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National Science Foundation Division of Astronomical Sciences and Department of Energy Office of High Energy Physics

Report on the Joint Review of the

**Large Synoptic Survey Telescope (LSST) Project Status and Commissioning Plan**

*With the Project Response*

**Tucson, AZ**

**July 30 – August 3, 2018**

**2 Oct 2018**

*28 March 2019*

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# EXECUTIVE SUMMARY

A joint NSF and DOE review of the Large Synoptic Survey Telescope (LSST) Project Status and Commissioning Plan was held on July 30−Aug. 3, 2018 at the Marriott University Park Hotel, near the LSST headquarters on the University of Arizona campus in Tucson, AZ, using an independent review committee of 20 members. This was the second review of the LSST Commissioning Plan. The purpose of this dual review was to evaluate the progress to-date on the LSST construction and plans for transition from construction to commissioning and science operations in October 2022.

LSST is an integrated survey system designed to conduct a decade-long, deep, wide, fast time-domain survey of the optical sky. It consists of an 8-meter class wide-field ground-based telescope, a 3.2 Gpix camera, and an automated data processing system. The Project team is knowledgeable and experienced and is to be commended for guiding the Project to its present advanced state.

Telescope and Site Construction: The construction of LSST is progressing at an impressive and accelerating rate. The coming year will have a number of exciting milestones as the site facilities are finished, the telescope is assembled and tested at the vendor location, and other major subsystem contracts are completed. The Review Committee was impressed by the progress but is concerned, given recent schedule slips, that the current level of contingency is tight. The Project Management team must be careful to manage risk, budget, and schedule to prevent further slips.

Data Management: The LSST Data Management (DM) system is a major component of the LSST Observatory and is critical to accomplishing the science mission. The Project is on schedule to deliver the DM software and infrastructure on time, and significant progress has been made since the last review on organizing and staffing the DM team. The Science Platform is now in testing with community stakeholders. The workflow and middleware recommendations from the previous review have been addressed.

Camera: The LSST Camera construction at SLAC is nearing completion on schedule. The detector procurement is nearly complete. The review panel noted that roughly 50% of the ITL detectors have some amplifiers with elevated noise when used in the readout configuration planned for operations. The Camera team has studied the problem thoroughly, arranged the detectors to minimize impact, and estimated the relatively minor potential impact on the LSST science mission. In most filter bands, the added noise will be insignificant, and, if necessary, the readout time can be increased for some observations to mitigate the problem. The Camera team also reported delays with the refrigeration and vacuum systems and described credible plans to deal with these problems.

Systems Engineering: The Project has adopted a rigorous and thorough Systems Engineering approach. The SE team has developed excellent integrated verification and testing tools.

Environment, Safety, & Health: The committee was impressed by the level of communication and creation of a culture of safety that pervades the Project and subsystem teams. Accident rates at LSST sites are much lower than average, especially for construction projects.

EPO: The LSST has a dynamic and goal-oriented Education and Public Outreach program designed to reach high-school students and adults. The EPO team is on track to complete the scheduled work during the construction phase of the Project. The committee suggested adding materials for younger learners, since they are often developing attitudes in elementary and middle school that impact career path decisions later in life.

Cost and Management: The Telescope and Site construction project is currently on the critical path, and the Review Committee paid close attention to the contingency planning, risk management, and descope options for these systems. The Camera subsystem is only a few days off the critical path. The Camera development is nearly complete, so there are no remaining descope options on the Camera. The Project has 8.5 months of schedule contingency remaining after a recent slip of 2.5 months. Cost contingency is low for this stage of the project and descope options need to be updated and carefully considered.

Commissioning Plan: The Committee was very impressed by the thorough and detailed Commissioning Plan developed over the last year since the first review in 2017. The current plan for the combined DOE and NSF commissioning effort contains a detailed work breakdown, personnel assignments, Basis of Estimate cost estimates, risk management, and sufficient cost and schedule contingency. The DOE and NSF projects treat commissioning differently with regards to their budgets. To enable proper cost accounting, the WBS needs to be segregated at sufficiently low levels to clearly identify DOE and NSF efforts and procurements.

The first phase of Commissioning activities is already under way. The Pathfinder projects are progressing rapidly and will be used to reduce risk during LSST integration and testing. The Commissioning Team will be involved with Systems Engineering during the subsystem acceptance, testing, and integration. The DM system will be tested at all levels during commissioning, and the DM team is working closely with the Commissioning Team and those planning for transition to regular operations. The Committee strongly recommends that the current level of effort for safety be maintained through commissioning and during the transition to regular operations.

# INTRODUCTION

A joint NSF and DOE review of the Large Synoptic Survey Telescope (LSST) Project Status and Commissioning Plan was held on July 30-August 3, 2018 at the Marriott University Park Hotel, near the LSST headquarters on the University of Arizona campus in Tucson, AZ, using an independent review committee of 20 members. This was the second review of the LSST Commissioning Plan. The purpose of this dual review was to evaluate the progress to-date on the LSST construction and plans for transition from construction to commissioning and science operations in October 2022.

The LSST is a new large-aperture, wide-field, ground-based 8.4 m telescope facility under construction on Cerro Pachón, Chile. It will provide a time-domain imaging survey of the entire southern hemisphere sky in six optical bands. LSST will image the entire available sky every four days to address the following primary science missions: discover transient and varying objects; identify supernovae to determine the nature of dark energy; measure the weak lensing distortion of galaxy images to map dark matter; make a census of small bodies in the Solar System, particularly those that could impact earth; and thoroughly map the Milky Way and measure the motions of its stars.

The LSST staff will carry out operations of the telescope and camera system, and the data system that will process, archive and distribute the survey data, which includes transient event alerts (Level 1 data products) and annual catalog data releases (Level 2 data products). Survey deliverables will be provided to U.S., Chilean, and international contributor communities without a proprietary period. The science community will carry out planning and analysis activities independently of the LSST construction and facility operations and deliverables.

The National Science Foundation (NSF) Division of Astronomical Sciences and the Department of Energy’s High Energy Physics Division (HEP) jointly support the construction of the LSST and also partner in the commissioning and science operations phases. NSF is the lead federal agency, funding construction of the telescope, site facilities, and data management system. DOE is responsible for the 3.2-billion pixel camera, and construction is being managed by the SLAC National Accelerator Center. The first phase of commissioning activities have begun. The LSST facility starts its 10-year science survey operations at the beginning of FY 2023, with pre-operations activities starting in FY 2019.

Prior to the review, the LSST team provided extensive documentation on project status, a revised and updated Commissioning Plan, and other documents requested by the Committee members. Presentations describing the LSST status responding to the charge questions were made during the review. The charge letter, Review Committee members and assignments, panelist biographies, other attendees, and the agenda are included in Appendices A, B, and C. The management organization, acronym list and review materials are included in appendices D, E, and F. The following sections include the findings, comments and recommendations from the review committee for each of the areas defined in the charge.

*The following sections have been reduced to the specific recommendations and each has a Project response provided in Italic blue text.*

# COMMITTEE REPORT

## SC1 – Data Management (DM) System

**DATA MANAGEMENT SYSTEM RECOMMENDATIONS:**

1. Reassess within the next year the risks associated with relying on a non-path-redundant summit-to-base optical fiber network connection, based on recent project experience.

*Accept.*

*Based on the experience with the fiber this past period, the Project acknowledges that reassessment of the summit-to-base network risk is needed. This will be carried out before Feb 2019.*

*Update:*

*We examined all the posts in the fiber run and implemented the following improvements:*

* *A single contractor was engaged for repair, improvement, and maintenance of power and fiber posts*
* *Fiber was moved to separate posts (not on same posts as power lines) in the steepest parts of the path up to Cerro Pachón*
* *Wooden posts were replaced by concrete posts in areas where both fiber and power lines are on the same post such as in river beds and bends >20deg*
* *Wooden posts were retained where terrain and access did not permit concrete posts*
* *Brackets connecting fibers to posts were corrected where they had been mounted improperly*
* *We will continue to monitor the failure rate and maintenance status of the posts, and a diverse underground path remains a future option*

1. Start a process within the next 6 months to demonstrate how the Science Platform will satisfy the full suite of envisioned users and use cases, by engaging the user community to evaluate the functionality of the Science Platform against those use cases and different types of LSST users.

*Accept.*

*The Project agrees that the activity of engaging the community with the Science Platform must continue. A detailed design review of the full operations-era platform, involving members of the Science Collaborations and other stakeholders, has been scheduled for the first quarter in 2019. We will continue to engage the community with tutorials during meetings (such as the recent Project and Community Workshop), and actively solicit feedback in response.*

*Update:*

*The Science Platform Review is scheduled for 10 April 2019. The reviewers include both internal and external participants. See the review site for details of the committee, charge and agenda.* [*https://project.lsst.org/reviews/lsp-fdr/agenda*](https://project.lsst.org/reviews/lsp-fdr/agenda) *(credentials required)*

## SC2 – Camera System

**CAMERA RECOMMENDATIONS:**

2.1 Increase oversight of the heat exchanger vendor for the remainder of the fabrication/testing period. Consider visiting the vendor as soon as possible to ensure the integrity and quality of the internal components prior to closing the vacuum vessel, as well as visiting immediately before shipment of the final assembly, to ensure all QA/QC is completed properly. [Oct. 2018]

*Accept.*

*The LSST Camera team concurs with the committee and the camera refrigeration team has continued visiting the vendor to assess manufacturing process and review testing results. A local consultant was contracted to provide on-site weekly oversight at the vendor every Tuesday and also participate with the weekly oversight telecon with the team at SLAC. The LSST Camera team has also reached out to Tom Nicol (camera sub-committee reviewer) from FNAL and collected lessons learned that were available and applicable to the LSST heat exchanger scope of work. The LSST camera team, as a result, has re-tested all received part for leaks and flow rates at SLAC in B25 and plans to re-test parts to be delivered.*

2.2 Continue the tiger team effort to explore technical solutions for achieving the cryostat vacuum requirements within a time frame commensurate with the current I&T plan. [Nov. 2018]

*Accept.*

*The tiger team effort led by Martin Nordby for the camera has continued as planned and is described below:*

* *Final recommendations regarding the vacuum design upgrade required were completed by end of August 2018. Cost and schedule impact analysis were completed as part of this phase. The following items were addressed:*
  + *Definition of a dryout plan prior to closing the cryostat (Dry out cryostat using cryo and cold plate trim heaters, pumping and purging cryostat with room-temp N2)*
  + *Definition of a bakeout plan to be implementing during initial pumping (heat the cryo plate and CCDs to 40C, heat the cold plate and REBs to 60C, and heat the outer housing, L3, and back flanges to 40C)*
  + *Completion of updated schematics with additional on-camera holding pumps*
* *Implementation of the dryout and bakeout plan using temporary pumping system was completed by December 2018 and tested successfully in February 2019.*
* *Implementation of on-board additional pumping capacity planned by end of April 2019 in support of start of raft integration. This phase will include revised vacuum system performance verification, including vibration impact to image quality if any.*

2.3 The LSST Optical Systems Engineer should develop an aerial image best focal surface to Focal Plane Array Error Budget and compare to CBE sensor flatnesses, positions, and angles. [Feb. 2019]

*Accept.*

*Several documents generated during the design process and definition of the requirement flow down have been collected and are available to the review committee. The list of relevant documents to be provided is listed below:*

* *Document-7866 (08/20/2009): Focal Plane surface height (aka non-flatness) distributions and their effect on image size and ellipticity*
* *Document-7824 (07/29/2009): A parametric model for LSST's PSF: Optical design version 3.2*

## SC3 – Telescope and Site

**TELESCOPE AND SITE RECOMMENDATIONS:**

* 1. Implement a software deployment configuration process prior to the beginning of AIV.

*Accept.*

*The T&S Software deployment architecture has been implemented and is being tested both on the summit and in Tucson. It includes the following elements: (1) a puppet based system for automated deployment of assets; (2) RPM repositories containing pre-complied runtimes (will be moved to a Nexus server soon); (3) Github repositories for version controlled source code; (4) a Jenkins continuous integration system including “Robot Framework” test management.*

* 1. Create and maintain a test-driven software schedule demonstrating delivery of software capabilities prior to the dates needed for AIV or Commissioning. [within the next three months.]

*Accept.*

*The LSST Baseline Primavera plan has been updated with T&S Software epics tied to key Project milestones. The T&S Software Team has implemented tests for SAL, XML, and recently integrated the vendor-provided tests for the Pointing Component. The Software Team has moved to a new continuous integration platform on Jenkins and is collaborating with DM to complete an end-to-end process to build, test and deliver code prior to the need dates for AIV and Commissioning. The Team has setup a test environment for the Auxiliary Telescope and conducts regular integration tests as new components become available. In addition, we have a cluster of machines dedicated to functional and integration testing using vendor-supplied and internally-developed application simulators. Both environments are used as deployment test locations, allowing the Team ample opportunities to implement and refine the software deployment process.*

* 1. Allocate additional SE effort to T&S systems testing and contract oversight. [within 6 months, or earlier, if needed.]

*Accept.*

*The T&S systems engineer efforts are being assisted via the increased participation in verification activities by subsystem CAMs, technical documentation resources, and additional SE members from the LSST PO. In parallel, Chilean resources are being organized to support increased on-site verification as final acceptance efforts are being completed.*

* 1. For determination of the absolute accuracy of M2 conic constant, LSST Optical Systems Lead and the M2 Vendor Metrology Lead should review all details of the tests and agree on at least two independent methods of verification.

*Accept.*

*Prior to the closeout of the Harris contract, the final M2 optical test data package was thoroughly reviewed to understand the optical test set design and approach, final measured results, measurement uncertainties, and computations/calculations of optical parameters. Several closed loop active control tests were also conducted to verify opto-mechanical model predictions versus measured optical values. These tests of low order aberrations demonstrated an extremely high level of agreement between simulation and measurement. Both parties have agreed on the optical test results and these parameters have been included into the baseline LSST as-built optical model.*

## SC4 – Systems Engineering and Transition to Operations

**SYSTEMS ENGINEERING RECOMMENDATIONS:**

* 1. Perform a cost/benefit analysis as to whether the Camera team should be required to use the new SE V&V tools for managing the V&V process for in-house acceptance at SLAC. The benefit would be project-wide consolidation on a single approach, at the cost of disruption to existing Camera teamwork practices. This analysis should be performed prior to the start of Camera in-house AIV activities.

*Accept in part.*

*We believe forcing the Camera team to change their V & V methodologies at this stage would be too disruptive given current programmatic pressures within the DOE MIE effort.  For the V & V effort at SLAC the Camera team will continue as is.  However, once the Camera is accepted at SLAC and transferred to Chile the planning and tracking of its re-verification will be managed through the Project’s SE V & V process and tooling as part of the joint DOE/NSF System Integration and Commissioning effort.*

## SC5 – Environment, Safety, and Health (ES&H)

ES&H findings, comments, and recommendations may also be found in other sections in this report, as this aspect of the project is included in several other categories and was discussed in great detail in many of the subcommittee meetings.

**ES&H RECOMMENDATIONS:**

None.

## SC5 – Education and Public Outreach (EPO)

**EPO RECOMMENDATIONS:**

* 1. Seat an advisory group that includes elementary and middle school education specialists and/or curriculum developers, and explore with them LSST EPO products targeting elementary and traditional middle school students that can be developed and integrated into the EPO work plan.

*Acknowledge.*

*We agree that an advisory committee is a potential benefit to the EPO effort and we are preparing to set one up.  We feel that including elementary and traditional middle school education specialists on the panel would not be an appropriate use of the time of those individuals. Those student group are not part of our target audiences and any activities focused on them that are distinct from what we are already planning would be adding scope to the EPO Project, which we cannot do at this time.*

* 1. Understanding user needs and characteristics is critical to LSST EPO success. The ESO team should engage with education researchers focused on teaching and learning with big data to inform the construction of EPO data collection infrastructure, and analysis practices.

*Accept.*

*We agree that the field of education research and the emergence of teaching with big data is important and that LSST may have potential to be part of this. Prior to Operations, EPO will engage in discussions with education researchers to understand more about their work and needs and then evaluate the appropriate way, if any, to be involved. EPO is committed to evaluating deliverables and components. The purpose of evaluation is to determine the extent to which program outcomes are achieved and improve program functioning (National Science Foundation; W.K. Kellogg Foundation; Pell Institute). EPO recognizes that this is different from the purpose of education research which uses rigorous methods and “seeks to describe, understand, and explain how learning takes place throughout a person’s life and how formal and informal contexts of education affect all forms of learning” (American Education Research Association).*

*Sources*

*W.K. Kellogg Foundation*

*The Step-by-Step Guide to Evaluation, 2017*

[*https://www.wkkf.org/resource-directory/resource/2017/11/wk-kellogg-foundation-step-by-step-guide-to-evaluation*](https://www.wkkf.org/resource-directory/resource/2017/11/wk-kellogg-foundation-step-by-step-guide-to-evaluation)

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## SC6 – Cost and Schedule

**COST AND SCHEDULE RECOMMENDATIONS:**

* 1. Update the Scope Contingency Options in document LPM-72 to identify which options remain open to the Project including their updated projected cost savings as a function of time. [Sept 2018]

*Accept.*

*LPM-72 has been updated and continues to be renewed quarterly. The document and associated data spreadsheet have been updated to clearly identify the remaining value at the time of document publishing. The value as a function of time has always been calculated and plotted but the register is now sortable by remaining value to support focused evaluation.*

* 1. Incorporate Decision Milestones for remaining Scope Contingency Options into the P6 Schedule to trigger timely management decisions to implement, defer, or reject Scope Contingency Options. [To be completed shortly after updating the Scope Contingency Options document.]

*Accept.*

*The Project Schedule has been updated to include the trigger dates for the available Scope Options.*

## SC7 – Management

**MANAGEMENT RECOMMENDATIONS:**

7.1 The Project should revisit and revise the Descoping Plan to ensure that potential cost avoidance values are accurate and up to date.  Provide milestone dates for potential descope execution. (September, 2018)

*Accept.*

*LPM-72 has been updated and continues to be renewed quarterly. The document and associated data spreadsheet have been updated to clearly identify the remaining value at the time of document publishing. The value as a function of time has always been calculated and plotted but the register is now sortable by remaining value to support focused evaluation. The Project Schedule has been updated to include the trigger dates for the available Scope Options.*

7.2 Identify significant cost savings to offset liens in order to maintain sufficient contingency, and include these cost-offsets in the EAC so that the EAC can be used as an accurate assessment of expected execution and as a prelude to bringing these into the baseline. (October, 2018)

*Accept.*

*The Project has updated the EAC in October 2018, reviewed the significant available scope options and changed the process for maintaining the Liens/EAC.*

*Update:*

*EAC is now being updated monthly and all accepted liens are being included.*

# COMMISSIONING PLAN REVIEW

## SC11 – Commissioning Plan (Integration and Science Validation)

**SUMMARY:**

The Commissioning Plan has progressed substantially since the first review in 2017. Commissioning has been organized into four phases, the first of which is already in progress. The Commissioning team has been organized, and the work plan and Basis of Estimate costs are detailed and robust. The Project has made significant progress with the pathfinder systems (ConCam, refrigeration system, etc.) in support of early commissioning activities and to mitigate risk. The pathfinder projects will allow subsystem teams to work closely with the Commissioning and Systems Engineering teams. Commissioning team members are involved in subsystem testing, and the Systems Engineering team is responsible for key system performance metrics and models.

**COMMISSIONING INTEGRATION AND SCIENCE VALIDATION RECOMMENDATIONS:**

None.

## SC12 – Commissioning Plan (Computing and Software)

**COMMISSIONING COMPUTING AND SOFTWARE RECOMMENDATIONS:**

* 1. Demonstrate that the DM software can successfully support full science operations by scheduling an operational readiness review of the DM software, after the final DM software release and prior to the commencement of full science operations.

*Accept.*

*The Project will work with the Agencies and Operations team to establish a robust transition plan that includes readiness reviews at all appropriate completion milestones.*

## SC15 – Environment, Safety, and Health

**COMMISSIONING ES&H RECOMMENDATIONS:**

* 1. Maintain the current level of safety officer staffing (3 FTE) through the AIV/commissioning phase to help ensure that effective safety management, work planning, and control mechanisms are implemented for activities associated with this phase of the project.

*Acknowledge.*

*The budget remains in place to maintain the current level of Safety staffing through the AIV and System Integration periods. As the work evolves on the summit the Project will continue to evaluate the appropriate staffing that continues the same level of safety oversight and coordination.*

## SC15 – Education and Public Outreach

**COMMISSIONING EPO RECOMMENDATIONS**:

None.

## SC16 – Commissioning Cost and Schedule

**COMMISSIONING COST AND SCHEDULE RECOMMENDATIONS:**

16.1 Update the Commissioning WBS to facilitate cost accounting between DOE and NSF.  (2018 Sep 30)

*Accept.*

*The resource assignments already supported separate evaluation of DOE and NSF costs but the resources have now been separated in the Project Plan so each work package is assigned to only one resource type (DOE/NSF).*

*Update:*

*The Baseline Project Plan has been updated to include separate activities for DOE and MREFC funded work scope.*

## SC17 – Commissioning Management

**COMMISSIONING MANAGEMENT RECOMMENDATIONS**:

* 1. The cost and schedule presented was based on the early finish of the MREFC project. Schedule slips in the MREFC project will shift the commissioning schedule later.  The Project should work with the DOE office to provide planning scenarios. [January, 2019]

*Acknowledge.*

*We acknowledge that the DOE Commissioning Plan is integrated with the baseline MREFC schedule. The Project will continue to work closely with both Agencies to review funding levels necessary to support the work. Specific scenarios are not in place but the close coordination with the DOE supports the necessary discussions so both the Agency and the Project can evaluate funding level contingencies.*

*Update:*

*Several strategic planning scenarios have been developed to adapt to schedule uncertainties depending on the source – DOE driven, MREFC driven and globally driven. These have been presented in detail to the AMCL at the January 2019 meeting and summarized to the Agencies at the January Progress Update meeting. Further an AIV-Commissioning workshop was held in February 2019 where several detailed scenarios were developed that pull forward in time significant Commissioning work scope that will serve to relieve schedule risks.*

* 1. The Commissioning WBS should be segregated at lower levels to clearly identify DOE and NSF effort and procurements.

*Accept.*

*The resource assignments already support separate evaluation of DOE and NSF costs but the resources have now been separated in the Project Plan so each work package is assigned to only one resource type (DOE/NSF).*

*Update:*

*Done – see recommendation from SC16 above.*

# APPENDICES

## APPENDIX A - Charge

MEMORANDUM FOR HELMUT MARSISKE, EDWARD AJHAR, KATHY TURNER

FROM: RALPH A. GAUME

DEPUTY DIVISION DIRECTOR

DIVISION OF ASTRONOMICAL SCIENCES

NATIONAL SCIENCE FOUNDATION

JAMES SIEGRIST

ASSOCIATE DIRECTOR OF SCIENCE FOR HIGH ENERGY PHYSICS

DEPARTMENT OF ENERGY

SUBJECT: CHARGE FOR JOINT DOE/NSF ANNUAL STATUS REVIEW AND REVIEW OF LSST COMMISSIONING PLANS

We request that you hold a review of the plans for the commissioning of the Large Synoptic Survey Telescope (LSST) in combination with the annual Joint Status Review.

The LSST is a large-aperture, wide-field, ground-based telescope facility designed to provide a time-domain imaging survey of the entire southern hemisphere night time sky in six optical spectral bands.

The National Science Foundation (NSF) Division of Astronomical Sciences (AST) and the Department of Energy (DOE) Office of High Energy Physics (HEP) jointly support the construction of the LSST. The NSF is the lead agency, funding construction of the telescope, site facilities, data infrastructure, systems engineering, and education and public outreach capabilities, with an award from the Major Research Equipment and Facilities Construction (MREFC) program, restricted by the National Science Board not to exceed $473M. The DOE-deliverable portion of the LSST Project is the imaging camera system, fabricated as a Major Item of Equipment (MIE), with a Total Project Cost of $168M. With private support of $39M, the full LSST construction cost is $680M.

Commissioning preparations and activities began in fiscal year (FY) 2018 and are being planned by the Construction Project team. Support for Commissioning Phase activities is included in the MREFC Project funded by NSF. The corresponding activities on the DOE side are supported by an operations funding line as they are not included in the Camera MIE Project.

The LSST facility is scheduled to begin its full 10-year survey operations on October 1, 2022, with pre-operations starting in FY 2019. The pre-operations activities and funding are part of a separate planning exercise.

This review should conduct an annual assessment of the construction project status as well as an assessment of the scope, cost, schedule, organization, and funding profile for the Commissioning Phase. Specific items that should be addressed at a level consistent with the current phase of the planning are as follows:

***Part 1. Considering the LSST Project’s performance to date, and the execution plan for the future, including technical scope, cost, schedule, and the safety and risk management plans, can the planned facility be delivered according to the current project plan?***

***Part 2. Following a comprehensive assessment of the scope, cost, schedule, organization, and funding profile for the Project’s commissioning phase, is the project prepared to commission the facility successfully and effectively coordinate its activities with the pre-operations team?***

The panel should answer the following questions, as noted under primary numbering and in bold-face. Wherever possible, any identified shortcomings should be accompanied by recommendations that the panel believes will correct the problem. Although there are specific questions in this charge, the panel is asked to be active and to be willing to draw attention to any issue they should happen to notice, even if it does not appear in this charge.

**1. Overall Progress Review**

**1.1. Is the LSST Project progressing as planned, and are they making appropriate plans for future work?** Are all activities consistent with the baseline project objectives as described in the Project Execution Plan? Is there adequate progress across all WBS elements, including both in-house efforts and external procurements and contracts? Are there appropriate plans for realizing opportunities and for mitigating risks?

**1.2. Are the current cost and schedule (C&S) performance and their future trends acceptable?** Do the performance to-date, C&S trends, and C&S contingency, together give confidence that the project can complete successfully on time and within budget? Have changes to the Project Management Control System (PMCS) been properly incorporated? Is the change control process solid and is it being followed correctly?

**1.3. Is the project management functioning well?** Are new risks being uncovered and are identified risks being actively mitigated and/or retired? Are there concerns over the distributed nature of the second level WBS teams and how well they are communicating and working together? Does the systems engineering team monitor progress and performance across the project using proper methodology? Is the systems engineering documentation being suitably created and refined as the project progresses? Are all necessary written procedures in place, documented, and followed? Are contracts and procurements properly monitored? Is the project staffing adequate for the work?

**1.4. Is the planning for the transition to operations adequate for this stage of the project?**  Are the plans for assembly, integration, test, and commissioning phases at an appropriate level of development (this is brief here but see Part 2 below)? Will essential materials, including manuals, maintenance plans, and as-built drawings, be ready when needed? Is planning for the transition of personnel sufficiently developed and being appropriately communicated to staff?

**1.5. EPO: Are the Education and Public Outreach activities properly planned?** Is the EPO team the right size with the right skills, and completely engaged and integrated?

**1.6. ES&H: Are Environment, Safety & Health (ES&H) issues handled appropriately?** Does the project have an acceptable safety record? Are Integrated Safety Management Principles being followed?

**1.7. Has the project responded satisfactorily to recommendations from previous reviews?**

**2. Review of the Commissioning Phase**

**2.1.  Technical Scope and Requirements:** Have the technical scope and requirements for the Commissioning Phase been clearly articulated and are they well understood by the Commissioning Team? Is the planned scope complete? Are the requirements achievable given the proposed approach?

**2.2.  Management and Organization:** Is there a well-defined Work Breakdown Structure (WBS) for the Commissioning Phase? Has an adequate management plan been developed to implement the work? Are there clear lines of authority and responsibility? Are the interfaces between DOE- and NSF-supported activities managed appropriately? Is an appropriate risk registry maturing and have the appropriate risks and mitigations been identified?

**2.3.  Cost & Schedule:** Have appropriate cost and schedule estimates been developed for the Commissioning Phase? Are the full scope costs and contingencies covered by the combination of DOE and NSF funding? Is there a clear understanding and justification for the breakdown of costs that will be supported by separate DOE and NSF funding lines? Is an appropriate Project Management Control System being developed to estimate and track this work, and will it provide adequate reporting for both funding agencies? Is the schedule consistent and coordinated with the ongoing construction effort and planned onset of Full Operations?

**2.4.  Transition to Full Operations:** Is LSST developing a concept for the transition from commissioning through pre-operations to full operations that is appropriate for this stage of the project?

**2.5.  ES&H:** Are the ES&H (Environment, Safety, and Health) aspects of all anticipated work being properly assessed and managed? Are Integrated Safety Management Principles being followed?

**2.6.  Previous Reviews:** Has the Project responded satisfactorily to recommendations from previous reviews that bear on the Commissioning Phase.

This review will take place from July 30 to August 3, 2018, at the Tucson Marriott University Park in Tucson, Arizona. Edward Ajhar is the NSF program manager for LSST and will serve as the NSF contact for the review. Helmut Marsiske is the DOE program manager for the LSST Camera MIE and will serve as the HEP contact for the review.

Reviews of this type play an important role in ensuring the success of our projects and programs. We very much appreciate your carrying out this review and expect to receive a final report within 60 days of the review.

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Ralph A. Gaume James Siegrist

Deputy Division Director Associate Director of Science

Division of Astronomical Sciences for High Energy Physics

National Science Foundation Department of Energy

## APPENDIX E – Acronyms

The following is a comprehensive list of acronyms used by the LSST project, regardless of whether or not they are found in this report.

|  |  |
| --- | --- |
| **Acronym** | **Definition** |
| ACWP | Actual Cost of Work Performed |
| AOS | Arizona Optical System (Tucson,AZ based company building L1 and L2 lenses) |
| ASIC | Application-specific integrated circuit |
| ASPIC | Analog Signal Processing Integrated Circuit |
| BAC | Baseline at Completion |
| BATC | Ball Aerospace Technologies Corporation (Boulder, CO based ompany delivering the L1-L2 assembly) |
| BCR | Baseline Change Request |
| BCWP | Baseline Cost of Work Performed |
| BCWS | Baseline Cost of Work Scheduled |
| BNL | Brookhaven National Laboratory |
| BOT | Bench for Optical Testing (Camera test fixture) |
| CCD | Charge Coupled Device |
| CCS | Camera Control System |
| ComCam | Commissioning Camera |
| COTS | Commercial Off-The-Shelf |
| CP | Cost Variance |
| CPI | Cost Performance Index |
| CRADA | Cooperative Research and Development Agreement |
| CREC | Corner Raft Electronics Cage |
| CRSA | Corner Raft Sensor Assembly |
| CRTM | Corner Raft Tower Module |
| DAQ | Camera Data Acquisition System |
| EAC | Estimate At Completion |
| ECM | Engineered Ceramic Materials (Germany based company fabricating the Camera Grid and sensor baseplates) |
| EPR | Equipment Procurement review (applies to Camera I&T only) |
| ETC | Estimate To Complete |
| ETU | Engineering Test Unit Raft (ETU2 is used as ComCam) |
| EVMS | Earned Value Management System |
| FDR | Final Design Review |
| GREB | Guide sensor Raft Electronics Board |
| I&T | Camera Integration and Test sub-system |
| ICD | Interface Controlled Document |
| IG | Integration Gantry (camera I&T fixture) |
| IN2P3 | Institut national de physique nucléaire et de physique des particules |
| IPR | Integration Planning Review (applies to Camera I&T only) |
| IR2 | LSST Camera Clean Room at SLAC |
| IRR | Integration Readiness Review |
| KPP | Key Performance Parameter |
| L1 | Camera Lens 1 (entrance lens) |
| L2 | Camera Lens 2 (second lens) |
| L3 | Camera Lens 3 (also serves as the cryostat window) |
| LL | Long Lead |
| LLNL | Lawrence Livermore National Laboratory |
| MIE | Major Item of Equipment |
| MRR | Manufacturing Readiness Review |
| ORR | Operation Readiness Review |
| PCP | Camera Project Control Plan |
| PDR | Preliminary Design Review |
| PEP | Project Execution Plan (one exist for the Camera and one for the observatory) |
| PM | Project Manager |
| PMP | Camera Project management Plan |
| PRNU | Photo Response Non-Uniformity |
| PSAP | Camera Performance and Safety Assurance Plan |
| PSR | Pre-Ship Review |
| REB | Raft Electronics Board (REB5 is the last revision) |
| REC | Raft Electronics Cage |
| RSA | Raft Sensor Assembly |
| RTM | Raft Tower Module |
| SEMP | Camera System Engineering Management Plan |
| SPI | Schedule Performance Index |
| SV | Schedule Variance |
| TDR | Test Definition Review (applies to Camera I&T only) |
| TRR | Test Readiness Review |
| TS3 | Test Stand 3. Single sensor electro-optical test stand. |
| TS5 | Test Stand 5. Single Raft metrology test-stand |
| TS7 | Test Stand 7. Single Raft Test Dewar (used with TS7, TS8 and for ComCam) |
| TS8 | Test Stand 8. Single Raft Electro-Optical test-stand |
| VAC | Variance at Completion to the baseline |
| WBS | Work Breakdown Structure |
| WFS | Wavefront Sensor |
| WREB | Wavefront sensor Raft Electronics Board |