Large Synoptic Survey Telescope

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The LSST: A System of Systems

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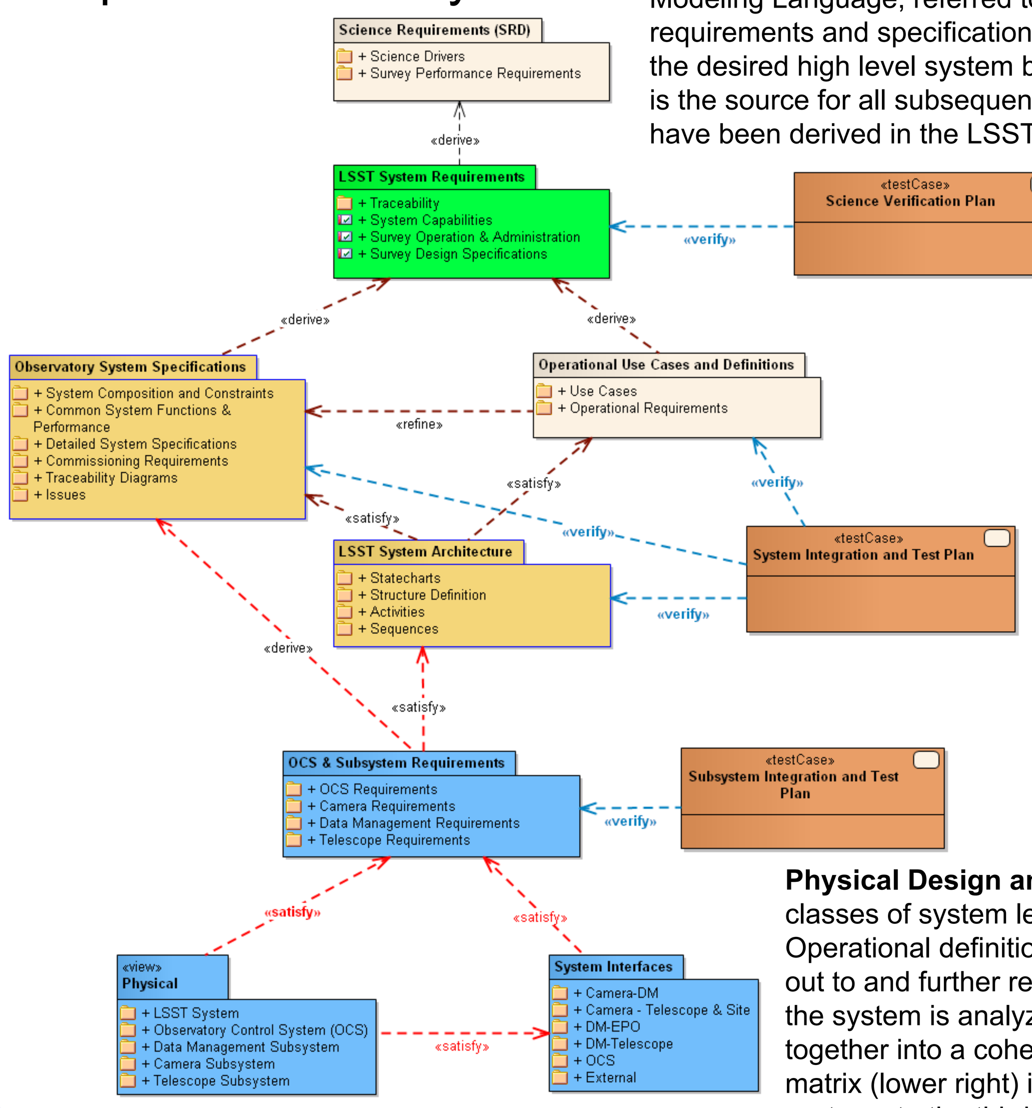
The Large Synoptic Survey Telescope (LSST) is a complete observing system that acquires and archives images, processes and analyzes them, and publishes reduced images and catalogs of sources and objects. The LSST will operate over a ten year period producing a survey of 18,000 square degrees over the entire [Southern] sky in 6 filters (ugrizy) with each field having been visited several hundred times enabling a wide spectrum of science from fast transients to exploration of dark matter and dark energy. The LSST itself is a complex system of systems consisting of the 8.4m 3-mirror telescope, a 3.2 billion pixel camera, and a peta-scale data management system. The LSST project uses a Model Based Systems Engineering (MBSE) methodology to ensure an integrated approach to system design and rigorous definition of system interfaces and specifications. The MBSE methodology is applied through modeling of the LSST's systems with the System Modeling Language (SysML). The SysML modeling recursively establishes the threefold relationship between requirements, logical & physical decomposition and definition, and system and component behavior at successively deeper level of abstraction and detail. The LSST modeling includes the analysis and documenting the flow of command and control information and data between the suite of systems in the LSST observatory that are needed to carry out the activities of the survey. The MBSE approach is applied throughout all stages of the project from design, to validation and verification, though to commissioning.

Requirements Analysis



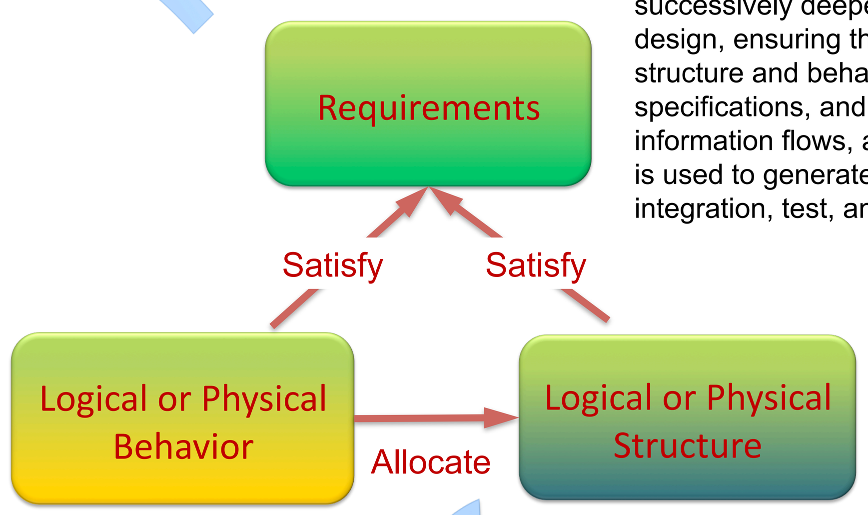
Requirements: The MBSE System Architecture has been implemented using the System Modeling Language, referred to as SysML, capturing more than 1400 system and subsystem requirements and specifications along with more than 250 operational use cases to describe the desired high level system behavior. The LSST Science Requirements Document (SRD) is the source for all subsequent derived requirements. Top level functional requirements have been derived in the LSST System Requirements providing a high level description of ***what*** the LSST is and must do. These in turn have been used to derive the Observatory System Specifications as refined by ~250 Operational Use Cases and Definitions, which are satisfied by the overall system architecture. These three parts of the System Architecture model provide the highest level description of ***how*** the LSST is meeting its functional and performance requirements and provides the foundation from which all subsystems derive their requirements.

System Verification: Requirements at each level are verified by thorough integration and test plans. Subsystem integration and test plans verify that both requirements and ICDs are met and conclude with system acceptance testing. System Integration and Test commences when the camera is installed on the telescope following its acceptance on the summit. The science verification plan is executed during the final year of the 2-year commissioning period where the LSST SRD survey performance specifications are demonstrated.

Physical Design and Interfaces: Subsystem requirements satisfy all three classes of system level requirements, Observatory Specifications, System Operational definitions, and the overall System architecture. These are parsed out to and further refined by the physical system design. As the design matures the system is analyzed for the necessary interfaces that tie the subsystems together into a coherent integrated system of systems. The N-Squared interface matrix (lower right) is used to identify system interfaces between the three LSST subsystems to the third level in the WBS.

Using SysML for Model Based Systems Engineering

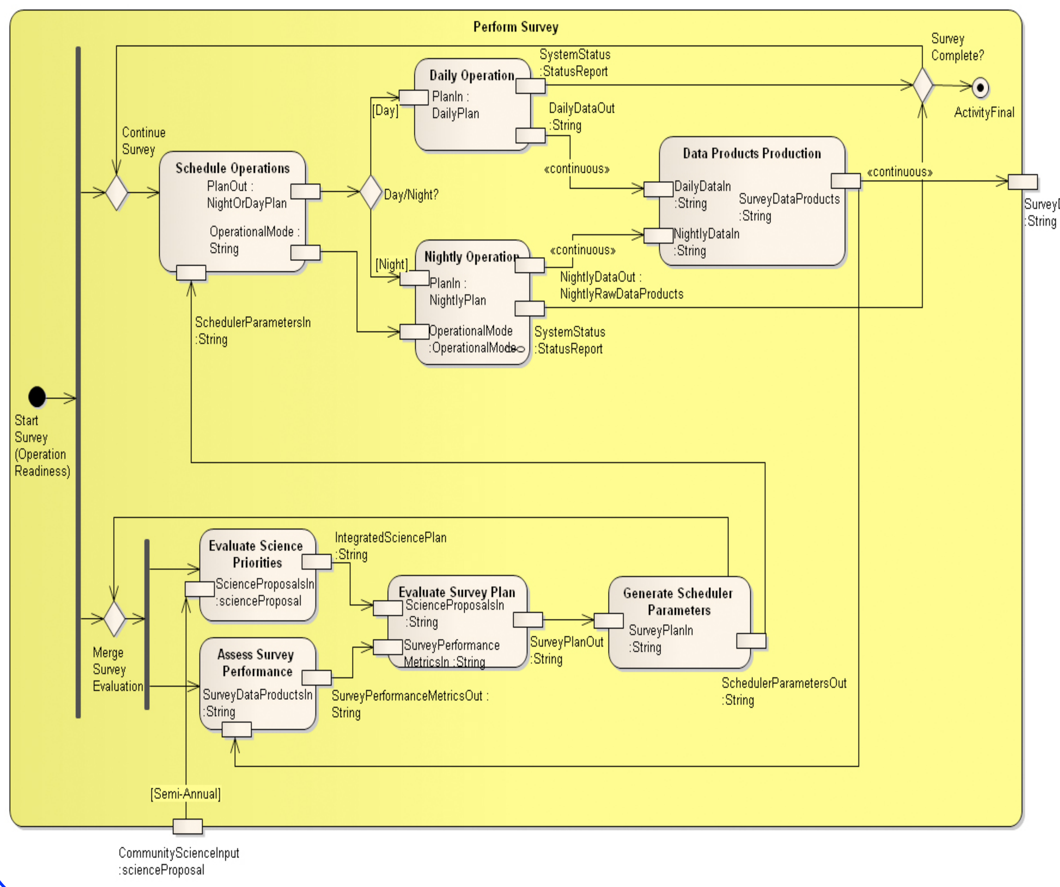
As a project, the LSST is using model based systems engineering (MBSE) methodology for developing the overall system architecture coded with the Systems Modeling Language (SysML). SysML is a graphical object oriented language used to model all aspects of complex systems. With SysML we use a recursive process to establish three-fold relationships between requirements, logical & physical structural component definitions, and overall behavior (activities and sequences) at successively deeper levels of abstraction and detail. Using this process we have analyzed and refined the LSST system design, ensuring the consistency and completeness of the full set of requirements and their match to associated system structure and behavior. As the recursion process proceeds to deeper levels we derive more detailed requirements and specifications, and ensure their traceability. We also expose, define, and specify critical system interfaces, physical and information flows, and clarify the logic and control flows governing system behavior. The resulting integrated model database is used to generate documentation and specifications and will evolve to support activities from construction through final integration, test, and commissioning, serving as a living representation of the LSST as designed and built.



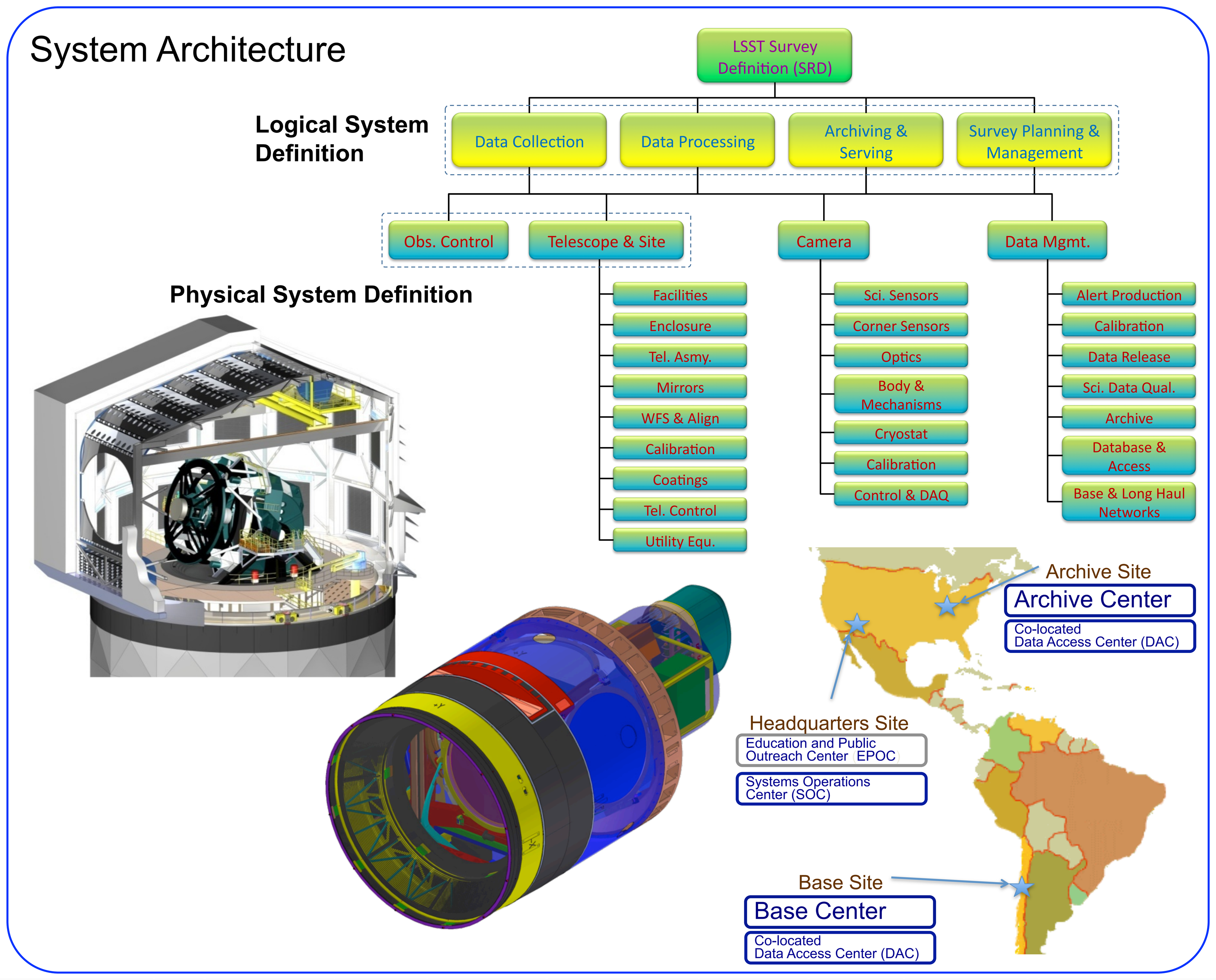
System Validation: Within the SysML MBSE framework the system design is validated when a three way relationship (left) between requirements, logical and/or physical structure, and logical and/or physical behavior is established. The system analysis process starts at a high logical level to establish key system level functions. The triangulation process proceeds recursively to finer levels of abstraction leading to the definition of the physical system components and their specifications. The recursive process documents the complete traceability of the overall system architecture and design.

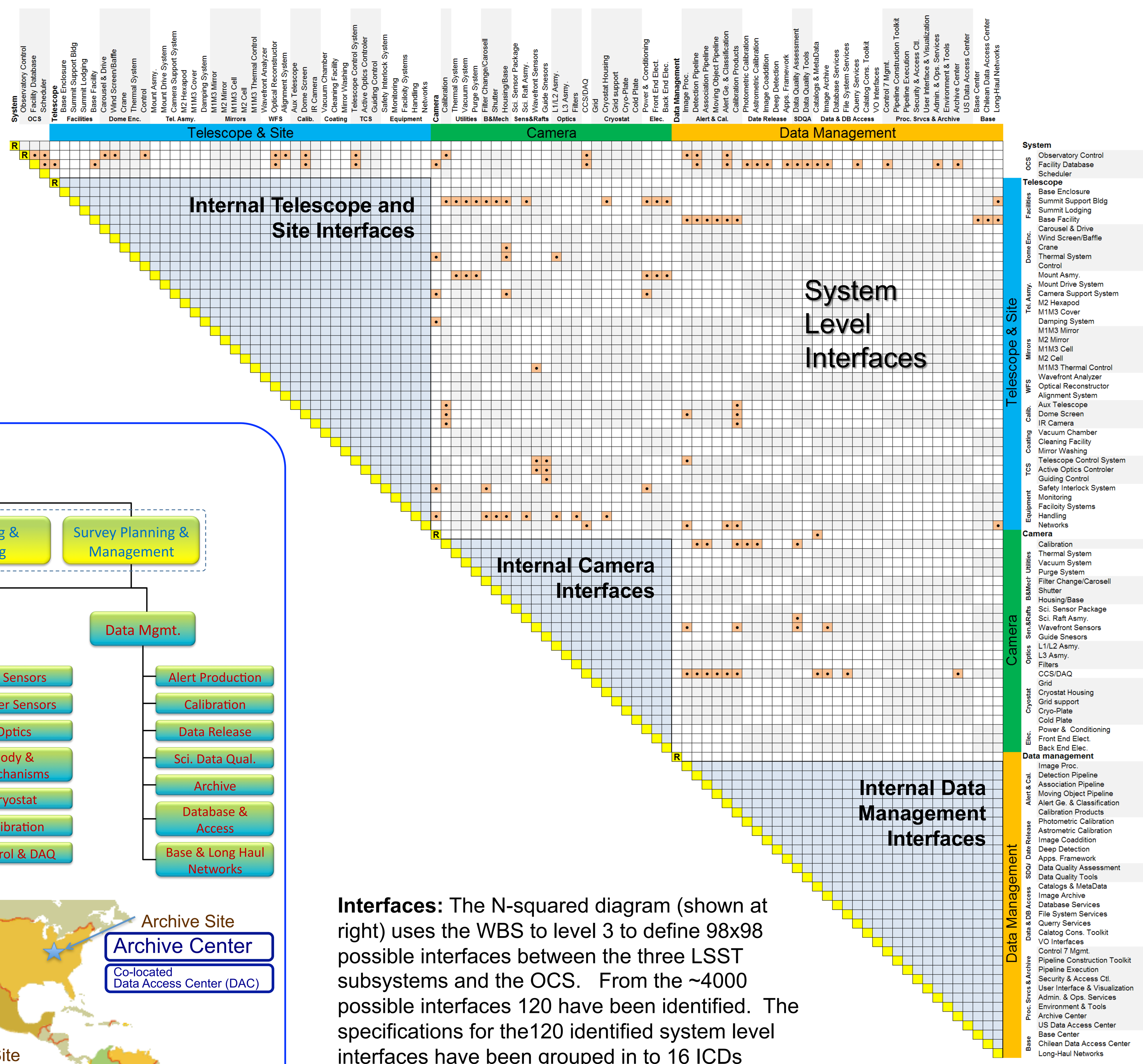
System Behavior

System Activity: In this example the logical information flows between activities necessary for conducting the survey are modeled. Activities are allocated to structural elements to define operational specifications.

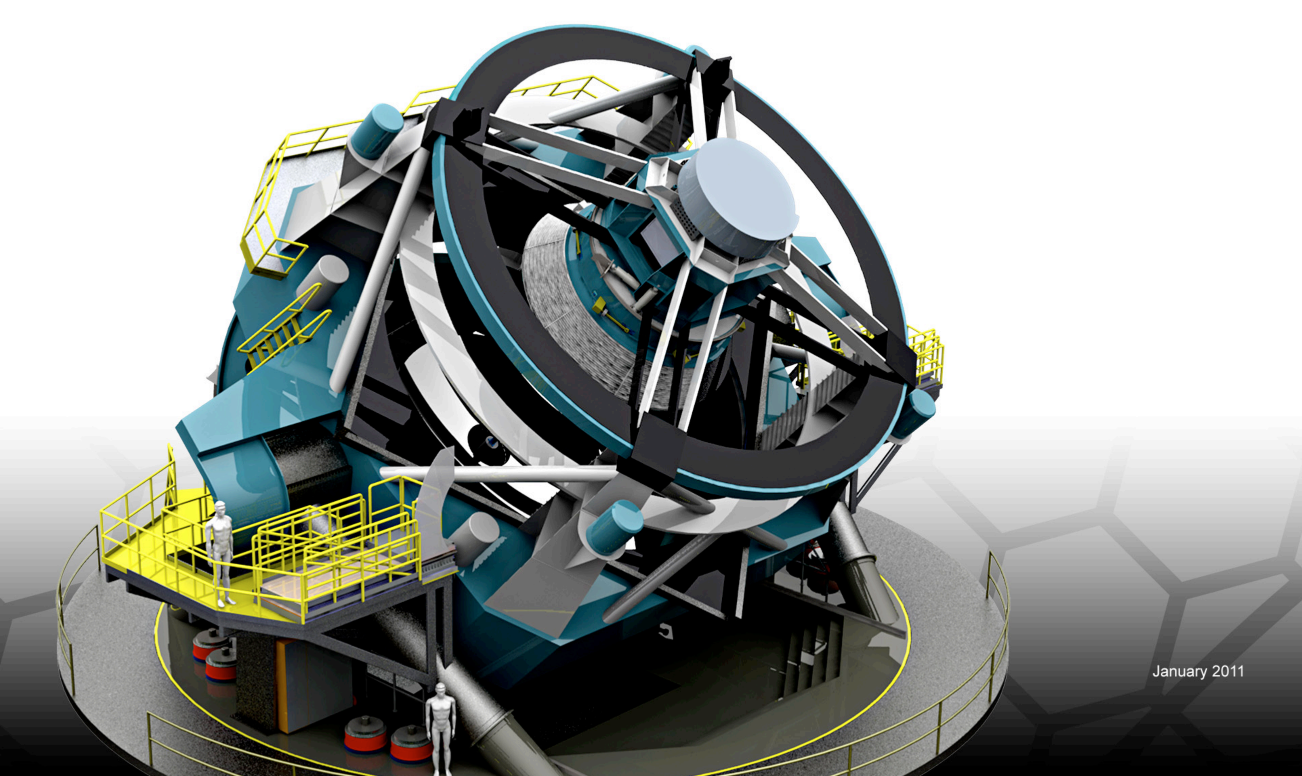


System Architecture





Interfaces: The N-squared diagram (shown at right) uses the WBS to level 3 to define 98x98 possible interfaces between the three LSST subsystems and the OCS. From the ~4000 possible interfaces 120 have been identified. The specifications for the120 identified system level interfaces have been grouped in to 16 ICDs covering similar topics. Many of the critical interfaces that influence design decisions have been fully detailed and specified. Others will be specified as the design for the LSST matures.



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