Large Synoptic Survey Telescope

www.lsst.org

From Science to Design: Systems Engineering for the LSST

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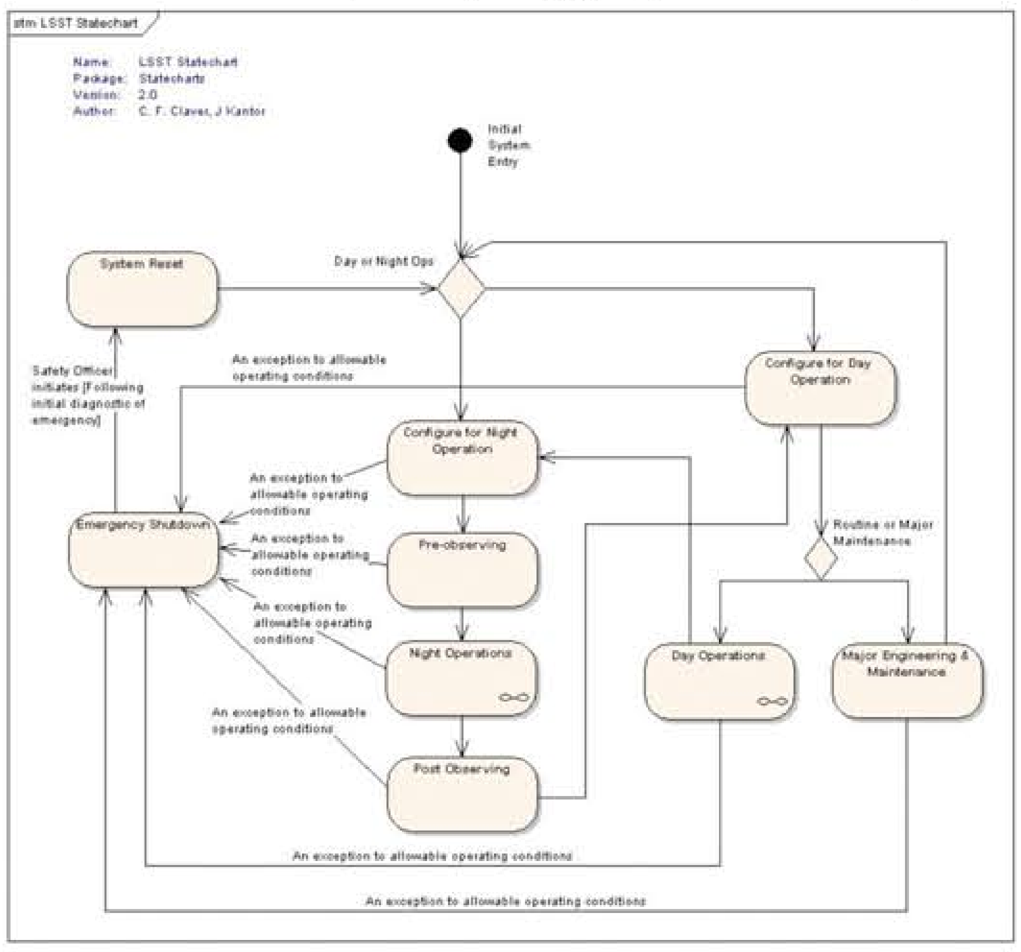
The LSST is a universal-purpose survey telescope that will address scores of scientific missions. To assist the technical teams to convergence to a specific engineering design, the LSST Science Requirements Document (SRD) selects four stressing principle scientific missions: 1) Constraining Dark Matter and Dark Energy; 2) taking an Inventory of the Solar System; 3) Exploring the Transient Optical Sky; and 4) mapping the Milky Way. From these 4 missions the SRD specifies the needed requirements for single images and the full 10 year survey that enables a wide range of science beyond the 4 principle missions. Through optical design and analysis, operations simulation, and throughput modeling the systems engineering effort in the LSST has largely focused on taking the SRD specifications and deriving system functional requirements that define the system design. A Model Based Systems Engineering approach with SysML is used to manage the flow down of requirements from science to system function to sub-system. The rigor of requirements flow and management assists the LSST in keeping the overall scope, hence budget and schedule, under control.

The Operations Model

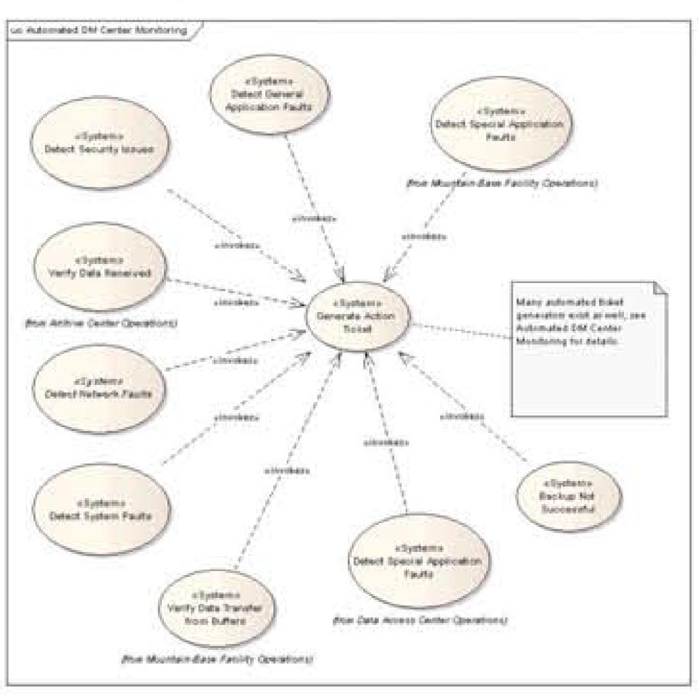
At the heart of the LSST Operation Model are state and activity diagrams and supporting use cases for each state, transition, or activity. Taken together these diagrams and use cases form the basis of the LSST operational requirements captured in the Requirements model. They also form the necessary inputs in developing and documenting the LSST operation plan. This operation model is not to be confused with the Operations Simulator that is used to model the survey observing strategy (see posters in this session).

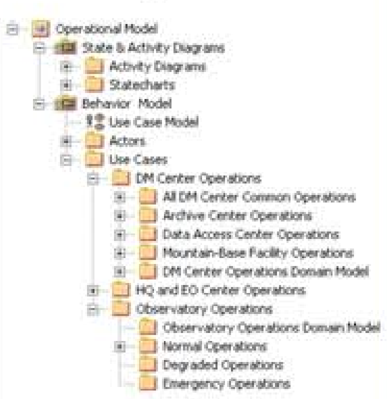


The state diagram (above) shows the 9 unique top level states the LSST system can be in and the allowed transition paths between one and another. Each of these high level states themselves consist of several sub-states, which are subsequently supported by multiple use cases.

The use cases are organized (see below right) around the general centers of operations, the Headquarters and Education And Outreach, the Observatory (summit and base), and the Data Management system. In addition, for each of the three operation centers we are developing use cases for three distinct operational modes – normal, degraded (not fully functional but usable) and emergency (event recovery and safety planning).

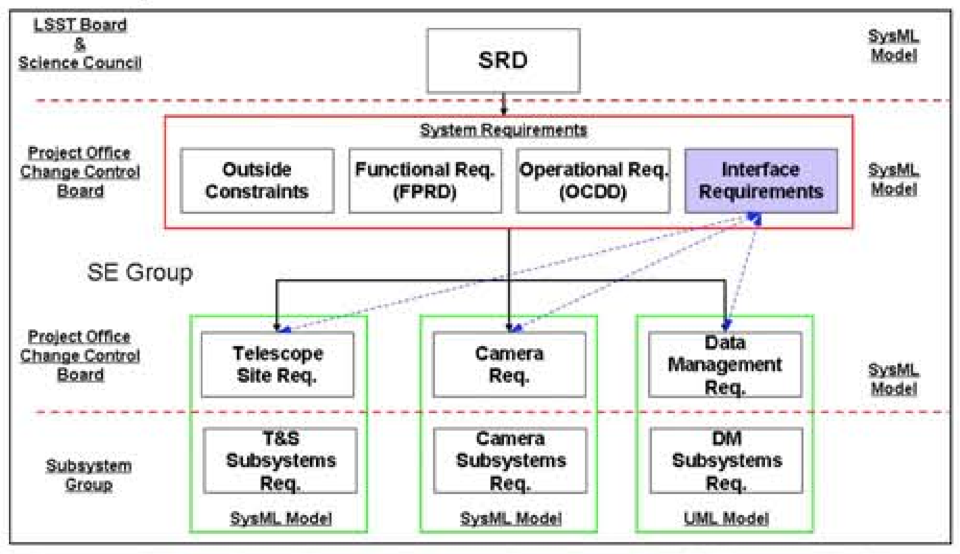
In the example given below, the activity of 'Automated DM Center Monitoring" is supported by the "General Action Ticket". In this case a single activity is supported by a single use case. However, the one use case invokes 9 additional use cases to carry out its function.



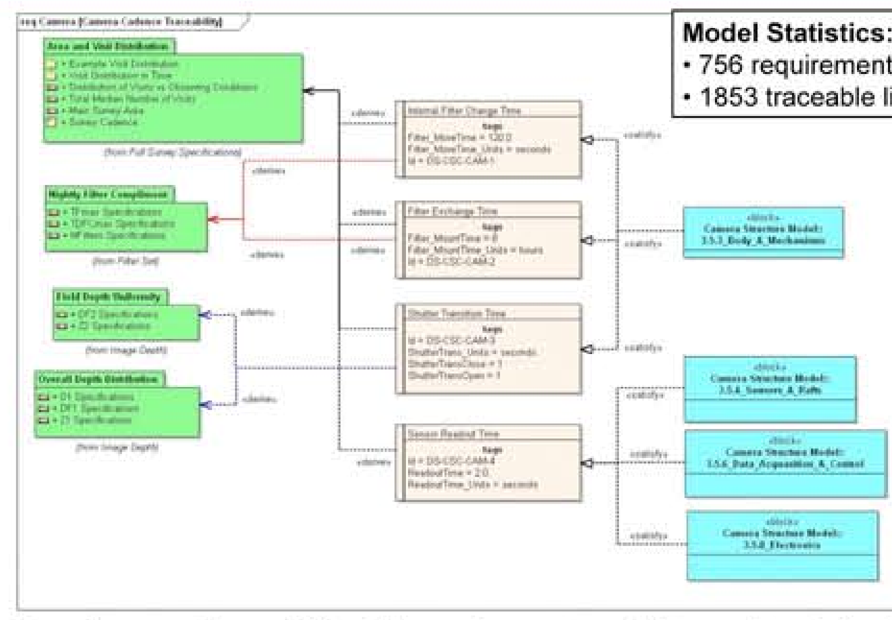


Model Statistics:
- 19 Primary States
- 105 Use Cases

The Requirements Model



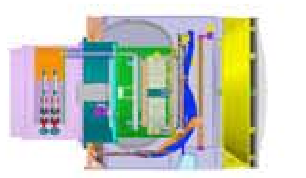
Requirements Hierarchy: The requirements flow down in LSST generally follows the hierarchy shown in the diagram. The operational requirements are derived from the Operations Models (left). The Functional Requirements flow directly from the SRD or are derived from a variety of sources including the Operations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



Model Statistics:
- 756 requirements tracked
- 1853 traceable links

Requirements Traceability: The requirements model traces the relationships and rationale between upper and lower level requirements. In the traceability example above functional system requirements (beige) are derived from science requirements (green). The last step in the traceability process is to identify the subsystem or component blocks (blue) that satisfies the assigned requirements.

Model Based Systems Engineering



The LSST is a complex system of systems consisting of an 8-m class telescope, a large 3 billion pixel digital camera, and a highly distributed data management system. Ensuring such a complex system as LSST works to specification requires a rigorous and early approach to systems engineering.

The LSST project has adopted a model based systems engineering (MBSE) methodology to develop the overall system design. The MBSE approach uses various models to drive the systems engineering process rather than standard documents. The LSST systems engineering effort uses four models that describe the over all system and sub-systems, these are: 1) a requirements and flow down model, 2) an operational and functional behavior model, 3) a system performance model, and 4) a structure and components model.

An important benefit of the MBSE approach to systems engineering is the ability to have all of the models interact with each other. This allows the systems engineering effort to capture subtle and complex interactions between various parts of the LSST system that may not otherwise have been identified until the system has been built.

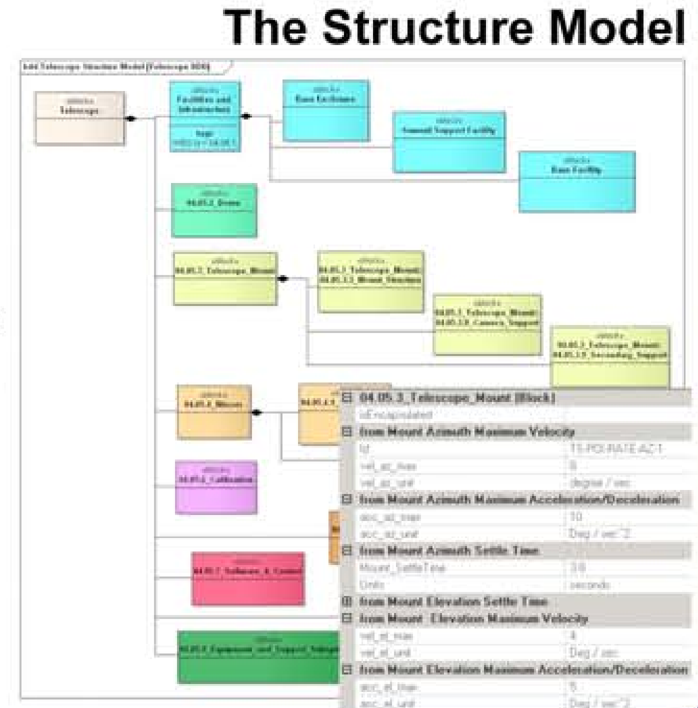
The LSST system models are implemented in Sparx Enterprise Architect. The LSST project uses Enterprise Architect on a centralized server which allows the distributed systems engineering team access to a common set of information describing the LSST and a single point of control for the LSST system configuration.

The Structure Model

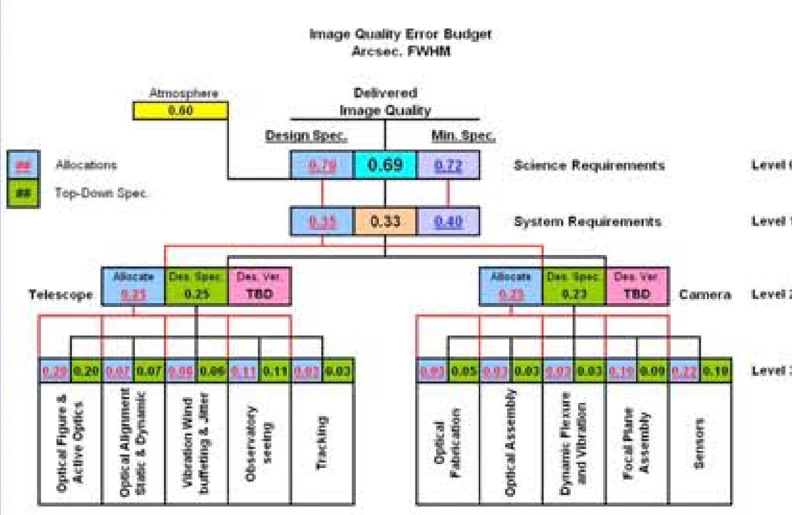
The structure model defines the physical breakdown of the LSST systems and subsystems into blocks. The top level telescope structure is shown (right).

As the traceability process proceeds the blocks serve as a place to collect requirements that defines what that block must do to satisfy the system. The inset shows an example of some of the requirements allocated to the Telescope Mount block.

Interface requirements are a special case. These are negotiated joint requirements between two subsystems, hence are allocated to two blocks simultaneously.



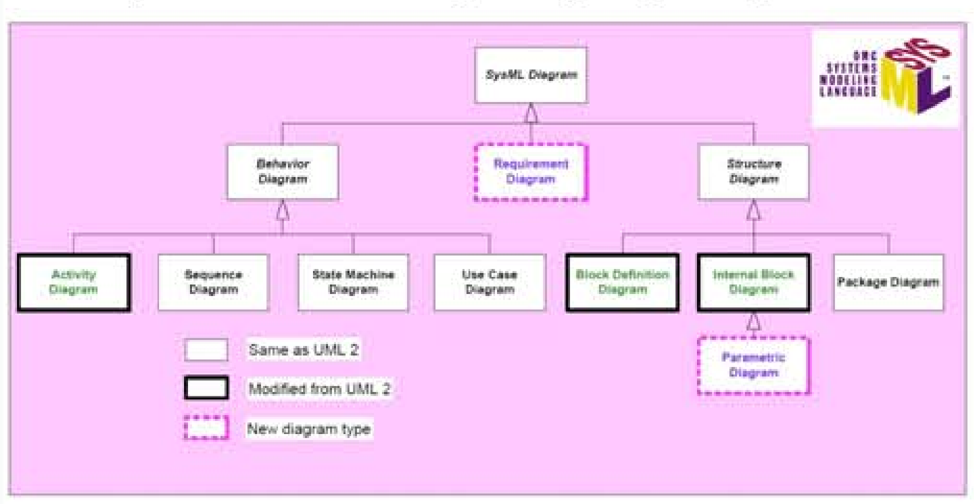
The Performance Model (System Budgets)



The performance of the LSST system is monitored and controlled using 5 types of system budgets:

1) Image quality
   a) PSF FWHM (left)
   b) PSF Ellipticity
2) Point Source Depth
3) Photometric Quality
   a) Absolute
   b) Relative
4) Astrometric Quality
   a) Absolute
   b) Relative
5) System Operational Efficiency

The Systems Modeling Language: SysML



What SysML is:
- A graphical language for modeling complex systems.
- It supports specification, analysis, design, validation, verification composed of hardware, software, data, personnel, facilities and procedures.
- It supports information exchange using XMI.

What SysML is not:
- It is not a tool
- It is not dependant on methodology

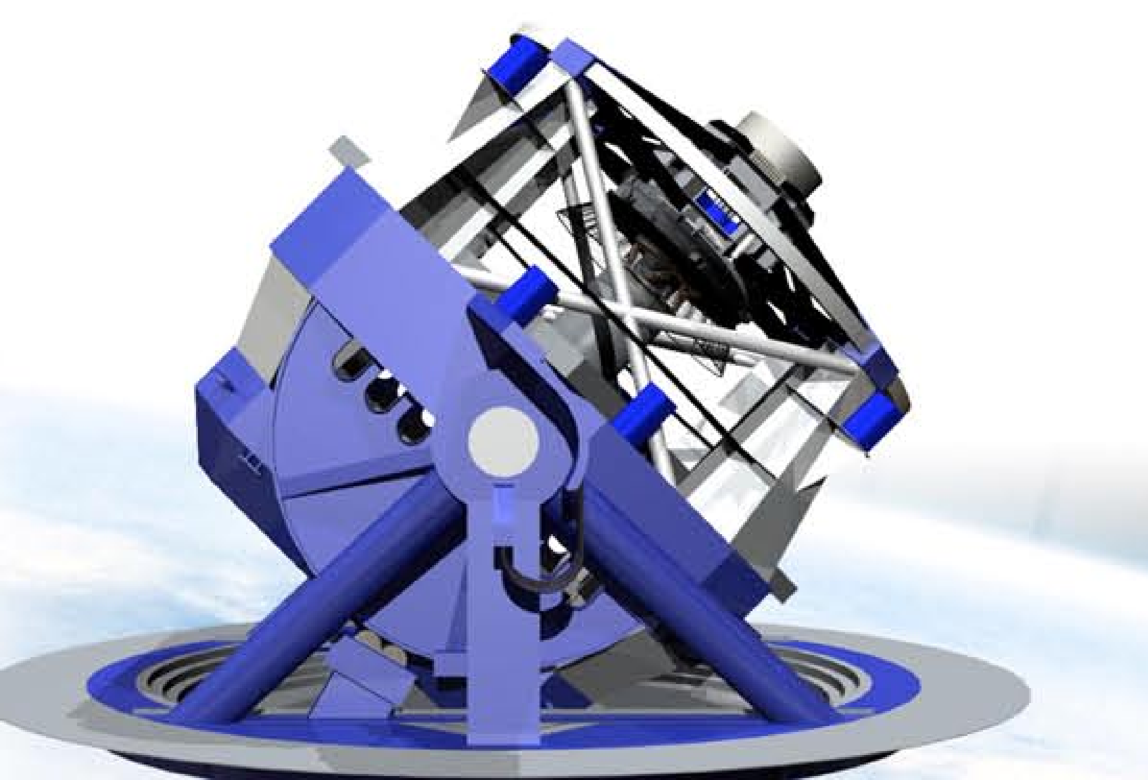
SysML derives its origins from the Unified Modeling Language (UML) commonly used in large software projects. SysML was first proposed by OMG in 2003 and was formally adopted in 2006. SysML uses a substantial fraction of the modeling elements defined in UML, but modifies and adds several new types that are specific to the needs of systems engineering (see above). See www.omgsysml.org.

Summary

The LSST Systems Engineering team has established a comprehensive model based methodology enabled by the recent emergence and standardization of SysML. This approach has proved to be invaluable towards maintaining a common system vision and design over a widely distributed project such as the LSST.

The LSST project will use the SysML as the single point of configuration control. From the model content we can generate documents that resemble standard formats for review by general project personnel.

We find that the use of a common centralized tool to capture the system requirements, behavior descriptions, use cases, and definitions to be essential for such a widely distributed project as LSST.



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