Large Synoptic Survey Telescope

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The LSST: A System of Systems

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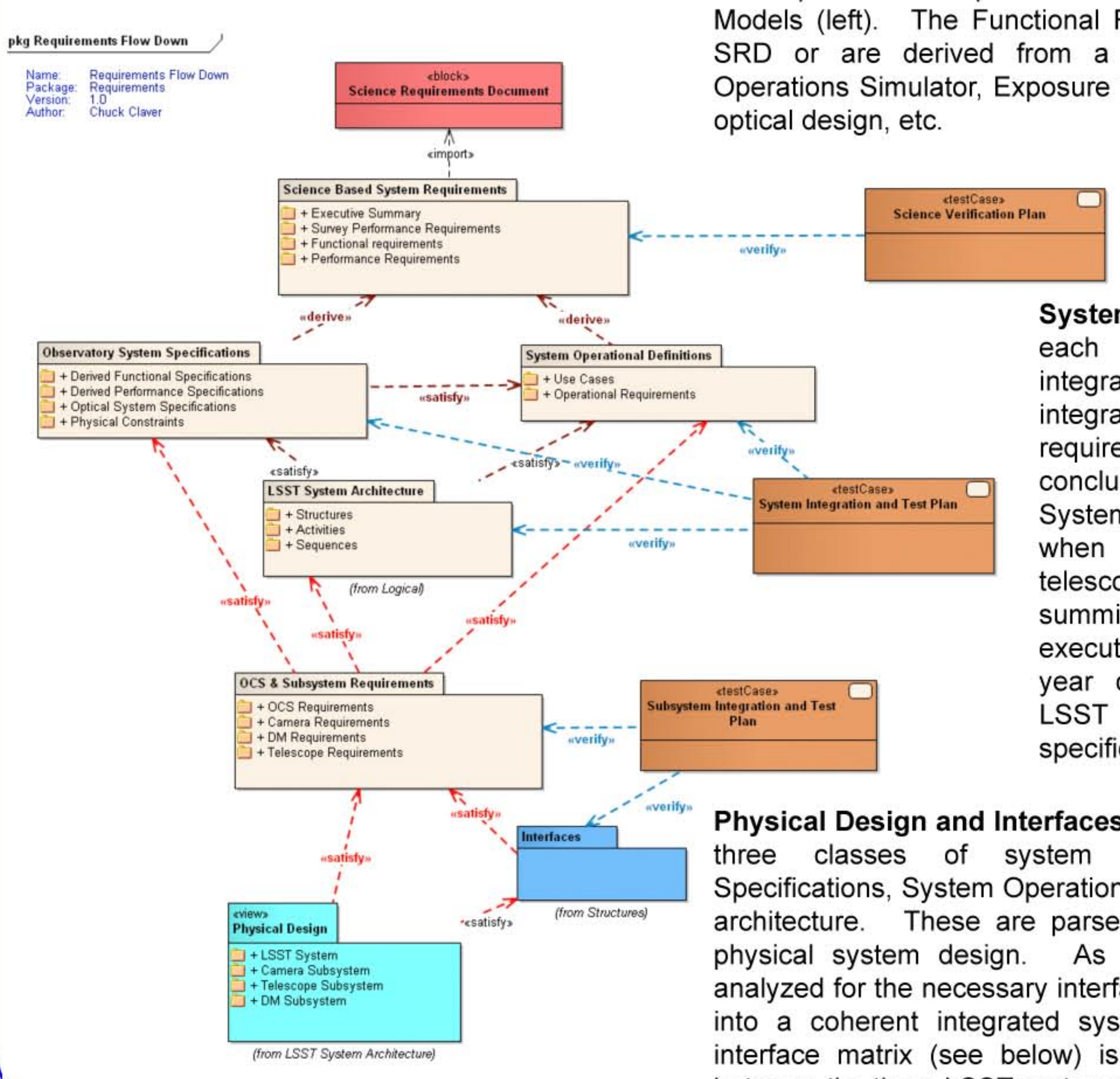
The LSST is a complete observing system that acquires and archives images, processes and analyzes them, and publishes reduced images and catalogs of sources and objects. The LSST will operate over a ten year period producing a survey of 20,000 square degrees over the entire southern sky in 6 filters (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 three 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 functional decomposition and definition, and system and component behavior at successively deeper levels of abstraction and detail. The MBSE approach is applied throughout all stages of the project from design, to validation and verification, though to commissioning.

Requirements Analysis

Requirements Hierarchy: The requirements flow down in LSST generally follows the hierarchy shown in the diagram (below-left). The operational requirements are derived from the Operations Models (left). The Functional Requirements flow directly from the SRD or are derived from a variety of sources including the Operations Simulator, Exposure Time Calculator, site characteristics, optical design, etc.

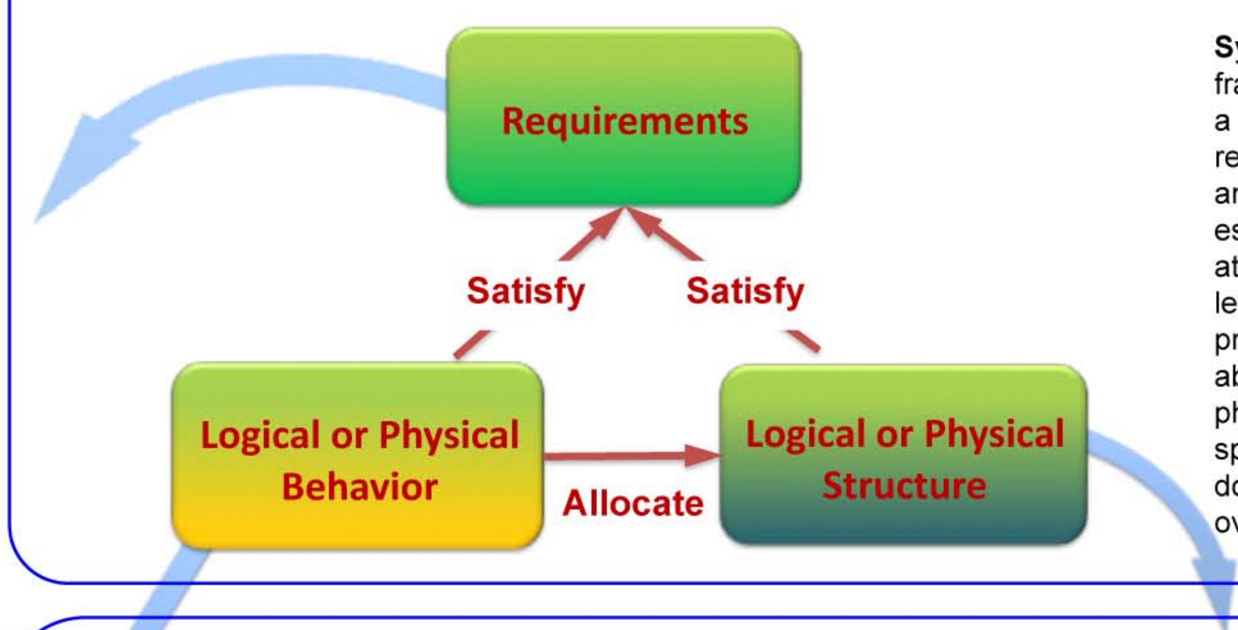


System Verification: Requirements at each level are verified by thorough integration and test plans. Subsystem integration and test plans verify that both requirements and ICDs are met and conclude with system acceptance testing. System Integration and Test commences when the camera is installed on the 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 (see below) is used to identify system interfaces between the three LSST systems to the third level in the WBS,

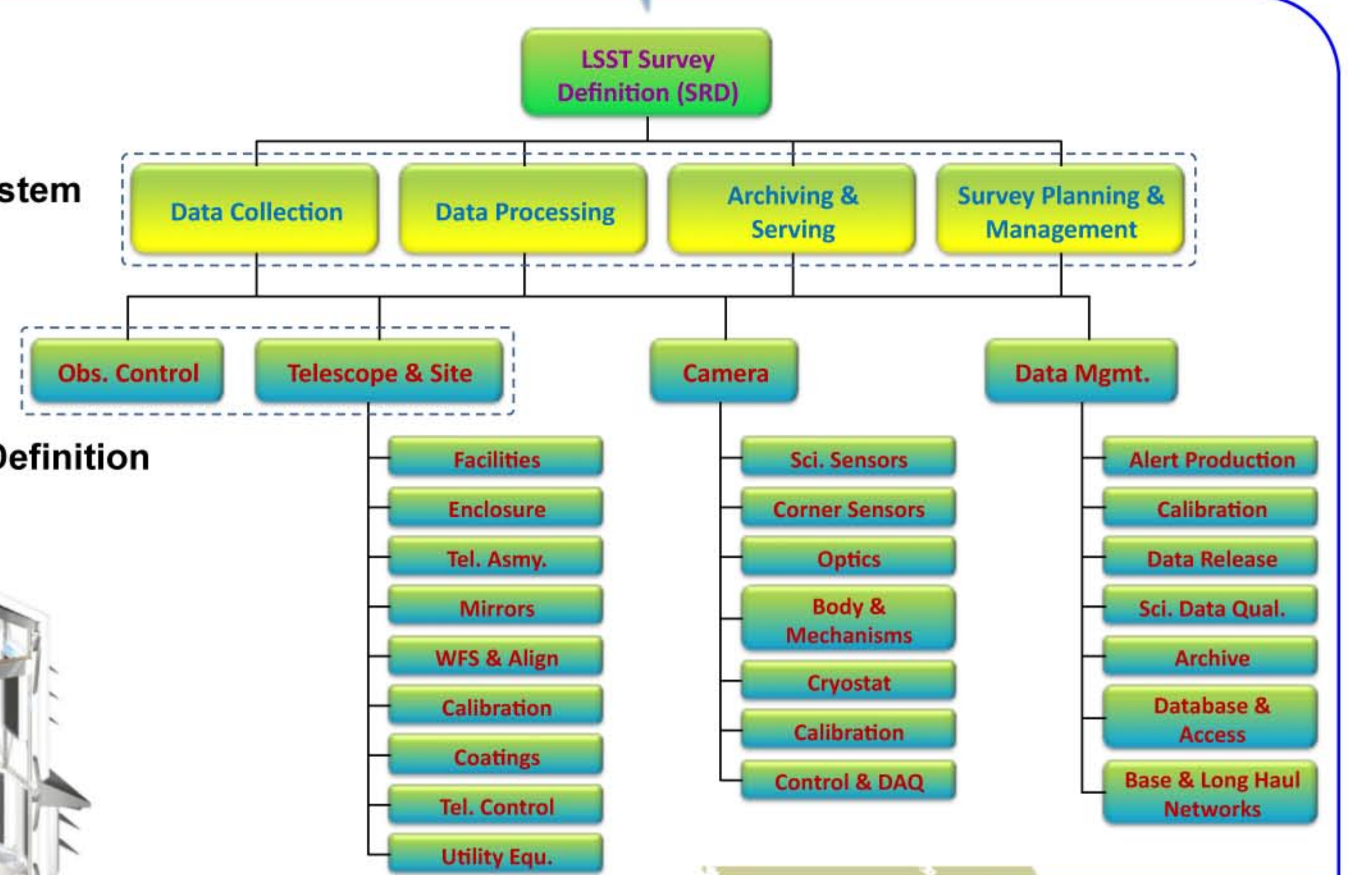
Using SysML for Model Based Systems Engineering

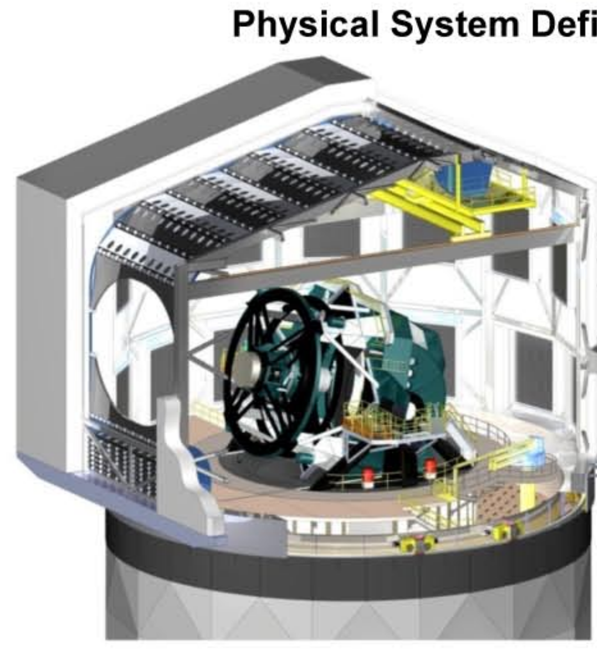
As a project, the LSST is using model based systems engineering (MBSE) methodology for developing the overall system architecture coded with the Systems Modeling Language (SysML). SysML is a graphical object oriented language used to model all aspects of complex systems. With SysML we use a recursive 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.

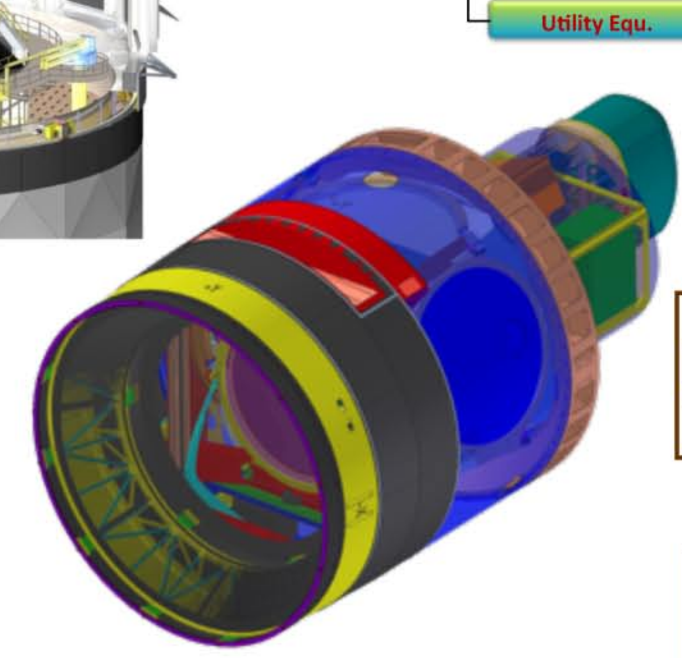


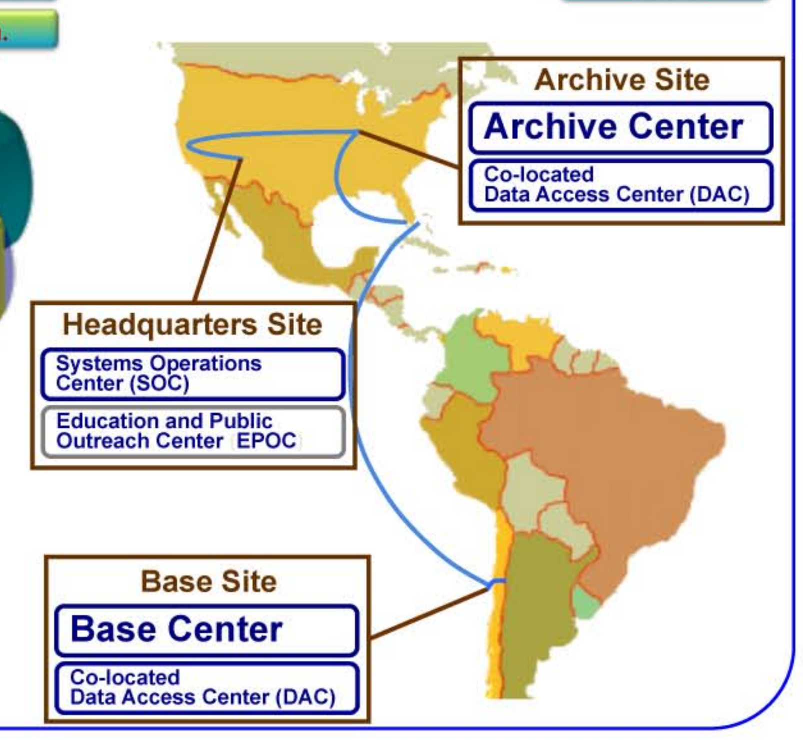
System Validation: Within the SysML MBSE framework the system design is validated when a three way relationship (left) between requirements, logical and/or physical structure, and logical and/or physical behavior is established. The system analysis process starts at a high logical level to establish 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 Architecture



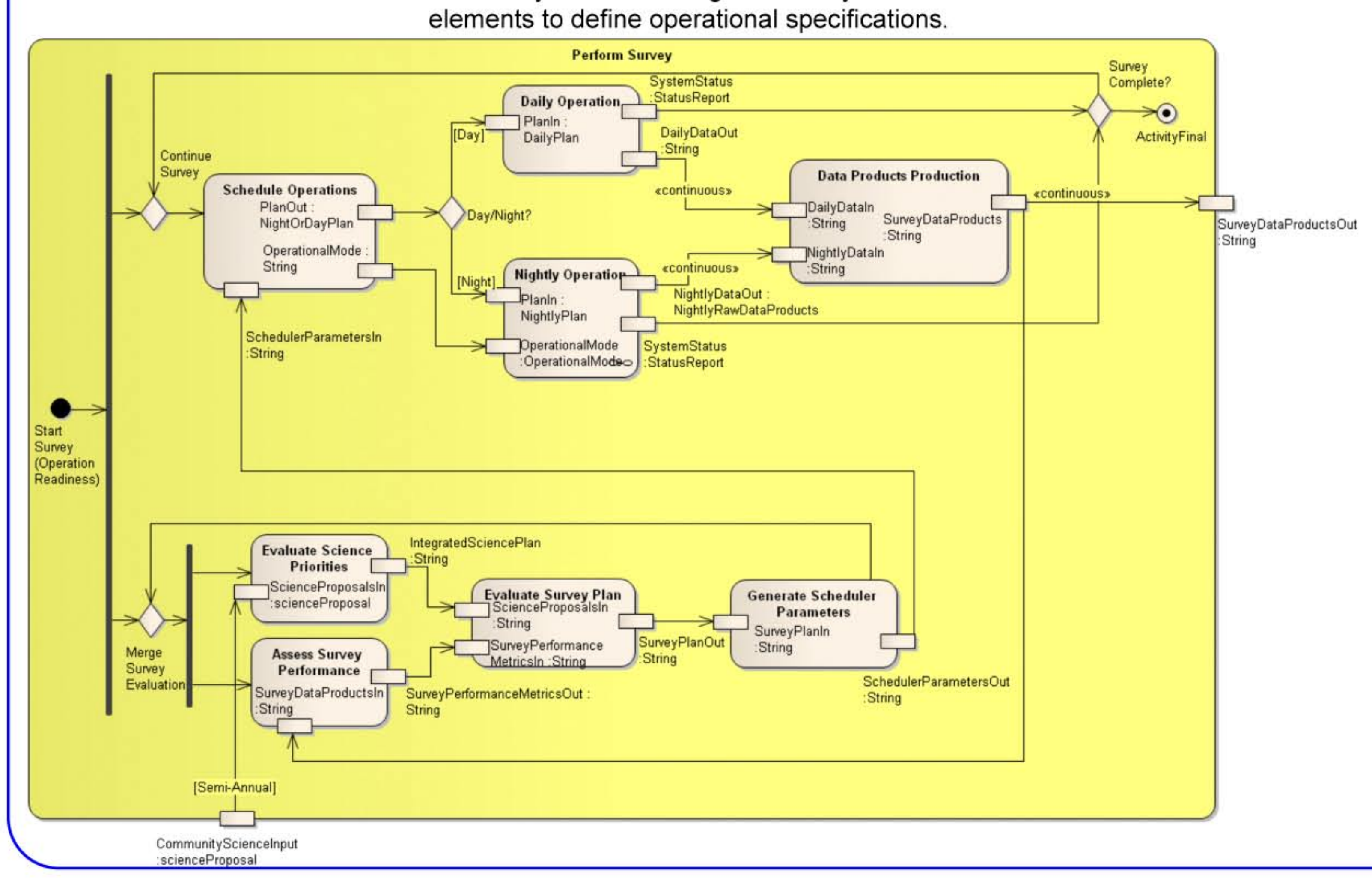


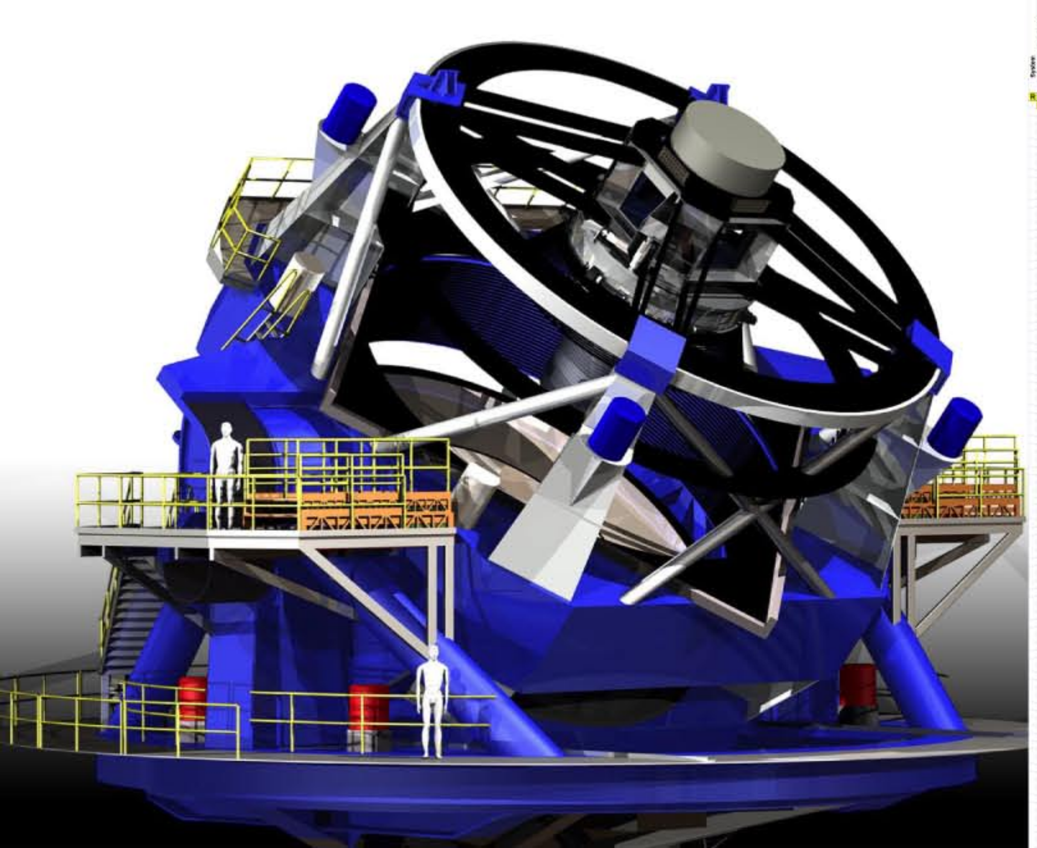


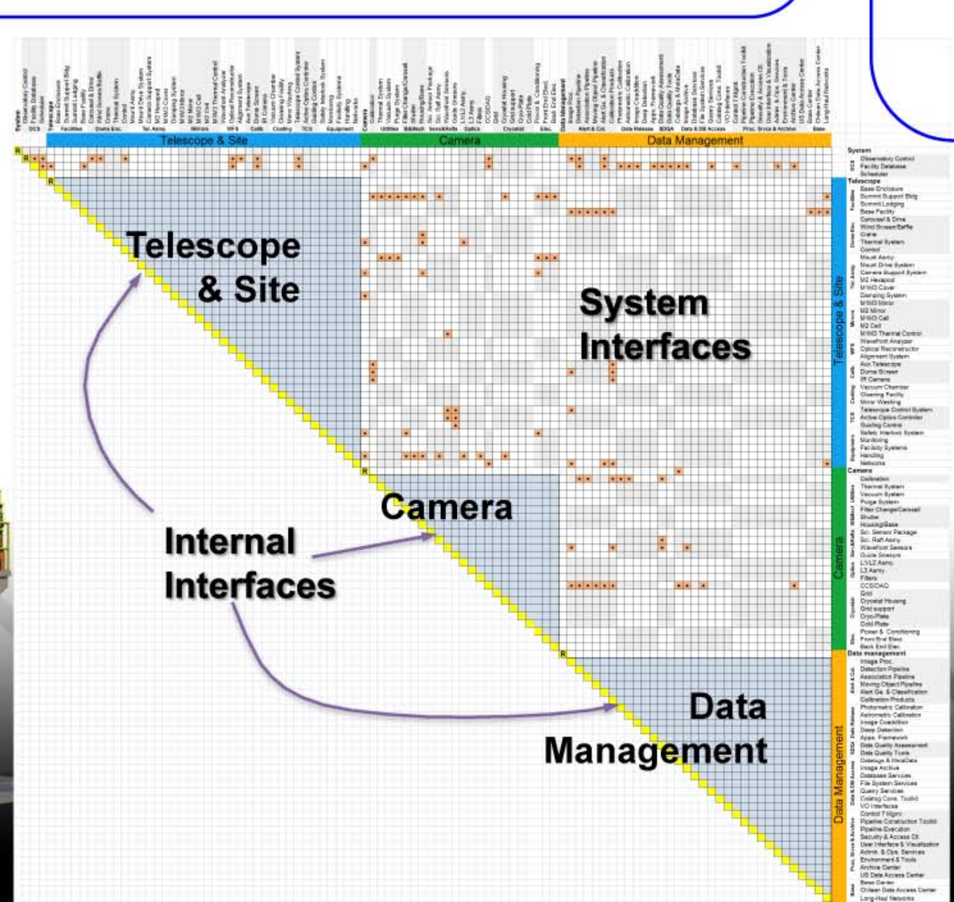


System Behavior

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.







Interfaces define the interactions of the system components. There are 98 x 98 possible intersections between the LSST's three subsystems and their major components.

16 System ICDs capture specifications for 120 system interfaces.

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