			WBS Dictionary Report
WBS ID 1.01C	WBS Description Project Management Office Construction	Level 1	WBS Dictionary Thie WBS element includes all activities related to the management and administration of the project. This includes quality assurance and safety, reliability, document control, cost/schedule reporting and control systems, and configuration management. The PMO is responsible for the Project Execution Plan (LPM-54) which includes defining the long-term vision and the near-term policies and procedures guiding the Large Synoptic Survey Telescope (LSST) project through design & development, construction, and into Operation. The PMO is responsible for meeting Federal and non-Federal Sponsor expectations for the construction; provide maximum transparency into the levels and types of effort required to meet the project's goals; and inform and hold accountable LSST team members throughout the project's various work elements.
1.01C.00	PMO Level 2 Milestones	2	This WBS Element defines the Level 2 milestones for this project. These milestones are used to capture milestones
1.01C.01	LSST Project Office	2	This WBS element includes the efforts of the Project Management Office that inlcde specifically the offices for the Project Director and Project Manager. The effort includes management of the LSST schedules, budgets, plans, organization, procedures, policies, partnering, and resources, including:
			 Management and Administration of the Project Management and Control System (PMCS) Managing the LSST Headquarters physical assets (hardware, software, facilities, documents) during the Construction Phase, as well as preparing for the same activities during the Operations Phase.
1.01C.01.01	Project Office and Support	3	 Managing software and document repositories Control, Storage, and Distribution of all Project Documentation including Technical Publications, Management Letters and Memoranda, Contract Documentation, Drawings, Graphics, Presentations, Administrative Support Personnel, Supplies, and Communications. Procuring, configuring, administering, and maintaining computing, communications and storage infrastructure documentation library (developmental and production configurations) Configuration control and asset management for all physical assets Domestic and international travel expenses Office equipment, including computers Communications service for LSST Project Management office Quality Planning, Quality Engineering, Quality Assessment, Quality Control This WBS element includes the efforts of the Project Management office that inIcde specifically the offices for the Project Director and Project Manager. The effort includes management of the LSST schedules, budgets, plans, organization, procedures, policies, partnering, and resources, including: Managing the LSST Headquarters physical assets (hardware, software, facilities, documents) during the Construction Phase, as well as preparing for the same activities during the Operations Phase. Managing software and document repositories Cortorlo, Storage, and Distribution of all Project Documentation including Technical Publications, Management Letters and Memoranda, Contract Documentation, Drawings, Graphics, Presentations, Administrative Support Personnel, Supplies, and Communications. Procuring, configuring, administering, and maintaining computing, communications and storage infrastructure documentation library (developmental and production configurations) Configuration control and asset management for all physical assets Domestic and international travel expenses Office equipment, including computers Communications service for L
1.01C.01.02	Chief Scientist Support	3	 Quality Planning, Quality Engineering, Quality Assessment, Quality Control The Chief Scientist WBS supports the principal advisor to the LSST Director with regard to science issues. Duties and Responsibilities will be defined to support the Director with scientific and community-related issues as they develop. The Chief Scientist is familiar with project history and the process that prescribed
1.01C.01.03	Communications	3	the science requirements. This WBS supports the project communications efforts on a level of effort throughout the duration. Specifically the effort addressed includes: Maintaining the LSST Website and Social Network Sites Supporting LSST at the Annual AAS Meeting Developing Public Relations Materials Producing and Manageing Press Releases to Adhere to NSF policy

			Publishing Quarterly E-News
			Maintaining Project mailing lists and contacts database
1.01C.01.04	Project Controls	3	This WBS element includes the management of LSST Cost/Schedule Reporting and Control Systems, Subcontract Management, NSF Reporting, DOE Reporting, including:
			 Management and Administration of the Project Management and Control System (PMCS) Control and operation of EVMS
			- Preparation and conduct of Monthly Progress/Cost Reviews
			- Preparation and submission of all NSE- and DOE-required reports
			- Preparation and monitoring of all subcontracts
1 01C 01 05	ISST Project Science	з	The Project Science WBS has primary responsibility for understanding and optimizing the scientific performance of the
1.010.01.05		5	LSST facility. The Project Scientist reports to the LSST Director, but takes input from, and may be assigned specific prioritized activities by the Project Manager in order to ensure that the funded science trade-off studies are well
			aligned with the project development schedule.
			Specifically:
			 Develop, review, and baseline the LSST Science Requirements Document
			- Develop, review, baseline, and verify compliance with the LSST Data Quality Assurance Plan
			 Manage the interfaces from the LSST project to the scientific community
1.01C.02	Site Office	2	This WBS Element captures the adminsitrative effort for the La Serena based site office. It is responsible for the administrative support for LSST Staff permanent in Chile and staff coming to Chile for short term work.
1.01C.02.01	Site Office	3	This WBS Element captures the adminsitrative effort for the La Serena based site office. It is responsible for the
			administrative support for LSST Staff permanent in Chile and staff coming to Chile for short term work.
1.01C.03	Safety and	2	This WBS Element includes management and performance of the LSST Safety and Environmental Assurance activities,
	Environmental Assurance		including:
			- Safety Planning, Safety Engineering, Safety Assessment, Safety Assurance
			- Maintaining Safety and Environmental Assurance plans and procedures
			- Conducting safety inspections and audits
			- Conducting Annual Safety Review
1.01C.03.01	Safety and Environmental	3	This WBS Element includes management and performance of the LSST Safety and Environmental Assurance activities, including:
	Assurance		
			 Safety Planning, Safety Engineering, Safety Assessment, Safety Assurance Maintaining Safety and Environmental Assurance plans and procedures
			- Conducting safety inspections and audits
			- Conducting Annual Safety Review
1.01C.04	Facility and Staff	2	This WBS Element includes all the office facility rent and improvements necessary to house the LSST team in Tucson
	Administration		and at the Bae Facility in La Serena.
1.01C.04.01	Facility	3	This WBS Element includes all the office facility rent and improvements necessary to house the LSST team in Tucson and at the Bae Facility in La Serena.
1.01C.04.02	Staff Administration	3	This WBS Element includes all the office facility rent and improvements necessary to house the LSST team in Tucson
			and at the Bae Facility in La Serena.
1.01C.05	AURA	2	This WBS element covers the activities provided by AURA for LSST. These include:
			Financial oversight and audits
			Legal oversight and services
			NSF Agency liaison
1.01C.05.01	AURA	3	This WBS element covers the activities provided by AURA for LSST. These include:
			Financial oversight and audits
			Legal oversight and services NSF Agency liaison
1.02C	Data Management	1	This WBS element provides the complete LSST Data Management System (DMS). The DMS has these main
	Construction		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.

1.02C.00	DM Level 2 Milestones	2	This WBS element defines the Level 2 milestones for this project. These milestones represent the top-level subsystem deliverables and interface milestones with other subsystems.
1.02C.01	System Management	2	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.
			No products are defined at this level of the WBS.
1.02C.01.01	Project Management	3	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:
1 02C 01 02	[Legacy] Science Data	3	This WBS element was used early in construction, and is maintained only for archival accounting nurnoses. No work is
1.020.01.02	Quality Integration and Test	5	scheduled here; all budget has been transferred to 1.02C.10.
			No products are defined at this level of the WBS.
1.02C.01.02.01	Science Data Quality	4	This WBS element includes software programs, configuration files, unit tests, component integration tests, and
	Assessment Pipeline		documentation that implement the SDQA Pipeline capabilities. This WBS element implements the UML use cases and activities associated by WBS number to this element.
1.02C.01.02.02	Science Data Quality Analyst Toolkit	4	This WBS element includes software programs, configuration files, unit tests, component integration tests, and documentation that implement the SDQA Toolkit capabilities.
			This WBS element implements the UML use cases and activities associated by WBS number to this element.
1.02C.01.02.03	Science Pipeline Toolkit	4	This WBS element includes software programs, configuration files, unit tests, component integration tests, and documentation that implement the Science Pipeline Toolkit capabilities. Science Pipeline Toolkit provides capabilities that permit users of the DMS to perform processing of LSST data with LSST open software and user-supplied codes, for Level 3 Data Product production.
			This WBS element implements the UML use cases and activities associated by WBS number to this element.
1.02C.01.02.04	Software Developer Support Tools	4	In this WBS, tooling for software developers is provided and supported
1.02C.02	Systems Engineering	2	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.
1 02C 02 01	Data Management	3	NO PRODUCTS are defined at this level of the WBS.
1.020.02.01	Science	5	
			Specifically, the activities covered by this WBS element include:
			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	3	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.

1.02C.02.02.01	System Architecture Definition	4	No products are defined at this level of the WBS. 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 highlevel 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	System Architecture Oversight	4	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 decisionmaking 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 Board.
1.02C.02.02.03	Architecture Investigation	4	No products are defined at this level of the WBS. This WBS element includes all activities related to obtaining the data necessary to make architectural decisions, including literature research, prototyping, and model-building.
1.02C.03	Alert Production	2	No products are defined at this level of the WBS. 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
1.02C.03.00	Management, Leadership & Other Costs	3	L1 QC measurement generators 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).
1.02C.03.01	Single Frame Processing	3	No products are defined at this level of the WBS. 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

1.02C.03.02	Catalog Association for	3	Spatial models PSF estimation (1 CCD) This WBS element covers the construction of the software, together with its associated configuration files, test suites
	Alert Production		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
1 030 03 03	Alant Distribution Contant	2	DIAObject association This MICS algorithm to according to the antibuotic terration with its second and investigation files test with
1.020.03.03	Alert Distribution System	3	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:
			Offline alert generation pipeline
			Alert distribution service
			Alert filtering service
1 000 00 01		2	Alert database
1.02C.03.04	Alert Generation Pipeline	3	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
			Image decorrelation
			Variability characterization
1.02C.03.05	Tools for Science	3	This WBS element covers the construction of the software, together with its associated configuration files, test suites
	Pipelines		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:
			Cartesian geometry
			Coordinate transformations
			Chromaticity utilities
			Interpolation and approximation of 2-D fields
			Common functions and source profiles
			Camera descriptions
			Fourier transforms
			Tree structures (for searching)
1.02C.03.06	Moving Object	3	This WBS element covers the construction of the software, together with its associated configuration files, test suites
	Processing System (MOPS)		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 E) are defined at this level of MPC.
			Moving object pipeline

1.02C.03.07	Transform Fitting on Stacks of Images	3	Ephemeris calculation Tracklet generation Attribution and precovery Orbit fitting Orbit merging This WBS element covers the construction of the software, together with its associated configuration files, test suites and documentation, which will allow for high precision photometric and astrometric calibration of objects using multiple apparitions of each object. Major features of this work will be: Photometric zeropoint fitting on scales larger than a chip. Support photometric zeropoints which vary on scales smaller than a chip. Support fitting composeable astrometric models that can represent distortions on a variety of scales from multiple different sources. The above will allow the distortions from the optical system to be separated from the distortions imprinted by the atmosphere. The following products (per Section 5) are defined at this level of WBS: Astrometric fitting
1.02C.03.08	Integration	3	Photometric fitting 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.
1.02C.04	Data Release Production	2	No products are defined at this level of the WBS. 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.
1.02C.04.00	Management, Leadership & Other Costs	3	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).
1.02C.04.01	Software Primitives	3	No products are defined at this level of the WBS. 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, developerfocused 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
1.02C.04.02	Calibration Products	3	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;

1.02C.04.03	Image Characterization	3	 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 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
1.02C.04.04	Coaddition	3	Background estimation Background reference PSF estimation (visit) 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 Decounting processing
1.02C.04.05	Detection & Deblending	3	The following products (per Section 5) are defined at this level of WBS: Image coaddition and differencing PSF matching Image coaddition 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.
1.02C.04.06	Characterization & Measurement	3	The following products (per Section 5) are defined at this level of WBS: Coadd processing Overlap resolution Source 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 characterize objects detect in LSST images. This includes: Application of fundamental measurement algorithms; Fitting of source models to data; Multi-epoch measurement; Exerced measurement;
1.02C.04.07	Maintenance, Quality & Documentation	3	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 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	2	This WBS element covers the work performed by the Science User Interface and Tools group. It includes the following:
			 The Firefly framework to support infrastructure and common functionalities for all SUIT applications, including low-level Python API and JavaScript API; Components to provide connection between the core data search/visualization components and the rest of the "LSST Science Platform"; The web portal aspect of the LSST Science Platform, to enable the science user community to access, discover, explore, analyze, and download LSST data:
1.02C.05.00	Management, Leadership & Other Costs	3	 A web-based user interface to alert subscription and searches. No products are defined at this level of the WBS. 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).
1.02C.05.01	Basic Archive Access Tools	3	No products are defined at this level of the WBS. This WBS element includes software programs, configuration files, unit tests, component integration tests, and documentation that implement the Archive access capabilities. Archive catalog data is selected based on user specifications of catalog properties. This WBS element implements the UML use cases and activities associated by WBS number to this element.
1.02C.05.02	Data Analysis and Visualization Tools	3	This WBS element includes software programs, configuration files, unit tests, component integration tests, and documentation that implement the Data Analysis and Visualization capabilities. Data visualization capabilities include the ability to view large-scale, multi-dimensional data in a variety of plots and views. Data Analysis permits querying, formatting, analyzing, and plotting data in a variety of 2D and 3D representations, with analytical overlays and statistical data.
			This WBS element implements the UML use cases and activities associated by WBS number to this element.
1.02C.05.03	Alert/Notification Toolkit	3	This WBS element includes software programs, configuration files, unit tests, component integration tests, and documentation that implement the Alert subscription and notification capabilities.
			This WBS element implements the UML use cases and activities associated by WBS number to this element.
1.02C.05.04	User Assistance/Help Desk	3	This WBS element includes software programs, configuration files, unit tests, component integration tests, and documentation that implement the User Assistance/Help Desk capabilities.
			This WBS element implements the UML use cases and activities associated by WBS number to this element.
1.02C.05.05	User Workspace Toolkit	3	This WBS element includes software programs, configuration files, unit tests, component integration tests, and documentation that implement the User Workspace capability. This WBS element implements the UML use cases and activities associated by WBS number to this element.
1.02C.05.06	Client-server Query & Visualization Framework	3	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.

1.02C.05.07	LSST Science Platform Interfaces	3	The following products (per Section 5) are defined at this level of WBS: - LSST-independent Firefly framework and visualization capabilities 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 JupterHub/Portal bridges - Low-level Python API to Firefly
1.02C.05.08	Applications	3	 Interfaces to DAX, user workspace, SuperTask, identity management Firefly components to visualize LSST Science Pipelines data objects 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:
1.02C.05.09	Alert Interfaces	3	 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 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:
1.02C.05.10	Integration & Test	3	- Portal alert interfaces to configure alert subscriptions 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.
1.02C.06	Science Data Archive and Application Services	2	No products are defined at this level of the WBS. 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	3	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).
1.02C.06.01	Science Data Archive	3	No products are defined at this level of the WBS. 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 thearchive.
1.02C.06.01.01	Database Catalogs, Alerts and Metadata	5 4	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
1.02C.06.01.02	Image and File Archive	4	- DRP-internal database This WBS element includes software programs, database tables, configuration files, unit tests, component integration tests, and documentation that implement the Image and File Archive.
1.02C.06.02	Data Access Services	3	It implements tools for managing image and files (ingestion, import/export). 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.
1.02C.06.02.01	Data Access Client Framework	4	No products are defined at this level of the WBS. 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	4	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:
1.02C.06.02.03	Query Services	4	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:
1.02C.06.02.04	Image and File Services	4	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	4	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
1.02C.06.03	Task Framework	3	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
			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 now 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:
			- Super Lask - Activator base and Command Line Activator
			- Pipeline configuration - Multi-node Task API
			- Multi-core Task API
1.02C.06.04	Middleware, Infrastructure, and Toolkits	3	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.
1.02C.06.04.01	Logging	4	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	4	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.
1.02C.06.04.03	Sphgeom	4	No products are defined at this level of the WBS. 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	2	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.
1.02C.07.00	Processing Control and Site Infrastructure Management Engineering and Integration	3	No products are defined at this level of the WBS. This WBS element includes activities related to integrating the Processing Control with the other applications and middleware elements.
1.02C.07.00.01	Satellite Processing Center Coordination	4	This WBS element includes activities related to integrating the Processing Control with the other applications and middleware elements.
1.02C.07.01	Processing Control	3	This WBS element is a summary element that includes software programs, database tables, configuration files, unit tests, component integration tests, and documentation that implements the Processing Middleware capabilities.
			These services provide the ability to execute DMS processing on distributed, heterogeneous computing and communications platforms, in parallel clustered and grid configurations. All services will be implemented to provide reasonable fault-tolerance and autonomous recovery in the event of software and hardware failures.
1.02C.07.01.01	Data Management Control System	4	This WBS element includes software programs, database tables, configuration files, unit tests, and documentation that implement the Data Management Control System (DMCS). The DMCS at each site is responsible for initializing and running diagnostics on all equipment, including computing nodes, disk storage, tape storage, and networking. It establishes and maintains connectivity with the other sites including the Headquarters Site. It monitors the operation of all hardware and software.
			At the Base Center, the DMCS is responsible for interfacing with the Observatory Control System (OCS). At the Archive Center, the DMCS performs resource management for the compute cluster and initializes replication services. At each Data Access Center, the DMCS performs resource management for the Level 3 Data Products compute cluster and initializes replication services. This WBS element also contains end user tools that allow management and monitoring of all Data Management System operational status, including: system health and welfare, pipeline/production execution status, data transfer status, operational modes and schedules. It contains hardware and end-user display tools to monitor the LSST DMS subsystem. This is also known as the Data Management Systems Operations Center.
			This WBS element implements the UML use cases and activities associated by WBS number to this element.
1.02C.07.01.02	Orchestration Manager	4	This WBS element includes software programs, database tables, configuration files, unit tests, and documentation that implement orchestration services. Orchestration services are responsible for deploying pipelines and Policies onto nodes, ensuring that their input data is staged appropriately, distributing dataset identifiers to be processed, recording provenance, and starting pipeline execution. This WBS element implements the UML use cases and activities associated by WBS number to this element.
1.02C.07.01.03	Pipeline Execution Services	4	This WBS element is a summary element that includes software programs, database tables, configuration files, unit tests, component integration tests, and documentation that implement Pipeline Execution Services capabilities.

1.02C.07.01.03.01	Pipeline Construction Toolkit	5	This WBS element includes software programs, database tables, configuration files, unit tests, and documentation that implement a framework library for constructing multi-processing, distributed pipelines, including configuration capabilities and capture of provenance and metadata.
			This WBS element implements the UML use cases and activities associated by WBS number to this element.
1.02C.07.01.03.02	Logging Services	5	This WBS element includes software programs, database tables, configuration files, unit tests, and documentation that implement Logging Services capabilities. Logging Services provide the capability to record information during the course of pipeline processing.
			This WBS element implements the UML use cases and activities associated by WBS number to this element.
1.02C.07.01.03.03	Inter-Process Messaging Services	5	This WBS element includes software programs, database tables, configuration files, unit tests, and documentation that implement a framework library for communicating between processes.
			This was element implements the owil use cases and activities associated by was number to this element.
1.02C.07.01.03.04	Checkpoint/Restart Services	5	This WBS element includes software programs, database tables, configuration files, unit tests, and documentation that implement Checkpoint/Restart capabilities.
			This WBS element implements the UML use cases and activities associated by WBS number to this element.
1.02C.07.02	Infrastructure Services	3	This WBS element is a summary element that includes software programs, database tables, configuration files, unit tests, component integration tests, and documentation that implements the Infrastructure Services capabilities.
			Infrastructure Services provide portable, integrated access to fundamental operating system, network, and graphics capabilities via software interfaces and tools.
1.02C.07.02.01	Event Services	4	This WBS element includes software programs, database tables, configuration files, unit tests, and documentation that implement Event Services.Event services are used to communicate among components of the DM System, including between pipelines in a production. Event Services also provides an Event Monitor to detect and trigger actions based on missing or otherwise-notable patterns of events.
			This WBS element implements the UML use cases and activities associated by WBS number to this element.
1.02C.07.02.02	Security and Access Control Services	4	This WBS element includes software programs, database tables, configuration files, unit tests, and documentation to implement Security and Access Control Services. Security and Access Control Services is composed of low-level tools that provide authentication, authorization, and access control for all compute and storage resources.
			This WBS element implements the UML use cases and activities associated by WBS number to this element.
1.02C.07.02.03	Dashboard and Performance Visualizations	4	This WBS element includes software programs, configuration files, unit tests, component integration tests, and documentation that implement User Interface/Visualization Services. User Interface/Visualization Services is composed of low-level tools that provide basic user interface toolkit and visualization rendering capabilities.
			This WBS element implements the UML use cases and activities associated by WBS number to this element.
1.02C.07.02.04	System Administration and Operations Services	4	This WBS element includes software programs, configuration files, unit tests, component integration tests, and documentation that implement the System Administration and Operations capabilities.
			System Administration and Operations Services is composed of low-level tools that monitor systems and provide information on current status.
			This WBS element implements the UML use cases and activities associated by WBS number to this element.
1.02C.07.02.05	File System Services	4	This WBS element includes software programs, database tables, configuration files, unit tests, component integration tests, and documentation that implement distributed File System Services. File System Services provides file-based access over local storage, local area networks, and wide area networks.
			This WBS element also includes off-the-shelf distributed file system capabilities, e.g. iRODS, Lustre, gpfs.
			This WBS element implements the UML use cases and activities associated by WBS number to this element.
1.02C.07.02.06	VO Interfaces	4	This WBS element includes software programs, database tables, configuration files, unit tests, component integration tests, and documentation that implement the VO interace capabilities. VO Interfaces provide the capability to access all LSST data products via VO-standard formats and protocols.

This WBS element implements the UML use cases and activities associated by WBS number to this element.

1.02C.07.03	Environment and Tools	3	This WBS element is a summary element that includes tools and data needed in the development, integration and test, and support of the DM systems and software.
1.02C.07.03.01	Software Development Tools	4	This WBS element includes off-the-shelf tools for DMS software development, including:
			Compilers
			Interpreters
			Linkers
			Make Utilities
			Editors
			Debuggers
			Test Generators
			CASE Tools
			Version Control System
			Document Generators
1 020 07 02 02		4	Profilers
1.02C.07.03.02	Camera/DAQ Test Bed	4	This WBS element contains a test environment that includes the Camera/DAQ interfaces and a raw science image
			Simulated data scream generator. It is provided by the camera team under a camera was element and comigured for
1 020 07 03 03	Telescone/OCS	Л	This WBS element contains a test environment that includes the integrated control system interfaces, and simulated
1.020.07.03.03	Interfaces Test Red	4	TCS/QCS command and status data streams generator. It is provided by the Telescope and Site team under a T&S
			WBS element and configured for DM use under this element.
1.02C.07.04	Site Infrastructure	3	This WBS element is a summary element that includes all infrastructure acquisition, configuration, test, and where
			required packaging and shipping for the Archive and Base Sites. It also includes the acquisition, configuration,
			deployment, and administration of all development tools and environments, including both development and
			integration clusters.
			Once every 6 months, in January and July, NCSA will update the LSST Data Management Sizing Model [references]
			with fresh unit cost quotes and LSST provided estimates of required hardware/system software infrastructure.
			Once every 12 months in July, NCSA will prepare an extract of the Sizing Model showing the expected acquisitions for
			the next Fiscal Year.
			This extract will be subjected to an NSF Cost Analysis as necessary and, if exceeding \$1M total, to an AMCL approval
			process.䀀 The LSST PO will be responsible, with NCSA support, for executing the cost analysis and securing AMCL
			approval by september.
			to NCCA as an amondment to the NCCA contract
1 02C 07 04 01	Archive Center	Δ	to NCSA as an amendment to the NCSA contract. This WBS element includes the acquisition configuration test and operation of infrastructure for the Archive Center
1.020.07.04.01	Infrastructure	7	
1.02C.07.04.02	US Data Access Center	4	This WBS element includes the acquisition, configuration, test, and operation of infrastructure of the US DAC.
	Infrastructure		
1.02C.07.04.03	Base Center	4	This WBS element includes the acquisition, configuration, test, packing, and shipping of infrastructure for the Base
	Infrastructure		Center.
1.02C.07.04.04	Chilean DAC	4	This WBS element includes the acquisition, configuration, test, packing, and shipping of infrastructure for the Chilean
	Infrastructure		DAC.
1.02C.07.04.05	Development and	4	This WBS element is a summary element and includes the acquisition, configuration, test, and operation of the
	Integration		Development and Integration clusters at the Archive Site.
4 000 07 04 05	Infrastructure		
1.02C.07.04.06	Archive Site External	4	This WBS element includes the acquisition, configuration, test, and operation of external network infrastructure for
	Network		the Archive Site, which connects that site to a network center in Chicago, Illinois.
1 02C 07 05	ISST Data Facility	3	This element of the WBS contains the work to oversee and manage the LSST Data Facility's performance and strategy
1.020.07.03	Management, Service	5	design and interface controls, and project controls and reporting
	Architecture, and Project		
	Controls		
			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

Project Controls and Reporting
 No products are defined at this level of the WBS.
 1.02C.07.06.01: LDF-offered Services

LDF-offered Services & 3 Reusable Production 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.

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.07.07

Data, Compute and IT Security Services 3

1.02C.07.06

1.02C.07.08	LDF Service Software	3	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	3	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 IIC
			5. General Production 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	2	This WBS element is a summary element that includes the infrastructure for the Base Center and the national and
Cc Ba	Communications and Base Site		international networks connecting the Mountain Summit, Base, Archive, and Headquarters sites.
			No products are defined at this level of the WBS.
1.02C.08.00	International Communications and Base Site Management Engineering and Integration	3	This WBS element includes activities related to integrating the International Communications and Base Site with the other DMS WBS elements.
1.02C.08.01	Base Center	3	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	3	This WBS element is a summary element that includes the infrastructure for the Chilean Data Access Center. The
	Center		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	3	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 PELINA (Childan) and EUL/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 one6. 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 one7.
1.02C.08.03.01	Chile National WAN	4	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 Contracts for the Chilean portion of LSST high-speed network
			1) La Serena-Santiago Fiber Contract A contract with REUNA covering the acquisition of an 18-year (2016 to 2034) "Irrevocable and Exclusive Use" (IEU) on ten (10) wavelengths on a REUNA-operated dark fiber link (one pair) from La Serena to Santiago capable of at least 100Gbps, plus a path diverse backup link providing at least 40Gbps.
			Total Value = \$5,760,000 USD + IVA Contract execution date: February 2, 2015 Period of Performance: January 1, 2015 - January 1, 2020 1A) La Serena to AURA-O Gatehouse An amendment to contract #1 above to include the acquisition of an 18-year (2016-2034) "Irrevocable and Exclusive Use" (IEU) on two fiber pairs (four fibers) from La Serena to the AURA-O Gatehouse, within a bundle of commercial fibers installed between La Serena and Vicu X + a
			Total Value = \$868,500 USD + IVA Contract amendment execution date: December 15, 2015 Period of Performance: December 15, 2015 - January 1, 2020 (end date same as contract #1, since it is an amendment to contract #1) 2) F. Liello Consultancy Contract
			A contract for the services of Professor Fernando Liello, working with REUNA in the design, contract negotiations, and implementation of the Chilean portion of the LSST high-speed network. Since 1993, Dr. Liello has been a leading figure in the planning and implementation of research and educational networks in Europe and South America, with extensive recent experience in Chile negotiating a fiber contract for the ALMA Observatory.
			Total Value = \$240,000 USD Estimated contract execution date: February 11, 2015 Period of Performance: January 1, 2015 - April 30, 2017
			3) Not included in this WBS 4) Network Equipment Contract (Only part associated with Chilean National WAN in this WBS) A contract for, or purchase of, the networking end equipment for both the La Serena-Santiago fiber link and the Mountain-Base fiber link. This may be executed as a contract through REUNA, or executed as a direct purchase by AURA. It is being postponed both (a) to wait until the purchase is necessary, to allow prices to fall, and (b) to investigate which option (REUNA contract or AURA purchase) better serves both LSST and REUNA.
			Total Value (tentatively) = \$1,400,000 USD + IVA (value depends on final value of equipment purchase, or negotiated contract with REUNA) Estimated contract execution date (if applicable): March 1, 2016 Period of Performance: March 1, 2016 - January 1, 2018 5) Network Operating Costs during MREFC Contract (Only part associated with Chilean National WAN in this WBS)
			A contract with REUNA for the operations and maintenance of both the La Serena-Santiago link, providing at least one 100Gbps channel over the fiber link and at least 40Gbps dedicated bandwidth over the backup link, and the Mountain-Base link, providing at least two (2) 100Gbps channel over one first of the two pairs, and at least one 100Gbps channel over the second pair. Nominal Value
			Softwere a Serena-Santiago link \$25,000/year + IVA (FY2017 - FY2018) \$60,000/year + IVA (FY2019 - FY2021) For the Mountain-Base link

1.02C.08.03.01.01	Contract 1 La Serena - Santiago Network	5	 \$25,000/year + IVA (FY2017 - FY2021) Estimated contract execution date: October 1, 2016 (start of FY2017) Period of Performance: October 1, 2016 - September 30, 2021 (end of FY2021) Terms of Contract: REUNA will deliver: -3€€An "Irrevocable and Exclusive Use" (IEU) of ten (10) functional channels (wavelengths), capable of at least 100Gbps pending equipment installation, on a REUNA operated fiber connection (1 pair of fibers), covering an 18 year period, from October 1, 2016 to September 30 2034. The connection will be made from the AURA/LSST facilities on the AURA Campus in La Serena to a TBD connection point in Santiago. - An "Irrevocable and Exclusive Use" (IEU) of one operational path diverse backup link, of AT LEAST 40Gbps, on a different route from that of the fiber link, covering the 15 year period from September 30, 2019 to September 30, 2034. The connection will be made from the AURA/LSST facilities on the AURA Campus in La Serena to a TBD connections date of September 30, 2019 to September 30, 2034. The connection will be made from the AURA/LSST facilities on the AURA Campus in La Serena to a TBD connection point in Santiago. - An "Irrevocable and Exclusive Use" (IEU) of one operational path diverse backup link, of AT LEAST 40Gbps, on a different route from that of the fiber link, covering the 15 year period from September 30, 2019 to September 30, 2034. The connection will be made from the AURA/LSST facilities on the AURA/LSST (100% capacity, at least 40Gbps) at all times from no later than the initial full network operations date of September 30, 2019. - A "pre-operations" link of AT LEAST 4Gbps from La Serena to Santiago, starting no later than April 1, 2016 and lasting until December 30, 2019 or the delivery of the functional path diverse backup link, whichever comes later. The connection will be made from the AURA/LSST facilities on the AURA Campus in La Serena
			Agreement (SLA). AURA will pay REUNA \$5,760,000 USD for the provision of network connectivity, including the pre-operations link and the specified IEUs for the fiber link and backup channel link, pending the operational agreement to be negotiated as a separate contract, which includes the Service Level Agreement (SLA).
1.02C.08.03.01.01A	Contract 1a La Serena - Gatehouse Network	5	AMENDMENT TO CONTRACT #1: La Serena-Gatehouse Fiber Contract
			(aka Contract #1A) In the context of the LSST baseline, the Mountain-Base connection was considered one segment. In reality it consists of at least two segments with very different conditions. The first is from the mountaintop to the AURA-O "Gatehouse" near the highway up the Elqui Valley. This first segment is completely on AURA property. The second segment is from the Gatehouse to La Serena, running along the highway up the valley. This segment requires fiber runs along the highway, on either public right-of-ways or poles owned by utility companies. The terms of the two contracts are therefore very different for these two segments.
			In mid-2015, it was decided to split these two segments, and attach the Gatehouse to La Serena segment to Contract #1 as an amendment to that contract (this section). This has the benefit of aligning the AURA-REUNA contract obligations with those in the first REUNA-Telefonica contract, which includes both the Santiago-La Serena fiber IEU and the La Serena-Gatehouse fiber IEU. The Summit-Gatehouse segment is left as Contract #3.
			 Terms of Contract Amendment: REUNA will deliver: - An "Irrevocable and Exclusive Use" (IEU) of a network connection of 2 pairs of dark fibers (4 fibers) from the Gatehouse on the AURA "Estancia" to the AURA/LSST facilities on the AURA Campus in La Serena. The 2 pairs of fibers shall be connected at the Gatehouse to the fibers installed from the Gatehouse to the summits. The IEU shall cover an 18 year period, from October 1, 2016 to September 30, 2034.
			During the period of the IEU, REUNA is committed to providing operational support for the jointly-operated fiber infrastructure providing at least 3 channels of 100 Gbps (pending equipment definition) on the complete Summits to La Serena network link, pending the operational agreement to be negotiated as a separate contract, which includes the Service Level Agreement (SLA). The operational support will consist of a fiber maintenance contract (from the original fiber provider) and an equipment maintenance contract (from the equipment provider). Operations and management of the network equipment will be the responsibility of AURA.

AURA will pay REUNA (tentatively) = \$868,500 USD + IVA for the provision of network infrastructure, including the 18year IEU for the fiber infrastructure from the Gatehouse to the AURA Campus in La Serena.

1.02C.08.03.01.02	Contract 2 Liello Consultancy	5	Terms of Contract:
			Professor Fernando Liello will provide consultancy services to AURA/LSST and its sub-awardee REUNA in the design, contract negotiations, and implementation of the Chilean portion of the LSST high-speed network. He will contribute critical experience both in the design and implementation of research networks, based on his 20 years of experience in developing such networks in Europe and South America. He will actively participate in the development and execution of contract negotiations, definitions of terms and specifications for the final contract(s), and the definition and execution of test plans for the deliverables.
1.02C.08.03.01.03	Contract 3 Gatehouse - Summits Network	5	Sole Source Justification: attached as a separate document, including CV. Note: in the context of the LSST baseline plan, this consultancy service is considered part of the work planned for REUNA. Effectively we subtracted the payment for these consultancy services from the total payment planned for REUNA for the La Serena-Santiago network connectivity. In the context of the LSST baseline, the Mountain-Base connection was considered one segment. In reality it consists of at least two segments with very different conditions. The first is from the mountaintop to the "Gatehouse" near the highway up the Elqui Valley. This first segment is completely on AURA property (plus/minus the 1km from the highway to the Gatehouse), and once installed, will be wholly owned by AURA, with a maintenance and repair contract managed by REUNA during operations under a Service Level Agreement (SLA), as described in Contract #1 and its amendment.
			Terms of Contract:
			Telefonica will deliver: - Installation of a fiber bundle of 24 fibers from the Gatehouse on the AURA "Estancia" in the Elqui Valley to the summits of both Cerro Pachón and Cerro Tololo, with connections to be specified in the fiber installation design document. This fiber should be delivered by no later than July 1, 2016. This fiber shall become the property of AURA upon completion of the installation and successful delivery of functional tests.
			AURA will pay Telefonica = \$331,500 USD + IVA for the provision of network infrastructure, specifically including the installation and testing of the fiber bundle from the Gatehouse to Cerro PachÃ ³ n and Cerro Tololo, to be wholly owned by AURA.
1.02C.08.03.01.04	Contract 4 DWDM Equipment	5	This network equipment purchase covers all of the equipment for both the mountain-base and the La Serena to Santiago segments. The motivation for combining this into one purchase is to achieve volume discounts from the provider, and at the same time provide a more homogenous network equipment design, which may help keep maintenance costs lower.
			This network equipment purchase does not include long-haul network monitoring systems (perfMon and equivalent), as that is being designed, developed, and implemented separately.
			The options for this purchase are a. direct purchase by AURA, through a standard solicitation process with vendors, requesting volume and whatever other discounts we can achieve due to the projects profile and AURA's not-for-profit status
			b. a purchase through the University of Illinois purchasing program, taking advantage of their special purchasing arrangements with vendors,
			c. a purchase contract through REUNA, in which REUNA manages a solicitation for the purchase of this equipment together with equipment for other segments of its network, achieving even larger volume discounts
			Whichever option we select, for the La Serena-Santiago segment we will provide the equipment to REUNA on a long- term loan basis for the operations of the La Serena-Santiago links. This equipment will be used to support our traffic as well as other REUNA traffic.
			Terms of Contract: The budget for this purchase is \$1,400,000 USD (+ IVA if purchased in Chile), composed of
			ຈັບບັບບັບວັນ for the La Serena - Santiago link \$600,000 USD for the Mountain - Base link
			Details are pending decision of either AURA purchase, purchase through Illinois, or purchase contract with REUNA.
			For the direct AURA purchase option, we have two quotes in hand: PADTEC = \$1.000.000 USD Ciena = \$1.600.000 USD

These are pre-negotiation, no volume discount quotes. Purchasing through REUNA we expect significant discounts for volume purchase (REUNA would be outfitting additional segments of their Chilean national backbone). Purchasing through University of Illinois would similarly bring discounts through their special vendor purchase program.

1.02C.08.03.01.05 Contract 5 Operating Terms of Contract: 5 Costs during Construction and Commissioning REUNA will deliver network operations support starting from the installation of the LSST network segments in Chile and lasting for the 16 to 18 year duration of the associated IEUs. (Note: operational costs of "pre-operations" link is covered in Contract #1, the La Serena-Santiago fiber contract) - La Serena-Santiago fiber infrastructure operations and maintenance, including maintenance contracts on equipment for one 100Gbps channel. If AURA/LSST chooses to bring additional channels into service, it will pay for the equipment installation costs and maintenance contracts on that equipment, while REUNA will provide standard operations support for the additional channels. - Operations and maintenance of a path diverse backup link from La Serena to Santiago of at least 40Gbps. - Mountaintop-Gatehouse fiber bundle and equipment maintenance contracts (covering the costs of what Telefonica commitments, i.e., AURA/LSST funds cover REUNA costs in Telefonica contract) plus the maintenance contracts on the core network equipment (that purchased in the Network Equipment Contract or replacement purchase) - Gatehouse-La Serena fiber pairs (2) and equipment maintenance contracts (covering the costs of what Telefonica commitments, i.e. AURA/LSST funds cover REUNA costs in Telefonica contract) plus the maintenance contracts on the core network equipment (that purchased in the Network Equipment Contract or replacement purchase) AURA is responsible for: - AURA/LSST will pay REUNA a sum of \$25,000 per year (FY2017 - FY2018) and \$60,000 USD per year (FY2019-FY2021), for the operations of the La Serena-Santiago links (main and backup). Subject to NSF funding of LSST Operations, there will be the option to extend the agreement at the same cost through the end of the IEU (2034). - AURA/LSST will pay REUNA a sum of (\$25,000) USD per year (FY2017-FY2021), for the operations support of the La Serena-Mountain link, covering costs associated with REUNA commitments with Telefonica for the maintenance of the Summit-to-Gatehouse fibers and the Gatehouse-to-La Serena fibers. Subject to NSF funding of LSST Operations, there will be the option to extend the agreement at the same cost through the end of the IEU (2034). AURA will be responsible for all day-to-day operational issues on the La Serena-Mountain link not included above. Note that the personnel costs for AURA operations of this link, as well as monitoring all links described in this document, are included in the baseline Data Management Operations plan. International Chile - US 4 1.02C.08.03.02 Contracts for the International portion of LSST high-speed network: WAN 1. 100G managed ring ï€ A sub-contract through FIU-CIARA with a telecommunications carrier, Latin American Nautilus (LANautilus), covering the acquisition of an 18-year (2016 to 2032) Indefeasible Right of Use (IRU) on two (100g) circuits on the South American Crossing (SAC) cable system. Total Value LSST contribution = \$12,000,000 (depending on lease vs. spectrum decision). Total system approximate value \$42,000,000. Period of Performance: January 1, 2016 - January 1, 2032 http://www.submarinecablemap.com/#/submarine-cable/south-american-crossing-saclatin-american-nautilus-lan 2. FIU-CIARA (CIARA) Management Contract ï€ ï€ A contract for the services of CIARA, working together in the design, contract negotiations, and implementation of the international portion of the LSST high-speed network. CIARA has lead U.S. Latin American Network collaboration through the AmLight project and its successor bringing international research and networking collaboration to South America for more than a dozen years. Total LSST contribution = \$825,000USD. Period of Performance: January 1, 2015 - October 30, 2019.

			Spectrum Contract A contract with Google, Inc covering the acquisition of a 18-year (2016 to 2034) Indefeasible Right of Use (IRU) on 10% of the spectrum available on the Monet dark fiber link from Boca Raton, Florida to Santiago, Chile, providing optical bandwidth that with today's technology can be lit to offer 100g of connectivity. Further exchange with RNP will extend the optical spectrum to Santiago, Chile from Santos, Brazil. Total LSST contribution= \$4,333,000 USD. Total system value \$90,000,000. Period of Performance: April 1, 2017 - September 30, 2021, with the IRU extending to January 1, 2032.
1.02C.08.03.02.01	Contract 1 100 Gbps	5	Terms of Contract:â€"FIU-CIARA will deliver:
	Managed Ring		- Two path diverse 100G Ethernet circuits from the Level 3 POP in Santiago to the NAP of the Americas in Miami; One circuit through the Pacific, and one through the Atlantic. The acquisition of the ring at this capacity is dependent on funds outside of the contributions of LSST. In the case of a failure at any time of other parties to contribute to this contract, the default guaranteed capacity is two 10G circuits guaranteed to LSST through 2032.
		By advancing \$1,000,000 to this contract in FY 2015 from FY 2022 the vendor will provide a \$400,000 discount, which can be used to secure spectrum rather than leased capacity for the domestic segment from Miami to Boca Raton on to the ESnet POP in Atlanta. The operational funds will be then used to light and operate this spectrum. The tactical advantage will be an end-to-end spectrum solution providing for the possibility of applications of new technology to enable unforeseen opportunities for LSST.	
1.02C.08.03.02.02 Contract 2 FIU-CIARA Management	Contract 2 FIU-CIARA	5	Agreement (SLA): AURA will pay FIU \$12,000,000 USD for the provision of network connectivity, including the pre-operations link and the specified circuits pending the operational agreement to be negotiated as a separate contract, which includes the Service Level Agreement (SLA). Terms of Contract:
		FIU-CIARA will provide the management, installation, operation and support for the LSST network construction. This includes the negotiation of contracts, design of infrastructure and the coalescing of a collaboration to mutually benefit the baseline of LSST network infrastructure, and the research and education community's advanced networking. This design is focused on a sustainable infrastructure to meet the defined goals of LSST and provide a dynamic infrastructure to limit the impact of network events on LSST operations.	
1.02C.08.03.02.03	Contract 3 Spectrum	5	Terms of Contract:
			 FIU-CIARA will deliver: A 100G lit linear wave for the exclusive use of LSST from Santiago, Chile to Boca Raton, Florida, from October 1, 2019 to January 1, 2032. This wave will be constructed through purchasing into a contract with Google for a new cable build from Boca Raton to Santos, Brazil. Lighting this infrastructure and linking to an RNP provided infrastructure from Santos to Santiago. RNP will receive unlit spectrum on the consortium purchased Boca-Santos system at no cash cost in exchange for an equal quantity of spectrum lit to Santiago as RNP uses from Santos to Boca Raton, with a minimum of 100G and a maximum of 200G.
1.02C.08.03.02.04	Contract 4 US National	5	A contract with ESNET for spectrum from Miami, to Boca Raton to the ESNET Point of Presence (POP) in Atlanta.
	WAN		It was possible to advance \$1M USD from FIU-CIARA's construction FY budget in 2021 to FY 2015 providing an opportunity to purchase a private spectrum from the savings of \$400,000 from Miami to Boca Raton to Atlanta. In Atlanta ESnet can offer lit private spectrum (at their discretion) or provide shared (yet very private due to the restrictive nature of shared network use of ESnet's DOE guidelines) network conveyance to Chicago Starlight, to then connect on to NCSA. The most likely sub contractor for this service is Allied Fiber.
1.02C.08.03.03	US National WAN (Superceeded by	4	Contracts for the International portion of LSST high-speed network:
	1.020.08.03.02.04)		4) U.S. National Network A potential contract with ESNET for spectrum from Miami, to Boca Raton to the ESNET Point of Presence (POP) in Atlanta. â€"Total Value (tentatively) = \$1,788,000 USD was zeroed out in the LDM-142 as a result of moving payments from 2020 and 2021 up to FY2015 for international network. The cost of leased capacity one-time charge is \$400,000 less, but the difference in value is the spectrum over capacity allowing more secure transport and greater long-term flexibility. Period of Performance: April 1, 2017 - September 30, 2021. (The LSST operations period after this will be funded under a separate award from the NSF.)

1.02C.08.03.04 Mountain - Base Link 4 Contracts for the Chilean portion of LSST high-speed network

1.020.08.03.04	(Superceeded by 1.02C.08.03.01.01A and .03)	4	
			1) Not Associated with this WBS
			2) Not Associated with this WBS
			3) Summits-Gatenouse Fiber Contract A contract with Telefonica covering the installation of 12 pairs (24 filaments) from the ALIRA O Gatebourg to Corre
			Pach \tilde{A}^3 n and Cerro Tololo, to be wholly owned by AURA.
			Total Value (tentatively) = \$331.500 USD + IVA
			Estimated contract execution date: December 15, 2015
			Period of Performance: December 15, 2015 - January 1, 2018
			4) Network Equipment Contract (Only elements associated with Mountain Base in this WBS)
			A contract for, or purchase of, the networking end equipment for both the La Serena-Santiago fiber link and the
			Mountain-Base fiber link. This may be executed as a contract through REUNA, or executed as a direct purchase by
			investigate which option (REUNA contract or AURA purchase) better serves both LSST and REUNA.
			Total Value (tentatively) = \$1,400,000 USD + IVA
			(value depends on final value of equipment purchase, or negotiated contract with REUNA)
			Estimated contract execution date (if applicable): March 1, 2016
			Period of Performance: March 1, 2016 - January 1, 2018
			5) Network Operating Costs during MREFC Contract (Only elements associated with Mountain Base in this WBS)
			A contract with REUNA for the operations and maintenance of both the La Serena-Santiago link, providing at least one
			100Gbps channel over the fiber link and at least 40Gbps dedicated bandwidth over the backup link, and the Mountain-
			over the second pair.
			Nominal Value
			For the La Serena-Santiago link
			\$25,000/year + IVA (FY2017 - FY2018)
			\$60,000/year + IVA (FY2019 - FY2021)
			For the Mountain-Base link
			\$25,000/year + IVA (FY2017 - FY2021) Estimated contract execution date: October 1, 2016 (start of EY2017)
			Period of Performance: October 1, 2016 - September 30, 2021 (end of FY2021)
1.02C.09	System Level Testing & Science Validation	2	This WBS element covers oversight and management of integration and test activities. Each WBS has its own elements of the integration and test for specific items. It includes:
			- Support for the activities of the DM Validation Scientist and the management of the Science Validation team.
			- Maintenance of the overall subsystem testing plan (LDM-503).
			- Participation in large scale tests, with specific responsibility for gathering of test results.
			- Curation of fixed data sets and associated tests assembled to provide a rich set of test data for the Software & Science Quality Control Service (1.02C.10.02.01) and, where necessary, for validation activities.
			No products are defined at this level of the WBS.
1.02C.09.01	Archive Center Integration	3	This WBS element includes DM subsystem integration and test activities of the Archive Center, including:
			Creation of Integration Test Plans and Test Cases
			Execution of Test Plans and Test Cases
			Recording and Analysis of Integration Test Results
			Debug and correcting defects found in testing Data Product documentation and aids (print, web, media)
1.02C.09.02	Base Center Integration	3	This WBS element includes DM subsystem integration and test activities of the Base Center, including:
			Creation of Integration Test Plans and Test Cases
			Execution of Test Plans and Test Cases
			Recording and Analysis of Integration Test Results
			Data Product documentation and aids (print, web, media)
			· · · · · · · · · · · · · · · · · · ·

1.02C.09.03	Chilean Data Access Center Integration	3	This WBS element includes DM subsystem integration and test activities of the Chilean Data Access Center, including:
	-		Creation of Integration Test Plans and Test Cases
			Execution of Test Plans and Test Cases
			Recording and Analysis of Integration Test Results
			Debug and correcting defects found in testing
			Data Product documentation and aids (print, web, media)
1.02C.09.04	US Data Access Center Integration	3	This WBS element includes DM subsystem integration and test activities of the US Data Access Center, including:
			Creation of Integration Test Plans and Test Cases
			Execution of Test Plans and Test Cases
			Recording and Analysis of Integration Test Results
			Debug and correcting defects found in testing
			Data Product documentation and aids (print, web, media)
1.020.09.05	Headquarters Network	3	This WBS element includes DM subsystem integration and test activities of the Long Haul Networks, including:
			Creation of Integration Test Plans and Test Cases
			Execution of Test Plans and Test Cases
			Recording and Analysis of Integration Test Results
			Debug and correcting defects found in testing
4 000 40			Data Product documentation and aids (print, web, media)
1.02C.10	Reliability Engineering	2	products and reliability of services.
			This WDC alamant source three bread areas of works
			Automated Software and Science Quality Control (Verification) Sonvices
			- Science Platform Notebook Environment for $\Omega\Delta$ 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,	3	This WBS element consists of function associated with the project, technical and scientific management of the
	Leadership, & Other Costs		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.	3	This WBS element consists of software, services, unit tests, integration tests, configuration and deployment
	Dataspace Services, and		automation, availability monitoring and documentation for: guality analysis, enabling of science analysis, automated
	Developer Infrastructure		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.
			ine tollowing products (per Section 5) are defined at this level of WBS:
			- UC Halliess
			- ac an eshold notification reporting
			- QC vermeation reporting - Alert stream OC harness
			- Alex Stream & Hamess 1. N2C 10. N2: Science Platform Notebook Environment for OA. Commissioning & Hear 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.10.02.03: 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
- JupterHub 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 adhoc 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 producti

on 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

1.03C.00	Camera Level 2	2
	Milestones	
1.03C.01	System Management	2
1.03C.01.01	Project Office	3
1.03C.01.02	Technical Support	3
1.03C.01.03	Safety and	3
	Environmental	
	Assurance	
1.03C.01.04	Performance Assurance	3
1.03C.02	Systems Engineering and	2
	Design Integration	
1.03C.02.01	Systems Engineering	3
1.03C.02.02	System Analyses	3

Camera Construction

1

1.03C

This WBS Element defines the Level 2 milestones for this project.

1.03C.02.03	Design Integration	3
1.03C.03	Science Raft System	2
1.03C.03.01	Science Raft System	3
1 03C 03 02	Science Sensor	2
1 02C 02 02	Science Front End	2
1.050.05.05	Flectronics	5
1.03C.03.04	Science Back End	3
	Electronics	
1 03C 03 05	Science Baft Cabling	3
1.03C.03.06	Sensor Array Mechanics	3
		-
1.03C.03.07	Science Raft Tower	3
	Mechanics	
1.03C.03.08	Science Control Crate	3
	Mechanics	
1.03C.03.09	Science Array A&T	3
1.03C.04	Corner Raft System	2
1.03C.04.01	Control Raft System	3
1 03C 04 02	Wayefront Sensor	2
1.030.04.02	Waverront Sensor	2
1.030.04.03		3
	Electronics	_
1.03C.04.04	WFS Back End	3
	Electronics	
1.03C.04.05	WFS Cabling	3
1.03C.04.06	Guide Sensor	3
1.03C.04.07	Guider Front End	3
	Electronics	
1.030.04.08	Guider Back End	3
	Flectronics	0
1 030 04 00	Cuiden Cablina	2
1.03C.04.09	Guider Cabling	3
1.03C.04.10	Corner Raft Sensor	3
	Mechanics	
1.03C.04.11	Corner Raft Tower	3
	Mechanics	
1.03C.04.12	Corner Raft Control Crate	3
	Mechanics	
1.03C.04.13	Corner Raft A&T Facility	3
1 020 05	Ontics	r
1.030.05	Optics	2
1.030.05.01	Optics	3
1.03C.05.02	Filters	3
1.03C.05.03	L1-L2	3
1.03C.05.04	L3 Flange	3
1.03C.06	Camera Body and	2
	Mechanisms	
1.03C.06.01	Camera Body and	3
	Mechanisms	
1.03C.06.02	Camera Body	3
1.03C.06.03	Exchange System	3
1.03C.06.04	Shutter	3
1.03C.06.05	Camera Body Cooling	3
	System	
1.03C.07	Cryostat	2
1 03C 07 01	Cryostat	- २
1 020 07 02	Cryostat Housing	2
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1.030.07.03	Cryo and Cold Plates	5
1.03C.07.04	RESERVED	3
1.03C.07.05	Grid Assembly	3
1.03C.07.06	Getter Pumps	3
1.03C.07.07	Cryostat Back End	3
1.03C.07.08	In-Situ Metrology System	3
1.03C.07.09	Cryostat Utillities	3

1.03C.08	Control System and DAQ	2	
1.03C.08.01	Central Control System - Protocols	3	
1.03C.08.02	DAQ	3	
1.03C.08.03	Local Device Control Systems	3	
1.03C.08.04	Cabling & Power	3	
1.03C.08.05	Monitoring & Protection System	3	
1.03C.09	Camera System Integration and Test	2	
1.03C.09.01	Facilities, Integration, Testing & Calibration	3	
1.03C.09.02	I&T Facility	3	
1.03C.09.03	Cryostat I&T	3	
1.03C.09.04	Camera I&T and Calibration	3	
1.04C	Telescope and Site Construction	1	This element includes the procurement, construction, and integration, of the telescope system, its enclosure and support facilities, the summit site, and the base facility. This includes quality assurance and safety, reliability, document control, cost/schedule reporting and control systems, configuration management, and systems engineering for these elements.
1.04C.00	T&S Level 2 Milestones	2	This WBS element defines the Level 2 milestones for this project.
1.04C.01	Telescope System Management	2	This element includes all activities associated with the management and administration of the Telescope and Site team and WBS responsibilities. This includes all activities and support to maintain a core team responsible for the execution of all Telescope and Site tasks. Effort in this area insures compliance with Project level controls, documentation, and reporting.
1.04C.01.01	TS Team Office	3	This element includes all administration of the offices to support the core T&S engineering and construction team including equipment and software tools for individual and common use. This effort is primarily in the Tucson, Arizona Office during the start of the construction effort, but transitions to Chile.
1.04C.01.02	Summit Office	3	This element includes all administration of the offices to support the LSST construction team at the site. This includes equipment and software tools for individual and common use. This effort is primarily focused in La Serena, Chile and the summit.
1.04C.01.03	Safety and Environmental Assurance	3	This element includes Safety Engineering, On-going Safety assessment, and Safety assurance for the Telescope and Site Subsystem construction. Verification of compliance with environmental regulations and permitting requirements is supported in this element. This effort compliments the LSST Project Office Safety effort, focusing on the summit and base safety inspections.
1.04C.01.04	Performance Assurance	3	This is a placeholder element for Quality Assessment and Control efforts for the Telescope and Site Subsystem if such tasks are required. The primary Quality Assurance is currently captured in the effort of the System Engineering team. Quality assurance is also tasked to the technical program officers within each WBS. Independent Quality assessment is also tasked at the LSST Project Level.
1.04C.02	Telescope System Engineering	2	This element includes all T&S system engineering activities. All efforts to insure proper interface and requirement distribution within the T&S system as well as from the T&S to other LSST systems are included. Administration and verification of ICDs, error budgets, risk and hazard analysis, and other system control documentation for the T&S is included as well as input and participation in LSST system level efforts in these areas.
			This WBS element includes the participation in the Project System Engineering Team for specification and analysis of system level details that cross LSST system boundaries. This WBS element also includes the effort for Quality Assessment and Control efforts. Systems Engineering provides the Quality Assurance plan with quality metrics and the final results of verification testing as sub-systems and the final system are tested.
			The T&S System Engineering effort transitions to the Telescope and Site Telescope integration activity (WBS 4.14) in year 5 and year 6. The T&S System Engineer leads the technical effort during the subsystem integration effort and continues into the Early Commission stage in Year 6 to support the WFS commissioning after the Camera is installed.

1.04C.02.01	Telescope System Engineering Management	3	This element includes all T&S system engineering activities. All efforts to insure proper interface and requirement distribution within the T&S system as well as from the T&S to other LSST systems are included. Administration and verification of ICDs, error budgets, risk and hazard analysis, and other system control documentation for the T&S is included as well as input and participation in LSST system level efforts in these areas.
			This WBS element includes the participation in the Project System Engineering Team for specification and analysis of system level details that cross LSST system boundaries. This WBS element also includes the effort for Quality Assessment and Control efforts. Systems Engineering provides the Quality Assurance plan with quality metrics and the final results of verification testing as sub-systems and the final system are tested.
			The T&S System Engineering effort transitions to the Telescope and Site Telescope integration activity (WBS 4.14) in year 5 and year 6. The T&S System Engineer leads the technical effort during the subsystem integration effort and continues into the Early Commission stage in Year 6 to support the WFS commissioning after the Camera is installed.
1.04C.03	Summit Facilities and Infrastructure	2	This element includes all summit facility construction activities, including the architectural and engineering services, project team management and all support effort necessary for the development of the summit infrastructure.
1.04C.03.01	Summit Construction Management	3	This element includes all the engineering and management necessary to support the contracted efforts for summit construction. It includes both project team labor effort as well as any contracted A&E work, testing, and other independent activities to support the construction efforts on the summit.
1.04C.03.02	Summit Site Preparation	3	This element includes summit site preparation to include the final forming of the site through to the final site improvements for regular use, landscaping and safety. This includes any site leveling still necessary to support the Facility design, constructing access roads, installation of the utility lines to the vicinity of the site, and upon completion of the construction activities, final ground treatments and road improvements.
1.04C.03.03	Summit Support Facility	3	This element includes the construction of the summit support facility that includes 1)the Telescope Building, the fixed building under the dome extending from the building and telescope foundations up to the observing floor and Dome interface, 2) the Service and Maintenance Building, connected to the Telescope building providing the high bay coating and camera maintenance areas, basic facility level support equipment and refined control areas, and 3) the fixed building parts of the Calibration telescope. This element includes power, lighting, lifts and built-in equipment and utilities that fall within the category of general construction.
1.04C.03.04	Summit Lodging and	3	This element includes the construction of the dining and lodging facilities on the summit to support LSST integration,
1.04C.04	Dome	2	This element defines the dome system. The Dome is the upper rotating portion of the Telescope Building. It provides the environmental protection of the telescope from the elements during the day. It has an observing aperture that operates to allow the telescope to view the night sky, rotating and maneuvering to keep the aperture within line with the telescope pointing, while shielding the telescope from stray light and excessive wind. The Dome includes the structural and sealing elements, the vents for natural flow of air through the telescope enclosure at night and the drive and control systems to provide the necessary motions.
1.04C.04.01	Dome System Management	3	This element captures the Project engineering and management of the parent WBS. The responsibility will be to provide the technical interface with the contractor to manage the technical requirements and progress. This element includes the resources necessary to conduct the effort required to maintain the technical interaction, support the specified periodic reviews and to manage the internal efforts for independent analysis and testing.
1.04C.04.02	Dome Fabrication Contract	3	This element includes the contracted effort to produce the fabrication drawings, final sub element specifications, and the full fabrication and parts procurement necessary to complete the full Dome for the Telescope and Site System. The effort includes factory testing, shipping, and installation support at the summit.
1.04C.04.02.01	Dome Fabrication Contract Vendor NRE	4	This element includes the effort of creating construction drawings and performance specifications for the subsystems and parts. It includes several stages of construction document preparation with intermittent reviews. This effort includes the NRE and ongoing managemnt tasks at the vendor for the full effort.
1.04C.04.02.02	Fabrication Phase	4	This element includes the contracted effort to construct, assemble, and purchase all materials, hardware, structural elements, electronics, and computer control for the Dome
1.04C.04.02.03	Factory Assembly and Test	4	This element includes the Dome assembly and test effort. The Dome will be substantially assembled and performance tested at the fabrication facility prior to LSST acceptance and shipping to the summit.
1.04C.04.02.04	Dome Shipping to Summit	4	This element includes the transportation efforts to bring the dome components from the manufacturer to the LSST site.

1.04C.04.02.05	Installation of Dome onto Summit Facility	4	This element includes the contracted effort for integration of the dome onto the summit facility lower enclosure.
1.04C.04.02.05.1	ON SITE ASSEMBLY INTEGRATION PHASE (OAI)	5	This element includes the contracted effort for integration of the dome in Chile
1.04C.04.02.05.1.1	Dome structure	6	This element includes the contracted effort for integration of the dome structure onto the summit facility lower enclosure.
1.04C.04.02.05.1.1.1	Steel Structure Installation	7	This element includes the contracted effort for integration of the steel structure onto the summit facility lower enclosure.
1.04C.04.02.05.1.1.1. 1	Side Walls and Roof	8	This element includes the contracted effort for integration of the side walls and roof onto the summit facility lower enclosure.
1.04C.04.02.05.1.1.1. 2	Purlins	8	This element includes the contracted effort for integration of the purlins onto the summit facility lower enclosure.
1.04C.04.02.05.1.1.1 0	Calibration screen	7	This element includes the contracted effort for integration of the dome calibration screen.
1.04C.04.02.05.1.1.2	Access	7	This element includes the contracted effort for integration of the dome access areas onto the summit facility lower enclosure.
1.04C.04.02.05.1.1.3	External scaffolding	7	This element includes the contracted effort for integration of the external scaffolding onto the summit facility lower enclosure.
1.04C.04.02.05.1.1.4	Cladding	7	This element includes the contracted effort for integration of the dome cladding onto the summit facility lower enclosure.
1.04C.04.02.05.1.1.4. 1	Dome sandwich panels	8	This element includes the contracted effort for integration of the dome sandwich panels onto the summit facility lower enclosure.
1.04C.04.02.05.1.1.4. 1.1	Scaffolding partial dismounting	9	This element includes the contracted effort for removal of the dome scaffolding .
1.04C.04.02.05.1.1.4. 2	Dome corrugated aluminium sheet and finishing	8	This element includes the contracted effort for integration of the dome corrugated aluminiun sheets onto the summit facility lower enclosure.
1.04C.04.02.05.1.1.5	Mechanisms	7	This element includes the contracted effort for integration of the dome mechanisms onto the summit facility lower enclosure.
1.04C.04.02.05.1.1.5. 1	Louvers	8	This element includes the contracted effort for integration of the dome louvers onto the summit facility lower enclosure.
1.04C.04.02.05.1.1.5. 2	Light Baffles	8	This element includes the contracted effort for integration of the dome light baffles onto the summit facility lower enclosure.
1.04C.04.02.05.1.1.6	Auxiliary Equipment	7	This element includes the contracted effort for integration of the dome equipment onto the summit facility lower enclosure.
1.04C.04.02.05.1.1.6. 1	Dome Seals and Air Tightness	8	This element includes the contracted effort for integration of the dome seals onto the summit facility lower enclosure.
1.04C.04.02.05.1.1.6. 2	Thermal Control System	8	This element includes the contracted effort for integration of the dome thermal control system onto the summit facility lower enclosure.
1.04C.04.02.05.1.1.7	Electrical Installation	7	This element includes the contracted effort for integration of the dome electrical installation.
1.04C.04.02.05.1.1.7. 1	Cable trays & cables	8	This element includes the contracted effort for integration of the dome cable trays.
1.04C.04.02.05.1.1.8	OB Crane	7	This element includes the contracted effort for integration of the dome overhead bridge crane.
1.04C.04.02.05.1.1.9	Mechanism final alignment	7	This element includes the contracted effort for integration of the dome mechanical systems and final alignment.
1.04C.04.02.05.2	ON SITE ACCEPTANCE TEST PHASE (OAT)	5	This element includes the contracted effort for integration of the dome on site acceptance test phase.
1.04C.04.02.05.2.1	Acceptance test	6	This element includes the contracted effort for integration of the dome acceptance tests.
1.04C.04.03	Calibration Screen Fabrication	3	This element includes the contracted effort for fabrication of the calibration screen by the dome vendor.

1.04C.05	Telescope Mount	2	This element defines the Telescope Mount construction and installation effort. The telescope mount is the structure that supports the mirrors and camera at their proper conjugate positions with stiff structure and active positioning where necessary. It also positions the optical system for pointing at any part of the visible sky and tracks these positions due to their apparent motion from earth. The telescope mount also includes auxiliary systems to protect the sensitive components of the systems and to meet the demanding, stability, pointing, and tracking survey cadence requirements. This effort also includes the Camera and M2 hexapod positioning systems, Camera rotator, mount damping system, the primary/tertiary mirror cover, the stray light baffles, and the dummy masses for testing. (M2 Dummy Cell, Camera Dummy)
1.04C.05.01	Mount System Management	3	This element captures the Project engineering and management of the parent WBS. The responsibility will be to provide the technical interface with both the Telescope mount contractor and the Camera / M2 support system contractor. This element includes the resources necessary to conduct the effort required to maintain the technical interaction, support the specified periodic reviews and to manage the internal efforts for independent analysis and testing.
1.04C.05.02	Mount Fabrication Contract	3	This element includes the mount fabrication contract effort. A single fabrication contract will be awarded for the fabrication, factory testing, and integration support of the telescope mount. The fabrication and delivery of the camera and M2 hexapod/rotator is not included in this element. (See 04C.05.03).
1.04C.05.02.01	Mount Fabrication Contract Vendor NRE	4	This element includes the Mount Contractor effort for management and engineering of the contracted mount system. It includes completing the non-recurring engineering, contract management, and creation of construction drawings and performance specifications for the subsystems and parts. It includes intermittent reviews. This effort includes delivery of integration, testing, and shipping documents.
1.04C.05.02.02	Mount Fabrication Phase	4	This element includes the contracted effort to construct, assemble, and purchase all materials, hardware, structural elements, electronics, plumbing and computers for the telescope mount fabrication phase.
1.04C.05.02.03	Mount Factory Assembly, Test, and Packing	4	This element includes the mount factory assembly, test, and packing effort. The vendor will provide trial assembly of the telescope mount system and demonstrate performance in the factory to the fullest extent possible. Following LSST acceptance the vendor packs the deliverables and loads them for shipping.
1.04C.05.02.04	Mount Installation	4	This element includes the contracted effort to supervise the Telescope and Site integration team in the assembly and integration of the telescope mount on the summit.
1.04C.05.03	TMA Shipping to Summit	3	Obsolete
1.04C.05.04	Camera / M2 Hexapod Support System	3	This element includes the Camera/M2 hexapod support system. The camera and secondary support systems are an integral part of the telescope pointing and control system. These systems support the camera and secondary mirror at their proper conjugate positions and adjust those positions in concert with the other optical elements to provide the best possible image quality. The Camera Support includes a hexapod and an integral rotator that is controlled with the telescope tracking to remove the rotation of the image on the focal plane caused by the azimuth rotation. The requirements for the two hexapod systems are nearly identical, thus both have been specified to match and will be developed and purchased together. This WBS element includes the procurement process, vendor shop drawings with reviews, fabrication and test by the vendor, independent performance and life cycle testing, and delivery of the system to the summit. An extra rotator is also included to be used on the camera handling equipment.
1.04C.06	Mirror Systems	2	This element includes the telescope Mirror Systems. It includes the specification and construction of the three mirror systems in the telescope. Included is the purchase of glass substrate materials, forming the glass into a substrate, and optical polish and testing of the mirror surfaces. The mirror substrates have been procured through non-federal funds and are not included in the construction cost estimate. It also includes the design, fabrication, assembly and integrated testing of the active support systems necessary to safely support and control the shape of the optical surface during operations. Each mirror system is to be tested in the factory prior to shipping to the summit. This element does not include the final on-telescope testing of the individual or system of mirrors. This is captured in the 04C.14 Telescope Integration and Test WBS element.
1.04C.06.01	Mirror System Team Management	3	This element captures the Project engineering and management of the parent WBS. The responsibility will be to provide the technical interface with in-house and contracted efforts. This element includes the resources necessary to conduct the effort required to maintain the technical interaction, support the specified periodic reviews and to manage the internal efforts for independent analysis and testing.

1.04C.06.02	M1M3 Substrate	3	This element includes the fabrication, polishing and testing of a single glass substrate which provides both the Primary and Tertiary mirror optical surfaces. This element does not include the active optical system or mirror cell assembly.
1.04C.06.02.01	NNS Substrate	4	This element is the preparation phase where the final casting process is defined, the raw glass is purchased and the mold is built. This element includes reviews and interface meetings between the vendor and LSST to coordinate the effort to meet specific requirements. Forming of the monolithic substrate is accomplished by spin casting and subsequent heat treating by slow controlled cooling. This element also includes the clean out of the mold material and the preparation of the back surface with a general polish and mounting of the six hardpoint wedges, 156 load spreaders and 146 precision thermocouples.
1.04C.06.02.02	Optical Polishing	4	This element includes the near net shape grinding, fine figuring, and final polishing of the two optical surfaces until both surfaces achieve optical specification both individually and together. This optical testing occurs on the fabrication support system.
1.04C.06.03	M1M3 Cell	3	This element includes the engineering, the fabrication, integration and testing of the Primary/Tertiary mirror cell. The mirror cell assembly includes hardpoint position actuators, static wire rope isolators, pneumatic support actuators, and a thermal control system. After the Primary/Tertiary mirror polishing and test effort is complete, the primary mirror cell assembly will be integrated with the mirror to enable full system optical testing at the factory prior to shipping to the summit.
1.04C.06.03.01	Fabrication, Assembly, Integration and Test	4	This element includes the fabrication and purchase of all the mechanical, electrical, thermal and controls parts of the primary mirror cell system. This effort provides assembly, calibration, and test of the primary mirror cell components to support the integration task. It also includes the process step where the glass and its support system are integrated in the optical fabrication shop for a form and functional test. The complete mirror system will be tested under interferometers to verify the figure control system can be operated to specification.
1.04C.06.04	Secondary Mirror M2 Contract	3	This element includes the fabrication, polishing and testing of a low expansion glass substrate which provides the Secondary mirror optical surface. This element does not include the active optical system or mirror cell assembly.
1.04C.06.04.01	NNS Substrate	4	This element is the specification, procurement, and construction of the glass substrate for the M2 mirror. This element includes the basic forming of the material to create the final substrate, acid etching, and the grinding to bring the glass to near-net-shape.
1.04C.06.04.02	Optical Polishing	4	This element is the optical polishing of the M2 substrate. The near net shape glass is fine ground and optically finished to specification. This element includes specification of all necessary metrology and fabrication support equipment and the optical figure processing. This optical testing occurs on the fabrication support system.
1.04C.06.05	Mirror Shipping and Storage	3	The element includes the final engineering, fabrication, integration, and test of the miror cell structure (M2 Cell), the support actuators to provide the proper force support and location definition, the position sensors, and the control system to manage the mirror support system. This element includes the development of the hardware, the transport of the hardware to the M2 optical polishing contractor, and the effort to assemble the glass to the hardware for integrated testing. The secondary mirror cell assembly will be integrated with the mirror to enable full system optical testing at the factory prior to shipping to the summit.
1.04C.06.05.01	M1M3 Shipping and Storage	4	This element is the fabrication and purchase of all the mechanical, electrical, thermal, and controls parts of the secondary mirror cell system. This effort provides assembly, calibration, and test of the secondary mirror cell components to support the integration task. It also includes the process step where the glass and its support system are integrated in the optical fabrication shop for a form and functional test. The complete mirror system will be tested under an interferometer to verify the figure control system can be operated to specification.
1.04C.06.05.02	Secondary Mirror	4	This element is the effort for transportation of the secondary mirror from the vendor facility to the summit.
1.04C.07	Wavefront and Alignment Sensing	2	This element includes the two telescope metrology systems used to monitor the optical figure of the mirror surfaces (Wavefront Sensing (WFS)) and the rigid body positions of the optical subsystem (Alignment). These systems provide the measurement of the critical positions and delivered wavefront necessary to provide correction signals to each appropriate subsystem. WFS is accomplished by the method of curvature sensing utilizing intra and extra focal star images from the Camera. This WBS element does not include the sensors in the focal plane. Alignment sensing is accomplished by an independent metrology system (laser tracker) that can operate at anytime.

1.04C.07.01	WFS/AOS System Mgmt and Engineering	3	The element is the WFS/Active Optics System (AOS) management and engineering effort. WFS and Alignment system will be developed through direct project control. This Element captures the technical management and engineering team responsible for the full system development, integration, and testing. The Sensor Modules will be provided by the Camera System mounted in the focal plane to the specifications defined by this engineering team. Extra sensor modules will be provided for lab testing.
1.04C.07.02	WFS/AOS Software Pipeline	3	This element is the WFS/Active Optics System (AOS) software pipeline. Multiple wavefront sensors in the focal plane provide signals that will be combined and analyzed by the WFS and Reconstructor pipeline. The pipeline takes raw intra and extra focal images from the camera and the output is alignment and figure adjustment commands to be sent to each individual subsystem.
1.04C.07.02.01	Wavefront Estimation Pipeline	4	This element brings together the Wavefront Data Client, Image Processing, Estimator and Reconstructor into one software module
1.04C.07.02.02	Wavefront Data Client	4	This element is to interface with the Camera DAQ system through its development in conjunction with DM
1.04C.07.02.03	Wavefront Image Preprocessing	4	This element is the image processing module. This is the front end image processing portion of the WFS and Reconstruction pipeline where the images will be processed and prepared for the WFS analysis code.
1.04C.07.02.04	Wavefront Estimator	4	This element includes the wavefront estimation module. This is the portion of the pipeline that does the wavefront analysis of each intra and extra image pair provided by the Camera
1.04C.07.02.05	Wavefront Reconstructor	4	This element includes the Reconstructor module. The Wavefront estimates provided for the multiple field locations will be processed to determine the appropriate corrections to mirror figures and optical alignment by the reconstruction portion of the pipeline.
1.04C.07.03	Telescope Alignment System	3	This element is the telescope alignment system, principally a laser tracker. The alignment system is an independent metrology system to provide rigid body positioning feedback for the critical optical elements of the system. This laser tracker based system operates independent of focal plane activity. Both mirror systems (Primary/Tertiary and M2) and the Camera will include permanent fiducials to allow this system to be used for absolute alignment when necessary in construction and anytime during operations when coarse alignment of the system is necessary.
1.04C.08	Calibration System	2	This WBS element captures the effort to design and build the telescope and site parts of the LSST Calibration System. The WBS includes the project and subawarded efforts to complete final design and specification of the hardware to meet the requirements. The Calibration subsystem elements in this WBS provides optical system and atmospheric measurements at prescribed intervals to determine the conditions under which data was acquired to assist in data calibration. There are two major elements provided by the Telescope and Site Observatory: the Telescope and Camera Calibration System to determine the transfer function of the entire optical system and detector as a function of wavelength, and an Auxiliary Atmospheric Calibration System that is dedicated to monitor the atmospheric extinction present during the observing night.
1.04C.08.01	Calibration System Management	3	The element is the Calibration System management and engineering effort. The Calibration system design will be managed within the group, with hardware procured, fabricated, and shipped to the summmit.
1.04C.08.02	In-Dome Calibration System	3	The calibration screen design has changed due to calibration requirement updates (see LCR-140). Consequently, document-11900 and document-11901 are now obsolete. One of the results is a simpler diffusive calibration screen similar to the screen recently fabricated for DECam calibration.
			The In-Dome calibration package handles the two calibration systems that are located in the LSST enclosure. This includes the hardware components that are located within the building to support these activities but not necessarily in the enclosure. These systems are used in combination (albeit not necessarily simultaneously) to measure the optical transfer function, monitor evolution of the optical system, and perform detector characterization.
			The first system is the Calibration Screen which is an ~11-meter wide reflective dome screen with a 3-meter center hole. This large structure will be placed in the dome and will be able to move between two positions (park and servicing). This reflective screen is illuminated and reflects light into the LSST telescope.
			The second system is illumination system that is used to illuminate the screen and collimated beam projector (contained in 16-02.04C.08.04) as well as monitor and characterize the light reflected from the screen. The illumination system consists of two rings of illuminators contained on the secondary support structure of the TMA. One ring of illuminators is located on the outer supporting ring whereas the second is contained on the inner ring. These illuminators will illuminate the calibration screen with white and monochromatic light.

			The monochromatic light will be generated from a tunable pulsed laser system from Ekspla that spans a wide wavelength range (300nm-1100nm) and has the ability to step in very narrow bandwidth increments (~1nm steps) as required for selective calibration of the camera filter pass bands. The two sources provide the adequate flux on the screen to enable the measurements to be made in the allocated time. The white light will be generated from a broadband laser-driven light source that will span the entire wavelength range of the LSST detectors.
1.04C.08.03	Auxillary Telescope System	3	The light sources will be located in a special laser room located in the Utility Room on an optical bench. The light will then be coupled into fibers and directed towards the desired source (either dome screen illuminators or the Collimated Beam Projector). The light from the lasers and white light sources will be monitored using a commercial spectrograph and a series of NIST calibrated photodiodes. This is required to monitor both intensity variations of the sources and to measure the laser wavelength to high precision. This element summarizes the atmospheric calibration system. This is an instrumented 1-meter class telescope sited adjacent to the LSST to monitor the atmospheric extinction present during the observing night. The system includes the calibration telescope, building, dome, and support facilities necessary for an operational autonomously operated system. The operations of the system are conducted from the main LSST control room. The system also includes an imaging system to be mounted and bore-sighted with the main LSST telescope to probe the specific sky being observed with the main telescope.
1.04C.08.04	Collimated Beam Proiector	3	This element includes the Collimated Beam Projector
1.04C.09	Reflective Coating System	2	This element includes the coating facility and associated cleaning facility necessary to apply the reflective coating onto the primary, secondary, and tertiary mirror surfaces. This facility includes the equipment necessary to strip a coating, clean the mirror, and apply the coating in a vacuum based coating system. This element does not provide the fixed facility assets necessary for effluent capture, facility barriers for cleanliness or the mirror transport system to convey the mirrors into the process stations.
1.04C.09.01	Coating System Mgmt & Engineering	3	This element provides the project engineering and direct supervisory effort to manage the final specification, procurement, acquisition, and system integration of the parent elements.
1.04C.09.02	Coating Chamber System	3	This element is the coating chamber system. The coating system includes the vacuum chamber and all the ancillary equipment necessary for a turnkey coating system for depositing the specified coating on the three reflective mirror surfaces. This includes the contracted efforts for constructing the coating facility, testing, shipping, and installation on site.
1.04C.09.03	Mirror Cleaning System	3	This element includes the mirror cleaning facility to allow the removal of previously deposited reflective coatings and the cleaning of the three mirror surfaces to prepare them for the coating process. This system includes the physical hardware and the support equipment to achieve these procedures safely. Personnel access equipment, as necessary, is included in this element.
1.04C.10	Observatory Control System	2	This element includes the Observatory Control System (OCS). The OCS is the primary high level master of the hierarchical control system that schedules, commands, coordinates and monitors the summit observatory, in order to conduct the process of achieving the survey goals. The OCS consists of software subsystems that interact though a software connectivity backbone on top of the observatory communications network. It provides the means to support safe and efficient operations on the summit, day and night when the observatory is in any operational state.
1.04C.10.01	Management and Engineering	3	The OCS will be developed through direct project control. This element captures the technical management and engineering team responsible for the full system development, integration, and testing. The management of OCS implementation is critical, being the OCS the physical glue and coordinator of the subsystems in the LSST, requiring a great deal of attention to the integration phases.
1.04C.10.02	Scheduler	3	This element summarizes the OCS scheduler. The scheduler is that portion of the software that generates the targets to be observed. The targets are generated based on the scientific programs demands, the present observatory conditions and the survey progress. This element also includes integration of the software into the OCS system.
1.04C.10.03	Application	3	This element includes the Observatory Telemetry System (OTS). The OTS is the hardware and software necessary to capture, monitor, analyze, and archive conditions and state of the observatory during operations. It will generate predefined packets of condition information for each image, it will store engineering and maintenance conditions to support operations and it will connect to the LSST Data Management System for persistence of the data.
1.04C.10.04	Sequencer	3	This element includes the OCS software application. This software implements the logic to perform observations. It sequences and coordinates subsystems operations, and performs monitoring activities system wide. This element also includes the supervision of the contractual efforts.

1.04C.10.05	Operator	3	This element includes the OCS operator. This software component contains all the interfaces and access control for the different kinds of users to the OCS.
1.04C.10.06	Remote	3	This element summarizes the OCS Remote Operations System (ROS). The ROS provides the software and hardware to allow the observatory to operated and monitored from a remote location. A summit based telescope operator is still required, but remote operations add the scientific and engineering monitoring of the hardware and survey progress, for real time feedback and adjustment of scheduling priorities.
1.04C.10.07	Monitor	3	This element includes the OCS monitoring system. The LSST will produce thousands of telemetry signals that need to be monitored and analyzed. The monitoring system provides the displays, interfaces and the basic set of tools to deliver meaningful information out of the telemetry and data coming out from the LSST
1.04C.10.08	Maintenance	3	This element includes the OCS integration into the LSST maintenance system
1.04C.10.09	Middleware	3	This element summarizes the OCS communications middleware. This is the communications software utilized to transport messages and status information across the system. This element includes the development of software interfaces, for the other system components to utilize this communications middleware. Also includes support for other software developers in the use of the interface package.
1.04C.10.10	Telemetry	3	This element includes the Observatory Telemetry System (OTS). The OTS is the hardware and software necessary to capture conditions and state of the observatory during operations.
1.04C.10.11	Engineering and Facility Database	3	This element includes the OCS Engineering and Facility Database (EFD). The EFD is the database that stores all the generated telemetry produced by all the subsystems during the LSST operations.
1.04C.10.12	Computer Hardware	3	This element includes the OCS computer hardware. This includes independent CPUs and all summit control room monitors and peripheral equipment to interface with the system.
1.04C.11	Telescope Control System	2	This element summarizes the Telescope Control System (TCS). The TCS is the central coordination facility for the delivery of high quality field images to the camera. The TCS includes the software and hardware necessary to efficiently and safely control all aspects of the telescope and its subsystems, both under local or remote control. This element contains all work required to design, code, integrate and test, in the lab and in the field, the high level coordination software. It also provides support for engineering, set-up and maintenance, and creates a dynamic environment for development and evolution of control applications. Telescope Control System does not contain: subsystem local computers, controls and electronics, if any, delivered by other work packages.
1.04C.11.01	TCS System Mgmt and Engineering	3	This element summarizes the TCS system management and engineering effort. The TCS element will be developed through direct project labor and control. This element captures the technical management and engineering team responsible for the full system development, integration, and testing. The Telescope, Optics and Subsystems, will be provided by other contract packages.
1.04C.11.02	TCS Active Optics	3	This element defines the software to control image quality. This includes algorithms for open-loop control and for closed-loop control based on measured wavefront data. This element sends demands to other systems, not included in this WBS element, responsible for controlling the motions of the corrective elements.
1.04C.11.03	TCS Calibration	3	This element identifies the TCS Calibration components, including the Illumination Control, Illumination Measurement System, Screen Control, Field Calibration System and the Collimated Light Projector Control.
1.04C.11.04	TCS Enclosure Control	3	This is management of an external contract for the software to control the enclosure (dome).
1.04C.11.05	TCS M2	3	This element covers management of an external contract for the M2 Control System, which controls the position and figure of the Secondary mirror. This element includes the integration of the M2CS software into the TCS.
1.04C.11.06	TCS Mount	3	This is management of an external contract for the Mount control system software.
1.04C.11.07	TCS Pointing	3	This is management of an external contract for the pointing calculations. This software perfroms astrometric transformations and computes the demands to point and track the mount and rotator.
1.04C.11.08	TCS Rotator	3	This covers management of an external contract for the Rotator control system software.
1.04C.11.09	TCS M1M3	3	This element covers the M1M3 Control System (M1M3CS), which controls the position, figure, and thermal conditioning of the Primary/Tertiary mirror. This element includes the integration of the M1M3CS software into the TCS.
1.04C.11.10	TCS Enclosure Environment	3	This element includes systems to monitor or control the environment within the enclosure. This includes systems for monitoring mirror temperatures, monitoring vibrations, and controlling enclosure ventilation and lighting.

1.04C.11.11	TCS Teststands	3	This element includes software systems for testing TCS-related devices, including ILCs and actuators.
1.04C.11.12	TCS Aux Telescope	3	This element comprises the development software for the Auxiliary Telescope (Calypso), along with its enclosure and spectrograph, and the interface software to integrate with the TCS system.
1.04C.11.13	TCS Aux Instruments	3	This element defines the Auxiliary System Modules (ASM). The ASM comprises the development of interface software to integrate into the TCS system equipment to provide environmental and calibration information for the observing processes. A partial list of equipment includes weather station, infrared all-sky camera, MASS/DIMM telescope, seismic monitor, microwave radiometer, and GPS water vapor sensor.
1.04C.11.14 1.04C.11.15	TCS Facility TCS Hexapod	3 3	This element includes monitoring and control software for the TCS Facility. This is management of an external contract for the control software for the camera and M2 hexapods.
1.04C.11.16	TCS Application	3	This element defines the TCS high-level control application, which handles coordinated interactions of its
1.04C.11.17	TCS Guiding System	3	subcomponents. This element includes functionalities to select guide stars and associated ROIs for the guide sensors, process the data
1.04C.11.18	TCS Hardware	3	from the guide sensors, and calculate and publish guide offsets. This element defines the TCS computer hardware, including CPUs in the computer room, as well as all telescope
			operator monitors and periphery equipment to operate the telescope system in the engineering control room.
1.04C.11.19	TCS Software Architecture	3	This element describes global architectural design work, resulting in design models and documents.
1.04C.11.20	TCS ILC	3	This element defines work associated with tools and applications required for the Inner Loop Controller.
1.04C.11.21	WFS/AOS Software Pipeline	3	This element is the WFS/Active Optics System (AOS) software pipeline. Multiple wavefront sensors in the focal plane provide signals that will be combined and analyzed by the WFS and Reconstructor pipeline. The pipeline takes raw intra and extra focal images from the camera and the output is alignment and figure adjustment commands to be sent to each individual subsystem.
1.04C.11.22	TAS Telescope Alignmen System	t 3	This element is the telescope alignment system, principally a laser tracker. The alignment system is an independent metrology system to provide rigid body positioning feedback for the critical optical elements of the system. This laser tracker based system operates independent of focal plane activity. Both mirror systems (Primary/Tertiary and M2) and the Camera will include permanent fiducials to allow this system to be used for absolute alignment when necessary in construction and anytime during operations when coarse alignment of the system is necessary.
1.04C.11.23 1.04C.12	TCS Common Utilities and Support Equipment	3 2	This element covers items common to all TCS interfaces. This element includes the equipment and subsystems needed for initial integration, operation of the facility, and routine maintenance of the summit facility and local hardware. These equipment and subsystems are all delivered for use during the construction phase and will remain with the facility for long term use.
1.04C.12.01	Utilties and Equipment Mgmt and Engineering	3	This element captures the Project engineering and management of the parent WBS. The tasking provides the technical interface with in-house and contracted efforts. This element includes the resources necessary to conduct the effort required to maintain the technical interaction, support verification testing, and shipment of the deliverables to
1.04C.12.02	Safety Systems	3	This element includes the telescope safety systems. Facility wide emergency stop system to cut power to all motion systems and pressurized systems and a separate interlock system to prohibit certain system operation or movement when all systems are not in a nominal operational state or specific lockout is necessary for personnel safety.
1.04C.12.02.01	Access Control System	4	
1.04C.12.02.02	Laser Interlock System	4	This element includes the telescope safety systems to support the Access Control System
1.04C.12.02.03	Auxiliary Telescope	4	This element includes the telescope safety systems to support the Laser Intelock System
	inchock System		This element includes the telescope safety systems to support the Auxiliary Telescope Interlock System
1.04C.12.03	Monitoring Systems	3	This element includes the telescope monitoring systems. This is the equipment for summit facility exterior and interior condition monitoring that included weather data stations to monitor temperature, humidity, wind speed and direction, video and audio systems for remote situational awareness.

1.04C.12.04	Facility Systems	3	This element includes the telescope facility systems. This provides the necessary common utility systems necessary to support all power, air, and coolant supplies and returns. This does not include the custom utility systems for the camera cooling and coating facility.
1.04C.12.05	Summit Network System	3	This element includes the telescope summit network system. It is the hardware, software, and fiber links necessary to support the communications needs within the summit facility. This includes the fiber runs, end equipment, and switches to provide both common and dedicated networks. It does not include the conduits and cable trays to carry the infrastructure, it does not include the cables and network equipment for the camera focal plane data stream, nor does it include the end equipment for the summit to base data lines.
1.04C.12.06	M1M3 Cell Cart and Tools and Equipment	3	This element includes the permanent equipment and tooling, and leasing of special equipment necessary for initial integration and testing.
1.04C.12.06.01	Summit Fiber Optics Tools	4	This element includes the fiber optic tools for initial integration and testing.
1.04C.12.06.02	Summit Electrical/Electronics Tools	4	This element includes the Summit Electrical and Electronics tools for initial integration and testing.
1.04C.12.06.02.01	Assembly and Crimping Tools	5	This element includes the Assembly and Crimping tools for initial integration and testing.
1.04C.12.06.02.02	Electrical Test Tools	5	This element includes the electrical testing tools for initial integration and testing.
1.04C.12.06.02.03	Electronics Tools and Communications	5	This element includes the electronics tools and communications materials for initial integration and testing.
1.04C.12.06.03	Summit Vibration Analysis Tools	4	This element includes the Assembly and Crimping tools for initial integration and testing.
1.04C.12.06.04	Summit Thermal Analysis Tools	4	This element includes the summit thermal analysis tools necessary for initial integration and testing
			This element includes the summit thermal analysis tools necessary for initial integration and testing.
1.04C.12.06.05	Summit Monitoring Audio-Visual Equipment	4	This element includes the summit monitoring Audio-Visual equipment necessary for initial integration and testing.
1.04C.12.06.06	Summit Monitoring Weather Equipment	4	This element includes the summit monitoring weather equipment necessary for initial integration and testing.
1.04C.12.06.07	Summit Monitoring Earthquake Display Equipment	4	This element includes the summit monitoring earthquake display equipment necessary for initial integration and testing.
1.04C.12.06.08	Summit Monitoring DIMM Equipment	4	This element includes the Summit monitoring DIMM equipment necessary for initial integration and testing.
1.04C.12.06.09	Slings and Scales	4	This element includes the slings and scales necessary for initial integration and testing.
1.04C.12.06.10	Integration Handling	4	This element includes the integration and handling equipment necessary for initial integration and testing.
1.04C.12.07	Vehicles and Transportation	3	This element includes the capital purchase, maintenance and expendables for the vehicle fleet necessary to support summit observatory construction, integration and commissioning.
1.04C.12.08	Shipping and Logistics	3	This element includes the details to ship the Telescope Mount Assembly from Spain, the Hexapod/Rotator from AZ, the M1M3 mirror from AZ, the M2 mirror from NY, the calibration telescope from AZ, and the Coating Plant from Germany.
1.04C.12.09	Camera Support Assembly Cart	3	
1 04C 12 10	M2 Equipment	3	This element includes the Camera Support Assembly Cart for initial integration and testing.
1.04C 12 10.01	M2 Equipment	1	This element includes the M2 equipment necessary for initial integration and testing.
1.04C.12.10.01	Relocation Mount	4	This element includes the Baffle Temporary Relocation Mount necessary for initial integration and testing.
1.04C.12.10.02	M2 Baffle and Fixture	4	
			This element includes the M2 Baffle Removal and Installation Fixture necessary for initial integration and testing.
1.04C.12.11	M1M3 Equipment	3	This element includes the M1M3 specific equipment necessary for initial integration and testing.

1.04C.12.11.01	M1M3 Maintenance Cover	4	
			This element includes the M1M3 Maintenance Cover necessary for initial integration and testing.
1.04C.12.11.02	M1M3 Surrogate Lift Spreader Bar	4	
			This element includes the M1M3 Surrogate Lift Spreader bar necessary for initial integration and testing.
1.04C.12.11.03	M1M3 Maintenance Deployable Tent	4	This element includes the M1M3 Maintenance Deployable Tent necessary for initial integration and testing.
1.04C.12.11.04	M1M3 Cart Rail Sections, Shims and Transition Section	4	This element includes the summit M1M3 Cart rail Sections necessary for initial integration and testing.
1.04C.12.12 1.04C.12.12.01	Summit Equipment Jib Crane in Lower Enclosure	3 4	This element includes the Summit Equipment necessary for initial integration and testing.
1.04C.12.12.02	Fixed Articulating Manlift in Dome	4	This element includes the Jib Crane necessary for initial integration and testing.
1 04C 12 12 02	Forkl ifts	1	This element includes the Fixed articulating Manlift necessary for initial integration and testing.
1.040.12.12.03	FUIKLIILS	4	This element includes the fork lifts necessary for initial integration and testing.
1.04C.12.12.03.01	Outdoor/Indoor Forklift	5	This element includes the Indoor/Ourdoor fork lifts necessary for initial integration and testing.
1.04C.12.12.03.02	Electric Forklift	5	
			This element includes the electric fork lifts necessary for initial integration and testing.
1.04C.12.12.04	Scissor/Indoor Lifts	4	This element includes the Scissor and Indoor Lifts necessary for initial integration and testing.
1.04C.12.12.05	Boom Lift	4	I his element includes the Outdoor Articulating Boom Lift necessary for initial integration and testing.
1.04C.12.12.06	Summit Furniture	4	
1.04C.12.12.07	Power Tugs	4	This element includes the Summit Furniture necessary for initial integration and testing.
	C C		This element includes the Power Tugs necessary for initial integration and testing.
1.04C.12.12.08	Hydrasets	4	This element includes the Hydrasets necessary for initial integration and testing.
1.04C.12.12.09	Ladders	4	This element includes the Ladders necessary for initial integration and testing.
1.04C.12.12.10	Summit Machine Shop Equipment	4	This element includes the Summit Machine Shop Equipment necessary for initial integration and testing.
1.04C.12.12.11	Summit Hand Tools	4	This element includes the Summit Hand Tools necessary for initial integration and testing.
1.04C.12.13	Coating Optical	3	This element includes the Coating Optical Equipment necessary for initial integration and testing.
1.04C.12.13.01	Receiving Area Containment Structure	4	This element includes the Receiving Area Containment Structure necessary for initial integration and testing.
1.04C.12.14	Pointing Test Equipment	3	This element includes the Pointing Test Equipment necessary for initial integration and testing.
1.04C.12.15	VRCAC and Roof Locks	3	This element includes the VRCAC and Roof Locks necessary for initial integration and testing.
1.04C.12.15.01	VRC Auxiliary Control	4	This element includes the VRC Auxiliary Control necessary for initial integration and testing.
1.04C.12.15.02	Roof Folding Flap Edge Actuators	4	This element includes the Roof Folding Flap Edge Actuators necessary for initial integration and testing.
1.04C.12.15.03	Roof-Building Locks	4	This element includes the Roof-Building Locks necessary for initial integration and testing
1.04C.12.16	Dynalene Cooling System	3	This element includes the Dynalene Cooling System necessary for initial integration and testing.
1.04C.12.17	Post Construction	3	This WBS contains support effort to support subsystems at the end of tthe vendor completion. This includes contraced effort to support the Pflow lift, Clean rooms, AuxTel, and additional road work.
1.04C.12.18	Environmnetal Awareness System	3	1. Sense aspects of the dome and surrounding environment in order "to optimize science data quality and operational efficiency." temperature stratification via temperature sensors airflow via bulk airflow sensors and 2D anemometers turbulence via 3D high frequency anemometers and/or spot motion sensors vibration via accelerometers, delivered image quality (DIMMs, CMOS Camera/SH, Guider data) humidity (external and internal)

			RFI Power ground loops Other weather components 1. Control dome environment constant temperature with ambient via HVAC, downdraft system smooth and steady airflow via louvers, fans, downdraft system vibration optimization with a, b to deliver best image quality 1. Feed environmental data to other components M1/M3 cell - temperature set point, aspects in LUTs via AOS M2 cell - temperature set point, aspects in LUTs via AOS Camera - temperature set point TMA drives - temperature set point, wind reactive loop Cabinets inside pier/lower enclosure (TMA, Dome, others?) - temperature set point Glycol system - flow, temperature Dynalene system Scheduler - avoidance region/map interface Safety/personnel security awareness via microphones, webcams
1.04C.12.19	Special Utilities	3	Graphical display (INRIA/React)s, Engineering Offor ECS) This WBS element contains the scope to design, manufacture, and install the following utility systems: Dynalene, Compressed Air, Condensate Drains, Fixed temperature EGW, Oil supply system, Power (TMA, OSS, Camera compressors), Low temperature EGW, Power (staging and test area), Fiber (staging and test area), and camera compressor cabinet utilities (power, fixed temp EGW, low temp EGW, refrigeration line connections).
1.04C.13	Base Facility and Infrastructure	2	This element summarizes the telescope base facility. The base facility provides the local offices, lab space, and computing facility off the mountain in the closest town or city. The base facility provides the space to serve as the local headquarters for the project. The LSST Base Facility is expected to be a cooperative development with other programs headquartered on the La Serena AURA Recinto. Each program would contribute proportionately to the amount of space dedicated to their use.
1.04C.13.01	Pre-Construction Specs and A&E Contract Prep	3	This element is the effort to complete the specfications and design documents necessary to select an architecture and engineering firm.
1.04C.13.02	A&E Construction Documents	3	This is the effort of developing a design and producing construction documents (drawings and specifications) for the La Serena Base Facility. The facility is expected to be located on the AURA recinto, as either a stand-alone structure or an addition to the existing CTIO headquarters facility. The contracted services include several stages of design with intermittent reviews. The process concludes with the issuance of a bid package for the construction effort and review of construction proposals.
1.04C.13.03	Base Construction Management	3	This element defines the telescope base facility construction management. Following pre-construction discussions with A&E firms, a final requirement package is assembled and bidding for architectural and engineering support is conducted. This effort of developing a design and producing construction documents (drawings and specifications) for the La Serena Base Facility. The facility is expected to be located on the AURA recinto, as either a stand-alone structure or an addition to the existing CTIO headquarters facility. The contracted services include several stages of design with intermittent reviews. The process concludes with the issuance of a bid package for the construction effort and review of construction proposals.
1.04C.13.04	Base Facility Construction Phase 1 - Remodeling and Site Preparation	3	This element defines the telescope base facility site construction. Includes all site work from initial preparation of the site and extension of existing site utilities through final site improvements for regular use. This includes site leveling, provision of driveways and parking areas, site electrical, water & sewer connections, final pavements, walks, landscaping and other improvements. If the addition option is pursued, this would also include some minor demolition of existing structures.
1.04C.13.05	La Serena Base Facility Construction	3	This element includes construction of the Base Facility from foundations and primary structure, exterior walls and roof, all interior utility systems, and all interior construction and finishes. Base Facility is expected to be either an addition to the existing CTIO headquarters facility in the AURA Recinto or a new stand-alone building at another Recinto location.

1.04C.14	Telescope Integration and Test	2	This element includes the telescope integration and test efforts, mainly in Yr5 and Yr6. This is the WBS element to capture all site activities to integrate and test the telescope system. Some effort for subsystem integration on site is included in the respective construction categories. This task covers the primary labor and equipment support to all activities toward integration and functionally testing the system. This effort leads to Early Commissioning in FY20 with the ComCam (Commissioning Camera).
1.04C.14.01	Telescope Integration Mgmt and Engineering	3	This element provides the technical management of the Telescope integration effort. The Lead is provided by the Telescope and Site System Engineer and supported by the technical team responsible for the development of the constituent hardware.
1.04C.14.02	Integration Tooling and Equipment	3	This element provides the laser tracker as facility alignment system, support system for M3 interferometric test (interferometer on loan) and tools and equipment for 3-mirror optical testing identified for the telescope integration and test.
1.04C.14.02.01	ComCam	4	This WBS covers the procurement of the optics for the ComCam system. This includes 2 lenses in an assembly, and a loose optic to be sent to the camera team to integrate to a test dewar.
1.04C.14.02.02	Interferometer	4	This WBS supports the design and fabricatin of support structures and counterweights needed for the telescope for M3 interferometric testing.
1.04C.14.02.03	Image Quality Diagnostics System	4	This WBS supports the design and fabricatin of the SHWFS and CMOS Cameras
1.04C.14.02.04	ComCam Integrating Structure	4	This WBS supports the design and fabrication of the Camera Mass Simulator
1.04C.14.02.05	Laser Tracker Summit	4	This WBS supports the design and procurement of the Laser tracker
1.04C.14.03	Major Equipment Leasing and Rental	3	This element provides the major equipment (cranes, etc.) that will be rented or leased during the telescope integration and test.
1.04C.14.04	Subsystem Integration and Test	3	This element summaries the effort to provide telescope subsystem integration and test.
1.04C.14.04.01	TMA Integration & Test	4	This element summaries the effort to provide TMA subsystem integration and test.
1.04C.14.04.02	M1M3 Integration & Test	4	This element summaries the effort to provide M1M3 subsystem integration and test.
1.04C.14.04.03	Top End Assembly Integration & Test	4	This element summaries the effort to provide tope end assembly subsystem integration and test.
1.04C.14.04.04	M2 Integration & Test	4	This element summaries the effort to provide M2 subsystem integration and test.
1.04C.14.04.04.01	M2 Cart & Cell Operations	5	This element summaries the effort to provide M2 subsystem integration and test with the M2 cart and cell.
1.04C.14.04.04.02	M2 Maintenance Operations	5	This element summaries the effort to provide M2 subsystem maintenance and operations.
1.04C.14.04.04.03	M2 Coating Operations	5	This element summaries the effort to provide M2 coating.
1.04C.14.04.04.04	M2 TMA & Dome Operations	5	This element summaries the effort to provide M2 integration with the TMA.
1.04C.14.04.05	Integrated Optical Testing	4	This element summaries the effort to provide telescope subsystem integration and test.
1.04C.14.04.06	Coating Chamber Integration & Test	4	This element summaries the effort to provide calibration subsystem integration and test.
1.04C.14.04.07	Calibration Systems Integration & Test	4	This element summaries the effort to provide computing and software subsystem integration and test.
1.04C.14.04.08	Computing & Software Integration & Test	4	This element summaries the effort to provide monitoring subsystem integration and test.
1.04C.14.04.09	Monitoring Systems Integration & Test	4	This element summaries the effort to provide monitoring subsystem integration and test.
1.04C.14.04.10	Dome Integration and Test	4	This element summaries the effort to provide Dome integration and test.
1.04C.14.04.11	Roof and Platform Lift Integration and Test	4	This element summaries the effort to provide Roof and Platform Lift integration and test.
1.04C.14.04.12	Global Interlock Safety Integration and Test	4	This element summaries the effort to provide the Global Interlock and Safety integration and test.

1.04C.14.04.13	General Equipment Integration and Test	4	This element summaries the effort and materials to support subsystem integration and test.
1.04C.14.04.14	Verification	4	This element summaries the effort to provide verification if all subsystems during integration and testing.
1.04C.14.04.15 1.04C.15	General Tasks Telescope and Site Software	4 2	This element summaries the effort to provide general support for subsystem integration and test. This WBS element contains the remaining effort to complete all OCS and TCS related effort, previously reported under 1.04C.10 and 1.04C.11. The TCS is the central coordination facility for the delivery of high quality field images to the camera. The TCS includes the software and hardware necessary to efficiently and safely control all aspects of the telescope and its subsystems, both under local or remote control. This element contains all work required to design, code, integrate and test, in the lab and in the field, the high level coordination software. It also provides support for engineering, set-up and maintenance, and creates a dynamic environment for development and evolution of control applications. Telescope Control System does not contain: subsystem local computers, controls and electronics, if any, delivered by other work packages.
			The OCS is the primary high level master of the hierarchical control system that schedules, commands, coordinates and monitors the summit observatory, in order to conduct the process of achieving the survey goals. The OCS consists of software subsystems that interact though a software connectivity backbone on top of the observatory communications network. It provides the means to support safe and efficient operations on the summit, day and night when the observatory is in any operational state.
1.04C.15.01	Telescope and Site Software Management	3	This element captures the technical management and engineering team responsible for the full system development, integration, and testing.
1.04C.15.02	Main Telescope Software	3	
			This element captures the efforts needed to create & maintain all software generated in-house that will be used to control the main telescope and its auxiliary systems. This also include on-boarding control software from various vendors who are building software for components on the main telescope. This also includes the efforts for the pointing control contract.
1.04C.15.03	Auxiliary Telescope Software	3	This element captures the efforts needed to create & maintain all software generated in-house that will be used to control the auxiliary telescope and its auxiliary systems. This also include on-boarding control software from various vendors who are building software for components on the auxiliary telescope.
1.04C.15.04	Telescope Software Infrastructure	3	This element captures the efforts for all middleware software. This includes work on the System Abstract Layer (SAL) and the Engineering Facility Database (EFD).
1.04C.15.05	Telescope and Site Software Quality Assurance	3	This element captures all efforts for software testing irregardless of where that software comes from (main telescope, auxiliary telescope, middleware, etc.).
1.04C.15.06	Telescope and Site Software Build	3	This element captures all work by the Telescope and Site Team for the build and deployment efforts
1.04C.15.07	LSST Operator Visualization Environment (LOVE)	3	
			This element captures the contract for the Telescope and Site Operator's Visualization System and the management of said contract.
1.04C.15.08	Telescope and Site Computing Hardware	3	This element captures all hardware and services purchases that are necessary to run the software in the rest of the WBS
1.04C.15.09	Telescope and Site Software Integration and Test	3	This element captures all efforts for integrating the various TSSW components either with its hardware or with other TSSW components or components from other parts of the project.
1.05C	Education and Public Outreach Construction	1	To enable the broadest participation in the LSST, our EPO program will put into place a robust system to meet defined user needs and establish modes of best practice for use of the system in place. Construction deliverables include a public database, software tools, user interfaces, and documentation that enables use of the system at distributed locations.
1.05C.00	EPO Level 2 Milestones	2	This WBS Element defines the Level 2 milestones for this project.

1.05C.01	System Management	2	This WBS includes all activities associated with management of the EPO WBS, building infrastructure, interfaces, and software tools to provide access to non-specialist users of the LSST. LOE activities include connecting with end-users as part of the construction project: needs assessments, focus groups, usability testing, and support for the Outreach Advisory Board. An evaluator is costed in this WBS element, for all years of the construction project, providing external expertise on the development and implementation of the EPO Evaluation Plan.
1.05C.01.01	System Management	3	This WBS includes all activities associated with management of the EPO WBS, building infrastructure, interfaces, and software tools to provide access to non-specialist users of the LSST. LOE activities include connecting with end-users as part of the construction project: needs assessments, focus groups, usability testing, and support for the Outreach Advisory Board. An evaluator is costed in this WBS element, for all years of the construction project, providing external expertise on the development and implementation of the EPO Evaluation Plan.
1.05C.02	EPO Database and Data Access Services	2	This includes the specification and construction of the EPO database which will hold LSST data products specifically staged in support of EPO activities and public access. Staffing includes one shared position with DM (EPO/DM Database Developer). The DM/EPO Interface (LSE-131) moves to Phase 3 at the indicated milestone; the EPO data receives data from ImSim, ComCam, and the LSST US DAC as part of the construction project.
1.05C.02.01	EPO Database and Data Access Services	3	This includes the specification and construction of the EPO database which will hold LSST data products specifically staged in support of EPO activities and public access. Staffing includes one shared position with DM (EPO/DM Database Developer). The DM/EPO Interface (LSE-131) moves to Phase 3 at the indicated milestone; the EPO data receives data from ImSim, ComCam, and the LSST US DAC as part of the construction project.
1.05C.03	Infrastructure for Citizen Science	2	This WBS element includes building infrastructure for implementing Citizen Science projects during operations. In construction we build interfaces to both the data and the users. Mechanisms for sharing Citizen Science results with the professional community are constructed. User interfaces include interactive strategies to promote participant learning. The initial Citizen Science project will have participants visually inspect a filtered alert stream for specific characteristics to advance algorithm efficiency and science productivity of LSST. Later Citizen Science projects will involve use of catalog data.
1.05C.03.01	Infrastructure for Citizen Science	3	This WBS element includes building infrastructure for implementing Citizen Science projects during operations. In construction we build interfaces to both the data and the users. Mechanisms for sharing Citizen Science results with the professional community are constructed. User interfaces include interactive strategies to promote participant learning. The initial Citizen Science project will have participants visually inspect a filtered alert stream for specific characteristics to advance algorithm efficiency and science productivity of LSST. Later Citizen Science projects will involve use of catalog data.
1.05C.04	Classroom / Online Research Toolkit	2	This includes building infrastructure for implementing authentic research projects during operations, both in the classroom and individual learning environments. In construction we build interfaces to the data, software tools, and user interfaces. A collaborative workspace allows participants to join an existing LSST research project or initiate one of their own. A limited suite of projects will be developed by LSST, along with online tutorials for implementation, and content and structure for professional development workshops.
1.05C.04.01	Classroom / Online Research Toolkit	3	This includes building infrastructure for implementing authentic research projects during operations, both in the classroom and individual learning environments. In construction we build interfaces to the data, software tools, and user interfaces. A collaborative workspace allows participants to join an existing LSST research project or initiate one of their own. A limited suite of projects will be developed by LSST, along with online tutorials for implementation, and content and structure for professional development workshops.
1.05C.05	Visualization including Science Museums	2	Here we enable access to LSST data products for visualization purposes, on screens of all sizes. A web interface is employed to allow users to zoom, pan, and roam while exploring the LSST sky. We stage data at the EPOC in appropriate resolutions and formats for access, including AVM metadata tagging. We'll use the Open Exhibits (or similar) suite of software to develop modules using LSST data that can be deployed in many settings on devices such as multi-touch, multi-user tables. Adler Planetarium is responsible for this WBS element.
1.05C.05.01	Visualization including Science Museums	3	Here we enable access to LSST data products for visualization purposes, on screens of all sizes. A web interface is employed to allow users to zoom, pan, and roam while exploring the LSST sky. We stage data at the EPOC in appropriate resolutions and formats for access, including AVM metadata tagging. We'll use the Open Exhibits (or similar) suite of software to develop modules using LSST data that can be deployed in many settings on devices such as multi-touch, multi-user tables. Adler Planetarium is responsible for this WBS element.

1.05C.06	User Interfaces	2	Work towards elements of user interfaces that are common across audiences are captured here. This includes the EPO Portal and collaborative workspace. The primary public interface, currently called LSST AT HOME, is developed in this WBS, from the browsing to adopting stages including communication between participants.
1.05C.06.01	User Interfaces	3	Work towards elements of user interfaces that are common across audiences are captured here. This includes the EPO Portal and collaborative workspace. The primary public interface, currently called LSST AT HOME, is developed in this WBS, from the browsing to adopting stages including communication between participants.
1.06C	Systems Engineering and Commissioning	1	All top level system engineering and commissioning activities for the LSST project are covered under this WBS element.
	-		Incuded are the development and documentation of the system requirements, system interfaces, and of the overall system architecture and designt. At this phase in the design, the major system trade-off studies and open systems issues, and an approach for their resolution, are defined.
			This WBS element also includes all system level modeling and simulation development The principal deliverables of this WBS element are:
			System Requirements documents
			System interface documents and needed support document
			Physical integrated layouts: Define and maintain a CAD model of the integrated physical layout of all detector elements
			System Block Diagrams: Define and maintain block diagrams for the integrated control and data systems.
			Documentation of the as-built system to support operations
			Compliance and verification reports for system level requirements and specifications
			It includes the following LSST System Engineering activities:
			Developing, reviewing, and baselining all LSST System and Observatory requirements specifications
			Performing critical LSST System analyses and tradeoff studies Developing, reviewing, baselining the LSST System Engineering Management Plan and Risk Management Plan
			Developing, reviewing, baselining the LSST System Verifcation and Commissioning Plans This is the primary WBS element for activities in the Commissioning Phase of the project. The primary focus is on demonstrating that the LSST system is compliant with the system level requirements and characterizing the system in terms of the SRD survey performance specifications. It is recognized that there is still significant engineering activity occurring during this period responding to the commissioning effort. The commissioning period is separated into 3 phases; 1) a 6-month period using a commissioning camera to bring the telescope into a fully operational state and initial testing of the data analysis algorithms and pipelines; 2) a 9-month period when the completed Camera is integrated onto the Telescope and full capacity of the Data Management asystem is testeed; and a 9-month period focused on verification and characterization of the survey performance requirements.
			At the conclusion of the activities in the WBS element the LSST system is ready for regular operations and the MREFC funded construction is concluded.
1.06C.00	Systems Engineering and Commissioning Level 2 Milestones	2	This WBS Element defines the Level 2 milestones for this project.
1.06C.00.01	Interfaces	3	Level 2 milestones for tracking system interface development phases from the subsystems.
1.06C.00.02	Early Deliverables &	3	Level 2 milestones for tracking significant integration and testing event occuring in other subsystems that Project
1 000 00 00	System Integration	2	Systems Engineering shiould watch over.
1.060.00.03	Commissioning	3	Level 2 milestones used for monitoring the occurance of significant events during the commissioning Phase.
1.06C.01	Systems Engineering	2	The scope of this WBS is all project level systems engineering tasks, including to - manage and coordinate all LSST systems engineering activities - develop, maintain, and apply all system level (integrated and end-to-end) simulation tools for predicting observatory performance,
			- plan and oversee system verification
1.06C.01.00	Systems Engineering Level 3 Milestones	3	This WBS tracks key Systems Engineering reated milestones
1.06C.01.01	Systems Engineering Management	3	The scope of the WBS is to
			- manage the Project Systems Engineering (PSE) team

			 run the project-wide Systems Engineering Integrated Product Team, the primary body where technical issues are identified, managed, and resolved; it consists of the PSE, the subsystem systems engineering teams, and key professionals contributing to the overall systems engineering effort
			- facilitate and enforce systems engineering processes as defined in the Systems Engineering Management Plan (SEMP)
			- manage the project level change control process
			- manage the project level Risk Register
			- maintain and enforce project controlled design and interface requirements, including their implementation in SysML;
			facilitate interface negotiations between subsystems
			- define and carry out system trade studies
1.06C.01.02	Simulations and Analytic	3	The scope of the WBS is to
	Tools		- Develop and validate a detailed LSST model in PhoSim that is capable of calculating the optical effects of engineering,
			environmental, and operational specifications, tolerances, and uncertainties;
			-Link this PhoSim LSST model to engineering simulations to establish and validate an Integrated Model for LSST
			predicting compliance with Key Performance Metrics
			- Develop and validate the LSST Operations Simulator (OpSim) using the actual Scheduler code to be delivered by the
			OCS team to explore prospective observing strategies and evaluate them in the Metric Analysis Framework against
			- Establish and maintain an end-to-end simulation of LSST providing realistic full focal plane sky images: improve and
			validate its inputs, the sky catalog and atmospheric behavior (sky brightness, photometric transparency, weather)
1.06C.01.04	Verification & Validation	3	This WBS element contains the effort to support verification and validation of the Commissioning phase of the
			project. This includes developing verification plans, test cases, test specifications and procedures as well as working
			with members of the PSE team to develop responses to non-compliances.
1.06C.01.05	Tool Dev &	3	This WBS element provides the SE Team with a variety of Model Based Systems Engineering (MBSE) tasks. Such tasks
	Customization		include assisting the SE team implement approved change requests, configuring an add-on tool for MagicDraw called
			OpenMBEE (Which will make the project's model much more accessible to non-modelers), and assist with clean up
1.06C.01.06	System Analyses	3	This WBS element contains the effort to support Failure Modes Effects and Causality Analysis (FMECA), Hazard
			Analysis, Failure Reporting Analysis, and Corrective Action System (FRACAS) for the system to understand system
4 969 99	o · · · ·		behavior leading into Commissioning and Operations
1.06C.02	Commissioning	2	The LSST Commissioning Plan covers the final system level assembly, integration and testing (Al&T) of the three principal subsystem - Telescope, Camera and Data Management - plus the infrastructure supporting EPO and
			Headquarters operations. The procedures, activities and schedule contained within the commissioning plan are
			derived from the following inputs:
			- System level Verification Plan per LSE_160 including SysML based verification event sequences and logic;
			- Subsystem assembly, integration and test plans (T&S: LTS-104; Camera: LCA-40; DM; ???)
			- Scientifically motivated system performance characterization; and
4 000 00 00		2	- Technical optimization of system operations.
1.06C.02.00	Milestones	3 1	This WBS tracks Key Commissioning reated milestones
1.000.02.00.00	Assembly & Test	4	
1.06C.02.00.01	Data Delivery	4	This WBS tracks Data Delivery milestones.
1.06C.02.00.02	Subsystem Readiness	4	This WBS tracks Subsystem integration milestones.
1.06C.02.01	Commissioning	3	This WBS element provides support for the managment and oversight specific to the overall Project Commissioning
	Management		effort. Speccifically this work package supports the Project's System Scientist and core commissioning team. Also
			includes, non-Labor activities for LOE management types, travel, accomodations including rental houses/apts., etc
1.06C.02.01.01	MREFC Personell	4	This WBS element provides MREFC related support to the overall Project Commissioning effort. Speccifically this work
			package supports the Project's System Scientist and core commissioning team.
1.06C.02.01.02	DOE Personell	4	This WBS element provides DOE related support to the overall Project Commissioning effort. Speccifically this work
			package supports the Project's System Scientist and core commissioning team.

1.06C.02.01.03	Materials and Supplies	4	This WBS element provides MREFC materials budget related support to the overall Project Commissioning effort. This includes, non-Labor activities for material and supply procurements.
1.06C.02.01.04	External Support	4	This WBS element provides MREFC subcontracted science support to the overall Project Commissioning effort.
1.06C.02.01.05	Data Services and	4	
1.06C.02.01.05.01	LDF-offered Services	5	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).
1.06C.02.01.05.02	Reuseable Production Services	5	 Services for Observatory Operations Services for Designated Offline Campaign Processing Data Access Services for Authorized Users Services for General Staff Data Facility Service Desk 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).
1.06C.02.01.05.03	Data, Compute, and IT Security Services	5	 Prompt Processing Service Internal Transient Event Handling Service Telemetry Gatewaying Service Master Batch Job Scheduling Service QA Portal Hosting Service Implementation of File Management Policies and High-level Data Movement Workflows Management of End-user Data Rights Central Elements of Workflows, Reports, and Interactive Informative Displays based on IdM Service Endpoints 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).
1.06C.02.01.05.03 1.06C.02.01.08	Data, Compute, and IT Security Services	5	 Prompt Processing Service Internal Transient Event Handling Service Telemetry Gatewaying Service Master Batch Job Scheduling Service QA Portal Hosting Service Implementation of File Management Policies and High-level Data Movement Workflows Management of End-user Data Rights Central Elements of Workflows, Reports, and Interactive Informative Displays based on IdM Service Endpoints 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 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). File-oriented Services within the Data Backbone Managed Database Services Backup and Disaster Recovery Services Backup and Disaster Recovery Services Containerized Application Management Service This VWBS element and Monitoring Support Service This WBS element and Monitoring Support Service

1.06C.02.02	Commissioning Planning, Preparation, Tooling, & Simulations	3	This WBS element contains work scope to develop, detail and support the LSST Commissioning Plan (LSE-79), including:
			- The continued development and procedure detailing in alignment with system verification planning
			 Early work needed to prepare for commissioning Hardware and software tools specifically needed to support the Commissioning Plan Simulations needed to validate the commissioning plan and procedures
1.06C.02.02.00	Planning & Reviews	4	This WBS element contains work scope related to reviews and planning to support the LSST Commissioning Plan.
1.06C.02.02.01	ComCam Development & Oversight	4	This WBS element contains work scope to develop, detail and support the LSST ComCam Effort (see LSE-199), including:
			- The LSST Telescope and Site hardware deliverables for ComCam - The LSST Camera hardware deliverables for ComCam - The LSST Data Maangement deliverables for ComCam
1.06C.02.02.02	LSSTCam Summit Servicing Area Preparation	4	This WBS element contains work scope to develop, detail and support the on summit build out of the LSST summit clean room:
			 Initial cleaning/commissioning Outfitting of facility, equipment, test stands etc Initial suply of garments and consumables Tooling Final certification before use
1.06C.02.02.03	Analysis Software and Procedure Simulation & Validation	4	This WBS element contains the work scope needed to develop analysis scripts corresponding to defined test and observatio procedures used to meet verfication requirements along with characterization and optimization of the LSST Observatory System. Procedures and analysis scripts will be validated by simulating planned observing sequences using the Project's simulations tools (e.g. OpSim and PhoSim). Scripts are based on the LSST DM software stack.
1.06C.02.02.04	Special Tooling	4	The WBS element contains the work scope to develop, procure and test special tooling need to support the overall commissioning plan.
1.06C.02.02.05	Shipping, Receiving and	4	The WBS element contains the work scope to ship commissionig related elements.
1.06C.02.03	Early System AI&T	3	This WBS element contains the work scope for system level assembly, integration and test relating to ComCam, early interface testing and verification and sub-scale DMS data processing and handling. Specific work scope is described under subsequent WBS elements.
1.06C.02.03.01	ComCam Re-Verification	4	This WBS element contains work scope to shipComCam and associated hardware from USA to summit, receive ComCam at summit and to reverify ComCam prior to installation on the telescope:
			 shipping of ComCam (shipping container in T&S scope) to summit with associated hardware receiving ComCam at summit reverification of ComCam at summit in clean (white room)
			- Work needed in preparation for installation on telescope
1.06C.02.03.02	Calibration System AI&T	4	This WBS element contains the work scope need to integrate the output of the calibration hardware - both in dome and auxiliary telescope - with the Calibration Data Products Pipeline and their application to data produced by ComCam and the full science Camera. Note: the hardware deliverables are part of WBS04C and are expected to installed and running to support this work.
1.06C.02.03.03	LSSTCam Refrigertion Pathfinder AI&T	4	This WBS element contains work scope to commission the Camerra refrigeration lines at both the camera white room and on telescope:
			- Installation of compressors, pathfinder heat exchangers in white room, connection of refrigeration lines, running and optimization of compressers etc.
			- installation of pathfinder heat exchangers into ComCam mass simulator, connection of refrigeration lines, running and optimization of compressers etc, swapping of lines between optimization runs.
1.06C.02.03.04	ComCam - Telescope	4	 Suppying needed hardware and consumables for these tests This WBS element contains the work scope to assemble, integrate and test the ComCam on the telescope including:
	AI&T		 Integration of the ComCam onto the hexapod-rotator and Top End Intagration assembly Moving the integrated ComCam + hexapod-rotator assembly to telescope floor

			 Installation on of ComCam on the telescope Camera-Telescope interface testing and verification OCS command and control verification tests Major maintenance procedure validation
1.06C.02.03.05	DMS + TCS/OCS + ComCam AI&T	4	This WBS element contains the work scope to process and analyze the image data from ComCam and redevous the data properties with engineering telementry. Processing includes: - Generation of image meta-data from Engineering Facility Database telementry - ComCam specific calibration data products generation - Instrument signature removal - sub-scale Level 1 alert processing including PSF characterization, template generation, image differencing and source detection
			- sub-scale Level 2 processing including muti-fit, forced photometry, database queries, and SDQA
1.06C.02.04	Full System AI&T	3	This WBS element contains the workscope for final system level assembly, integration and test relating to the LSST Camera, final interface testing and verification and full-scale DMS data processing and handling. Specific work scope is described under subsequent WBS elements.
1.06C.02.04.01	LSSTCam Re-Verification	4	This WBS element contains the work scope to ship the LSST camera and associated hardware from SLAC to Summit Facility on Cerro Pachon, receive LSST Camera at the summit and to reverify LSST prior to installation on the telescope:
			- Shipping of LSST Camera (shipping container in Camera I&T scope) to summit with associated hardware
			- Receiving and inspection of LSST Camera at summit
			- Re-verification of LSST Camera functions and performance at summit in white room/camera maintenance area on camera integration stand
			- Reverification of LSST Camera at summit installed in front end assembly in camera integration stand
1.06C.02.04.02	LSSTCam - Telescope Al&T	4	This WBS element contains the work scope to assemble, integrate and test the LSST Camera on the telescope including:
			 Megration of the LSST Camera onto the nexapod-rotator and rop and hearafted assembly Moving the integrated LSST Camera + hexapod-rotator assembly to telescope floor Installation on of the Camera telescope Camera-Telescope interface testing and verification OCS command and control verification tests
1.06C.02.04.03	DMS+ TCS/OCS +	4	 Major maintenance procedure validation This WBS element contains the work scope to process and analyze the image data from the LSST Camera and
	LSSTCam AI&T		redevous the data properties with engineering telementry. Processing includes:
			- LSST Camera specific calibration data products generation
			 Instrument signature removal Full-scale Level 1 alert processing including PSF characterization, template generation, image differencing and
			source detection - Full-scale Level 2 processing including muti-fit, forced photometry, database queries, and SDQA
1.06C.02.05	Science Verification	3	This WBS element covers the work scope needed to demonstrate the LSST Observatory System is ready for science operations through the execution a two mini-Surveys. The science verification period is structured around demonstrating that the survey functional and performance specifications given in the Science Requirements Document (LPM-17) and LSST System Requirements (LSE-29) are being met.
			The Science Verification period is organized into 2 part frame work; - verification of the full survey performance requirements for image stacks and area coverage; and
			 final science verification and acceptance tests for operation readiness. The effort in this WBS includes time for engineering related activities throughout, but is more heavily proportioned at the beginning transitioning to something near early operational levels by the end.
			At the conclusion of the activities under this WBS element the project will have executed a 2 6-week long mini- surveys, processed as a sub-scale data release and made it available to the community as an early release "shared risk" data product. The data from this mini survey will be used to determine the operationse readiness of the project.

1.06C.02.05.01	Scheduler Driven mini- Survey 1	4	This WBS elment supports activities focused on controlled observations to demonstrate compliance with SRD Single Image Specifications. Each observing trial consists of a roughly 50/50 spit between on-sky observations plus daytime analysis of images and engineering periods to address issues uncovered during the trial. At the conclusiong the activities under this WBS element the LSST system is showing full compliance with single image specifications for size and shape and is showing compliance at least 75% of the time with photometric and astrometric specifications. The full compliance of astrometric and photometric specifications will be achieved under the full survey performance verification WBS element.
1.06C.02.05.02	Scheduler Driven mini- Survey 2	4	This WBS element covers activities focused on demonstrating compliance with SRD Full Survey Specifications. The activities are geared to measure the survey performance derivatives that when integrated over a 10 years period meet the full survey specifications. Each trail is in itself a mini-survey where its data will be processed as if it were from the regular survey and made available to the LSST Commissioning Team and science collaborations for analysis.
1.06C.02.05.03	Operation Readiness Preparation	4	This WBS element supports activities that executes a 30-40 day mini survey under full autonomous operation to demonstrate readiness for full LSST science operations. The data from this effort will be treated as if it were part of normal survey operations and will be an early release data product for the community.
1.06C.02.05.04	SV Data Handling and Processing	4	The operations readiness review activity is also supported under this WBS element. This WBS element includes all DM activities in support of overall LSST Commissioning. These activities will be enumerated in the detailed LSST Commissioning Plan, and will include operating the DMS in all observatory modes (normal operations, emergency operations).