U.S. DEPARTMENT OF ENERGY | Office of Science

Acquisition Strategy (CD-2 Update) for the Large Synoptic Survey Telescope Camera (LSSTCAM)

Project ID: SC-25-11-LSST (MIE 11 WB)

at

SLAC National Accelerator Laboratory

Office of High Energy Physics
Office of Science
U.S. Department of Energy

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Acquisition Strategy for the
Large Synoptic Survey Telescope Camera (LSSTCAM) Project at the
SLAC National Accelerator Laboratory

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Change Log

Revision History		
Rev.	**Date**	**Reason**
R0	7/05/2011	Draft for review.
R1	12/14/2011	Initial version for SC-2 approval.
R2	2/07/2012	Incorporate SC-2 comments.
R3	4/11/2012	CD-1 approval; increase upper cost range (per HEP guidance).
R4	02/08/2014	Updated funding profile (per HEP guidance), cost, and milestones for consistency with the revised PPEP for CD-3A.
R5	11/25/2014	CD-2 Performance Baseline – updated milestones, funding profile (per HEP guidance), cost, and KPPs.

Acronym List

AE	Acquisition Executive
AURA	Association of Universities for Research in Astronomy
BCCB	Baseline Change Control Board
BNL	Brookhaven National Laboratory
CD	Critical Decision
FNAL	Fermi National Accelerator Laboratory
FPD	Federal Project Director
HEP	DOE Office of High Energy Physics
HQ	Headquarters
IN2P3	Institute National de Physique Nucleaire and de Physique des Particules
KPP	Key Performance Parameter
LLNL	Lawrence Livermore National Laboratory
LSST	Large Synoptic Survey Telescope project (NSF funded)
LSSTCAM	LSST Camera Project (DOE funded)
LSSTC	LSST Corporation
M&O	Managing and Operating
MIE	Major Item of Equipment
MNS	Mission Need Statement (CD-0 prerequisite)
MOU	Memorandum of Understanding
MPO	Memorandum of Purchase Order
NEPA	National Environmental Policy Act
NSF	National Science Foundation
OPC	Other Project Cost
PB	Performance Baseline
PEP	Project Execution Plan
SC	Office of Science
SC-2	Deputy Director for Science Programs, Office of Science
SLAC	SLAC National Accelerator Laboratory
SSO	DOE SLAC Site Office
TEC	Total Estimated Cost
TPC	Total Project Cost

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1. JUSTIFICATION OF MISSION NEED

As detailed in the approved Mission Need Statement, this project is for the support of a new, next generation, state-of-the-art ground-based dark energy experiment. This initiative for the Department of Energy (DOE) High Energy Physics (HEP) program is to determine the nature of dark energy, which is causing the acceleration of the expansion of the universe.

The HEP mission is to understand how our universe works at its most fundamental level. This is achieved by our program goal of exploring the fundamental interactions of energy, matter, time and space in order to understand the unification of fundamental particles and forces, and the mysterious forms of unseen energy and matter that dominate the universe; search for possible new dimensions of space; and investigate the nature of time itself.

In 1998, observations of Type 1a supernovae indicated that the expansion of the universe is accelerating. If the universe is permeated by an energy field with negative pressure, Einstein's theory of general relativity can be made consistent with an accelerating expansion. This putative new energy field has been dubbed "dark energy". In the intervening years, a wealth of diverse cosmological data has been shown to be consistent with what is now the standard model of cosmology, where dark energy currently accounts for 73% of the total mass-energy of the universe.

To date, there are no compelling theoretical explanations for the origin of the dark energy, so future progress will be driven by increasingly more precise observational measurements. Experiments to study the nature of dark energy offer new insights and a deeper understanding of fundamental physics and the makeup and ultimate fate of the universe.

The Large Synoptic Survey Telescope (LSST) will generate the necessary data to enable the key "Mission-Level Assumptions" as envisioned in the Mission Need Statement (MNS), including developing strong constraints on models of dark matter and dark energy through statistical studies of the shapes and distributions of faint galaxies at moderate to high red-shift, and the detections of large numbers of Type Ia supernovae. The SLAC LSST Camera (LSSTCAM) will become part of a unique wide-field ground-based telescope that will provide time-lapse digital imaging of faint astronomical objects across the entire visible sky every few nights for 10 years.

2. PROJECT DESCRIPTION AND PERFORMANCE PARAMETERS TO OBTAIN EXPECTED OUTCOME

The construction and operation of the LSST is a joint initiative of the National Science Foundation (NSF), DOE HEP, and the privately-funded Corporation (LSSTC), a non-profit entity located in Tucson, AZ. The NSF is the lead agency and will be responsible for the telescope, facility and data management system. DOE is responsible for the optical camera, with associated instrumentation, for the LSST Facility, which will be sited atop the El Penon peak in Chile. The NSF has named the Association of Universities for Research in Astronomy (AURA) as the lead contractor for its areas of responsibility (LSST).

HEP has named SLAC National Accelerator Laboratory (SLAC) as the lead contractor to host the HEP LSST Camera Project Office (LSSTCAM). All current DOE funded LSST R&D efforts and proposed future fabrication and operations efforts, as well as related "off-project" efforts required for the success of the LSST experiment, will be coordinated and managed by LSSTCAM. Major collaborators include the Brookhaven National Laboratory (BNL), the Lawrence Livermore

National Laboratory (LLNL), Fermi National Accelerator Laboratory (FNAL), a consortium of U.S. based Institutions, and the Institute National de Physique Nucleaire and de Physique des Particules (IN2P3- several members of national science laboratories in France).

DOE has determined that SLAC will manage the acquisition of the LSSTCAM under the existing DOE M&O contract (DE-AC02-76SF00515). DOE Office of High Energy Physics is funding the LSSTCAM design and fabrication as a Major Item and Equipment (MIE) project.

The LSSTCAM will design, fabricate, and lab-test an integrated camera system prior to delivery for installation onto the LSST telescope in Chile. The camera as an integrated functional system will be assembled and completed at SLAC prior to CD-4, Approve Project Completion. The LSSTCAM is the HEP contribution to the LSST, the schedule of which is not under the direct control of HEP or LSSTCAM. Therefore, the shipment of the camera to Chile and final installation on the telescope are placed outside of the project scope to be supported by HEP program funds. Key Performance Parameters (KPPs) have been identified as LSSTCAM deliverables in table 1.

Table 1 – Threshold and Objective KPPs

Description of Scope	Threshold KPP	Objective KPP
Field of view coverage (square degrees)	9.3	9.6
Pixel size	0.2 arcsec	0.2 arcsec
Number of pixels	2.6 Gigapixels	3.2 Gigapixels
Array readout time	3 seconds	2 seconds
Sensitivity range	320-1050 nm	320-1050 nm
Shutter minimum exposure time	2 seconds	1 second
Readout electronic noise, single exposure	13 electrons	9 electrons

The achievement of the Threshold KPPs will be a prerequisite for approval of CD-4, Project Completion. Achievement of these parameters will be verified as part of the integration and testing phase at SLAC. In order to achieve the LSST overarching science requirements, as part of the baseline scope, the LSSTCAM Project will deliver a 3.2 Gigapixels capable camera and major subsystems including an array of Charge Coupled Device (CCD) science sensors, guide sensors and wave front sensors, refractive optics, optical filters and filter exchange system, shutter system, utility trunk, cryostat with cryogenic system, control system and DAQ, and camera ground support equipment.

The base facility for LSST operations will be located in La Serena, in Chile, within the AURA owned and operated compound. The archive data center will be based at National Center for Supercomputing Applications (NCSA) in Illinois.

3. ALTERNATIVES ANALYSIS

As part of the CD-1 process, the following alternatives were analyzed to ensure the proposed strategy is the most cost-effective method of meeting the HEP mission goals. The advantages and disadvantages for each of these three alternatives were considered and are described below. The cost estimates referenced below are the current DOE (CD-2) and NSF estimates, which have been updated since CD-1.

Alternative 1: Build a new camera for the LSST as a cooperative interagency project with NSF, in accordance with the highest priority ground-based project recommendation of the 2010 National Research Council (NRC) decadal survey; New Worlds, New Horizons in Astronomy and Astrophysics (Astro2010). This alternative would meet the needs of improving our understanding of dark energy using all four methods identified by the Dark Energy Task Force (DETF), with a combined level of precision appropriate to a "Stage IV experiment", as they have defined that term. NSF would serve as the lead agency and would take responsibility for the provision of the telescope and data system. The two agencies would work together in operating this joint facility. The LSST would also enable a wealth of other science investigations of interest to the larger astronomical community. The total cost of the NSF LSST project is expected to be ~ \$473M for construction and fabrication of the LSST facility. The total cost for the DOE MIE LSSTCAM Project, the HEP contribution, is expected to be \$168M for design, construction and fabrication. The total cost to operate the observatory is ~\$37.7M per year in FY14 dollars for the ten years of operation including the DOE contribution of \$9M per year in FY14 dollars. At this early stage, the dismantlement cost for the camera is roughly estimated to be \$8M or about 10% of the camera fabrication/assembly cost (direct Total Estimated Cost, TEC, less design cost). It is assumed that a reasonable portion of the camera dismantlement cost will be recovered by the component salvage value.

Alternative 2: Develop new instrumentation for an existing ground-based telescope in cooperation with NSF, as a "mid-scale instrumentation initiative", in accordance with the second priority recommendation of Astro2010. The success of this alternative in meeting the need of addressing our understanding of dark energy would require that the instrumentation selected under this new initiative be appropriate for dark energy investigations. The total cost of this alternative is in the range \$30-50M for fabrication of the instrument and ~\$5M/yr of operating costs for five years of operation. At this early stage, the instrument dismantlement cost is roughly estimated to be about 10% of the camera fabrication/assembly cost (direct TEC less design cost). It is assumed that a reasonable portion of the instrument dismantlement cost will be recovered by the component salvage value.

Alternative 3: Collaborate with NSF on both of the alternatives identified above: The construction and fabrication of LSST and the development of new instrumentation for an existing telescope. If this alternative is invoked, the new instrument for an existing facility would have capabilities complementary to those of LSST. This alternative would provide the greatest advance in our understanding of dark energy, but would involve the highest cost to both agencies. The total cost would be the sum of the costs identified for Alternatives 1 and 2 above. At this early stage, the dismantlement cost is roughly estimated to be the sum of that quoted for alternative 1 plus 2. It is assumed that a reasonable portion of the camera dismantlement cost will be recovered by the component salvage value.

Alternative 4: Do nothing. In this case, the need of advancing our understanding of dark energy would remain unaddressed, or NSF could undertake this study without DOE participation. The capabilities and mission critical components that have already been developed at DOE laboratories and DOE-funded institutions would then go unutilized, essentially wasting that investment of resources. In addition, the unique approach and intellectual capabilities that the high energy physics community brings to the study of dark energy would not be realized.

The decommissioning cost for Alternatives 1 through 3 is estimated to be less than $1M. This would include camera removal from the observatory structure, shipment preparations and delivery back to SLAC.

4. RECOMMENDED ALTERNATIVE

The recommendation is to select Alternative 1, build a new camera for the LSST within a cooperative interagency project with NSF, as the preferred path to be pursued to meet the mission need in a timely and cost-effective manner. Alternative 1 was the top recommendation of Astro2010 and strongly supports the HEP programmatic goals for the study of dark energy science. NSF is planning to support this alternative and has requested that HEP supply the camera in a collaborate effort.

NSF has reviewed its portfolio of telescopes and is not prepared to agree to host Alternative 2 a mid-scale project at this time.

The stage III dark energy project and experiment DECam, is nearing completion and is entering its operational phase. It is important to begin the next, stage IV, instrument construction so that any science discovery made during the operation of DECam can be further advanced with a more powerful instrument.

Based on these considerations, the programmatic goals for HEP and the projected funding availability, Alternative 1 was chosen.

5. TOTAL PROJECT COST

The Total Project Cost (TPC) range is $120M to $175M. The Performance Baseline (PB) establishes the TPC at $168M. TPC includes a Total Estimated Cost (TEC) of $150.3M and Other Project Cost (OPC) of $17.7M. This includes the contingency of $33.4M.

The cost baseline information is presented below in Table 2.

Table 2—Cost Baseline

WBS[1] Title	Cost ($M)
3.01 Management	9.6
3.02 Systems Integration	6.4
3.03 Science Sensors	25.6
3.04 Science & Corner Raft Systems	15.3
3.05 Optics	24.8
3.06 Camera Body, Mechanisms, Cryostat	14.1
3.07 Control System, Data Acquisition, Aux Electronics	10.0
3.08 Integration and Test	11.6
TEC	117.4
TEC Contingency	32.9
TEC Total	**150.3**
OPC	17.2
OPC Contingency	0.5
OPC Total	**17.7**
TPC Total	**168.0**

1) *LSSTCam is @ WBS level 3.0 of the LSST Project.*

6. FUNDING PROFILE

The table below shows the approved funding profile that supports the PB. This profile reflects the DOE contribution to Alternative 1.

Table 3—Funding Profile

Fiscal Year	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	Total (M)
OPC	1.9	5.5	8.0	2.3					17.7
TEC				19.7	35.0	40.8	45.0	9.8	150.3
TPC	1.9	5.5	8.0	22.0	35.0	40.8	45.0	9.8	168.0

7. KEY MILESTONES AND EVENTS

The project received CD-3A approval on June 5, 2014 for the long-lead procurements of the camera sensors. The project is authorized to initiate the long-lead procurement of production sensors, for an amount not to exceed $13M, prior to the approval of CD-3. The sensors are on the critical path and expected to require the longest time to complete.

Schedule for the DOE milestones related to various phases of the project are shown below.

Table 4 Key Milestones and Events

Key Milestones	Schedule
CD-0, Approve Mission Need	*6/20/2011 (actual)*
CD-1, Approve Alternative Selection and Cost Range	*4/11/2012 (actual)*
CD-3A, Approve Start of Long Lead Procurements	*6/5/2014 (Actual)*
CD-2, Approve Performance Baseline	*2015 January*
CD-3, Approve Start of Construction	*2016 January*
CD-4, Approve Project Completion	*2022 March*

As described in section 2, the DOE *camera project* will be completed at SLAC prior to CD-4 schedule of March 2022. The schedule includes 23 months of float to CD-4 (project completion).

8. TAILORING STRATEGY

To minimize risk, optimize processes, and gain efficiency, tailoring principles are being applied. As a major risk mitigation strategy, the project has requested and secured approval for long lead procurement funding in June of 2014.

9. BUSINESS AND ACQUISITION APPROACH

DOE has determined that SLAC will manage the acquisition of the LSSTCAM under the existing DOE M&O contract (DE-AC02-76SF00515). The engineering and design for the technical equipment will be performed by SLAC and collaborating DOE institutions, based on specific areas of expertise at each Laboratory. The collaboration consists of Lawrence Livermore National Laboratory (LLNL), Brookhaven National Laboratory (BNL) and several DOE supported institutions. Prior to the 'construction' phase of the project, detailed procurement plans will be prepared at respective laboratories to identify the best acquisition approach, timelines, and required resource support. Procurement strategies will be chosen to obtain the best value based on the assessment of technical and cost risks on a case-by-case basis.

Overall, the acquisition of the LSSTCAM will be based on the following strategy:

- SLAC leads the collaboration with BNL and LLNL. Each National Lab is responsible for a specific scope of work, including the related procurements, as described in the respective Memorandum of Understandings (MOU) and Statement of Work. In summary, LLNL is contributing to project management and is responsible for management of Camera systems integration; design, acceptance test, and delivery of the optics; and management of the corner rafts. BNL is accountable for design, acceptance test, and delivery of sensors and science rafts.

- SLAC is responsible for the design and acquisition of camera body and mechanisms, cryostat subsystems, data acquisition, auxiliary electronics and camera controls (hardware and software); acquisition of sensors; design, fabrication and acceptance test of the corner rafts; Camera assembly and test (at SLAC); and the overall project management. In addition to work performed by other DOE national labs, a combination of institutional subcontracts and direct fixed price purchases with vendors are anticipated.
- Each collaborating laboratory will follow its approved procurement systems and processes using competitive practices to the maximum practical extent. Prior to the construction phase of the project, Advance Procurement Plans will be prepared to identify the best acquisition approach for procurements.
- During the R&D timeframe in 2009, under an approved MOU between Le Centre National de la Recherché Scientifique /Institute National de Physique Nucléaire and de Physique des Particules (CNRS/IN2P3) and LSST Corporation (LSSTC), CNRS/IN2P3 agreed to participate in the LSST project as a contributor to the camera subsystem. After CD-0, during the conceptual design phase, SLAC and IN2P3 revisited that agreement resulting in a draft MOU between the two organizations. By mid-2014 timeframe, SLAC and CNRS/IN2P3 updated the agreement in a Memorandum of Agreement (MOA) to fully capture the roles and responsibilities and schedule of deliverables for the remainder phases of the project. The MOA between SLAC and CNRS/IN2P3 was finalized in November 2014 in time for incorporation in the LSSTCAM Project Performance Baseline. The CNRS/IN2P3 effort is at no cost to the project and is incorporated in the integrated project schedule. The LSSTCAM project maintains adequate contingency to modify or take over the effort, should it become necessary.

10. MANAGEMENT STRUCTURE AND APPROACH

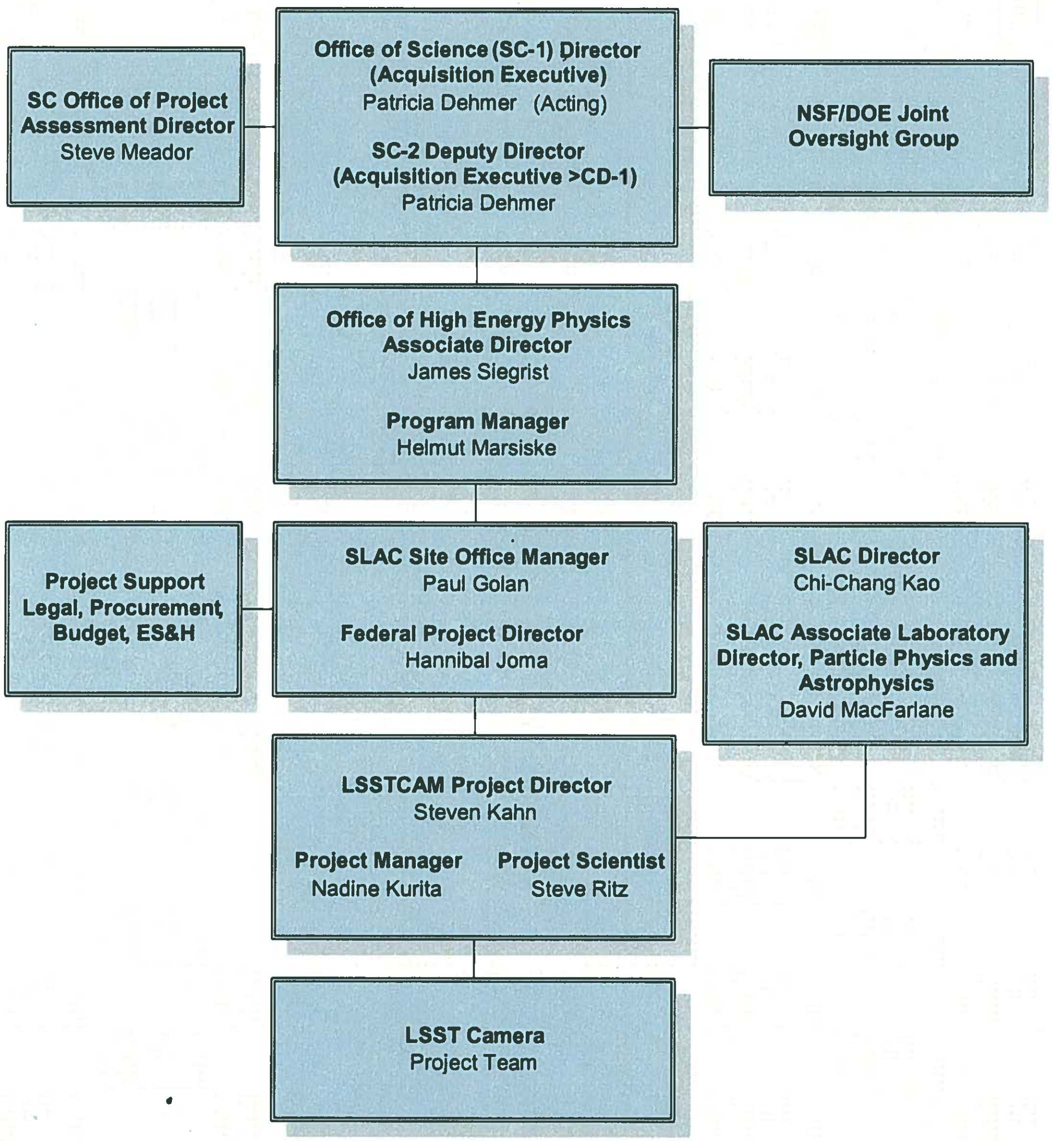
The Director of the Office of Science (SC-1) approves the CD-0 and CD-1 for the LSSTCAM project. The Deputy Director of Science Programs within the Office of Science (SC-2) serves as the Acquisition Executive (AE) for this project after CD-1 is approved. SC-2 approves the critical decisions post CD-1 as well as the Acquisition Strategy and Project Execution Plan.

The planned management structure for the LSSTCAM Project is summarized in Figure 1. The primary function of the Integrated Project Team (IPT) is to provide support to the Federal Project Director (FPD) in management of the LSSTCAM Project. The IPT is organized and led by the FPD, and consists of members from both DOE and SLAC lab and site offices. The FPD works closely with the HEP program manager to ensure that the project execution is consistent with program goals and objectives and to ensure the Acquisition Executive and appropriate DOE stakeholders are apprised of the project status. This is accomplished through routine conference calls, site visits, reviews, and other formal and informal communications.

The IPT is established and the membership will change as the project progresses from initiation to closeout to ensure the necessary skills are represented to meet the project's needs. The membership, roles and responsibilities are defined in the IPT Charter.

The PEP describes the approved PB and deliverables and is the primary management tool for the FPD in executing the project. Required changes to cost, scope, or schedule, during execution of the project will be controlled according to the thresholds and processes described in the PEP.

Figure 1—LSSTCAM Organization Structure



11. RISK ANALYSIS

The LSSTCAM Risk Management Plan, (LCA-29) describes the continuous risk management (CRM) process implemented by the project. CRM is a disciplined approach to managing project risks throughout the life cycle of the project. This plan is consistent with DOE O413.3B, "Project Management for the Acquisition of Capital Assets," and strives to incorporate "best practices" from other large-scale, first-of-a-kind science projects. The plan establishes the methods of assessing Camera project risk down to the subsystem level. Project risk is managed throughout the life of the project, from development through construction and early commissioning phases.

The primary goals to implement this system are to manage the risks associated with the development and construction of the Camera. Project risks are centrally managed, but are the result of project-wide risk assessment. The project-wide risk assessment supports management decision-making by providing integrated and quantitative assessments of risk. Current and comprehensive risk updates provide management with additional information in preparing for and reacting to contingent events and adverse outcomes to planned events. The process also provides a uniform language for tracking risk elements and communicating that information. A Risk Registry (LCA-30) documents the risk assessment, mitigation strategy, and the residual risk after mitigation. This database includes information about all identified risks within the project. The registry has incorporated lessons learned in several recent projects.

As DOE funds the LSSTCAM as a specific deliverable, there are no 'budget' related interdependencies between LSST and LSSTCAM. Furthermore, the NSF and DOE 'critical decisions' are closely coordinated between the agencies such that impacts of potential budget shortfalls and rescissions will be managed accordingly at the agency level. All identified risks and related contingencies have been captured in the respective DOE/NSF budgets and tracked in risk registries.