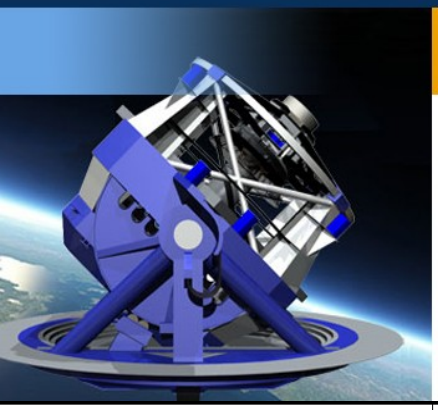
CASE STUDY



Designing the Large Synoptic Survey Telescope with Enterprise Architect

CHALLENGE

Apart from a critical design challenge to accommodate high-intensity processing of massive data sets, the LSST project team had to manage the complexity of widely distributed development across 10 locations, while maintaining end-to-end traceability of requirements at the science, system and sub-system levels.

WHY ENTERPRISE ARCHITECT

Enterprise Architect provided a scalable, shared model to integrate the work of the geographically dispersed LSST team. With built-in support for the ICONIX Process, Enterprise Architect also delivered complete requirements traceability, round-trip code engineering and detailed SysML support.

BENEFIT

Using Enterprise Architect together with the ICONIX Process, the LSST team has been able to move rapidly from requirements to design to functional prototype implementation, resulting in 90,000 lines of code and a shared, easy-to-understand view of the system.

Background

The Large Synoptic Survey Telescope (LSST) is a proposed ground-based 6.7 meter effective diameter, 10 square-degree-field telescope that will provide digital imaging of faint astronomical objects across the entire sky, night after night.

From its planned location in Northern Chile, the LSST will conduct a relentless campaign of 15 second exposures, covering the available sky every three nights. This process will open a movie-like window on objects that change or move on rapid timescales: exploding supernovae, potentially hazardous near-Earth asteroids, and distant Kuiper Belt Objects. The superb images from the LSST will also be used to trace billions of remote galaxies and measure the distortions in their shapes produced by lumps of Dark Matter, providing multiple tests of the mysterious Dark Energy.

LSST is currently in the Design and Development phase, in which the Science and System Requirements and Design are elaborated, and a series of reviews are conducted in order to assess readiness for the Construction phase, scheduled to start in 2010.

Data Management is one of the most challenging aspects of the LSST, as more than 30 Terabytes of data must be processed and stored each night in producing the largest non-proprietary data set in the world. Every pair of 6.4 GB images must be processed within 60 seconds in order to provide astronomical transient alerts to the community.

Goals

Members of the LSST collaboration identified four broad themes as key drivers of system requirements: [1]

- **The Nature of Dark Energy:** Researching dark energy imposes requirements such as excellent image quality and many short exposures (10-15 seconds). In turn, tracking image quality and rapid responses to changing observing conditions requires simultaneous data reduction with a latency of no longer than a few minutes.

- **Creating a Solar System Map:** By taking an inventory that includes the small-body populations of the Solar System, such as asteroids and comets, the LSST project will help in determining possible collisions of these objects with Earth. Creating such an inventory requires accurate absolute astrometry to link motion vectors.

"We could not manage the complexity and flow-down of requirements without an integrated tool such as Enterprise Architect."

— Jeff Kantor
Project Manager,
LSST Data Management

- **Exploring the Transient Optical Sky:** The LSST will enable the discovery and analysis of rare objects, such as neutron stars and black hole binaries, novae and stellar flares, and possibly new classes of transients, such as binary mergers of black holes. To achieve this requires low latency data processing to enable real time alerts.

- **Galactic Structure:** The separation of stellar populations also drives photometric precision requirements (1% internal, 2% absolute); proper motions and parallax measurements drive the requirements on relative astrometry.

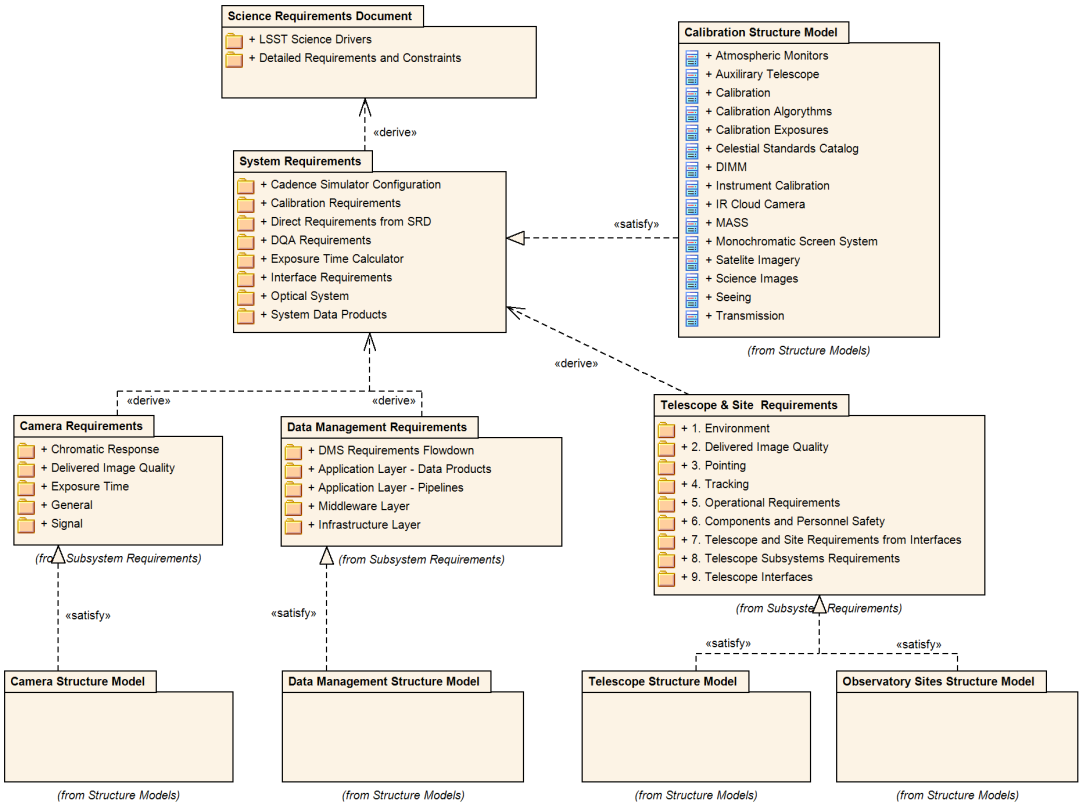


Figure 1: Requirements Packages for the LSST Project [2] modeled in Enterprise Architect

Model Development

The LSST team is performing system engineering using System Modeling Language (SysML) and software engineering using Unified Modeling Language (UML). In both cases, the ICONIX Process[3] and Sparx Systems Enterprise Architect[4] are used to facilitate modeling and traceability within and between these models.

The ICONIX Process provides inherent traceability between Use Cases and the Domain model via robustness diagrams and between the Use Case and Logical models via sequence diagrams. Traceability between the Logical model and code is achieved using Enterprise Architect's built-in reverse engineering and code generation capabilities for C++, Python and SQL.

Enterprise Architect was chosen as the modeling environment because the project needed a multi-user, full featured UML tool with traceability support from requirements to generated code. The LSST team also had experience successfully using Enterprise Architect and ICONIX Process on previous projects, such as the Large Binocular Telescope (LBT) – now operational and regarded as one of the world's most advanced optical telescopes[5]. This experience and Enterprise Architect's strong support for the ICONIX Process were key reasons for the LSST Data Management choosing Enterprise Architect. Subsequently, the System Engineering group adopted Enterprise Architect because it provides SysML and UML capabilities in one tool.

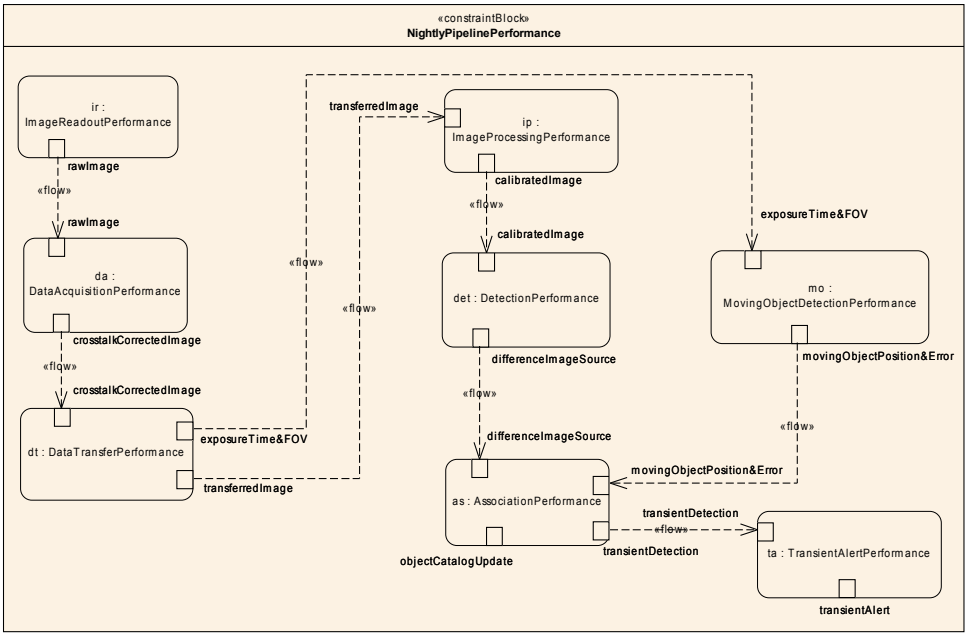


Figure 2: Data Management parametric model using SysML

Deployment

The UML was first deployed to LSST's Data Management team, followed by the introduction of SysML to the System Engineering team. Both of these modeling approaches have since been expanded to the Telescope, Site and Camera teams. A system level model for SysML and a subsystem level model for UML have been defined, both of which share a common Use Case package.

The LSST models are shared using Enterprise Architect's version control[6] integration capabilities. Individual packages are added to a central version control repository and these packages are then shared by several local Enterprise Architect project files[7].

The Enterprise Architect models and the application itself are hosted under Microsoft® Windows Server 2003®, allowing users to log in remotely using Remote Desktop Clients. This approach conveniently accommodates remote Macintosh, Linux and Windows users.

Achievements

The LSST Data Management team has used Enterprise Architect end-to-end in defining system and subsystem requirements, design, prototype implementation, testing and integration. Software and infrastructure is prototyped and tested under annual 'Data Challenges'. With each Data Challenge, increased capability and scalability are achieved, approaching the telescope's construction phase.

Each Data Challenge includes a full ICONIX Process UML model, starting with Use Cases and a Domain Model, Robustness Diagrams and a Logical Model. The as-built code is then reverse engineered back into Enterprise Architect to provide a design and estimating basis for subsequent Data Challenges.

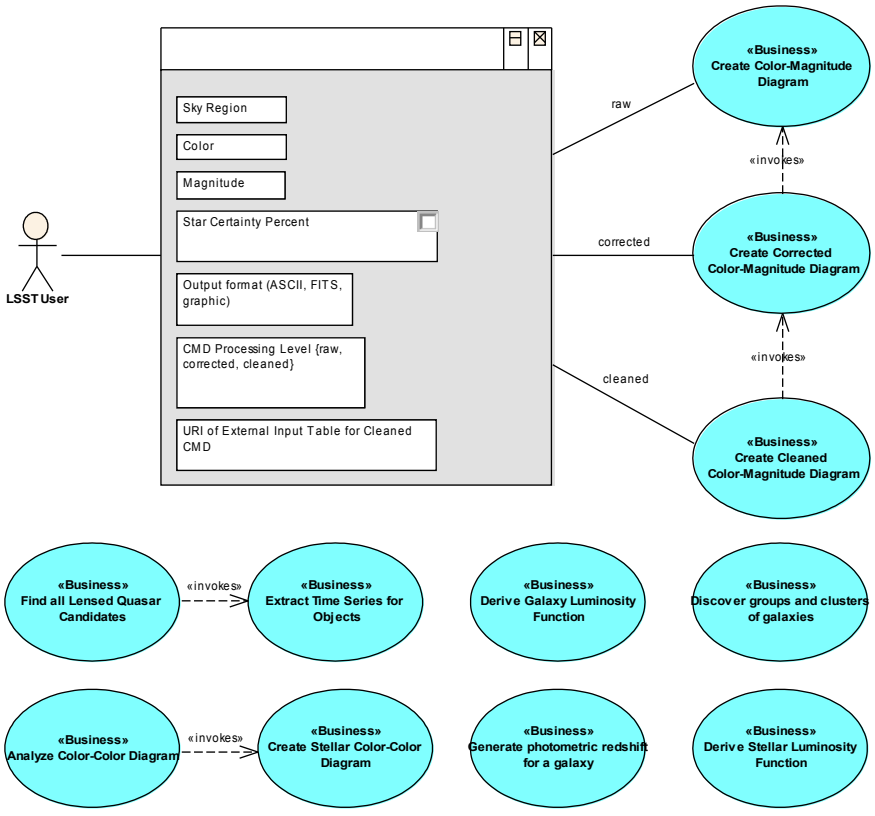


Figure 3: LSST Science Use Cases

As part of Data Challenge 2, the LSST team created end-to-end requirements, design and prototype development resulting in 90,000 lines of code. This included the capture of approximately 200 use cases and 200 objects that define the Data Management reference design.

These accomplishments resulted in a very successful Concept Design Review and positioned the team well for the upcoming Preliminary Design Review. Jeff Kantor, Project Manager of LSST's Data Management group, notes “We could not have achieved these results without a common methodology and shared models. Again, using Enterprise Architect in the context of the ICONIX Process gave us the ability to move rapidly from requirements to design to code.”

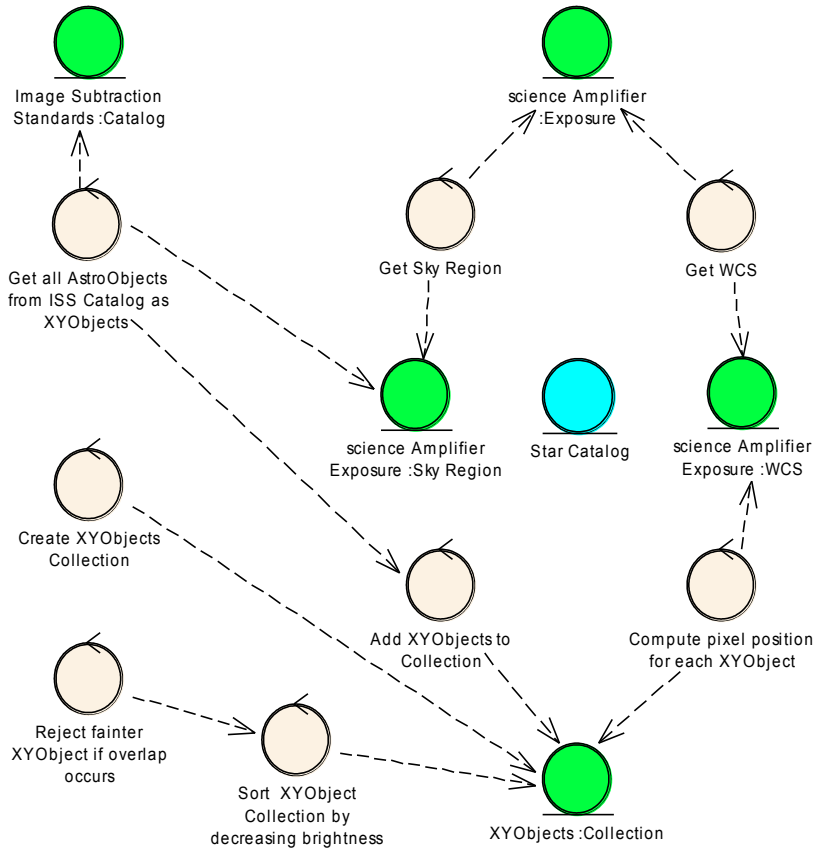


Figure 4: Robustness diagram for Image Subtraction functionality

Conclusion

The Data Management team of the LSST project has now successfully completed two of four annual Data Challenges leading up to the telescope Construction phase in 2010. Critical to the success of these preliminary phases, has been the team's ability to effectively communicate a shared view of the proposed system. The LSST team has achieved this using the Enterprise Architect modeling environment to facilitate distributed project work and realize end-to-end traceability, from requirements specifications to functional prototype implementation.

References

1 http://www.lsst.org/overview

2 http://dev.lsstcorp.org:8100/trac/wiki/SwDesign

3 http://www.iconixsw.com

4 http://www.sparxsystems.com/products/ea

5 http://lbto.org

6 http://www.sparxsystems.com/WhitePapers/Version_Control.pdf

7 http://www.sparxsystems.com/downloads/whitepapers/EA_Deployment.pdf

About The LSST Project

The LSST has been identified as a national scientific priority in reports by diverse national panels, including several National Academy of Sciences and federal agency advisory committees. This judgment is based upon the LSST's ability to address some of the most pressing open questions in astronomy and fundamental physics, while driving advances in data-intensive science and computing.

The LSST will provide unprecedented three-dimensional maps of the mass distribution in the Universe, in addition to the traditional images of luminous stars and galaxies.

The LSST is a Public-Private partnership, and the data will be made public immediately. A non-profit corporation, called the LSST Corporation, has been set up to manage the collaboration of over 250 scientists and engineers, and to raise private and agency funding. The LSST Corporation is a collaboration of 25 U.S. universities, national labs, private institutions and the host country of Chile.

About Sparx Systems

Sparx Systems (www.sparxsystems.com) specializes in high performance and scalable visual modeling tools for planning, designing and constructing software intensive systems.

With customers in industries ranging from aerospace and automotive engineering to finance, defense, government, entertainment and telecommunications, Sparx Systems is a leading vendor of innovative solutions based on the Unified Modeling Language (UML) and its related specifications. A Contributing Member of the Object Management Group (OMG), Sparx Systems is committed to realizing the potential of model-driven development based on open standards.

The company's flagship product, Enterprise Architect, has received numerous accolades since its commercial release in August, 2000. Now at version 7.1, Enterprise Architect is the design tool of choice for over 150,000 registered users in more than 60 countries world wide.

About ICONIX

ICONIX (www.iconixsw.com) offers a wide range of products and services with a focus on ICONIX Process; a streamlined approach to UML that reliably gets projects from use cases to code quickly and efficiently. ICONIX President Doug Rosenberg has authored 5 books on UML, including "Use Case Driven Object Modeling with UML--Theory and Practice" and "Agile Development with ICONIX Process".

ICONIX specializes in customized, hands-on, JumpStart Training. Available worldwide, these onsite, 5-day workshops allow students to use Enterprise Architect to model a real client project. "Hands-on EA for Power Users" is an ongoing series of two-day open enrollment public classes where students follow the design of a mapping project using Enterprise Architect.

Enterprise Architect for Power Users is a multimedia tutorial that provides over four hours of video tutorials covering a wide range of Enterprise Architect's features and capabilities.