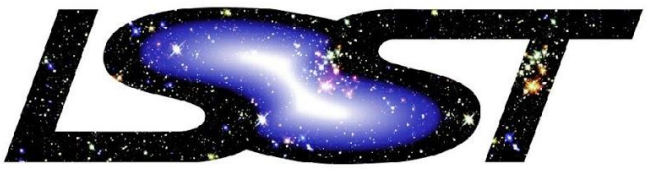

LARGE SYNOPTIC SURVEY TELESCOPE

Large Synoptic Survey Telescope (LSST)

EPO Design

LEP-31

Latest Revision Date: July 17, 2018

Change Record

Version	Date	Description	Owner name
2.0	10/7/2013	FDR version of EPO Baseline Design, D-12079	S. Jacoby
3.0	10/2016	Refreshed based on updated EPO Requirements (LSE-89) and planning subsequent to FDR	B. Emmons
4.0	07/18/2017	Refreshed based on Operations planning	A. Bauer, B. Emmons, E. Bechtol
4.1	09/05/2017	Major updates for EPO Review	E. Bechtol, A. Bauer, B. Emmons
5.0	07/2018	Content updated after EPO team growth	A. Bauer

Table of Contents

Executive Summary

This document provides an overview of the Education and Public Outreach (EPO) program for the Large Synoptic Survey Telescope (LSST). It defines specific EPO program elements that shape the cost, schedule, and scope detailed in the LSST Project Management Control System (PMCS) - WBS 5.0 for the construction of the LSST EPO program, to be delivered at the start of LSST Operations.

The mission of LSST EPO is to offer accessible and engaging online experiences that provide non-specialists access to, and context for, LSST data so anyone can explore the Universe and be part of the discovery process. The subset of LSST data to be made world public immediately will be referred to as the *EPO data set* in this document. Key objectives driving the EPO program are guided by requirements for user-centered learning tools that meet the needs of specific audiences with different levels of knowledge, experience, and skill.

LSST EPO will serve four main categories of users, with a focus on people in the United States and Chile:

1. general public (with an emphasis on science-interested teens and adults),
2. formal educators teaching astronomy content at the advanced middle school, high school, and undergraduate college levels,
3. principal investigators with LSST data rights leading citizen science projects, and
4. content developers at informal science centers.

For these audiences, EPO's vision is to facilitate a variety of engagement options, from entry-level exploration of astronomical imagery and information to more complex interaction with LSST data. To achieve this, EPO is creating a website featuring a multimedia gallery, an interactive Skyviewer, access to data via online science notebooks and other interactive visualizations, and links to citizen science projects that use LSST data. Each of these features provides context for LSST data, inviting users to explore images of the night sky, experiment with science tools such as Jupyter notebooks, and participate in LSST research through citizen science projects. Where possible, EPO products will be available in both English and Spanish.

Visitors to the website will find articles about LSST discoveries, features on people involved with the Project, introductory videos about LSST, and a multimedia gallery. An interactive Skyviewer will allow people to explore LSST data of the night sky visible to the telescope and take curated tours of scientifically interesting objects to offer deeper learning opportunities. Online notebook technology and a formal education program will provide access to the EPO data set.

Introductory notebooks will explain common science themes and introduce the notebook environment.

Formal educators will have access to online, easily adoptable classroom investigations that integrate LSST data into online notebooks. Investigations will be aligned with the Next-Generation Science Standards (NGSS)[1] in the USA and the Currículum Nacional in Chile, and will follow best practices for college level students. LSST EPO will also provide the professional development training and instructional materials necessary to help educators successfully engage their students in each investigation.

The EPO Team will work with Zooniverse[2] to add LSST data compatibility to their Project Builder tool, allowing scientists working with LSST data to easily create citizen science projects that help them accomplish their research goals and engage with a global community. EPO anticipates that the number of citizen science projects in the astronomy field will increase dramatically when LSST is operational, giving a new generation of citizen scientists the opportunity to deepen their engagement with astronomy using real data from LSST.

LSST EPO will provide free multimedia visualizations for use by museums, science centers, and planetariums around the world, offering maximum flexibility in adapting the materials to their specific needs. These visualizations, associated metadata, and distribution methods will follow industry standards and best practices.

Underlying all EPO programing is critical infrastructure that responds quickly to varying levels of demand. Therefore, a foundational component of LSST EPO is the cloud-based EPO Data Center (EDC) which allows for scalable, on-demand computing best suited to EPO audiences.

[1] https://www.nextgenscience.org/

[2] https://www.zooniverse.org/

1 Requirements

At the highest level, the need for an EPO program is established in the LSST System Requirements Document (LSE-29) and flows down to the LSST Observatory System Specifications (LSE-30). From there, full implementation requirements are detailed in EPO Subsystem Requirements (LSE-89) and DM/EPO Interface (LSE-131). Details related to EPO Commissioning are included in the LSST Commissioning Plan (LSE-79) and details for EPO Operations are included in the LSST Operations Plan (LPM-181).

This technical system-level documentation is under Change Control within the LSST Project and the work within is subject to Compliance and Verification Procedures (LSE-160) as defined by the LSST Systems Engineering Team.

Reference Documents:

- LSST System Requirements (LSE-29)
- Observatory System Specifications (LSE-30)
- EPO Subsystem Requirements (LSE-89)
- DM/EPO ICD (LSE-131)
- LSST Commissioning Plan (LSE-79)
- LSST Operations Plan (LPM-181)

2 Objectives

These objectives describe specific aims that drive the overall scope of LSST EPO and support achieving the requirements of the program:

- Provide non-specialists access to the LSST EPO data set through online tools and interfaces.
- Enable and facilitate citizen science projects that use LSST data.
- Further STEM education and training by engaging with educators to enable use of real LSST data in classrooms.
- Develop multimedia resources for content developers at informal science centers.
- Build relationships with institutions and organizations serving underrepresented groups in STEM and proactively engage with diverse audiences.
- Engage with the Chilean community by providing culturally responsive EPO products in Spanish.
- Remain agile and relevant during the full lifetime of LSST Operations by adjusting to technology trends and changes in educational priorities.
- Provide evidence-based evaluation of the LSST EPO program and publicly report findings and evidence of progress.

To achieve these objectives, the LSST EPO team will engage with our identified audiences to create and test powerful and easy-to-use digital tools for exploring the rich EPO data set, enabling users of any background to engage with the Universe like never before.

3 EPO Program

The vision of EPO is to facilitate a variety of engagement options, from entry-level exploration of astronomical imagery and information to more complex interaction with LSST data, using tools similar to those used by professional astronomers.

The individual components of the EPO Program are developed with this vision in mind. This section starts by identifying audiences and estimating reach, highlighting features of the website, and then describing the major EPO Program components: multimedia gallery, formal education activities, and citizen science.

Audience

Four primary audiences for LSST EPO are listed below with estimates of the number of users in each group and the relevant data products. We have analyzed user behavior by audience group and learned from related projects to determine the anticipated number of users for LSST. Note that EPO will reach some participants directly and others indirectly, for example, "content creators" at informal science centers; products they create will then indirectly reach very large audiences.

1. General Public (with an emphasis on science-interested teens and adults)

   Users will engage with the project through social media outlets and the EPO website. We estimate 1 million visitors to the website and 5 million reached through social media. LSST currently has accounts on facebook, twitter, and Instagram.

2. Formal educators teaching astronomy content at the advanced middle school, high school, and undergraduate college levels

   We estimate 1000 users a day will log into the Education Hub part of the website to use online notebooks to enable authentic research projects. It is also possible students will explore independently.

3. Principal Investigators with LSST data rights leading citizen science projects

   We estimate that 100-200 Citizen Science projects using LSST data will be launched by researchers over the 10 years of Operations. We estimate up to 10,000 LSST Citizen Science users based on the history of Zooniverse users.

4. Content developers at informal science centers.

In addition to content developers at planetariums and science centers who in reach very large numbers of in-person visitors to their locations, major hardware and software vendors are an audience for our multimedia products. We anticipate 12 vendors receiving annual updates of the full sky map and 100 content providers using multimedia products to integrate into their live, ongoing, or new.

Website

The website home page is intended to be the main landing page for visitors to the public LSST webpages during Operations. The home page could feature media, such as a promotional video and astronomical images, news from the Project, formal education highlights, featured citizen science projects, and highlights of recent discoveries with LSST data.

Through the website, the EPO Team will make the LSST alert stream meaningful and useful for the public in several ways: LSST EPO will offer information on interesting Solar System objects, supernovae, and other time-varying events, and generate listicles featuring interesting discoveries such as "The Top 10 closest asteroids detected by LSST" or "The most distant objects in our Solar System found by LSST to date." Such features are quickly consumable, relevant, and dynamic – a perfect fit for sharing on social media and encouraging repeat site visits by the public.

Throughout the website, users will find articles about LSST discoveries and people involved in the Project (e.g. scientists, engineers, developers, etc.); features on LSST science results; and videos that introduce the general public to LSST, its science goals, and general astronomy concepts. Information about the facility design and construction will also be available. There will be pages dedicated to interactive opportunities like citizen science projects using LSST data, the Skyviewer, and the Education Hub.

Where possible, features throughout the website will be shareable via social media; the entire website will be designed to be mobile-friendly to support this. The website will also share what is happening at the telescope site -- the current weather, the area where the telescope is viewing, etc. EPO will use status information from summit sensors, cameras, and the Engineering Facilities Database to populate this area of the website.

Skyviewer

The Skyviewer will allow users to pan and zoom around color co-add images from the annual LSST data release. The EPO Team color co-adds used for the website will likely be created using an algorithm defined by the EPO Team (not the general one used by DM). Users will be able to access additional information for many individual objects, such as metadata and basic graphs like light curves or values of magnitudes against wavelength.

The Skyviewer allows for freeform exploration and connects users to other features of the website that encourage deeper engagement.

Data Access

In addition to Skyviewer exploration, interaction with EPO data will be enabled by online science notebooks. Users will be introduced to the online notebook environment through videos, documentation, and sample notebooks designed to explore topics related to the science themes of LSST including Cosmology and the Dynamic Sky. Users can then modify these introductory notebooks or create their own investigations using common astronomy Python packages that will be pre-installed.

Multimedia

LSST EPO is developing a library of digital multimedia assets during Construction to be used in Operations on the EPO website as well as at science centers, planetariums, and media outlets. Assets include:

- Visualizations of astronomical phenomena related to LSST science
- Images and videos of progress on the construction of telescope components, including the camera assembly, the mount structure, the dome and telescope facility on Cerro Pachón
- Video interview footage of the broad range of people involved in the Project, from those who brainstormed its early design to the scientists, engineers, and other experts making LSST a reality

EPO will contract with external multimedia specialists, video production firms, and visual effects consultants to develop multimedia assets over time. We will not be developing a full-length planetarium show but will deliver short video clips ranging from 30-90 seconds in addition to some short introductory films on the Project up to a few minutes in length.

LSST EPO multimedia will use industry standard formats. Planetarium fulldome video footage will include Domemaster frames to maximize compatibility with various dome styles, projection systems, and software products. Image assets and flat-projection video footage (such as panoramas, sunset/sunrise, day/night time lapse, and aerial drone) will support the *Astronomy Visualization Metadata (AVM)*[3] standard for images to facilitate easy searching, cataloging, and

[3] https://www.virtualastronomy.org/avm_metadata.php

distribution via LSST's digital asset management system and the International Planetarium Society's *Data2Dome*[4] standard.

Models of the telescope structure and facility, mirror assembly, camera assembly, etc. will be distributed in OBJ[5] format, a common interchange format supported by all the major CAD vendors.

Formal Education

EPO will develop web-based astronomy investigations for advanced middle school, high school, and introductory college classrooms. These investigations are provided online through a standard web browser.

Offering online notebooks means that educators will not have to install or maintain software on local devices or download data sets. Additionally, Interactive widgets within the notebooks simplify the process of interacting with data. Hosting and software maintenance will be completed by our team in the EPO Data Center.

EPO will design and develop six sets of themed investigations based on the main LSST science pillars. These strategically chosen themes will support topics that instructors commonly teach, while aligning with the Next-Generation Science Standards (NGSS) in the USA and the Currículum Nacional in Chile. All investigations will be available in English and Spanish.

Investigations will be designed to improve the learner's critical thinking and evidence-based reasoning, data analysis skills, and complex problem-solving abilities. Investigations will also be designed based on best classroom teaching practices. They will be supported by introductory videos, a Teacher Guide, tutorials, and assessment materials.

All investigations will use LSST data as it becomes available. Extensive field testing with a diverse range of educators will be conducted throughout Construction using precursor data sets and LSST commissioning data. Field testing is important as it allows us to iteratively improve the design of the online notebook and support materials, as well as improve the ease of use for instructors and accessibility for different types of classrooms.

To increase adoption and encourage sustained use of EPO investigations in classrooms, EPO will offer professional development and support options for educators. Professional development options to be evaluated include holding sessions at professional society meetings and educator conferences, providing video materials online, and facilitating sessions in collaboration with museums and libraries that offer local professional development.

[4] http://www.data2dome.org/

[5] https://en.wikipedia.org/wiki/Wavefront_.obj_file

Citizen Science

Because of the size of the LSST data set, many professional research projects will benefit from the assistance of citizen scientists. Citizen science allows professional researchers to carry out large research projects by crowdsourcing classification and analysis from public volunteers. LSST EPO has partnered with Zooniverse[6], a popular online citizen science platform, to leverage and increase the potential for citizen science with LSST data.

The Zooniverse Project Builder[7] enables scientists to build their own online citizen science projects. As a result of the partnership between EPO and Zooniverse, Project Builder will enable members of the LSST Science Community to develop English and Spanish citizen science projects with tools specifically designed to utilize LSST data. All LSST data products can be used for LSST citizen science.

By focusing on the integration between LSST and Zooniverse, professional researchers will be able to create and run citizen science projects themselves, which enables far more projects than EPO could run itself.

To boost participation in citizen science projects, EPO will promote current LSST-related projects hosted on Zooniverse, throughout the EPO website, encouraging site visitors to participate in projects they find interesting.

To assess the success of the citizen science program, LSST citizen science principal investigators will be asked to document their project-building processes during the beta testing phase, and to provide EPO with feedback which will be used to make improvements. Zooniverse collects analytics on citizen scientists participating in projects which will be used to document participation rates.

LSST Science Community

EPO will provide opportunities for education and outreach that the LSST Science Community can participate in. These opportunities, while aligned with NSF Broader Impacts[8] criterion, will be available for the entire LSST Science Community. Examples include:

- Contribute to online notebook development
- Contribute to interactive widget design and development
- Create notebooks on relevant science topics

[6] https://www.zooniverse.org/

[7] https://www.zooniverse.org/lab

[8] https://www.nsf.gov/pubs/2007/nsf07046/nsf07046.jsp

- Expand EPO's network at strategic conferences/events
- Provide scientific input for EPO deliverables
- Prototype citizen science projects with LSST data
- Prototype EPO's professional development program

Diversity

EPO is committed to engaging with diverse audiences, in particular those traditionally underrepresented in STEM fields. EPO is undertaking a multi-faceted approach to reaching diverse individuals. Within each part of the EPO Program, design decisions are made that take into account diversity and inclusion issues. For example, care has been taken in designing diverse animated characters in educational videos; diverse scientists will be highlighted on the website; citizen science projects will be available in Spanish; and multimedia will be available in standards such that smaller planetariums can easily use them. Evidence-based design decisions around diversity and inclusion will be documented in EPO evaluation reports.

4 EPO Data Center (EDC)

All parts of the EPO program described above depend on making data available in a way that is responsive to requests and easy for non-specialists to use. Therefore, a foundational component of the EPO program is a scalable data center tuned to unique EPO audience needs.

User load and usage varies significantly throughout each day and during different parts of the year. Spikes in web traffic will follow references to LSST in media, science results, media references to citizen science projects, and social media references by popular individuals or organizations to a feature of the website.

To accommodate these patterns, the EDC will follow best practices popularized by cloud computing: leveraging containers, infrastructure-as-code, and scalable architecture.

The EPO data set will not exceed 10% of the full LSST data set, will be obtained from the Data Access Center (DAC) at NCSA, and will be transferred to the EDC as defined in the interface requirements document (LSE-131).

By designing an agile, scalable infrastructure, EPO can meet our challenging and unique audience needs while efficiently minimizing cost. As we develop these creative solutions, we anticipate that our contributions and insights can benefit future EPO programs associated with big data astronomy projects like the Square Kilometre Array (SKA) and thirty-meter class telescopes as well as the open-source community.

5 Evaluation

During Construction, EPO will engage in iterative prototype testing and evaluation to improve Program design.[9] As individual components of the EPO Program are developed, we will recruit people to interact with, test, and provide targeted feedback. Testing may be moderated, where EPO or contractors engage with participants in real time, or unmoderated, where they interact with programs online. Feedback from user testing sessions will be incorporated into ongoing development and design, adding improvements to the user experience and EPO deliverables. By regularly testing with diverse representatives of our main audiences, including our Spanish-speaking Chilean audience, we can ensure the goals and outcomes of our Program are more likely to be achieved when Operations begins.

Evaluation during LSST Construction will focus on answering questions such as:

- To what extent do users find deliverables intuitive and relevant?
- To what extent are deliverables and the website accessible to our core audiences?
- To what extent are audience needs being met?

[9] This process, known as formative evaluation, occurs during program development.

- What are short-term user outcomes as a result of using EPO deliverables?
- To what extent are activities sustainable through Operations?
- How can we improve deliverables to be more appropriate, efficient, effective, and sustainable?

User feedback and iterative testing during Construction offers an opportunity to test and refine evaluation questions for use during Operations.

Analytic tracking will be built into technical components of the program during Construction. For example, the website will use an analytic tracking system to determine user dwell time and click paths. These data will be delivered to an external evaluator who will be contracted to evaluate the impact of the EPO Program on our core audiences during Operations.

Outcomes for the main program components are being defined during Construction and are detailed in Table 1. Evaluation will be organized and performed at the program component level on the premise that if each component is successful, then EPO has successfully fulfilled its mission. Planning for evaluation in Operations is an ongoing process throughout the LSST Construction and Commissioning periods.

Program Component	Audience	Desired Outcomes	Evaluation Methods
Website	Science-interested teens and adults	• Awareness of LSST • Increased awareness of having access to LSST data • Awareness of the diversity of people working on LSST • Awareness of the main science themes of LSST • Awareness of scientific research methods	-Web surveys -Web analytics -Focus groups -Interviews
Multimedia	Content creators at informal science centers	• Awareness of LSST and its multimedia offerings • Perception that LSST multimedia resources are easy to adopt • Perception that LSST multimedia assets are useful for programming	-Web analytics -Surveys -Focus groups -Data2Dome-Gallery exchange

Formal Education	Educators in advanced middle school, high school, and undergraduate college classrooms	• Awareness of LSST and its educational offerings, particularly among underrepresented groups • Increased confidence using online science notebooks with students • Increased confidence and skills in customizing or designing notebooks. • Use one or more formal education investigations over multiple years	-Surveys -Focus groups -Login requests -Documentation of feedback from EPO team -Pre/post professional development surveys -Online feedback form -Forum monitoring
Citizen Science	Principal investigators of citizen science projects using LSST data	• Awareness by the LSST Science Community of the opportunity to build LSST data-driven citizen science projects using the Project Builder • Awareness by the LSST Science Community that they can use citizen science as a tool to achieve their science goals • Increased skills by citizen science principal investigators in developing citizen science projects	-Surveys -Focus groups -Online feedback form -Project Builder analytics -Documentation of feedback from science community

Table 1. Outcomes and associated evaluation methods for the main components of the LSST EPO Program.

Needs assessments, focus groups, interviews, and prototype testing sessions have and will continue to have concentrated effort around recruiting for diverse individuals and viewpoints. Through this work, EPO will create deliverables that are interesting, accessible, engaging, and relevant to as many people as possible and learn about the diverse ways people engage with astronomy.

Periodic summaries of evaluation findings will be made publicly available. This could be through published journal articles, presented talks at conferences or the LSST Project and Community Workshops, and/or publicly posted reports.

6 Communications and Marketing

During Construction, Communications is encompassed within the Project Office. As the Project transitions from pre-Operations (2021) into full Operations, Communications will start to transition to operating within EPO. In 2019, EPO will start developing the Operations Communication Plan. This plan will address topics such as the buildup of marketing activities before the start of Operations, the process for supporting and issuing press releases, social media strategy, and internal communication procedures.

7 Construction Staffing

To achieve these goals during LSST Construction, EPO will be staffed with content specialists, scientists, educators, and developers. Most team members will be based in Tucson at LSST Headquarters and led by the Head of EPO. The Chile EPO Coordinator will be located in Santiago or La Serena, Chile. LSST EPO will also work with other EPO groups in Chile to incorporate best practices and maximize efficiency.

The education and outreach focused members of the EPO team will develop structured online LSST data-based classroom activities that reflect national education priorities and are engaging for a diverse audience of educators and students. Members of this group will represent LSST at events like AAS and the IAU, document project progress as archival footage for use in LSST Operations, and work closely with the Head of EPO to build and maintain relationships with organizations serving underrepresented groups in STEM.

The technical members of the team are responsible for architecting, developing, and maintaining the EPO Data Center. They also maintain EPO website features like the online notebook infrastructure, widget development, Skyviewer, and multimedia gallery. They will coordinate with the LSST Science Platform development group, the LSST Data Facility (NCSA), and key technology partners to ensure data integrity, seamless integration, scalability, and fast performance.

Note: Operations staffing is described in the LSST Operations Plan (LPM-181).

8 Operational Readiness

There are three major phases of EPO:

1. Construction: EPO will use simulated and precursor astronomy data sets to perform testing of website features before Commissioning data from LSST becomes available
2. Pre-Operations and Commissioning: EPO will use LSST ComCam data, simulated data, precursor alert stream data, and then LSST Camera commissioning data to further build out and test website features
3. Operations: EPO will launch the public site. Commissioning data and precursor data will be used during the first year of telescope Operations prior to Data Release 1 and the beginning of LSST Alert Stream production.

Commissioning tasks are defined in the LSST Commissioning Plan (LSE-79). We include some EPO highlights here for reference:

4. Test network bandwidth and load between NCSA and EDC
5. Test loading the public subset of annual catalog data (the EPO Data set) into the EDC database
6. Test loading the color co-add images from NCSA into the EDC and converting to image tiles for Skyviewer display
7. Test science notebook platform and run education investigations using EDC data
8. Test integration of Zooniverse Project Builder with LSST data sources
9. Test website at full load using simulated users
10. Verify Data2Dome-compliant software at informal science centers can access EPO multimedia
11. Validate key use cases with small groups of actual users:
    - Usability testing of graphical user interfaces
    - Citizen science using prototype projects
    - Classroom investigations using science notebooks
    - Professional development for educators
    - Data2Dome multimedia search and fulldome display
12. Review cybersecurity as defined in the EPO security plan (LEP-21, LEP-22)

LSST EPO will be declared ready for Operations at the successful completion of an EPO Operational Readiness Review, signaling the formal end of Construction for EPO.

9 Document History

Version 3.0 (November 2016) The first version updated after Ben Emmons joined EPO Team

- Incorporated refreshed EPO Requirements (LSE-89)
- Replaced full text of LSE-29 and LSE-30 requirements with reference
- Added support section and removed telescope status reference
- Updated Operational Readiness section
- Updated authorship

Version 4.0 (September 2017) Major updates before Sept 2017 EPO Review

- Operations planning updates included
- Reorganized document structure and added introductory text
- Updated EDC derivative data sources
- Added evaluation information to each section and added own section
- Long term scope added
- Included community involvement and Broader Impacts
- Altered scope related to animated images

Version 5.0 (June 2018) Updates after team growth

- Reorganization of document
- Single evaluation section
- Updated scope
- Updated technical section
- Updated language and mission statement
- Operations planning updates