LARGE SYNOPTIC SURVEY TELESCOPE

Large Synoptic Survey Telescope (LSST)

EPO Design

Ben Emmons and Suzanne Jacoby

LEP-31

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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
3.1	10/26/2016	Replaced full text of LSE-29 and LSE-30 requirements with a reference.	B. Selvy
3.2	10/28/2016	Removed telescope status reference since Engineering Facilities Database (EFD) status is in flux	B. Emmons
3.3	10/28/2016	Added support section	B. Emmons
3.4	11/1/2016	Updated Operational Readiness appendix	B. Emmons
3.5	11/18/2016	Updated primary authorship to include S. Jacoby for proper attribution	B. Emmons
3.6	11/22/2016	Added light curve plot feature to Object Pages section	B. Emmons

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Summary

The purpose of this document is to provide an overview of the Education and Public Outreach (EPO) program for the Large Synoptic Survey Telescope (LSST) during construction. It defines the specific EPO program elements that shape the costs, schedule, and scope detailed in the LSST Project Management Control System (PMCS) - WBS 5.0.

Reference Documents

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

1 Introduction

As the top-ranked major ground-based facility, LSST requires an EPO program as broad as its scope. With an international audience of non-specialists ranging from formal educators, citizen scientists, content creators at planetariums / informal science centers, and the general public, the potential impact of unlocking LSST's "treasure trove of discovery" is immeasurable. The EPO program seeks to reach a diverse audience and encourage their deepening engagement with the data products, involving them in the research process to share and participate in science discovery. The system design synthesizes national education priorities, audience needs, and LSST science goals to address STEM education and science literacy within the engaging context of astronomy.

Numerous individuals and groups from the astronomy education and education research communities have collaboratively contributed to the development of the LSST EPO program since 2005. An Outreach Advisory Board (consisting of members selected to represent end-users or a particular area of expertise) contributed significantly to the LSST EPO program design. In addition, LSST Science Collaboration members have described EPO ideas in various chapters of the LSST Science Book and served as consultants and colleagues on EPO prototype projects.

2 EPO Goals and Requirements

At the highest level, the need for an EPO program is established in the LSST System Requirements Document (LSR, LSE-29) and flows down to the LSST Observatory System Specifications (OSS, LSE-30). From there, full implementation requirements are detailed in LSE-89 (EPO Subsystem Requirements) and LSE-131 (DM/EPO Interface). This technical system-level documentation is under Change Control within the LSST Project and the work within subject to Compliance and Verification Procedures (LSE-160) as defined by the LSST Systems Engineering Team.

2.1 EPO Goals

Although the LSST Systems Engineering Team manages the formal requirements validation process to officially quantify and assess the EPO deliverables, the EPO goals listed below are provided as a 'guiding light' for desired outcomes:

- Involve diverse participants in LSST science across a spectrum of environments and skill levels
- Create and evolve products to ensure ongoing relevance, interest, and deepening levels of engagement
- Leverage the openness of the Internet and power of the browser to unlock LSST's "treasure trove of discovery"

- Engage with English and Spanish-speaking educators to promote authentic research experiences in the classroom
- Support U.S. and Chilean national priorities in STEM education and Broader Impacts
- Empower the public to become citizen scientists, contributing meaningful scientific research from LSST data
- Increase awareness of LSST's capabilities and science objectives via multimedia for content creators, social media, conferences, and events
- Measure success with quantitative, evidence-based metrics

2.2 EPO Foundational Requirements

The high-level foundational requirements for EPO are found in LSE-29.

2.3 EPO Implementation Requirements

The high-level implementation requirements for EPO are found in LSE-30.

2.4 DM/EPO Interface Requirements

The low-level requirements defining the integration between Data Management (DM) and EPO are found in LSE-131.

2.5 EPO Subsystem Requirements

The low-level requirements for the EPO subsystem are found in LSE-89.

3 EPO Audiences

Four primary user groups have been defined and listed below, including user count estimates for each.

Note: it is difficult to estimate EPO demand accurately. While the potential audience is huge, we know that only a subset of the potential audience will actually make use of our deliverables. We have analyzed user behavior by audience group and learned from related projects to determine the anticipated number of users for LSST.

3.1 General Public (GP)

We estimate 250,000 EPO Portal users, based on average SDSS.org web traffic. We also estimate 1,000 Transient Events mobile application users – a conservative estimate based on somewhat similar apps like Star Walk HD.

3.2 Citizen Science (CS)

We estimate 250,000 LSST Citizen Science users, based on the history of Zooniverse, which in 2013 had more than 850,000 registered users involved with ~15 active projects. The original Galaxy Zoo project had more than 100,000 participants who contributed more than one million classifications ("clicks") of 800,000 SDSS galaxies in less than two weeks. Within a year, each galaxy had been classified more than 70 times.

3.3 Classroom Research (CR)

At the end of the 10-year survey, we estimate 72,000 secondary education (middle and high school) students and 250,000 higher education (introductory general-education and STEM undergraduate) students will have participated in EPO authentic research experiences based on figures from similar programs like QuarkNet.

3.4 Informal Science Education (ISE)

We anticipate at least 3 planetarium software vendors will integrate EPO data (such as the alert stream) into their products. We also anticipate at least 100 content providers will incorporate EPO feeds and multimedia into their live or ongoing programming at Informal Science Centers / Planetariums.

4 EPO Deliverables

The following EPO deliverables will be developed during construction *(see also: Appendix - Operational Readiness)*

4.1 EPO Portal

All users will have access to an online portal that serves as a clearinghouse for a variety of EPO products and services, including:

4.1.1 Dynamic Counters

Statistics will be shown of various object types (supernova, NEOs, etc.) and dynamically updated.

4.1.2 Full-Sky Viewer

The EPO Portal will contain a mobile-responsive, tile-based, color, full-sky view.

4.1.3 Near Real-Time Alerts

Alerts will be displayed as an overlay on the Full-Sky Viewer. Filtering controls will dynamically update the graphic overlay and allow the user to subscribe to future alerts matching those query

parameters.

4.1.4 Object Pages

The EPO Portal will contain object pages with associated visuals (postage stamp, light curve plot, animated image, etc.) and metadata (right ascension, declination, altitude, azimuth, etc.). The information will be displayed in the browser but also programmatically accessible via an Application Programming Interface (API) for use by third-party applications.

4.1.5 Links

- Active LSST citizen science projects
- Educator resources
- Multimedia resources

4.2 Transient Events Mobile Application

EPO will create and support a Transient Events mobile application to notify the public of alert stream events in near real-time. Features will include:

- Customizable filters to select objects of interest by event class, brightness and age
- Notifications of filtered events shortly after they are discovered
- Location-aware algorithm to detect if object is currently above the horizon
- Science image display
- Event metadata, including: right ascension, declination, altitude, and azimuth coordinates
- Offline-capable bookmarks to store interesting events on your device so that they can be viewed when network connectivity is unavailable

4.3 Zooniverse Integration

EPO has partnered with Zooniverse, a popular citizen science framework and hosting service, to leverage and improve the Zooniverse products listed below. At least two citizen science projects will be developed during construction to test these enhancements.

4.3.1 Zooniverse Project Builder

To maximize use of the data and encourage broad application, EPO will integrate its cloud-based EPO Center (EPOC) with the self-service Zooniverse Project Builder tool, thereby empowering end-users (even those lacking technical skills) to create their own projects based on public LSST data.

4.3.2 Zooniverse Federation

When multiple projects use the same data source, they can be grouped into a 'Zooniverse Federation' which will enable data usage tracking.

4.3.3 Zooniverse Talk

The custom community forum solution used by Zooniverse is called 'Talk' and it enables contextually-specific forum discussions, sharing of ideas, and a deepening level of engagement.

4.3.4 Zooniverse APIs

The Zooniverse Application Programming Interfaces (APIs) will allow Data Management (DM) to import project results as Level 3 products (if desired).

4.4 Classroom Research Options

EPO will offer two classroom research options:

4.4.1 Basic Option (week-long experience)

- Web-based
- Designed for secondary education (middle and high school)
- Co-hosted by Zooniverse, leveraging their framework
- Compliant with Next-Generation Science Standards (NGSS)
- Supports the Federal STEM 5-Year Strategic Plan
- Includes LSST scientist telecons or live interaction (when feasible)
- Full set of modifiable activity templates
- Supports Broader Impacts
- Minimal teacher commitment required

4.4.2 Advanced Option (semester-long experience)

- Science Notebook-based (such as Jupyter)
- Designed for higher education (introductory general-education and STEM undergraduate majors)
- Leverages LSST partner institutions
- Supports Broader Impacts
- Significant teacher commitment with provided professional development support

4.5 Multimedia

Meeting the needs of the informal science education community is difficult due to a number of

reasons, including: a general lack of standardization across planetarium software platforms, unique floorplans and space constraints, varying levels of technical skills and staffing, differing hardware such as wall displays, touch tables, kiosks, interactive exhibits, etc. Accordingly, EPO will concentrate on developing a library of digital multimedia assets since that deliverable reaches the maximum number of centers with the lowest barrier for adoption. By providing a variety of video clips, images, and 3D models, content creators at these institutions will be able to freely incorporate them as they deem best.

4.6 Infrastructure and Data Access Services

LSST EPO will build its own cloud-based EPO Center (EPOC) to enable and support the data-dependent EPO deliverables described in this document. The EPOC will host a public subset of the full LSST dataset as described in LSE-89, LSE-131, and LPM-181. Data products are listed below:

4.6.1 Nightly alerts from DM -> EPO

DM will supply a custom VOEvent Broker for EPO that winnows the full alert stream and outputs a 10% subset in XML format. EPO will use a cloud subscriber to consume that feed, process the alert data into smaller categories, and then publish a subsequent cloud-based feed for use by the Transient Events mobile application, EPO Portal, Informal Science Centers, and the public.

4.6.2 Nightly calibrated exposures from DM -> EPO

LSST's data has been referred to as 'the world's first motion picture of our universe' and dubbed 'the greatest movie ever made'. Nightly calibrated exposures will be combined in a format that supports animated playback on the EPO Portal's Object Pages.

4.6.3 Annual catalog data from DM -> EPO

LSST is projected to catalog 37 billion objects during its 10-year survey. A subset of that catalog data will be transferred to the EPO Center on an annual basis for use by the EPO Portal's Object Pages and Classroom Research via science notebook analysis.

4.6.4 Annual color (RGB) co-add images from DM -> EPO

DM will provide an annual set of color (RGB) co-add images for use by the EPO Portal's tile-based Sky Viewer and Object Pages.

4.6.5 On-demand Level 3 community data from EPO -> DM

Community data results from citizen science projects will be made accessible to DM for possible curation and inclusion.

5 EPO Evaluation

The evaluation plan for EPO is currently in-work by the EPO Evaluation Specialist and has not yet been finalized. Here we describe our current vision of the evaluation plan for construction and operations.

5.1 Construction Evaluation Plan

The scope of the evaluation plan during *construction* is to provide formative feedback on learning experiences and assessment tools to be used during operations. In addition, a User Experience (UX) assessment by an external firm will provide additional guidance. Periodic iterations of the EPO Portal design and EPO learning experiences will take place during years 4-8 of construction, providing many opportunities to measure participant improvement. Periodic workshops hosted by the EPO Evaluation Specialist for interaction among developers and focus groups are designed to provide regular feedback on project design and usability.

Since we will measure changes in knowledge and attitude of participants during operations, we must build assessment tools into the interfaces that reliably provide the required baseline information. These assessment tools will be prototyped and refined during construction, then used with early beta testers to establish baseline metrics.

5.2 Participant Outcomes during Operations

Individuals who participate in LSST EPO programs will demonstrate behavioral outcomes measured as changes in awareness, engagement, appreciation, skills, or knowledge. Each learning experience deployed during Operations will evaluate learner outcomes appropriate for that specific activity and scientific context.

5.2.1 General Public

Multiple levels of engagement are available to the General Public through the EPO Portal and Transient Events mobile application ranging from browsing the Full-Sky Viewer, visiting Object Pages for detailed metadata, and subscribing to alerts. Some users will move to LSST citizen science project, EPO classroom research projects, or engage in forum discussions via Zooniverse Talk.

Table 5-1: Levels of Engagement for the General Public

General Public (GP)		
Impact Category	**Anticipated Outcome**	**Evidence / Possible Measures Demonstrating Achievement of Objective**
Awareness	a. Search Engine Optimization (SEO) allows interested users to discover the EPO Portal and browse content b. Spanish-version encourages diversity c. External groups and social media increase awareness by referencing object page data (such as postage stamp cutouts, animated images, and catalog information)	a. Website traffic analytics b. Website geographic analytics c. Website referral analytics
Engagement	a. Mobile application engages users where they are b. Alert stream subscription provides near real-time feedback	a. Focus groups and app store download counts / comments b. Cloud-based EPO alert stream API usage analytics
Knowledge, Skill	a. Contextual links to Zooniverse Talk and associated forum discussion promotes perception of LSST as a human endeavor involving people like themselves b. Alert stream overlay, dynamic counters, and animated images demonstrate the universe is a dynamic place	a. Zooniverse Talk traffic analytics and analysis of Zooniverse Talk discussions for keywords or phrases that provide desired information b. Focus groups and surveys

5.2.2 Citizen Scientists

Multiple levels of engagement are provided with LSST citizen science projects. Some users will participate in existing projects and perform only the basic classification task, while others will engage more deeply in conversations on Zooniverse Talk. The most advanced will develop research interests and use the Zooniverse Project Builder tool to create their own projects.

Table 5-2: Levels of Engagement for Citizen Scientists

Citizen Science (CS)		
Impact Category	**Anticipated Outcome**	**Evidence / Possible Measures Demonstrating Achievement of Objective**
Awareness	a. Users join an LSST citizen science project and contribute clicks to characterize or classify	a. Zooniverse project traffic analytics
Engagement	a. Citizen scientists communicate and collaborate with other participants via Zooniverse Talk b. Citizen scientists demonstrate attitudes of self-efficacy, seeing themselves as scientists and knowing that science is a human endeavor c. Optional training tutorials are utilized by participants	a. Zooniverse Talk analytics b. Analysis of Zooniverse Talk discussions for keywords or phrases that provide desired information c. Zooniverse project web analytics
Knowledge, Skill	a. Dialogue sophistication increases b. Characterization or classification accuracy improves over time c. Citizen scientists contribute meaningful data to scientific research	a. Analysis of Zooniverse Talk discussions for keywords or phrases that provide desired information b. Analysis of Zooniverse results c. DM Level 3 integration and scientific papers that make use of LSST citizen science data sets

5.2.3 Classroom Research

Multiple levels of engagement are available through EPO classroom research projects. Educators can choose either a basic week-long research experience or an advanced semester-long program that includes professional development and Broader Impacts opportunities.

Table 5-3: Levels of Engagement for Classroom Research

Classroom Research (CR)		
Impact Category	**Anticipated Outcome**	**Evidence / Possible Measures Demonstrating Achievement of Objective**
Awareness	a. Educators become aware of the Classroom Research program through the EPO Portal, events, conferences, partnerships, word of mouth, etc.	a. Participant surveys
Engagement	a. Students in the week-long Zooniverse-hosted classroom experience continue with independent/extracurricular research b. Educators who started with the basic week-long option later elect to participate in the advanced semester-long option c. LSST partner institutions incorporate the EPO advanced option in their Broader Impacts proposals d. LSST scientists engage with the educators and students	a. Zooniverse analytics b. Participant surveys c. NSF analytics and participant surveys d. Count of telecons or live visits
Knowledge, Skill	a. Educators gain knowledge and confidence via the EPO professional development program b. Zooniverse users will demonstrate improved skills when analyzing data c. Advanced users will demonstrate knowledge of science notebook technology and the ability to query/analyze large data sets d. Students will demonstrate increased knowledge of STEM content aligned with Big Understandings of LSST science topics (see Appendix)	a. Participant surveys *b. See Citizen Scientists section above* c. Focus groups and professional development educator feedback d. Pre/Post tests and educator feedback

5.2.4 Content Creators for ISE

LSST EPO provides multimedia assets and near real-time feeds for Informal Science Education (ISE) Content Creators to include in their products and programs.

Table 5-4: Levels of Engagement for ISE Content Creators

Content Creators for ISE		
Impact Category	**Anticipated Outcome**	**Evidence / Possible Measures Demonstrating Achievement of Objective**
Awareness	a. Content Creators download LSST EPO multimedia assets b. Content Creators subscribe to near real-time feeds of the alert stream and telescope status c. Vendors use LSST data in software d. Social media sharing and promotion of LSST	a. Download counts b. Web traffic analytics c. Contact with vendors d. Google Trends analysis and social media monitoring
Engagement	a. Multimedia and feed utilization will increase over time	a. Same metrics as above, analyzed over time
Knowledge, Skill	a. Planetarium/science center visitors will increase their knowledge of Big Understandings of LSST science topics (see Appendix)	a. Focus groups and ISE staff feedback

6 EPO Support

EPO will offer three levels of support: *Tier 1* for general inquiries / entry-level triage, *Tier 2* for escalation to subject matter experts, and *Tier 3* for escalation to upper management. Support responsibilities will be distributed across the EPO staff:

Tier 1:

- Tier 1 Support Representative

Tier 2:

Head of Education and Public Outreach (internal LSST inquiries)

- Communications & Outreach Manager (inquiries from ISE/planetariums, the media/press, and strategic/institutional partners)
- Chile EPO Coordinator (Spanish-language inquiries)
- Cloud Systems Administrator (infrastructure inquiries or US DAC/DM interface troubleshooting)
- Web/Mobile Developer (EPO Portal inquiries)
- Zooniverse Framework Developer (citizen science inquiries and LSST-Zooniverse integration troubleshooting)
- EPO Scientist (science inquiries)
- Education Specialist (education inquiries)
- Education Technology Specialist (support for any implementation issues encountered during professional development workshops, classroom setup, and public use)

Tier 3:

Head of Education and Public Outreach

7 Appendices

7.1 EPO Science Topics

The following science topics align with LSST's capabilities and science objectives and EPO deliverables should target them in particular:

- **Dark Energy**
- **Dark Matter**
- **Transients & Variable Objects** (NEOs, supernovae)
- **Galactic Evolution** (N-body simulation, Low Surface Brightness [LSB])
- **Exoplanets**

7.2 Big Understandings of LSST Science

The following concepts are key benchmarks for evaluating proper understanding of LSST science topics:

- **Dark Energy & Dark Matter:** About 95% of the Universe is dark and has remained unobservable to us – we know about it through its gravitational effect on visible matter.
- **Mapping the Solar System:** [a] The outer Solar System is a debris-field of icy bodies that never coalesced to form planets. [b] Some asteroids cross the path of Earth's orbit and have the potential to collide with our planet.
- **Mapping the Milky Way:** Our Milky Way galaxy formed by merging and colliding with its celestial neighbors over billions of years.
- **Transient Universe:** From the Earth out to the farthest reaches of the Cosmos, the Universe is a dynamic and changing place on many timescales.
- **Science Discovery:** By looking for patterns and correlation in massive datasets like the LSST survey, we find answers to questions, some of which we never thought to ask.

7.3 Outreach Advisory Board

Historically, the EPO Outreach Advisory Board (OAB) served as both a working group and advisory board. The group met face to face annually, typically at an AAS or LSST All Hands Meeting. Telecons were scheduled monthly, with additional meetings on an as-needed basis. An LSST-supported mailing list was also available for OAB communication.

During 2016, the OAB was put on hiatus pending EPO management restructuring. Moving further

into Construction, the OAB may be reinstated and become a more formal, external advisory organization.

Former Members	Affiliation
Tim Axelrod	UA Department of Astronomy and Steward Observatory
Kirk Borne	George Mason University
Gina Brissenden	UA Center for Astronomy Education
Carol Christian	Space Telescope Science Institute
Arne Henden	AAVSO
Chris Lintott	Zooniverse, Oxford University
Steve Pompea	NOAO
Ed Prather	UA Center for Astronomy Education
Martin Ratcliffe	Sky-Skan, Inc.
Tim Spuck	Oil City High School / AUI
Gordon Squires	IPAC
Mark Subbarao	Adler Planetarium
Julia Olsen	UA College of Education
Susan Schultz	Stanford Center for Assessment, Learning and Equity
Karen Carney	Associate VP for Visitor Experience and Learning, Adler
Jordan Raddick	Education Director, Sloan Digital Sky Survey
Scott Bronson	Brookhaven National Laboratory Education

Figure 6-1: LSST EPO Outreach Advisory Board (OAB) former membership

7.4 Operational Readiness

There are three major phases of EPO:

1. Private Beta (Construction): using precursor astronomy data sets similar to LSST
2. Public Beta (Commissioning): using ComCam data and precursor data for the alert stream
3. General Availability (Operations): using LSST alert stream and production camera data

The full set of tasks for the Commissioning phase are defined in the LSST Commissioning Plan (LSE-79), but here are some EPO highlights for reference:

1. Test loading nightly calibrated exposures from DM, converting them to RGB animated images, and storing them in the EPO Center for web display
2. Test loading the public subset of annual catalog data into the EPO Center database
3. Test loading the RGB co-adds from DM into the EPO Center storage for web display
4. Test running science notebook queries against the EPO Center database
5. Test EPO portal at full load using simulated users
6. Validate key use cases using small groups of actual users:
   - Usability testing of Graphical User Interfaces
   - Citizen Science, using prototype projects
   - Classroom Research (both Basic and Advanced options)
   - Science Museums, such as Adler Planetarium and Flandrau Planetarium
   - Zooniverse Talk integration, including inter-user communication capability
   - Science Notebook integration, including shared workspace capability
7. Performance monitoring of EPOC and EPO Portal
8. Test ISE multimedia assets on both flat screens and fulldome screens
9. Test 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 Operational Readiness Review (ORR) which will occur at the end of the Commissioning phase and will signal the formal end of Construction for EPO.