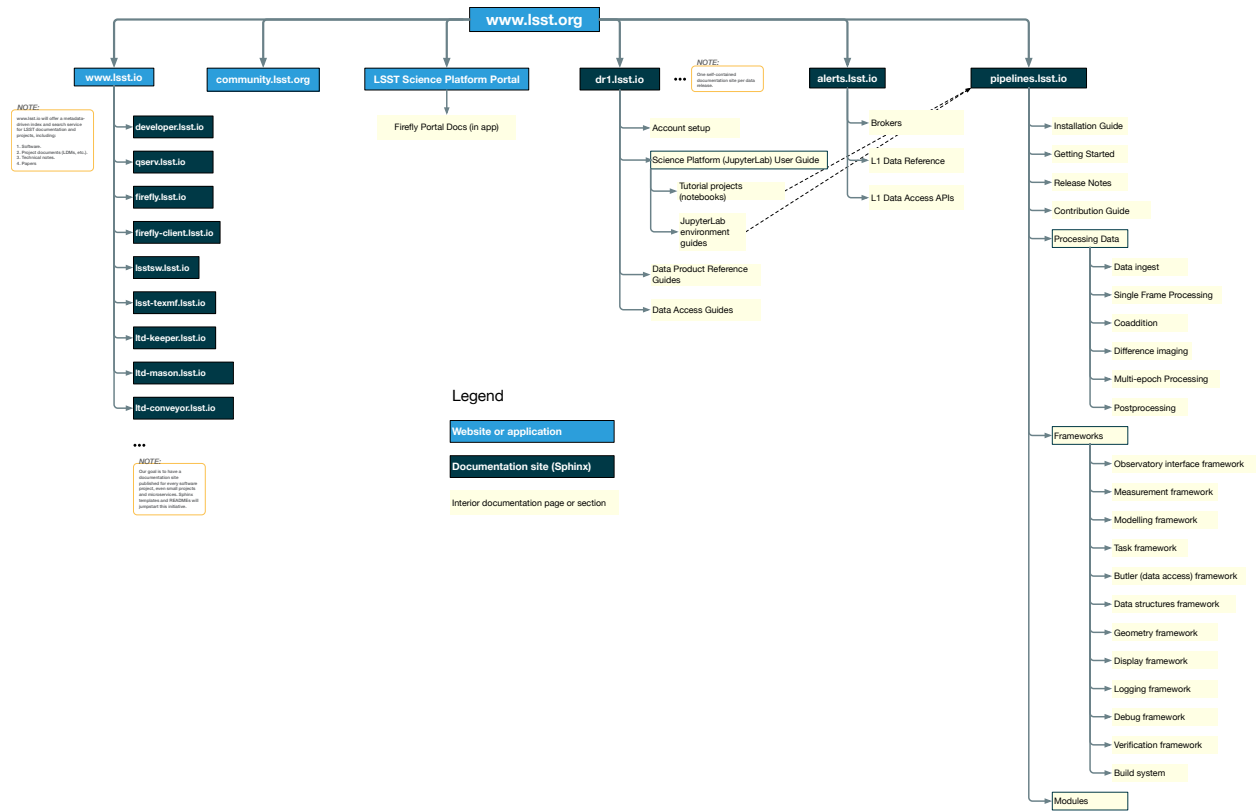


FIGURE 7: Outline of the web hierarchy for the DM end user documentation.

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

### 3.4.1 Documentation of Cross-Cutting Aspects for services

The cross-cutting aspects of the LSST Data Facility, Security and Operational Manageability, are represented by the vertical boxes. 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 (CMDDB), service monitoring.
2. LDF service management processes and context in the overall project: incident response,

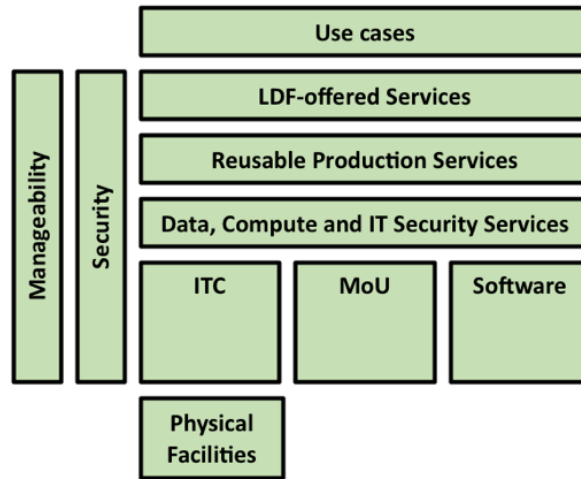


FIGURE 8: Outline of layered service architecture of the Data Facility.

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

### 3.4.2 Documentation of Service Layers

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

1. For each service, a Concept of Operations (ConOps) which summarizes how a service operates to satisfy a use case. The ConOps describes the operational characteristics of the production system, context within overall LSST operations, and representative scenarios.
2. For each service, a Theory of Operations, which provides a mental model of a constructed system. The Theory of Operations explains how the constructed service both

fulfills the ConOps and integrates with the cross-cutting aspects of the facility. The document describes the overall architecture of the service and dependency on supporting service layers; integration into aspects of computer security, information security and business continuity; and integration into incident reporting and response, availability and capacity management, and change management.

The next two layers, Reusable Production Services and Data, Compute, and 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 ITC layers, and integration with cross-cutting aspects of the facility.

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

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

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

### 3.4.3 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. Each repository will be included as a *submodule* of a single git repository located at <https://github.com/lsst-dm/dm-docs>.

Use of Google Docs or Confluence is tolerated but final delivered documents must conform to the standard LSST format, and hence either produced with LaTeX, using the `lsst-texmf` package<sup>1</sup>, or Word, using the appropriate LSST template [Document-9224, Document-11920]. The precursor document should then be erased with a pointer to the baseline document,

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<sup>1</sup><https://lsst-texmf.lsst.io>

stored in GitHub.

End user documentation is planned to be appropriately web based, and the scheme for that is described in LDM-493.

## 3.5 Configuration Control

Configuration control of documents is dealt with in Section 3.4. Here we consider more the operational systems and software configuration control.

### 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 <https://developer.lsst.io/processes/workflow.html> and is consistent with the Systems Engineering Management Plan LSE-17. The master branch is the stable code with development done in *ticket* branches (named with the id of the corresponding JIRA Ticket describing the work). Once reviewed a branch is merged to master, which should always be functional and releasable. Releases are recorded by tagging the master branch; release branches can be created if patches are required.

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

We cannot escape the fact that we will have multiple code branches to maintain in operations which will lead to an increase in work load. Hence one should consider that perhaps more manpower may be needed in commissioning to cope with urgent software fixes while continuing development. The other consideration would be that features to be developed post commissioning will probably be delayed more than one may think, as maintenance will take priority.<sup>2</sup>

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<sup>2</sup>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 Risk Management**

Risks will be dealt with within the LSST Project framework as defined in LPM-20. Risks in DM may be sent to the DM Project Manager or Deputy Project Manager at any time for consideration to be included in the formal risk register (appropriately costed and weighted). All risks are reviewed regularly by the DM Project Manager and Systems Engineer (minimum each 3 months).

### **3.7 Quality Assurance**

In accordance with the project QA plan [LPM-55] we will perform QA on the software products. This work will mainly be carried out by SQuaRE (Section 8.1.1). Quality assurance here means compliance with project guidelines for production, in our case for software production. A part of this is to have a verification/validation plan(s) which in and of itself is a major task (see Section 3.9).

### **3.8 Action item control**

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

### 3.9 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 including a high level test schedule; the top level schedule is given in Figure 9.



## 4 Project Controls

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

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

### 4.1 Schedule

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

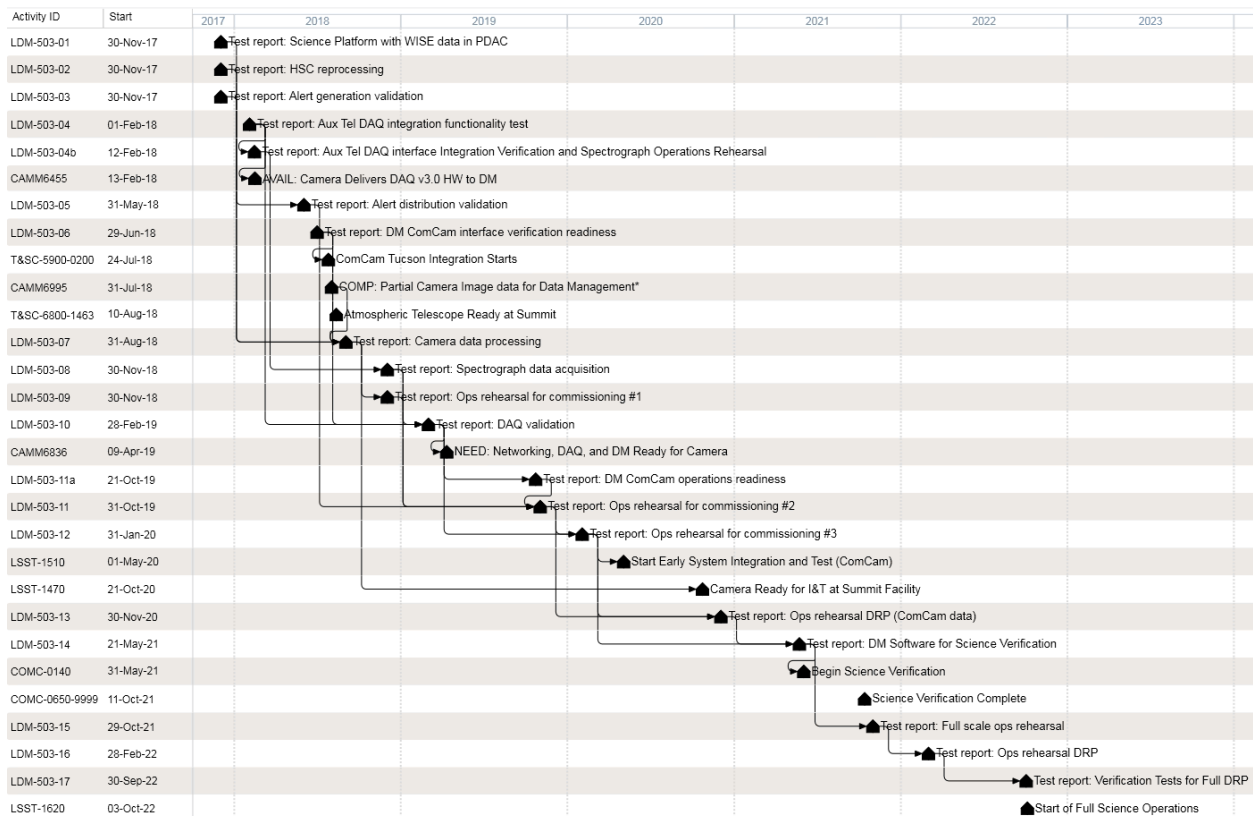


FIGURE 9: DM major milestones—designated as LDM-503-x—in the LSST schedule. These milestones are defined at level 2 according to the scheme described in Section 4.3.

TABLE 2: DM top level Work Breakdown Structure

| WBS      | Description                               | Lead Institution         |
|----------|---|--------------------------|
| 1.02C.01 | System Management                         | LSST Tucson              |
| 1.02C.02 | Systems Engineering                       | LSST Tucson              |
| 1.02C.03 | Alert Production                          | University of Washington |
| 1.02C.04 | Data Release Production                   | Princeton University     |
| 1.02C.05 | Science User Interface and Tools          | Caltech IPAC             |
| 1.02C.06 | Science Data Archive                      | SLAC                     |
| 1.02C.07 | Processing Control & Site Infrastructure  | NCSA                     |
| 1.02C.08 | International Communications. & Base Site | LSST Tucson              |
| 1.02C.09 | Systems Integration & Test                | NCSA & LSST Tucson       |
| 1.02C.10 | Science Quality & Reliability Engineering | LSST Tucson              |

## 4.2 Work Breakdown Structure

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

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

## 4.3 Planning Process

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

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

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

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

**Level 4** Internal milestones within a team.

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

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

As the due date for work approaches, the actions required to complete each planning package—and hence meet the associated milestones—must be defined in detail. The DM team divides the year into two six month long *cycles*, running from November through May (the “spring cycle”) and from June through October (the “fall cycle”). At the start of each cycle, the DM Leadership Team (Section 7.3) agrees on the detailed plan of work for the cycle, and this is loaded in to JIRA as a series of “epics”, corresponding to projects of a few person-months duration, each with defined start and end dates and resource loading. The DM team records work and tracks progress against epics using JIRA; the Project Controller (Section 6.4) arranges for this information to be ingested to and made available within the PMCS.

This process is described in detail in DMTN-020.

## 5 Products

The products of DM are not the data products defined in LSE-163, rather they are the artifacts, systems and services we need to produce those products. Section 2 outlines the highest level of this for DM while Appendix A defines the complete product tree for DM and it is pictorially represented at a trimmed level in Figure 10. LDM-148 provides a trace of products to

requirements, while Appendix A provides a full list with technical manager, WBS element and product owner for each. Our primary guiding requirements come from LSE-30, the Observatory System Specification (OSS), with Appendix D tracing DM requirements [LSE-61] to OSS, and Appendix E tracing the relevant OSS requirements to DM.

Figure 10 contains the WBS element associated with the component as well as any git repositories belonging to them. Since the figure stops at level 3 most git repositories will only be found in the full list in Appendix A.

Every git repository should appear in Appendix A and hence have a technical manager and product owner identified. The table is hierarchical hence if the manager/owner is not filled in (or the individual is no longer with the project) we may go to the parent element manager/owner. Some work remains to finish rationalizing the components and repositories.

Every JIRA component should map to one row in Appendix A thus providing a contact for that component. Some JIRA components are not physical products - they should still appear in the Appendix A which is the single source for DM of component ownership. Some work is also needed to rationalize the JIRA components.

## 6 Roles in Data Management

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

### 6.1 DM Project Manager (DMPM)

The DM Project Manager is responsible for the efficient coordination of all LSST activities and responsibilities assigned to the Data Management Subsystem. The DM Project Manager has the responsibility of establishing the organization, resources, and work assignments to provide DM solutions. The DM Project Manager serves as the DM representative in the LSST Project Office and in that role is responsible for presenting DM initiative status and submitting new DM initiatives to be considered for approval. Ultimately, the DM Project Manager, in conjunction with his/her peer Project Managers (Telescope, Camera), is responsible for delivering an integrated LSST system. The DM Project Manager reports to the LSST Project Manager. Specific responsibilities include:

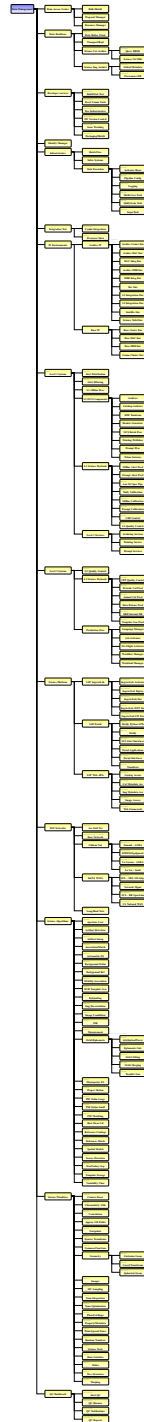


FIGURE 10: DM product tree. - there are over 200 products, this tree is to convey an idea of the products and is truncated to make it somewhat legible. The full list is given in Appendix A

- 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 (WBS), budgets and resource estimates
- Approve or execute as appropriate all DM outsourcing contracts
- Convene and/or participate in all DM reviews
- Co-chair the DM Leadership Team (Section 7.3)

## 6.2 DM Deputy Project Manager (DDMPM)

The PM and deputy will work together 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 DM Project Manager will keep the Deputy Project Manager informed of all DM situations such that the deputy may effectively act in place of the Project Manager when absent.

## 6.3 DM Subsystem Scientist (DMSS)

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

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

Specific responsibilities and authorities include:

- Communicates with DM science stakeholders (LSST Project Scientist and Team, advisory

bodies, the science community) to understand their needs and identifies aspects to be satisfied by the DM Subsystem.

- Develops, maintains, and articulates the vision of DM products and services responsive to stakeholder needs.
- Works with the LSST Project Scientist to communicate the DM System vision to DM stakeholders. Works with the DM Project Manager 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 DM Project Manager 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 DM Project Manager on science-driven prioritization of construction activities.
- Validates the science quality of DM deliverables and the capability of all elements of the DM System to achieve LSST science goals.
- Serves as Data Management Liaison as requested by LSST Science Collaborations
- Provides safe, effective, efficient operations in a respectful work environment.

Specific authorities include:

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

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

## 6.4 Project Controller/Scheduler

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

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

## 6.5 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.

## 6.6 Pipelines Scientist

Several DM products come together to form the LSST pipeline. The Pipelines Scientist is the product owner for the overall pipeline.

The Pipelines Scientist shall:



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

## 6.7 Systems Engineer

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

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

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

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

- Define and enforce standards for internal interfaces

- Direct the Interface Scientist's (Section 6.8) work on external ICDs

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

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

Finally, the Systems Engineer represents DM on the LSST CCB.

## 6.8 DM Interface Scientist (DMIS)

The DM Interface Scientist is responsible for all external interfaces to the DM Subsystem. This includes ensuring that appropriate tests for those interfaces are defined. This is a responsibility delegated from the DM Systems Engineer (Section 6.7).

## 6.9 Software Architect

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

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

The Software Architect will work closely with the Systems Engineer (Section 6.7) to ensure that processes are in place for tracing requirements to the codebase and providing hooks to ensure that requirement verification is possible.

## 6.10 Operations Architect

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

Specific responsibilities include:

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

## 6.11 Release Manager (RM)

The DM Release Manager (RM) is responsible for maintaining and applying the release policy. Specifically, the DM Release Manager 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 DM Sub-system Scientist, and the technical managers;
- Ensure that each release is accompanied by an appropriate documentation pack, including user manuals, test specifications and reports, and release notes;
- Ensure the release is delivered to NCSA for acceptance;
- Work with technical managers to coordinate bug fixes and maintenance of long-term support releases;
- Serve as a member of the DMCCB (Section 7.4).

## 6.12 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 DM Project Manager and Subsystem Scientist.

### 6.12.1 Technical/Control Account Manager (T/CAM)

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

- Develop, resource load, and maintain the plan for executing the DM construction project within the scope of their WBS
- Synchronize the construction schedule with development in WBS elements managed by other T/CAMs
- Maintain the budget for their WBS and ensuring that all work undertaken is charged to the correct accounts
- Work with the relevant Science Leads and Product Owners (Section 6.5) to develop the detailed plan for each cycle and sprint as required
- Work with the DM Project Controller (Section 6.4) to ensure that all plans and milestones are captured in the LSST Project Controls system
- Perform day-to-day management of staff within their WBS
- Perform the role of “scrum-master” during agile development
- Report activities as required, including providing input for monthly status reports.

### 6.12.2 Institutional Science/Engineering Lead

The Institutional Science/Engineering Leads serve as product owners (Section 6.5) for the major components of the DM System (Alert Production, Data Release Production, Science User

Interface etc).

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

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

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

### **6.13 DM Science Validation Scientist**

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

## **7 Data Management Groups/Bodies**

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

### **7.1 System Science Team**

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

### 7.1.1 Organization and Goals

The System Science Team includes:

- DM Subsystem Scientist (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 DM Subsystem Scientist (as the overall DM Product Owner) in ensuring that Data Management Subsystem's initiatives provide solutions that meet the overall LSST science goals.
- Support the Institutional Science Leads in their roles as Product Owners for elements of the DM system their respective institutions have been tasked to deliver.
- Support the DM Science Validation Scientist, who organizes and coordinates the science validation efforts (LDM-503).
- Guide the work of System Science Analysts, who generally lead and/or execute studies needed to support SST work.
- Provide a venue for communication with the Science Pipelines Scientist, who broadly advises on topics related to the impact of science pipelines on delivered science and vice versa (Section 6.6).

The members of the System Science Team report to the DM Subsystem Scientist 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 DM Project Manager and DM Technical Managers to communicate and articulate the DM System vision and requirements to the DM engineering team.
- Identify, develop, and champion new scientific opportunities for the LSST DM System, as well as identify risks where possible.
- Develop change proposals and/or evaluate the scientific impact of proposed changes to DM deliverables driven by schedule, budget, or other constraints.
- Lead the Science Verification of the deliverables of the DM subsystem.

### 7.1.2 Communications

DM System Science Team communication mechanisms are described on the SST Confluence page at <http://ls.st/sst>.

## 7.2 DM Systems Engineering Team

The Systems Engineering Team is led by the DMPM (Section 6.1) and looks after all aspects of systems engineering. It is comprised of not only the Systems Engineer (Section 6.7) but also the Software Architect (Section 6.9), Operations Architect (Section 6.10), Pipeline Scientist (Section 6.6) and Interface Scientist (Section 6.8).

While the product owners (Section 6.5) 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<sup>3</sup>

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<sup>3</sup>In this sense, “products” are the software and systems which produce data products, rather than the data

- 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.

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

### 7.2.1 Communications

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

## 7.3 DM Leadership Team

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

- Charter/purpose
  - Maintain scope of work and keep within resource allocation across DM
  - Ensure overall project management integrity across DM
  - Ensure Earned Value management requirements are met
- Membership
  - Co-chaired by the DM Project Manager (Section 6.1) and DM Project Scientist (Section 6.3)

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products themselves. See also 5.



- Lead Institution Technical/Control Account Managers (T/CAMs; Section 6.12.1)
- Institutional Science or Engineering Leads (Section 6.12.2)
- Members of the DM Systems Engineering Team (Section 7.2)
- Responsibilities
  - Prepares all budgets, schedules, plans
  - Meets every week to track progress, address issues/risks, adjust work assignments and schedules, and disseminate/discuss general PM communications

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

### 7.3.1 Communications

A mailing list<sup>4</sup> exists for DMLT related messages. On Mondays the DMLT hold a brief (30 to 45 minutes) telecon. This serves to:

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

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

- Discuss detailed planning for the next cycle

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<sup>4</sup>[lsst-dmlt@listserv.lsstcorp.org](mailto:lsst-dmlt@listserv.lsstcorp.org)

- Discuss technical topics in a face to face environment
- Work together on critical issues
- Help make DM function as a team

## 7.4 DM Change Control Board

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

- Charter/purpose
  - Ensure that the DM Technical Baseline (LDM-xxx) documents are baselined and subsequently changed only when necessary and according to LSST and DM configuration control processes
- Membership
  - Chaired by the Systems Engineer
  - Members include the DM Software Architect (§6.9), DM Operations Architect (§6.10), DM System Interfaces Scientist (§6.8), DM SQuaRE T/CAM (§6.12.1), DM Release Manager (§6.11) and DM Project Manager (§6.1)
  - For on-line virtual meetings, if a consensus or quorum or is not reached within one week, the DM Project Manager will make a unilateral decision
- Responsibilities
  - Determines when specification and deliverables are of sufficient maturity and quality to be baselined (placed under configuration controlled status) or released.
  - Reviews and approves/rejects proposed changes to baselined items

## 7.5 DM Science Validation Team

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

The DM Science Validation Team is chaired by the DM Science Validation Scientist (Section 6.13). Its membership includes the DM Pipelines Scientist (Section 6.6) and the various Institutional Science/Engineering Leads (Section 6.12.2). Depending on the activities currently being executed, other members of the System Science Team (Section 7.1), the wider DM Construction Project, and/or external experts may be temporarily added to the team.

## 8 Lead institutions in DM

### 8.1 LSST Tucson

The LSST Project Office in Tucson hosts the DM Project Manager (Section 6.1) and the Systems Engineer (Section 6.7). In addition, it is home to the Science Quality and Reliability Engineering (SQuaRE) group and LSST International Communications and Base Site (ICBS) groups, described below.

#### 8.1.1 Science Quality and Reliability Engineering

The SQuaRE group is primarily charged with providing technical feedback to the DM Project Manager 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<sup>5</sup>
- Infrastructure development to support the generation, collection, and analysis of data quality and performance metrics

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<sup>5</sup>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.

- 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
- Support of publicly released software products, including porting and distributing them according to the scientific community's needs

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 DM Subsystem Scientist.

### **8.1.2 LSST International Communications and Base Site**

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

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

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

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

## 8.2 Princeton University

Princeton University hosts the Pipelines Scientist (Section 6.6) and the Data Release Production group, described below.

### 8.2.1 Data Release Production

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

Development of software in support of annual data releases and of reusable software components are carried out under the direction of the DRP Science Lead, who acts as product owner for this part of the system. The DRP Science Lead is ultimately responsible to both the Pipelines Scientist (Section 6.6) and DM Subsystem Scientist (Section 6.3).

The product owner for the calibration products is the LSST Calibration Scientist (who doubles as the Pipelines Scientist, Section 6.6). 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 Science Pipelines T/CAM, reporting to the DM Project Manager (Section 6.1).

The DRP group is responsible for delivering software which adheres to the architectural and testing standard defined by the Software Architect (Section 6.9). In addition, the DRP group is responsible for testing each major product delivered to demonstrate its fitness for purpose, and working with the DM Subsystem Scientist and DM System Science Team (Section 7.1) to define, run and analyze “data challenges” and other large scale tests to validate the performance of the data release production system.

## 8.3 The University of Washington

### 8.3.1 Alert Production

The Alert Production (AP) group has 4 major areas of activity within DM.

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

Development of software in support of the alert generation pipeline, alert distribution system, MOPS and of reusable software components are carried out under the direction of the AP Science Lead, who acts as product owner for this part of the system. The AP Science Lead is ultimately responsible to both the Pipelines Scientist (Section 6.6) and DM Subsystem Scientist (Section 6.3).

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

The AP group is responsible for delivering software which adheres to the architectural and testing standard defined by the Software Architect (Section 6.9). In addition, the AP group is responsible for testing each major product delivered to demonstrate its fitness for purpose, and working with the DM Subsystem Scientist and DM System Science Team (Section 7.1) to define, run and analyze “data challenges” and other large scale tests to validate the performance of the data release production system.

## 8.4 California Institute of Technology/IPAC

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

### 8.4.1 Science User Interface and Tools

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

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

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

Design and implement the Portal Aspect of the LSST Science Platform for Data Access Center, based on Firefly, providing scientists an easy to use interface to search, visualize, and explore

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

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

## 8.5 SLAC

SLAC hosts the DM Software Architect (Section 6.9) 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 (DAX) group has the following major areas of activity within DM:

- Provides software to support ingestion, indexing, query, and administration of DM catalog and image data products, data provenance, and other associated metadata within the LSST Data Access Centers;
- Provides implementations of data access services (including IVOA services), as well as associated client libraries, to be hosted within the LSST Data Access Centers, which facilitate interaction between LSST data products and tools provided by both other parts of the LSST project and by the astronomical research community at large;
- Provides a Python framework (the “Data Butler”), used by the LSST science pipelines, to facilitate abstract persistence/retrieval of in-memory Python objects to/from generic archives of those objects;



- Provides a Python framework (“SuperTask”) which serves as an interface layer between pipeline orchestration and algorithmic code, and which allows pipelines to be constructed, configured, and run at the level of a single node or a group of tightly-synchronized nodes;
- Provides support for various middleware and infrastructure toolkits used by DM which would otherwise have no authoritative home institution within DM (e.g. logging support library, spherical geometry support library).

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

The DAX group is responsible for delivering software which adheres to the architectural and testing standard defined by the Software Architect (Section 6.9). 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 Project Office Information Security Officer and Computer Security group, as well as the DM group responsible for construction and integration of the LSST Data Facility (LDF), described below.

The LSST Data Facility group has the following major areas of activity within DM:

1. Construction of services, including software and operational methods, supporting observatory operations and nightly data production (Level 1 Services). Level 1 Services ingest raw data from all Observatory cameras and the Engineering and Facilities Database (EFD) into the central archive; provide a dedicated computing service controllable by the Observatory Control System (OCS) for prompt generation of nightly calibration assessments, science image parameters, and transient alerts; and provide computing services, data access, and a QA portal for Observatory staff.
2. Construction of services, including software and operational methods, for bulk batch data production. Batch Production Services execute processing campaigns, using re-

sources 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.

3. Construction of services, including software and operational methods, for hosting and operating data access services for community users. These services host the SUIT portal, manage the JupyterLab environment, provide computing and data storage for the Data Access Centers, enable bulk data export, and host the LSST limited alert-filtering service and feeds to community-provided brokers.
4. 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.
5. 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.
6. 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.
7. 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.
8. 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

DM is essentially a large software project; in particular we are developing scientific software with the uncertainties that brings with it. An Agile process [27] is particularly suited to sci-

entific software development. The development follows a six month cyclical approach and DM products are under continuous integration using the Jenkins tool. All code is developed in the GitHub open source repository under an open source license. Releases follow a six-month cadence but the code on the master branch is intended to be always working with the continuous integration system ensuring this.

How this fits with the Earned Value System is described in DMTN-020.

## 9.1 Communications

The main stories for the six-month planning period are discussed at the DMLT F2F meeting near the beginning of the cycle (See Section 7.3).

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

## 9.2 Conventions

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

## 9.3 Reviews

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

# 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 problem should be brought as early as possible to the DM Project manager. The PM will attempt to mediate a resolution. The PM will consult with DMLT, DM System Science Team and DM Systems Engineering if there are Scientific or technical impacts to be considered.

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

## A DM Product List

| WBS               | Product             | Description  | Manager           | Owner       | Packages                                       |
|-------------------|---------------------|--|-------------------|-------------|--|
| 1.02C             | Data Management     | Data Management System   | William O Mullane | Mario Juric |  |
| .                 | Data Access Center  | DAC Software   |                   |             |  |
| .                 | Bulk Distrib        | Bulk Distribution System   | Joel Plutchak     |             |  |
| .                 | Proposal Manager    | Proposal Manager   | Joel Plutchak     |             |  |
| .                 | Resource Manager    | DAC Resource Manager   | Joel Plutchak     |             |  |
| .                 | Data Backbone       | Data Backbone System   |                   |             |  |
| 1.02C.06.02.01    | Data Butler Client  | Data Butler data access client library                             | Fritz Mueller     |             | daf_persistence/ db/ daf_fmt_*                 |
| .                 | Transport/Repl      | File and database transport and replication with caching endpoints | Joel Plutchak     |             |  |
| .                 | Science Cat Archive | Science catalog archive  |                   |             |  |
| 1.02C.06.02.03    | Qserv DBMS          | Qserv distributed database system                                  | Fritz Mueller     |             | qserv/ partition/ scisql                       |
| .                 | Science Cat DBs     | Science catalog databases  |                   |             |  |
| 1.02C.03.03       | Alert DB            | Alert database   | Simon Krughoff    | Eric Bellm  |  |
| 1.02C.06.01.01    | L1 Catalog DB       | L1 catalog database  | Fritz Mueller     |             | cat  |
| 1.02C.06.01.01    | L2 Catalog DB       | L2 catalog database  | Fritz Mueller     |             | cat  |
| .                 | Science Img Archive | Science image archive  |                   |             |  |
| 1.02C.06.02.05    | Global Metadata     | Global metadata service  | Fritz Mueller     |             |  |
| 1.02C.06.01.01    | Provenance DB       | Provenance database  | Fritz Mueller     |             |  |
| .                 | Developer services  | Developer services   |                   |             |  |
| 1.02C.10.02.03.01 | Build/Unit Test     | Build and unit test service  | Frossie Economou  |             | sconsUtils/ base/ lsstsw/ lsst_build           |
| 1.02C.10.02.03.04 | Devel Comm Tools    | Developer communication tools                                      | Frossie Economou  |             |  |
| 1.02C.10.02.03.03 | Doc Infrastructure  | Documentation infrastructure                                       | Frossie Economou  |             | lsst-texmf/ templates/ lsstDoxygen             |
| 1.02C.10.02.03.01 | SW Version Control  | Software version control system                                    | Frossie Economou  |             |  |
| 1.02C.10.02.03.05 | Issue Tracking      | Issue (ticket) tracking service                                    | Frossie Economou  |             |  |
| 1.02C.10.02.03.02 | Packaging/Distrib   | Packaging and distribution   | Frossie Economou  |             | lsst/ shebangtron/ lsst_dm_stack_demo          |
| .                 | Identity Manager    | Identity (Authentication and Authorization) Manager                | Joel Plutchak     |             |  |
| .                 | Infrastructure      | Infrastructure Software Systems                                    |                   |             |  |
| .                 | Batch Proc          | Batch Processing System  | Joel Plutchak     |             |  |
| .                 | Infra Systems       | Filesystems/ provisioning/monitoring systems and system management | Joel Plutchak     |             |  |
| .                 | Task Execution      | Task execution framework   |                   |             |  |
| 1.02C.06.03       | Activator Bases     | Activator base and Command Line Activator                          | Fritz Mueller     |             |  |
| 1.02C.06.03       | Pipeline Config     | Pipeline configuration   | Fritz Mueller     |             | pex_config                                     |
| 1.02C.06.04.01    | Logging             | Logging  | Fritz Mueller     |             | log  |
| 1.02C.06.03       | Multi-Core Task     | Multi-core Task API  | Fritz Mueller     |             |  |
| 1.02C.06.03       | Multi-Node Task     | Multi-node Task API  | Fritz Mueller     |             | pipe_base/ ctrl_pool                           |
| 1.02C.06.03       | SuperTask           | SuperTask  | Fritz Mueller     |             | pipe_supertask/ pipe_base/ pex_exceptions      |
| .                 | Integration Test    | Integration and test   |                   |             |  |
| 1.02C.10.02.03.01 | Contin Integration  | Automated integration and test services                            | Frossie Economou  |             | Jenkins  |
| 1.02C.01.01       | Precursor Data      | Precursor data for development and testing                         | Mario Juric       |             | obs_*/ validation_data_*/ test-data_*/ afwdata |
| .                 | IT Environments     | Computing and Storage Infrastructure including provisioning        |                   |             |  |
| .                 | Archive IT          | Archive IT Environments  |                   |             |  |
| .                 | Archive Center Env  | Archive Production Center environment                              | Joel Plutchak     |             |  |
| .                 | Archive DAC Env     | Archive DAC environment  | Joel Plutchak     |             |  |
| .                 | DAC Integ Env       | DAC Integration environment (PDAC)                                 | Joel Plutchak     |             |  |
| .                 | Archive DBB Env     | Archive Data Backbone endpoints and storage                        | Joel Plutchak     |             |  |
| .                 | DBB Integ Env       | Data Backbone Integration environment                              | Joel Plutchak     |             |  |
| .                 | Dev Env             | Developer environment  | Joel Plutchak     |             |  |
| .                 | L1 Integration Env  | Level 1 Integration environment                                    | Joel Plutchak     |             |  |
| .                 | L2 Integration Env  | Level 2 Integration environment                                    | Joel Plutchak     |             |  |
| .                 | Satellite Env       | Satellite compute environment                                      | Joel Plutchak     |             |  |
| .                 | Science Valid Env   | Archive science validation environment                             | Joel Plutchak     |             |  |
| .                 | Base IT             | Base IT Environments   |                   |             |  |
| .                 | Base Center Env     | Base Production Center environment                                 | Joel Plutchak     |             |  |
| .                 | Base DAC Env        | Base DAC environment   | Joel Plutchak     |             |  |



|             |                     |   |                |                  |                         |
|-------------|---------------------|---|----------------|------------------|-------------------------|
|             | Base DBB Env        | Base Data Backbone endpoints and storage                  | Joel Plutchak  |                  |                         |
|             | Comm Cluster Env    | Commissioning Cluster environment                         | Joel Plutchak  |                  |                         |
| 1.02C.03    | Level 1 System      | Level 1 System  | Simon Krughoff | Eric Bellm       |                         |
| 1.02C.03.03 | Alert Distribution  | Alert distribution service                                | Simon Krughoff | Eric Bellm       |                         |
| 1.02C.03.03 | Alert Filtering     | Alert filtering service                                   | Simon Krughoff | Eric Bellm       |                         |
|             | L1 Offline Proc     | L1 Offline Processing System                              | Joel Plutchak  |                  |                         |
| .           | L1 OCS Components   | Level 1 Online (OCS-connected) components                 |                |                  |                         |
|             | Archiver            | Archiving Commandable SAL Component                       | Joel Plutchak  | Felipe Menanteau | ctrl_iip                |
|             | Catchup Archiver    | Catch-up Archiving Commandable SAL Component              | Joel Plutchak  | Felipe Menanteau | ctrl_iip                |
|             | EFD Transform       | EFD Transformation Commandable SAL Component              | Joel Plutchak  | Felipe Menanteau |                         |
|             | Header Generator    | Header Generator Commandable SAL Component                | Joel Plutchak  | Felipe Menanteau |                         |
|             | OCS Batch Proc      | OCS-Driven Batch Processing Commandable SAL Component     | Joel Plutchak  | Felipe Menanteau | ctrl_iip                |
|             | Pointing Publisher  | Pointing Prediction Publishing Commandable SAL Component  | Joel Plutchak  | Felipe Menanteau |                         |
|             | Prompt Proc         | Prompt Processing Commandable SAL Component               | Joel Plutchak  | Felipe Menanteau | ctrl_iip                |
|             | Telem Gateway       | Telemetry Gateway Commandable SAL Component               | Joel Plutchak  | Felipe Menanteau | ctrl_iip                |
| .           | L1 Science Payloads | L1 science payloads                                       |                |                  |                         |
| .           | Offline Alert Prod  | Offline Alert Production payload                          |                |                  |                         |
| 1.02C.03.03 | Offline Alert Gen   | Offline alert generation pipeline                         | Simon Krughoff | Eric Bellm       |                         |
| 1.02C.03.06 | Moving Object       | Moving object pipeline                                    | Simon Krughoff | Eric Bellm       | mops_daymops            |
| 1.02C.03.04 | Preccovery          | Preccovery and forced photometry pipeline                 | Simon Krughoff | Eric Bellm       |                         |
| 1.02C.03.01 | Offline SFP         | Offline single frame processing pipeline                  | Simon Krughoff | Eric Bellm       |                         |
| .           | Prompt Alert Prod   | Prompt Processing Alert Production payload                |                |                  |                         |
| 1.02C.03.03 | Alert Gen Pipe      | Alert generation pipeline                                 | Simon Krughoff | Eric Bellm       |                         |
| 1.02C.03.01 | Single Frame Pipe   | Single frame processing pipeline                          | Simon Krughoff | Eric Bellm       | pipe_drivers            |
| 1.02C.04.02 | Aux Tel Spec Pipe   | Offline Auxiliary Telescope spectrograph pipeline         | John Swinbank  | Jim Bosch        |                         |
| 1.02C.04.02 | Daily Calibration   | OCS-Controlled batch daily calibration update payload     | John Swinbank  | Jim Bosch        |                         |
| 1.02C.04.02 | Offline Calibration | Offline calibration single frame processing pipeline      | John Swinbank  | Jim Bosch        | pipe_drivers            |
| 1.02C.04.02 | Prompt Calibration  | Prompt Processing raw calibration validation payload      | John Swinbank  | Jim Bosch        | pipe_drivers            |
| 1.02C.04.02 | CBP Control         | OCS control scripts for collimated beam projector control | John Swinbank  | Jim Bosch        |                         |
| 1.02C.03    | L1 Quality Control  | L1 QC measurement generators                              | Simon Krughoff | Eric Bellm       |                         |
| .           | Level 1 Services    | Level 1 Services  |                |                  |                         |
| .           | Archiving Services  | Image and EFD Archiving Services                          |                |                  |                         |
|             | Aux Tel Archiver    | Auxiliary Telescope Archiving Service                     |                |                  |                         |
|             | ComCam Archiver     | ComCam Archiving Service                                  |                |                  |                         |
|             | LSSTCam Archiver    | LSSTCam Archiving Service                                 |                |                  |                         |
|             | ComCam Catchup      | ComCam Catchup Archiving Service                          |                |                  |                         |
|             | LSSTCam Catchup     | LSSTCam Catchup Archiving Service                         |                |                  |                         |
|             | EFD Transf Service  | EFD Transformation Service                                |                |                  |                         |
|             | Pointing Service    | Pointing Prediction Publishing Service                    |                |                  |                         |
| .           | Prompt Services     | Prompt Processing Services                                |                |                  |                         |
|             | ComCam Prompt       | ComCam Prompt Processing Service                          |                |                  |                         |
|             | LSSTCam Prompt      | LSSTCam Prompt Processing Service                         |                |                  |                         |
| .           | Level 2 System      | Level 2 System  |                |                  |                         |
| 1.02C.04.07 | L2 Quality Control  | L2 QC measurement generators                              | John Swinbank  | Jim Bosch        | validate_drp/<br>ci_hsc |
| .           | L2 Science Payloads | L2 science payloads                                       |                |                  |                         |
| 1.02C.04.02 | CPP Quality Control | CPP QC measurement generators                             | John Swinbank  | Jim Bosch        |                         |
| 1.02C.04.02 | Periodic Cal Prod   | Periodic CPP payload                                      | John Swinbank  | Jim Bosch        |                         |
| 1.02C.04.02 | Annual Cal Prod     | Annual CPP payload  | John Swinbank  | Jim Bosch        |                         |
| .           | Data Release Prod   | Annual mini-DRP and DRP payload                           |                |                  |                         |
| 1.02C.04.04 | Coadd and Diff      | Image coaddition and differencing                         | John Swinbank  | Jim Bosch        | pipe_drivers            |
| 1.02C.04.05 | Coadd Processing    | Coadd processing  | John Swinbank  | Jim Bosch        | pipe_drivers            |
| 1.02C.04.06 | DRP Postprocessing  | DRP Postprocessing  | John Swinbank  | Jim Bosch        |                         |



|   |                      |  |  |                           |  |
|---|----------------------|--|--|---------------------------|--|
| 1.02C.04.03                               | Image Char and Cal   | Image characterization and calibration   | John Swinbank                            | Jim Bosch                 | pipe_drivers                                   |
| 1.02C.04.06                               | Object Char          | Multi-epoch object characterization  | John Swinbank                            | Jim Bosch                 |  |
| 1.02C.04.05                               | Overlap Resolution   | Overlap resolution   | John Swinbank                            | Jim Bosch                 |  |
| 1.02C.06.01.01                            | DRP-Internal DB      | DRP-internal database  | Fritz Mueller                            |                           | daf_ingest                                     |
| 1.02C.03.04                               | Template Gen Prod    | Template generation payload  | Simon Krughoff                           | Eric Bellm                |  |
| .   | Production Exec      | Production Execution System  |  |                           |  |
|   | Campaign Manager     | Campaign Manager   | Joel Plutchak                            |                           |  |
|   | Job Activator        | Job Activator  | Joel Plutchak                            |                           |  |
|   | Pre-Flight Activator | Pre-flight Activator   | Joel Plutchak                            |                           |  |
|   | Workflow Manager     | Workflow Manager/Orchestrator  | Joel Plutchak                            |                           | ctrl_orca/<br>ctrl_execute/<br>ctrl_provenance |
|   | Workload Manager     | Workload Manager   | Joel Plutchak                            |                           |  |
| .   | Science Platform     | LSST Science Platform  |  |                           |  |
| .   | LSP JupyterLab       | LSST Science Platform JupyterLab Aspect  |  |                           |  |
| 1.02C.10.02.02.05                         | JupyterLab Activator | JupyterLab Activators  | Frossie Economou                         |                           |  |
| 1.02C.10.02.02.06                         | JupyterLab Deploy    | JupyterHub deployment  | Frossie Economou                         |                           |  |
| 1.02C.10.02.02.01                         | JupyterLab Env       | Basic JupyterLab environment   | Frossie Economou                         |                           |  |
| 1.02C.05.07                               | JupyterLab SUIT Intf | JupyterLab visualization widgets and other JupyterHub/Portal bridges                   | Xiuqin Wu                                |                           |  |
| 1.02C.10.02.02.04                         | JupyterLab SW Env    | JupyterLab software environments   | Frossie Economou                         |                           |  |
| .   | LSP Portal           | LSST Science Platform Portal Aspect  |  |                           |  |
| 1.02C.05.07                               | Firefly Python APIs  | Low-level Python API to Firefly  | Xiuqin Wu                                |                           | firefly_client                                 |
| 1.02C.05.06                               | Firefly              | LSST-independent Firefly framework and visualization capabilities                      | Xiuqin Wu                                |                           | firefly  |
| 1.02C.05.09                               | SUI Alert Interfaces | Portal alert interfaces to configure alert subscriptions                               | Xiuqin Wu                                |                           |  |
| 1.02C.05.08                               | Portal Applications  | Web application(s) implementing the Portal   | Xiuqin Wu                                |                           |  |
| user workspace                            | Portal Interfaces    | Interfaces to DAX  | identity management                      | 1.02C.05.07               | Xiuqin Wu                                      |
| 1.02C.05.07                               | Visualizers          | Firefly components to visualize LSST Science Pipelines data objects                    | Xiuqin Wu                                |                           |  |
| .   | LSP Web APIs         | LSST Science Platform Web APIs Aspect  |  |                           |  |
| 1.02C.06.02.05                            | Catalog Access       | Catalog access   | Fritz Mueller                            |                           | dax_dbserve                                    |
| 1.02C.06.02.05                            | Cat Metadata Acc     | Catalog metadata access  | Fritz Mueller                            |                           | dax_metaserv                                   |
| 1.02C.06.02.05                            | Img Metadata Acc     | Image metadata access  | Fritz Mueller                            |                           | dax_metaserv                                   |
| 1.02C.06.02.04                            | Image Access         | Image access   | Fritz Mueller                            |                           | dax_imgserv                                    |
| 1.02C.06.02.02                            | Web Framework        | Web services framework   | Fritz Mueller                            |                           | dax_webserv/<br>dax_webservcommon              |
| .   | DM Networks          | Data Management Provided Networks  |  |                           |  |
| 1.02C.07.08.06                            | Arc Extl Net         | Archive External Network   | Don Petravick                            | D Wheeler                 |  |
| 1.02C.07.08.03<br>(moving to<br>1.02C.08) | Base Network         | Base Local Area Network  | Don Petravick<br>(moving to Jeff Kantor) | Jeff Kantor/Don Petravick |  |
| .   | Chilean Nat          | Summit - Gatehouse La Serena - Gatehouse/ La Serena - Santiago Networks DWDM Equipment |  |                           |  |
| 1.02C.08.03.01.03                         | Summit - AURA        | Summit - AURA Gatehouse Network  | Jeff Kantor                              | Jeff Kantor               |  |
| 1.02C.08.03.01.04                         | DWDM Equipment       | DWDM Equipment   | Jeff Kantor                              | Jeff Kantor               |  |
| 1.02C.08.03.01.01A                        | La Serena - AURA     | La Serena - AURA Gatehouse Network   | Jeff Kantor                              | Jeff Kantor               |  |
| 1.02C.08.03.01.01                         | La Ser - Santi       | La Serena - Santiago Network   | Jeff Kantor                              | Jeff Kantor               |  |
| .   | Int/US WANS          | International WAN/US WAN   |  |                           |  |
| 1.02C.08.03.02.01                         | SCL - MIA 100 Gbps   | Santiago - Miami 100 Gbps Ring   | Jeff Kantor                              | Jeff Kantor               |  |
| 1.02C.08.03.02.02                         | Network Mgmt         | Network Management   | Jeff Kantor                              | Jeff Kantor               |  |
| 1.02C.08.03.02.03                         | SCL - BR Spectrum    | Santiago - Boca Raton Spectrum   | Jeff Kantor                              | Jeff Kantor               |  |
| 1.02C.08.03.02.01                         | US National WAN      | US National WAN  | Jeff Kantor                              | Jeff Kantor               |  |
| 1.02C.08.03                               | Long-Haul Nets       | Summit - Base/ Base - Archive/ US Networks   | Jeff Kantor                              | Jeff Kantor               |  |
| .   | Science Algorithms   | Common science algorithmic components  |  |                           |  |
| 1.02C.04.06                               | Aperture Corr        | Aperture correction  | John Swinbank                            | Jim Bosch                 |  |
| 1.02C.03.01                               | Artifact Detection   | Artifact detection   | Simon Krughoff                           | Eric Bellm                | meas_algorithms                                |
| 1.02C.03.01                               | Artifact Interp      | Artifact interpolation   | Simon Krughoff                           | Eric Bellm                |  |
| 1.02C.04.06                               | Association/Match    | Association and matching   | John Swinbank                            | Jim Bosch                 |  |
| 1.02C.03.07                               | Astrometric Fit      | Astrometric fitting  | Simon Krughoff                           | Eric Bellm                | jointcal/<br>meas_mosaic                       |
| 1.02C.04.03                               | Background Estim     | Background estimation  | John Swinbank                            | Jim Bosch                 | meas_algorithms                                |
| 1.02C.04.03                               | Background Ref       | Background reference   | John Swinbank                            | Jim Bosch                 |  |



|                   |                    |   |                  |            |  |
|-------------------|--------------------|---|------------------|------------|--|
| 1.02C.03.02       | DIAObj Association | DIAObject association                               | Simon Krughoff   | Eric Bellm |  |
| 1.02C.03.04       | DCR Template Gen   | DCR-corrected template generation                   | Simon Krughoff   | Eric Bellm |  |
| 1.02C.04.05       | Deblending         | Deblending  | John Swinbank    | Jim Bosch  | meas_deblender   |
| 1.02C.03.04       | Img Decorrelation  | Image decorrelation                                 | Simon Krughoff   | Eric Bellm | ip_diffim  |
| 1.02C.04.04       | Image Coaddition   | Image coaddition                                    | John Swinbank    | Jim Bosch  | coadd_utils/ coadd_chisquared                                      |
| 1.02C.03.01       | ISR                | ISR   | Simon Krughoff   | Eric Bellm | pipe_tasks/ ip_isr   |
| 1.02C.04.06       | Measurement        | Measurement   | John Swinbank    | Jim Bosch  | meas_base/ meas_algorithms/<br>meas_extensions_*/<br>meas_modelfit |
| .                 | Orbit/Ephemeris    | Orbit tools   |                  |            |  |
| 1.02C.03.06       | Attribution/Precov | Attribution and precovery                           | Simon Krughoff   | Eric Bellm | mops_daymops   |
| 1.02C.03.06       | Ephemeris Calc     | Ephemeris calculation                               | Simon Krughoff   | Eric Bellm | mops_night   |
| 1.02C.03.06       | Orbit Fitting      | Orbit fitting                                       | Simon Krughoff   | Eric Bellm |  |
| 1.02C.03.06       | Orbit Merging      | Orbit merging                                       | Simon Krughoff   | Eric Bellm |  |
| 1.02C.03.06       | Tracklet Gen       | Tracklet generation                                 | Simon Krughoff   | Eric Bellm | mops_daymops   |
| 1.02C.03.07       | Photometric Fit    | Photometric fitting                                 | Simon Krughoff   | Eric Bellm | jointcal/ meas_mosaic  |
| 1.02C.03.05       | Proper Motion      | Proper motion and parallax                          | Simon Krughoff   | Eric Bellm |  |
| 1.02C.04.03       | PSF Estim Large    | PSF estimation (visit)                              | John Swinbank    | Jim Bosch  |  |
| 1.02C.03.01       | PSF Estim Small    | PSF estimation (1 CCD)                              | Simon Krughoff   | Eric Bellm | meas_algorithms  |
| 1.02C.04.04       | PSF Matching       | PSF matching  | John Swinbank    | Jim Bosch  |  |
|                   | Raw Meas Cal       | Raw measurement calibration                         | John Swinbank    | Jim Bosch  |  |
| 1.02C.03.01       | Reference Catalogs | Reference catalogs                                  | Simon Krughoff   | Eric Bellm | meas_algorithms  |
| 1.02C.03.02       | Reference Match    | Matching to reference catalogs                      | Simon Krughoff   | Eric Bellm |  |
| 1.02C.03.01       | Spatial Models     | Spatial models                                      | Simon Krughoff   | Eric Bellm | afw  |
| 1.02C.04.05       | Source Detection   | Source detection                                    | John Swinbank    | Jim Bosch  |  |
| 1.02C.04.06       | Star/Galaxy Sep    | Star/galaxy classification                          | John Swinbank    | Jim Bosch  |  |
| 1.02C.03.04       | Template Storage   | Difference template storage/retrieval               | Simon Krughoff   | Eric Bellm |  |
| 1.02C.03.04       | Variability Char   | Variability characterization                        | Simon Krughoff   | Eric Bellm |  |
| .                 | Science Primitives | Science software primitives                         |                  |            |  |
| 1.02C.03.05       | Camera Descr       | Camera descriptions                                 | Simon Krughoff   | Eric Bellm | afw  |
| 1.02C.03.05       | Chromaticity Utils | Chromaticity utilities                              | Simon Krughoff   | Eric Bellm | afw  |
| 1.02C.04.01       | Convolution        | Convolution kernels                                 | John Swinbank    | Jim Bosch  | afw  |
| 1.02C.03.05       | Approx 2-D Fields  | Interpolation and approximation of 2-D fields       | Simon Krughoff   | Eric Bellm | afw  |
| 1.02C.04.01       | Footprints         | Footprints  | John Swinbank    | Jim Bosch  | afw  |
| 1.02C.03.05       | Fourier Transforms | Fourier transforms                                  | Simon Krughoff   | Eric Bellm | afw  |
| 1.02C.03.05       | Common Functions   | Common functions and source profiles                | Simon Krughoff   | Eric Bellm | afw  |
| .                 | Geometry           | Geometry primitives                                 |                  |            |  |
| 1.02C.03.05       | Cartesian Geom     | Cartesian geometry                                  | Simon Krughoff   | Eric Bellm |  |
| 1.02C.03.05       | Coord Transforms   | Coordinate transformations                          | Simon Krughoff   | Eric Bellm | afw/ astshim   |
| 1.02C.06.04.03    | Spherical Geom     | Spherical geometry                                  | Fritz Mueller    |            | sphgeom/ skypix/ skymap/ geom/<br>afw                              |
| 1.02C.04.01       | Images             | Images  | John Swinbank    | Jim Bosch  | afw  |
| 1.02C.04.01       | MC Sampling        | Monte Carlo sampling                                | John Swinbank    | Jim Bosch  | afw  |
| 1.02C.04.01       | Num Integration    | Numerical integration                               | John Swinbank    | Jim Bosch  | afw  |
| 1.02C.04.01       | Num Optimization   | Numerical optimization                              | John Swinbank    | Jim Bosch  | afw  |
| 1.02C.04.01       | PhotoCal Repr      | Photometric calibration representation              | John Swinbank    | Jim Bosch  | afw  |
| 1.02C.06.02.01    | Property/Metadata  | Multi-type associative containers                   | Fritz Mueller    |            | daf_base   |
| 1.02C.03.05       | Point-Spread Funcs | Point-spread functions                              | Simon Krughoff   | Eric Bellm | meas_algorithms/ shapelet  |
| 1.02C.04.01       | Random Numbers     | Random number generation                            | John Swinbank    | Jim Bosch  | afw  |
| 1.02C.04.01       | Science Tools      | Science tools                                       | John Swinbank    | Jim Bosch  | afw/ utils   |
| 1.02C.04.01       | Basic Statistics   | Basic statistics                                    | John Swinbank    | Jim Bosch  | afw  |
| 1.02C.04.01       | Tables             | Tables  | John Swinbank    | Jim Bosch  | afw  |
| 1.02C.03.05       | Tree Structures    | Tree structures (for searching)                     | Simon Krughoff   | Eric Bellm | afw  |
| 1.02C.04.01       | Warping            | Warping   | John Swinbank    | Jim Bosch  | afw  |
| .                 | QC Dashboard       | QC measurement collection/storage/dashboard service |                  |            |  |
| 1.02C.10.02.01.04 | Alert QC           | Alert stream QC harness                             | Frossie Economou |            |  |
| 1.02C.10.02.01.01 | QC Harness         | QC harness  | Frossie Economou |            | validate_base  |
| 1.02C.10.02.01.02 | QC Notifications   | QC threshold notification framework                 | Frossie Economou |            |  |
| 1.02C.10.02.01.03 | QC Reports         | QC verification reporting                           | Frossie Economou |            |  |



## B Proposed FY2018 WBS: 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 System

### 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.

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

- Precursor data for development and testing

### **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 been transferred to 1.02C.10.

No products are defined at this level of the WBS.

### **1.02C.02: Systems Engineering**

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

No products are defined at this level of the WBS.

### 1.02C.02.01: Data Management Science

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

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

No products are defined at this level of the WBS.

### 1.02C.02.02: DM System Architecture

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

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

No products are defined at this level of the WBS.

**1.02C.02.02.01: System Architecture Definition** This WBS element includes all activities related to documenting the high-level architecture of the LSST Data Management System.

This includes writing and maintaining documents that define and describe the DMS's high-level components and their interfaces, both internal and external, as well as how they work together and are operated to meet the DM System Requirements. This work is performed in conjunction with the technical leadership of the DM teams as well as that of other LSST subsystems.

No products are defined at this level of the WBS.

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

No products are defined at this level of the WBS.

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

No products are defined at this level of the WBS.

### **1.02C.03: Alert Production**

This WBS element covers three broad areas of work:

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

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

- Level 1 System
- L1 QC measurement generators

#### **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.

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

- Single frame processing pipeline
- Offline single frame processing pipeline
- Reference catalogs
- ISR
- Artifact detection
- Artifact interpolation
- Spatial models
- PSF estimation (1 CCD)

### 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.

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

- Matching to reference catalogs
- DIAObject association

### **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 generation pipeline
- Offline alert generation pipeline
- Alert distribution service
- Alert filtering service
- Alert database

### **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.

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

- Precovery and forced photometry pipeline
- Template generation payload
- Difference template storage/retrieval
- DCR-corrected template generation
- Image decorrelation
- Variability characterization

### **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.

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

- Proper motion and parallax
- Cartesian geometry
- Coordinate transformations
- Chromaticity utilities



- Interpolation and approximation of 2-D fields
- Common functions and source profiles
- Camera descriptions
- Point-spread functions
- Fourier transforms
- Tree structures (for searching)

### **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:

- Moving object pipeline
- Ephemeris calculation
- Tracklet generation
- Attribution and precovery
- Orbit fitting
- Orbit merging

### **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 composable 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.

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

- Astrometric fitting
- Photometric fitting

#### **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.

No products are defined at this level of the WBS.

#### **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.

No products are defined at this level of the WBS.

#### **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.

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

- Images
- Tables
- Footprints
- Basic statistics
- Photometric calibration representation
- Convolution kernels

- Numerical integration
- Random number generation
- Numerical optimization
- Monte Carlo sampling
- Warping
- Science tools

### **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:

- Prompt Processing raw calibration validation payload
- OCS control scripts for collimated beam projector control
- Offline Auxiliary Telescope spectrograph pipeline
- Offline calibration single frame processing pipeline
- OCS-Controlled batch daily calibration update payload
- Periodic CPP payload
- Annual CPP payload
- CPP QC measurement generators

### 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.

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

- Image characterization and calibration
- Background estimation
- Background reference
- PSF estimation (visit)

### 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:

- Image coaddition and differencing
- PSF matching
- Image coaddition

### **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.

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

- Coadd processing
- Overlap resolution
- Source detection
- Deblending

### **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 detect in LSST images. This includes:

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

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

- Multi-epoch object characterization

- DRP Postprocessing
- Measurement
- Aperture correction
- Star/galaxy classification
- Association and matching

#### **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:

- L2 QC measurement generators

#### **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 SUI applications, including low-level Python API and JavaScript API;
- Components to provide connection between the core data search/visualization components and the rest of the “LSST Science Platform”;

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

No products are defined at this level of the WBS.

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

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

No products are defined at this level of the WBS.

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

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

Firefly comprises a variety of capabilities, including the following:

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



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

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

- LSST-independent Firefly framework and visualization capabilities

#### **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:

- JupyterLab visualization widgets and other JupyterHub/Portal bridges
- Low-level Python API to Firefly
- Interfaces to DAX, user workspace, SuperTask, identity management
- Firefly components to visualize LSST Science Pipelines data objects

### **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:

- Web application(s) implementing the Portal

### **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.

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

- Portal alert interfaces to configure alert subscriptions

### **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:

- L1 catalog database
- L2 catalog database
- Provenance database
- DRP-internal database

**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.

No products are defined at this level of the WBS.

**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 data access client library
- Multi-type associative containers

**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.

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

- Web services framework

**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:

- Qserv distributed database system

**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 access

**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:

- Global metadata service
- Catalog access
- Image metadata access
- Catalog metadata access

### 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:

- SuperTask
- Activator base and Command Line Activator



- Pipeline configuration
- Multi-node Task API
- Multi-core Task API

#### **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.

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

- Logging

**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.

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

- Spherical geometry

### **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 providing services 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

No products are defined at this level of the WBS.

### **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

No products are defined at this level of the WBS.

#### **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:

- Base Local Area Network
- Archive External Network

#### **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

No products are defined at this level of the WBS.

### **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.

No products are defined at this level of the WBS.

### **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.

No products are defined at this level of the WBS.

### **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<sup>6</sup>.

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<sup>7</sup>.

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

- Summit - Base/ Base - Archive/ US Networks
- La Serena - Santiago Network
- La Serena - AURA Gatehouse Network
- Summit - AURA Gatehouse Network
- DWDM Equipment
- Santiago - Miami 100 Gbps Ring
- Network Management
- Santiago - Boca Raton Spectrum
- US National WAN

### **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:

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<sup>6</sup>Contractual details have been elided from the summary in this document.

<sup>7</sup>Ditto.



- 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:

- QC harness
- QC threshold notification framework
- QC verification reporting
- Alert stream QC harness

## **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:

- Basic JupyterLab environment
- JupyterLab software environments
- JupyterLab Activators
- JupyterHub deployment

**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

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

- Software version control system
- Build and unit test service
- Packaging and distribution
- Documentation infrastructure
- Developer communication tools
- Issue (ticket) tracking service
- Automated integration and test services

## C DM Discussion and Decision Making Process

The Escalation process only occurs when the issue cannot be resolved within the DM, i.e. when the following internal discussion and decision making process has failed to yield a decision.

### C.1 Empowerment

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

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

### C.2 RFC Process

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

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

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

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

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

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

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

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

### **C.3 Exceptions and Appeals**

Some proposed resolutions may require changes to one or more of the baselined, change-controlled documents describing the Data Management system (those in DocuShare with an LDM- handle or marked as change-controlled in Confluence). Note that major changes to budget or scope will almost certainly affect one or more LDM- documents. In this case only, the DM Configuration Control Board (DMCCB) (Section 7.4) may empanel an ad hoc commit-

tee including the lead author of the document and other relevant experts. This committee or the CCB itself must *explicitly* approve the change.

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

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

## C.4 Formalities

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

## D Traceability matrix of DMSR requirements to OSS Requirements

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

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

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

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

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

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

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

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

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

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| <b>DMS</b>  | <b>OSS</b>   |
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| DMS-REQ-0326 Storing Approximations of Per-pixel Metadata               |  |
| DMS-REQ-0327 Background Model Calculation                               | OSS-REQ-0056 System Monitoring & Diagnostics   |
| DMS-REQ-0328 Documenting Image Characterization                         |  |
| DMS-REQ-0329 All-Sky Visualization of Data Releases                     | OSS-REQ-0136 Co-added Exposures  |
| DMS-REQ-0330 Best Seeing Coadds   | OSS-REQ-0136 Co-added Exposures  |
| DMS-REQ-0331 Computing Derived Quantities                               |  |
| DMS-REQ-0332 Denormalizing Database Tables                              |  |
| DMS-REQ-0333 Maximum Likelihood Values and Covariances                  |  |
| DMS-REQ-0334 Persisting Data Products                                   | OSS-REQ-0136 Co-added Exposures  |
| DMS-REQ-0335 PSF-Matched Coadds   |  |
| DMS-REQ-0336 Regenerating Data Products from Previous Data Releases     | LSR-REQ-0049 Data Product Archiving  |
| DMS-REQ-0337 Detecting faint variable objects                           | OSS-REQ-0136 Co-added Exposures  |
| DMS-REQ-0338 Targeted Coadds  | OSS-REQ-0136 Co-added Exposures<br>LSR-REQ-0040 Data Quality Monitoring                  |
| DMS-REQ-0339 Tracking Characterization Changes Between Data Releases    | LSR-REQ-0040 Data Quality Monitoring   |
| DMS-REQ-0340 Access Controls of Level 3 Data Products                   | OSS-REQ-0142 Access<br><br>OSS-REQ-0176 Data Access<br>OSS-REQ-0187 Information Security |
| DMS-REQ-0341 Providing a Precure Service                                |  |
| DMS-REQ-0342 Alert Filtering Service                                    | LSR-REQ-0025 Transient Filtering   |
| DMS-REQ-0343 Performance Requirements for LSST Alert Filtering Service  | OSS-REQ-0184 Transient Alert Publication   |
| DMS-REQ-0344 Constraints on Level 1 Special Program Products Generation |  |
| DMS-REQ-0345 Logging of catalog queries                                 | OSS-REQ-0134 Level 2 Data Product Availability   |

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| <b>DMS</b>  | <b>OSS</b>  |
|---|---|
| DMS-REQ-0346 Data Availability                                      | OSS-REQ-0004 The Archive Facility<br>OSS-REQ-0167 Data Archiving<br>OSS-REQ-0313 Telemetry Database Retention |
| DMS-REQ-0347 Measurements in catalogs                               |   |
| DMS-REQ-0348 Pre-defined alert filters                              | LSR-REQ-0026 Predefined Transient Filters   |
| DMS-REQ-0349 Detecting extended low surface brightness objects      |   |
| DMS-REQ-0350 Associating Objects across data releases               |   |
| DMS-REQ-0351 Provide Beam Projector Coordinate Calculation Software |   |

## E Traceability matrix of OSS requirements to DMSR requirements

| OSS  | DMS  |
|--|--|
| LSR-REQ-0025 Transient Filtering                             | DMS-REQ-0342 Alert Filtering Service   |
| LSR-REQ-0026 Predefined Transient Filters                    | DMS-REQ-0348 Pre-defined alert filters   |
| LSR-REQ-0040 Data Quality Monitoring                         | DMS-REQ-0338 Targeted Coadds<br>DMS-REQ-0339 Tracking Characterization Changes Between Data Releases   |
| LSR-REQ-0049 Data Product Archiving                          | DMS-REQ-0336 Regenerating Data Products from Previous Data Releases  |
| LSR-REQ-0075 Survey Time Allocation                          | DMS-REQ-0320 Processing of Data From Special Programs  |
| OSS-REQ-0002 The Summit Facility                             | DMS-REQ-0168 Summit Facility Data Communications   |
| OSS-REQ-0003 The Base Facility                               | DMS-REQ-0315 DMS Communication with OCS<br>DMS-REQ-0171 Summit to Base Network<br>DMS-REQ-0176 Base Facility Infrastructure  |
| OSS-REQ-0004 The Archive Facility                            | DMS-REQ-0299 Data Product Ingest<br>DMS-REQ-0302 Production Orchestration<br>DMS-REQ-0303 Production Monitoring<br>DMS-REQ-0185 Archive Center<br>DMS-REQ-0193 Data Access Centers<br>DMS-REQ-0289 Calibration Production Processing<br>DMS-REQ-0346 Data Availability |
| OSS-REQ-0006 Sites   | DMS-REQ-0178 Base Facility Co-Location with Existing Facility  |
| OSS-REQ-0020 Usable Observing Time                           | DMS-REQ-0162 Pipeline Throughput   |
| OSS-REQ-0021 Base Site                                       | DMS-REQ-0196 Data Access Center Geographical Distribution<br>DMS-REQ-0197 No Limit on Data Access Centers<br>DMS-REQ-0131 Calibration Images Available Within Specified Time   |
| OSS-REQ-0022 Archive Site                                    | DMS-REQ-0187 Archive Center Co-Location with Existing Facility<br>DMS-REQ-0196 Data Access Center Geographical Distribution<br>DMS-REQ-0197 No Limit on Data Access Centers  |
| OSS-REQ-0034 System Control                                  | DMS-REQ-0303 Production Monitoring   |
| OSS-REQ-0036 Local Autonomous Administration of System Sites | DMS-REQ-0175 Summit to Base Network Ownership and Operation  |
| OSS-REQ-0037 Observatory Control System Definition           | DMS-REQ-0156 Provide Pipeline Execution Services   |
| OSS-REQ-0038 Scope of Control                                | DMS-REQ-0302 Production Orchestration  |

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| OSS  | DMS   |
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|  | DMS-REQ-0303 Production Monitoring  |
| OSS-REQ-0041 Subsystem Activation                | DMS-REQ-0297 DMS Initialization Component   |
| OSS-REQ-0044 Standard Operating States           | DMS-REQ-0301 Control of Level-1 Production  |
| OSS-REQ-0046 Calibration                         | DMS-REQ-0131 Calibration Images Available Within Specified Time<br>DMS-REQ-0060 Bias Residual Image<br>DMS-REQ-0282 Dark Current Correction Frame<br>DMS-REQ-0063 Monochromatic Flatfield Data Cube<br>DMS-REQ-0062 Illumination Correction Frame<br>DMS-REQ-0283 Fringe Correction Frame |
| OSS-REQ-0049 Degraded Operational States         | DMS-REQ-0174 Summit to Base Network Secondary Link<br><br>DMS-REQ-0183 Base to Archive Network Secondary Link   |
| OSS-REQ-0050 Summit Power Grid Loss              | DMS-REQ-0165 Infrastructure Sizing for "catching up"  |
| OSS-REQ-0051 Summit-Base Connectivity Loss       | DMS-REQ-0165 Infrastructure Sizing for "catching up"  |
| OSS-REQ-0052 Summit Data Buffer                  | DMS-REQ-0165 Infrastructure Sizing for "catching up"<br>DMS-REQ-0284 Level-1 Production Completeness  |
| OSS-REQ-0053 Base-Archive Connectivity Loss      | DMS-REQ-0177 Base Facility Temporary Storage<br><br>DMS-REQ-0180 Base to Archive Network<br>DMS-REQ-0181 Base to Archive Network Availability<br>DMS-REQ-0182 Base to Archive Network Reliability   |
| OSS-REQ-0054 Base Data Buffer                    | DMS-REQ-0177 Base Facility Temporary Storage  |
| OSS-REQ-0055 Base Updating from Archive          | DMS-REQ-0180 Base to Archive Network  |
| OSS-REQ-0056 System Monitoring & Diagnostics     | DMS-REQ-0327 Background Model Calculation<br><br>DMS-REQ-0029 Generate Photometric Zeropoint for Visit Image<br>DMS-REQ-0070 Generate PSF for Visit Images  |
| OSS-REQ-0057 Image Visualization                 | DMS-REQ-0160 Provide User Interface Services  |
| OSS-REQ-0111 Science Image Archiving Reliability | DMS-REQ-0309 Raw Data Archiving Reliability   |
| OSS-REQ-0114 Acquisition of Science Sensor data  | DMS-REQ-0024 Raw Image Assembly<br><br>DMS-REQ-0018 Raw Science Image Data Acquisition  |

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| OSS  | DMS   |
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|  | DMS-REQ-0022 Crosstalk Corrected Science Image Data Acquisition   |
| OSS-REQ-0117 Automated Production            | DMS-REQ-0156 Provide Pipeline Execution Services<br>DMS-REQ-0302 Production Orchestration<br>DMS-REQ-0304 Production Fault Tolerance<br>DMS-REQ-0294 Processing of Datasets   |
| OSS-REQ-0118 Consistency and Completeness    | DMS-REQ-0307 Unique Processing Coverage<br><br>DMS-REQ-0293 Selection of Datasets<br>DMS-REQ-0294 Processing of Datasets<br>DMS-REQ-0120 Level 3 Data Product Self Consistency  |
| OSS-REQ-0119 Completeness                    | DMS-REQ-0294 Processing of Datasets   |
| OSS-REQ-0120 Consistency                     | DMS-REQ-0307 Unique Processing Coverage<br>DMS-REQ-0294 Processing of Datasets<br>DMS-REQ-0120 Level 3 Data Product Self Consistency  |
| OSS-REQ-0121 Open Source, Open Configuration | DMS-REQ-0308 Software Architecture to Enable Community Re-Use<br>DMS-REQ-0032 Image Differencing<br>DMS-REQ-0033 Provide Source Detection Software<br>DMS-REQ-0297 DMS Initialization Component<br>DMS-REQ-0306 Task Configuration<br>DMS-REQ-0305 Task Specification<br>DMS-REQ-0125 Software framework for Level 3 catalog processing<br>DMS-REQ-0128 Software framework for Level 3 image processing   |
| OSS-REQ-0122 Provenance                      | DMS-REQ-0297 DMS Initialization Component<br>DMS-REQ-0306 Task Configuration<br>DMS-REQ-0305 Task Specification<br>DMS-REQ-0121 Provenance for Level 3 processing at DACs<br>DMS-REQ-0125 Software framework for Level 3 catalog processing<br>DMS-REQ-0128 Software framework for Level 3 image processing<br>DMS-REQ-0068 Raw Science Image Metadata<br>DMS-REQ-0074 Difference Exposure Attributes<br>DMS-REQ-0106 Coadded Image Provenance<br>DMS-REQ-0132 Calibration Image Provenance |

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| OSS  | DMS   |
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| OSS-REQ-0123 Reproducibility                   | DMS-REQ-0132 Calibration Image Provenance   |
| OSS-REQ-0124 Software Development Standards    | DMS-REQ-0314 Compute Platform Heterogeneity   |
| OSS-REQ-0127 Level 1 Data Product Availability | <p>DMS-REQ-0312 Level 1 Data Product Access</p> <p>DMS-REQ-0162 Pipeline Throughput</p> <p>DMS-REQ-0171 Summit to Base Network</p> <p>DMS-REQ-0002 Transient Alert Distribution</p> <p>DMS-REQ-0089 Solar System Objects Available Within Specified Time</p> <p>DMS-REQ-0022 Crosstalk Corrected Science Image Data Acquisition</p> <p>DMS-REQ-0004 Nightly Data Accessible Within 24 hrs</p>   |
| OSS-REQ-0128 Alerts                            | <p>DMS-REQ-0094 Keep Historical Alert Archive</p> <p>DMS-REQ-0274 Alert Content</p>   |
| OSS-REQ-0129 Exposures (Level 1)               | <p>DMS-REQ-0032 Image Differencing</p> <p>DMS-REQ-0311 Regenerate Un-archived Data Products</p> <p>DMS-REQ-0024 Raw Image Assembly</p> <p>DMS-REQ-0069 Processed Visit Images</p> <p>DMS-REQ-0072 Processed Visit Image Content</p> <p>DMS-REQ-0010 Difference Exposures</p> <p>DMS-REQ-0130 Calibration Data Products</p> <p>DMS-REQ-0059 Bad Pixel Map</p>  |
| OSS-REQ-0130 Catalogs (Level 1)                | <p>DMS-REQ-0033 Provide Source Detection Software</p> <p>DMS-REQ-0043 Provide Calibrated Photometry</p> <p>DMS-REQ-0310 Un-Archived Data Product Cache</p> <p>DMS-REQ-0292 Uniqueness of IDs Across Data Releases</p> <p>DMS-REQ-0285 Level 1 Source Association</p> <p>DMS-REQ-0287 DIASource Precovery</p> <p>DMS-REQ-0266 Exposure Catalog</p> <p>DMS-REQ-0269 DIASource Catalog</p> <p>DMS-REQ-0271 DIAObject Catalog</p> <p>DMS-REQ-0272 DIAObject Attributes</p> <p>DMS-REQ-0273 SSOBJECT Catalog</p> <p>DMS-REQ-0317 DIAForcedSource Catalog</p> |
| OSS-REQ-0131 Nightly Summary Products          | <p>DMS-REQ-0096 Generate Data Quality Report Within Specified Time</p> <p>DMS-REQ-0098 Generate DMS Performance Report Within Specified Time</p>  |

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| OSS   | DMS   |
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|   | DMS-REQ-0100 Generate Calibration Report Within Specified Time<br>DMS-REQ-0097 Level 1 Data Quality Report Definition<br>DMS-REQ-0099 Level 1 Performance Report Definition<br>DMS-REQ-0101 Level 1 Calibration Report Definition   |
| OSS-REQ-0132 Engineering and Facility Database Archive                            | DMS-REQ-0102 Provide Engineering & Facility Database Archive  |
| OSS-REQ-0134 Level 2 Data Product Availability                                    | DMS-REQ-0345 Logging of catalog queries<br><br>DMS-REQ-0163 Re-processing Capacity<br>DMS-REQ-0006 Timely Publication of Level 2 Data Releases  |
| OSS-REQ-0135 Uniformly calibrated and processed versions of Level 1 Data Products | DMS-REQ-0325 Regenerating L1 Data Products During Data Release Processing   |
| OSS-REQ-0136 Co-added Exposures   | DMS-REQ-0334 Persisting Data Products<br>DMS-REQ-0279 Deep Detection Coadds<br>DMS-REQ-0280 Template Coadds<br>DMS-REQ-0281 Multi-band Coadds<br>DMS-REQ-0330 Best Seeing Coadds<br>DMS-REQ-0337 Detecting faint variable objects<br>DMS-REQ-0338 Targeted Coadds<br>DMS-REQ-0278 Coadd Image Method Constraints<br>DMS-REQ-0047 Provide PSF for Coadded Images<br>DMS-REQ-0103 Produce Images for EPO<br>DMS-REQ-0329 All-Sky Visualization of Data Releases |
| OSS-REQ-0137 Catalogs (Level 2)   | DMS-REQ-0033 Provide Source Detection Software<br>DMS-REQ-0043 Provide Calibrated Photometry<br>DMS-REQ-0052 Enable a Range of Shape Measurement Approaches<br>DMS-REQ-0292 Uniqueness of IDs Across Data Releases<br>DMS-REQ-0267 Source Catalog<br>DMS-REQ-0275 Object Catalog<br>DMS-REQ-0276 Object Characterization<br>DMS-REQ-0277 Coadd Source Catalog<br>DMS-REQ-0268 Forced-Source Catalog   |
| OSS-REQ-0140 Production   | DMS-REQ-0122 Access to catalogs for external Level 3 processing<br>DMS-REQ-0126 Access to images for external Level 3 processing  |

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| OSS  | DMS  |
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|  | DMS-REQ-0123 Access to input catalogs for DAC-based Level 3 processing<br>DMS-REQ-0127 Access to input images for DAC-based Level 3 processing<br>DMS-REQ-0124 Federation with external catalogs<br>DMS-REQ-0290 Level 3 Data Import   |
| OSS-REQ-0141 Storage   | DMS-REQ-0299 Data Product Ingest   |
| OSS-REQ-0142 Access  | DMS-REQ-0340 Access Controls of Level 3 Data Products  |
| OSS-REQ-0143 Resource Allocation   | DMS-REQ-0119 DAC resource allocation for Level 3 processing  |
| OSS-REQ-0149 Level 1 Catalog Precision   | DMS-REQ-0042 Provide Astrometric Model<br>DMS-REQ-0030 Generate WCS for Visit Images   |
| OSS-REQ-0152 Level 1 Photometric Zero Point Error                              | DMS-REQ-0029 Generate Photometric Zeropoint for Visit Image  |
| OSS-REQ-0153 World Coordinate System Accuracy                                  | DMS-REQ-0042 Provide Astrometric Model<br><br>DMS-REQ-0047 Provide PSF for Coadded Images  |
| OSS-REQ-0159 Level 1 Moving Object Quality                                     | DMS-REQ-0285 Level 1 Source Association<br><br>DMS-REQ-0286 SSOBJECT Precovery<br>DMS-REQ-0288 Use of External Orbit Catalogs  |
| OSS-REQ-0160 Level 1 Difference Source - Difference Object Association Quality | DMS-REQ-0042 Provide Astrometric Model<br><br>DMS-REQ-0285 Level 1 Source Association  |
| OSS-REQ-0162 Level 2 Catalog Accuracy  | DMS-REQ-0042 Provide Astrometric Model<br>DMS-REQ-0030 Generate WCS for Visit Images   |
| OSS-REQ-0166 Alert Completeness and Purity                                     | DMS-REQ-0270 Faint DIASource Measurements  |
| OSS-REQ-0167 Data Archiving  | DMS-REQ-0346 Data Availability   |
| OSS-REQ-0170 Calibration Data  | DMS-REQ-0289 Calibration Production Processing   |
| OSS-REQ-0171 Engineering and Facilities Data                                   | DMS-REQ-0068 Raw Science Image Metadata  |
| OSS-REQ-0176 Data Access   | DMS-REQ-0155 Provide Data Access Services<br>DMS-REQ-0298 Data Product and Raw Data Access<br>DMS-REQ-0065 Provide Image Access Services<br>DMS-REQ-0075 Catalog Queries<br>DMS-REQ-0078 Catalog Export Formats<br>DMS-REQ-0186 Archive Center Disaster Recovery<br>DMS-REQ-0293 Selection of Datasets |

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| OSS  | DMS  |
|--|--|
|  | DMS-REQ-0295 Transparent Data Access<br>DMS-REQ-0340 Access Controls of Level 3 Data Products  |
| OSS-REQ-0177 Data Access Environment                         | DMS-REQ-0314 Compute Platform Heterogeneity  |
| OSS-REQ-0178 Data Distribution                               | DMS-REQ-0300 Bulk Download Service   |
| OSS-REQ-0180 Data Products Query and Download Availability   | DMS-REQ-0065 Provide Image Access Services<br><br>DMS-REQ-0122 Access to catalogs for external Level 3 processing<br>DMS-REQ-0126 Access to images for external Level 3 processing   |
| OSS-REQ-0181 Data Products Query and Download Infrastructure | DMS-REQ-0065 Provide Image Access Services<br><br>DMS-REQ-0291 Query Repeatability   |
| OSS-REQ-0184 Transient Alert Publication                     | DMS-REQ-0002 Transient Alert Distribution<br><br>DMS-REQ-0343 Performance Requirements for LSST Alert Filtering Service  |
| OSS-REQ-0185 Transient Alert Query                           | DMS-REQ-0312 Level 1 Data Product Access   |
| OSS-REQ-0186 Access to Previous Data Releases                | DMS-REQ-0313 Level 1 & 2 Catalog Access<br><br>DMS-REQ-0077 Maintain Archive Publicly Accessible   |
| OSS-REQ-0187 Information Security                            | DMS-REQ-0340 Access Controls of Level 3 Data Products  |
| OSS-REQ-0194 Calibration Exposures Per Day                   | DMS-REQ-0131 Calibration Images Available Within Specified Time<br>DMS-REQ-0265 Guider Calibration Data Acquisition<br>DMS-REQ-0130 Calibration Data Products  |
| OSS-REQ-0271 Supported Image Types                           | DMS-REQ-0130 Calibration Data Products<br>DMS-REQ-0059 Bad Pixel Map<br>DMS-REQ-0060 Bias Residual Image<br>DMS-REQ-0282 Dark Current Correction Frame<br>DMS-REQ-0063 Monochromatic Flatfield Data Cube<br>DMS-REQ-0062 Illumination Correction Frame<br>DMS-REQ-0283 Fringe Correction Frame |
| OSS-REQ-0275 Calibration Processing Performance Allocations  | DMS-REQ-0043 Provide Calibrated Photometry   |
| OSS-REQ-0307 Subsystem Initialization                        | DMS-REQ-0297 DMS Initialization Component  |
| OSS-REQ-0313 Telemetry Database Retention                    | DMS-REQ-0346 Data Availability   |
| OSS-REQ-0316 Wavefront Sensor Data                           | DMS-REQ-0020 Wavefront Sensor Data Acquisition   |

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| OSS  | DMS  |
|--|--|
|  | DMS-REQ-0047 Provide PSF for Coadded Images  |
| OSS-REQ-0339 Level 2 Source-Object Association Quality             | DMS-REQ-0034 Associate Sources to Objects  |
| OSS-REQ-0349 Data Release Production Crosstalk Correction          | DMS-REQ-0061 Crosstalk Correction Matrix   |
| OSS-REQ-0351 Difference Source Spurious Probability Metric         | DMS-REQ-0009 Simulated Data  |
| OSS-REQ-0353 Difference Source Spuriousness Threshold - Transients | DMS-REQ-0009 Simulated Data  |
| OSS-REQ-0354 Difference Source Spuriousness Threshold - MOPS       | DMS-REQ-0009 Simulated Data  |
| OSS-REQ-0373 Unscheduled Downtime Subsystem Allocations            | DMS-REQ-0318 Data Management Unscheduled Downtime<br>DMS-REQ-0172 Summit to Base Network Availability<br>DMS-REQ-0173 Summit to Base Network Reliability |

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## G Acronyms

The following table has been generated from the on-line Gaia acronym list:

| Acronym | Description   |
|---------|---|
| AP      | Alerts Production                                     |
| API     | Application Programming Interface                     |
| AURA    | Association of Universities for Research in Astronomy |
| CCB     | Change Control Board                                  |
| CMDB    | Configuration Management DataBase                     |
| DAC     | Data Access Center                                    |
| 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                                |

|       |   |
|-------|---|
| DMSS  | DM Subsystem Scientist  |
| DMTN  | DM Technical Note   |
| DRP   | Data Release Production   |
| EFD   | Engineering Facilities Database   |
| ICBS  | International Communications and Base Site  |
| ICD   | Interface Control Document  |
| IPAC  | No longer an acronym  |
| IS    | Interface Scientist   |
| IT    | Integration Test  |
| ITC   | Information Technology Center   |
| IVOA  | International Virtual-Observatory Alliance  |
| JIRA  | issue tracking product (not an acronym, but a truncation of Gojira, the Japanese name for Godzilla) |
| LCR   | LSST Change Request   |
| LDF   | LSST Data Facility  |
| LDM   | Light Data Management   |
| LPM   | LSST Project Management (Document Handle)   |
| LSE   | LSST Systems Engineering (Document Handle)  |
| LSST  | Large-aperture Synoptic Survey Telescope  |
| LaTeX | (Leslie) Lamport TeX (document markup language and document preparation system)                     |
| MOPS  | Moving Object Pipelines   |
| NASA  | National Aeronautics and Space Administration (USA)   |
| NCSA  | National Center for Supercomputing Applications   |
| NET   | Not Earlier Than  |
| NSF   | National Science Foundation   |
| OCS   | Observatory Control System  |
| OSS   | Observatory System Specifications   |
| PDF   | Portable Document Format  |
| PM    | Project Manager   |
| PMCS  | Project Management Control System   |
| PS    | Project Scientist   |
| PST   | Project Science Team  |
| QA    | Quality Assurance   |

|      |   |
|------|---|
| RFC  | Request for Comments                          |
| RM   | Reconfiguration Module                        |
| SA   | Science Alert(s)                              |
| SAT  | Science Archives Team (at ESAC)               |
| SEMP | Systems Engineering Management Plan           |
| SLA  | Service Level Agreement                       |
| SLAC | Stanford Linear Accelerator Center            |
| SS   | Subsystem Scientist                           |
| SST  | Space Surveillance Telescope                  |
| SUI  | Science User Interface                        |
| SUIT | Science User Interface and Tools              |
| TCT  | Technical Control Team (Obsolete - now DMCCB) |
| US   | United States                                 |
| WBS  | Work Breakdown Structure                      |
| WCS  | World Coordinate System                       |
| WISE | Wide-field Survey Explorer                    |