Report of the Director's Review

of

Annual Progress and Commissioning

of the

Large Synoptic Survey Telescope (LSST) Project

Performed at the

SLAC National Accelerator Laboratory
Menlo Park, CA

June 24-29, 2018

Table of Contents

1.0 Executive Summary.

The review committee concluded, after evaluating the LSST project's overall progress and performance to date as well as execution plans for the future (including technical scope, cost, schedule, safety and risk management plans) that the planned LSST facility can be delivered according to the current project plan subject to the following comments:

- The project is progressing as planned and appropriate plans are being made for future work. Progress since the last annual review has been impressive.
- The current cost and schedule performance and trends are acceptable; however, there is accumulating schedule risk from multiple converging controlling work paths as equipment fabrication is being completed and components are being delivered to the site for integration. The current budget contingency is not generous considering the overall risk exposure.
- The project management and team are functioning well; there are some ongoing changes in a number of positions that are important for site integration and future operations and these are being addressed with priority.
- Planning for the transition to operations, considering assembly, integration, test and commissioning, is appropriate for this stage of the project.
- The EPO organization and activities, while established and initiated later than originally envisioned, are making excellent progress.
- ES&H issues are being handled appropriately, and Integrated Safety Management principles are being followed.
- The project has responded appropriately to recommendations from the previous joint agency annual assessment of construction.

Further, following a comprehensive assessment of the scope, cost, schedule, organization and funding profile for the project's commissioning phase, the review committee concluded that the LSST project is prepared to commission the facility successfully and effectively coordinate its activities with the pre-operations team, with the following comments noted:

- The technical scope and requirements for the commissioning phase are clear, complete, understood and achievable by the commissioning team.
- The management team, organization and staff, plus the plans and management systems for the commissioning phase, are adequate for this phase of the project and should be in place to support the commissioning schedule.
- The budget estimates and schedules for commissioning are reasonable and covered by the DOE and NSF funding. Appropriate project management controls systems are in place to estimate, track and report on the progress of commissioning work.
- The concept for transitioning from construction to commissioning to pre-and full operations is appropriate for this stage of the project.
- ES&H aspects related to the commissioning phase are being properly assessed and managed properly and in accordance with ISM principles.

2.0 Project History & Background.

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, along with private and international contributions. Both agencies plan to support the operations phase. The NSF is the lead agency for LSST. The National Science Board has restricted the NSF-funded aspects of construction to no more than $473M for 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; The DOE-deliverable portion of the LSST construction project is the imaging camera system with a total project cost established at $168M as a Major Item of Equipment (MIE.) With additional private support of $39M, the full construction cost of LSST 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 these are not included in the Camera MIE project.

The LSST Operations planning team has carried out detailed planning for the pre-operations, planned to start in early FY 2019, as well as the full science survey operations starting October 1, 2022. The team has submitted a proposal to both the DOE and NSF which is the subject of a separate review. This joint Director's Review of annual progress and commissioning planning is focused on the current performance and status of the construction project, with emphasis on the coming year, in preparation for a joint agency independent project review scheduled from July 30-August 3, 2018.

3.0 Technical & Management reports.

3.1 Data Management (SC-1)

Presentation Comments.

It is suggested that presentation slides indicate which charge questions they address (where relevant).

The presentations cannot possibly cover the vast DM project in depth. Reviewers are likely to suspect that this fact is exploited to gloss over problem areas. We felt that this was the case for the middleware issues (that do appear to be a concern), and some of us felt uneasy about the minimal discussion of compute and storage hardware requirements and the limited presentation of database performance requirements (that may not be concerns). We suggest strongly that areas of concern are stressed in the presentations and that reviewers are made aware that the project is doing this.

The increase in contingency consumption in January 2018 could appear alarming - make sure it is explained clearly.

Observations/Comments.

Management: The DM manager is doing an excellent job and has a good understanding of all parts of this complex system. The team is dedicated to the success of the project. The DM team is being well-led and managed and appears to be mostly on schedule based on the usual metrics. The group shows all signs of functioning well as a team, with a clear view toward the deliverables and the project timeline. This is particularly impressive given the wide geographical distribution of the team and the very large range of project deliverables they are required to provide.

Cost and Schedule: The SPI and CPI metrics are acceptable across the DM WBS. However, SPI only takes account of level of effort and does not track progress towards completion. DM has recently added a comparison of tested milestone achievement with milestone planning. This an excellent approach, but after less than a year of data, it indicates that progress towards completion is correct with a precision of 20% to 30%. DM management believes that their main tool to ensure on schedule and on budget delivery is a highly motivated workforce that will be very responsive to needs of commissioning and science.

Descope Options: Most of the current de-scope options are not realistic at this stage of the project. Are there other more realistic options, e.g., buying machines later or postponing the delivery of some items?

Opportunities and Risks: Managing opportunities and risks is a continuing challenge, especially in the case of DM, where software and algorithms improve steadily and some software elements are based on third-party products. The team would benefit from a better understanding of how/which opportunities will be investigated, and by what metrics opportunities will be selected to be pursued. Examples of this are: the investigations of whether or not cloud computing is realistic for LSST-related science or operations; the utility of MultiFit.

Engagement with Scientists: The DM team has been engaging with other scientists, both within LSST (in other subsystem teams) and with the general user community, to help them test/improve the DM software and train other LSST scientists in the use of the DM software. This effort should continue, so that the commissioning and science verifications teams are ready

for those activities, and so that the general user community is ready to engage with LSST data products when the telescope begins to produce data. In particular, the interaction between DM and the commissioning team will help both subsystems and drive DM to produce user-friendly tools that test key subsystem performance metrics and create a user-base/feedback loop for their systems.

Transitions from Construction through Operations: The team is aware of the coming transition from the DM construction phase to the commissioning, pre-operations and operations phases and the need to retain skilled and knowledgeable individuals to facilitate this transition effectively. The number of required FTEs and their skill mix will change only slowly through these periods.

Benefits of scientist-driven tests: DM has engaged scientists in activities that help drive the function and performance of DM products and heighten mutual engagement and enthusiasm. These activities include the processing of HSC data, the “boot camp” exposing the Jupyter notebook system to non-DM users and the DM Stack Club.

Benefits of early end-to-end tests: The Auxiliary Telescope will be commissioned in July 2019. This represents the first real-world test of the DM systems applied to an LSST component, and will test all parts of the DM system (scheduling, data acquisition, data transfer, data pipelines, archiving, data analyses, deriving metrics, and data access). Various other subsystems will be engaging with (and very dependent on) the DM team and products during this phase, and it would benefit the team to present a clear plan for this activity. The current schedule for the AuxTel requires all related DM systems to be functional within 1 year.

“World-Public LSST data”: DM is focused on making data and resources available to the “LSST collaboration” members and teams, and not about what happens when the data go “world public”. Since the “LSST Collaboration” includes the entire US astronomical and public communities already, the distinction (or extra cost) associated with the “world public” seems unclear. Although support for world-public access is clearly not part of the LSST project, it may be wise to understand the likely cost of the level of support for world-public access that would be perceived as a success.

Risks associated with third-party software: Some third party software choices have been already decided (e.g., the selection of MariaDB over other database providers). This could create an associated risk where software coding becomes more specific to a certain set of predetermined choices and may inhibit / complicate the ability to switch to better options in the future. This general type of risk should probably be in the Risk Registry.

Workflow and Data-Management Middleware: These important middleware utilities are surprisingly late. A workflow manager has not been developed or chosen yet, and the distributed data management tools are far from complete.The extent of the need for failure recovery mechanisms seems undecided. Tools for astronomers, science platform, etc., are coming along well. But are these all going to be incorporated properly in time for the upcoming commissioning activities? The DM group is optimistic that they will make the deadlines (within a year for Aux Tel). LSST is building the middleware to interface with an off-the-shelf workflow manager. DM has been able in the past to run some HSC data through the pipeline with significant manual effort. The absence of automation at this stage is a risk. Much depends on middleware at this stage, which could end up on the critical path.

Full exploitation of qserv: Is qserv being adequately exploited for data other than the annual releases?

Documentation: Many of the tests that are supposed to be complete by end Nov 2018 are still not specified in LDM-503. Are these tests on schedule? (e.g., LDM-503-09a is “Pipelines Release Fall 2018”, but what exactly is in this release? LDM-503 lists this still as "unspecified”.)

Publications: It is important and valuable to encourage the developers of software that is expected to make a significant contribution to the success of LSST to take the time to write up and publish papers on this work. This helps to build a body of literature to which LSST scientists can refer. Publishing performance information gathered during the commissioning phase will be particularly difficult, due to time constraints, but also particularly valuable.

Observations/comments related to the Commissioning Phase:

(2.1) Technical scope and requirements are understood, and the requirements are achievable, but the exact technical solution for all the pieces has not yet been completed. Functional requirements are clear, but the *performance* requirements (how fast / how well) are currently implicit and not specified exactly. Might be good to clarify this, at least for key pieces needed for commissioning.

(2.2) DM management are confident that they can both support commissioning and continue development as needed. There will be a transition of how individuals are supported (i.e., NSF vs DoE), but DM manager says this should not affect how the interfaces with commissioning activities, command structure, and work priorities will be implemented. There are liaisons in place between commissioning team and the different subsystems which should enable effective communications and trust between the different groups.

Issues/Concerns.

Judicious exploitation of evolving technology opportunities forms a major part of successful DM delivery. The approach to this issue seems to lack appropriate formality both with respect to benefits and risks.

Workflow and distributed-data-management middleware are late. The situation is recoverable, but will require significant effort and leadership.

Could closer integration of Qserv, promoting more wide use for data-related tasks within LSST, be beneficial?

Recommendations.

Present, to the Agency Review, plans for prioritizing DM work in the next year, while noting that these plans will certainly evolve.

Introduce a more formal process to evaluate and incorporate new technologies.

Plan, document and execute a program of work that will assure the timely availability of the missing middleware functions.

Response to Charge Questions Assigned.

1.1 Progress and plans. Is the LSST project progressing as planned, and are they making appropriate plans for the future work?

Yes. DM is progressing as planned with appropriate future plans in most areas. All activities are

aligned with the objectives of the baseline project. All WBS level-4 elements show similar and likely adequate, progress. Realizing opportunities is a vital part of effective DM project management. Some added formal process may help here, at least in reassuring reviewers. Risk mitigation plans, by adjusting schedule, cost (draw on contingency) and scope, are probably appropriate, but lack detail.

1.2 Cost & Schedule performance. Are the current cost and schedule performance and their future trends acceptable?

Yes. The formal cost and schedule metrics are now quite acceptable across the DM WBS. However, it is well understood that, in DM, these metrics track effort expended and not necessarily progress to completion. In the last year, DM has developed a set of testable milestones that will track the progress through completion. Progress to date in achieving these milestones was presented and gives some confidence that progress towards completion can now be tracked. The new milestone-achievement metric is an excellent development. However its uncertainty in predicting on-schedule project completion is at least 20% at this time. DM is making use of a number of (close to) end-to-end tests of its systems to drive the prioritization of work. Among these are the processing of HSC data, end-to-end network tests, "boot camps" involving users from outside DM and the near-future end-to-end testing with the Auxiliary Telescope. This approach should help to ensure that the most critical needs of LSST are met, even if there is some delay in the full completion of the DM project. It should also be noted that the productivity of a software team can vary greatly depending on the level of motivation of its members and the quality of its leadership. The current DM management appears to be able to maximize productivity going forward.

1.3 *Management, risks, system engineering and procurements. Is the project management functioning well?*

Yes. The DM project management is functioning well. Historical issues with the coordination of the distributed teams appear to have been overcome. Risks are being managed to the extent possible, noting that some 'risks' are related to the uncertain future evolution of the needs of the scientists. DM staffing is appropriate in general. It was stated that they were "slightly understaffed in pipelines".

1.4 Transition to ops. Is the planning for the transition to operations adequate for this stage of the project?

Yes. DM staffing needs in terms of FTEs and skills will change only slowly through commissioning and operations. The planning is adequate at this stage.

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

Yes. Responses were shown to DM recommendations from prior reviews. The responses were satisfactory. Comments:

- *[LIT-390] Demonstrate the new planned work will be completed on schedule*

The calibrated rates of completion were unmeasured in the past. The tested milestone completion rate is a major improvement on the uncalibrated past, but it is too early to say that this can reliably predict completion on schedule.

- *[LIT-392] Develop de-scope options for each subsystem*
  The listed descope options are mainly unacceptable. In reality more subtle delays and reduced function decisions are likely to be appropriate.
- *[LIT-396] Develop a detailed testing plan*
  "Though infinitely better off than last year we should be further along with this" - the panel agrees
- *[LIT-398] Evaluate existing data and workflow management tools*
  Still a work in progress

Part 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?*

Yes. The plans of the commissioning team that involve DM products are clear and well-connected to the DM team. DM middleware can be ready for commissioning but significant effort and leadership will be required. DM functional requirements for commissioning are clear, but performance requirements are often implicit. DM is working to firm up these requirements.

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?

Yes. There is a DM WBS specific to commissioning. Some details are still to be worked out.

2.3 Cost and 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?

Yes.

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?

Yes.

2.6 Previous Reviews.

Has the Project responded satisfactorily to recommendations from previous reviews that bear on the Commissioning Phase?

Yes.

3.2 Camera (SC-2)

Observations/Comments.
It is great to have a list of acronyms, but make sure that at least all the acronyms in the first talk are included in the list (NCOA, AMCL, etc. are missing).

Funding for commissioning in FY19 has not yet been approved although commissioning is scheduled to start.

The camera remains close to the critical path. Most of the major subsystems are over 80% complete. Exceptions are the cryostat, refrigeration systems, filters and shutter. The cryostat and refrigeration system have major parts still in fabrication. The filter coatings and shutter are nearly ready to begin manufacture.

The project is procuring sensors from 2 different vendors. Roughly half of the sensors from one vendor do not meet the noise requirements on all channels.Over the past year, the project has performed an extensive response to the sensor problem:

- Additional sensors have been ordered. Only 8 of 21 science rafts will have the lower quality sensors.
- The impact on the scientific performance has been carefully assessed.
- Options exist to mitigate the impact on the survey and data.

The commissioning plan includes detailed planning for shipping, including a chartered plane for shipping the camera.

The project plans to collect templates for transient science during commissioning.

A detailed commissioning plan has been developed along with detailed BOE documentation.

The DOE commissioning plan has 35% cost contingency, but no schedule contingency. The project office holds 8.5 months of schedule contingency.

The commissioning period includes 3 weeks of science testing and 1 week for engineering punch list activities.

The camera team tested and concluded that the LSST CCDs can not be damaged by overexposure and that there are no explicit controls planned to prevent it.

Issues/Concerns (Project progress.)
Although the LSST CCDs seem to be resistant to damage caused by over-exposure to light, other projects have seen this and those projects discovered it late in the testing program because it did not affect all the CCDs. The risks of damage could be mitigated through interlocks and procedures that prevent opening the shutter or powering the CCDs when the environment is bright. This is particularly important during the pre-installation testing periods when non-standard operations may occur. Limiting or eliminating the collection of sky flats can

reduce the risk of pointing the camera at an overly bright sky. Sky-flats are not currently planned but also not explicitly prohibited. The CCD noise issue could be mitigated by taking longer exposures or readout times in u band.

The project and community are in the process of optimizing the observing plan. Now is a good time to lay out for the community the potential operational noise mitigation strategies with pluses and minuses (such as SNR/limiting magnitude performance gains versus spectral band, reduce the data volume, reduce the number of camera readouts hence more observing time, impact on mitigating cosmic ray tracks, and the increased difficulty of tracking near earth objects using observations taken 2-3 days apart rather than 15 seconds.) The team seems confident that they have seen enough thermal cycling of the CCDs to not worry about further read noise increases with future thermal cycling. The team should keep an eye on this.

The time allocated to cryostat integration and testing is very tight. In many cases the hardware required to begin is still in fabrication. The project is working with the vendors to ensure on-time delivery. The project should proceed as expeditiously as possible to fabrication of a full sized filter and to fabrication of the shutter and initiation of long terms tests of the moving parts.

The plenary session talks could be improved by:

- Reminding reviewers of the context (for example # rafts needed and planned operational activities such as warming up) in each talk;
- Rebalance content with more emphasis on future activities and more details/examples rather than process;
- Include a talk on the interfaces between camera and telescope and DM then cover the details of one or two. Include thermal management for the telescope and building.
- Normalize the FTE plots to compare the same time period for actuals and predictions (a full year). An example of where this was not done is Gressler slide 34, but the comparison of half a year of actuals to a full year prediction appeared in other places as well.

The time allocated to camera integration and testing is very tight. The project has carefully optimized and documented the steps and schedule for integration and testing. While it is still likely that some schedule slips will occur, the team is prepared to address issues as they arise to minimize the impact on the total schedule.

Rafts will be installed in two stages: 9 science rafts followed by about a month of testing followed by installation of the rest of the rafts. It may be useful to install at least one corner raft in the first stage to allow early testing for interactions between the guiders and the science rafts.

Issues/Concerns (Commissioning)

The commissioning camera provides an excellent opportunity for early identification of LSST system integration issues. The time on-sky for ComCam is bracketed by readiness of the telescope and the full camera. This window may shrink. A minimum useful on-sky period was stated as 3-4 months. This should be reassessed as the schedules develop.

Chartering a plane for the camera shipping minimizes the risks. When developing the contract for the charter, make sure to consider the lead time for scheduling the specific airplane.

While the schedule of tasks and BOEs are well developed, it was hard to get an overall picture of the number and frequency of milestones and how progress will be monitored. Each commissioning breakout talk should include milestones, cost and labor charts for that phase or system. Also include plans for critical people on the summit, in La Serena or off site. Make sure people are not double counted. The commissioning requirements are hard to dig out of the presentations. Collecting them in one document would help.

The plan for 1 week out of 4 devoted to an engineering punch-list during commissioning is reasonable and well motivated.

Consider detailing "descope" plans, for example this may include squeezing the science validation phase.

There may not be time to collect quality templates during commissioning. This could potentially impact the operations plans.

A more focused discussion of the communication channels during commissioning, including an example of how a change in planned activities (e.g. weather) would be addressed would be useful

Recommendations.
Proceed as quickly as possible to approval of the commissioning plan and funding.

Build into the camera and/or telescope control systems procedures and/or interlocks that prevent over exposure of the CCDs during pre-installation testing as well as during routine operations.

Collect the requirements for commissioning in a separate document.

Response to Charge Questions Assigned.
1.1 <u>Progress and plans</u>. Is the LSST project progressing as planned, and are they making appropriate plans for the future work?. **Yes,** Detailed plans have been developed including I&T, shipping, and commissioning. These include detailed BOE documentation *Are all activities consistent with the baseline project objectives as described in the Project Execution Plan?* **Yes.** The team is focused on their deliverables. *Is there adequate progress across all WBS elements, including both in-house efforts and external procurements and contracts?* **Yes,** however, in many cases the hardware required to begin is still in fabrication. The project is working with the vendors to ensure on-time delivery. In some cases, the vendors are working double shifts as a result of pressure from the project. *Are there appropriate plans for realizing opportunities and for mitigating risks?* **Yes**, The team is actively engaged in comprehensively assessing and mitigating the risks in the project. The DOE commissioning

plan has 35% cost contingency. The project has only 8.5 months of schedule contingency.

1.4 Transition to ops. Is the planning for the transition to operations adequate for this stage of the project?

Yes. The project has well developed plans for the transition to operations and is acting to implement them. They are cognizant that they have key people and they will need and are working to keep them informed of the opportunities. *Are the plans for assembly, integration, test and commissioning phases at an appropriate level of development? (See Part 2 below).* **Yes.** The project has carefully optimized and documented the steps and schedule. While it is still likely that some schedule slips will occur, the team is prepared to address issues as they arise to minimize the impact on the total schedule. *Will essential materials, including manuals, maintenance plans and as-built drawings be ready when needed?* **Yes.** The time allocated to cryostat assembly and testing is very tight. In many cases the hardware required to begin is still in fabrication. The project is working with the vendors to ensure on-time delivery. *Is planning for the transition of personnel sufficiently developed and being appropriately communicated to staff?* **Yes,** Management is discussing travel plans, opportunities to stay for Commissioning and for operations with staff and they are being kept apprised of the likelihood of timing.

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

Yes. *Is planning for the transition of personnel sufficiently developed and being appropriately communicated to staff?* **Yes,** Management is discussing travel plans, opportunities to stay for Commissioning and for operations with staff and they are being kept apprised of the likelihood of timing.

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?* **Yes,** However, the requirements are hard to dig out of the presentations. It would be better to collect the requirements for Commissioning in a separate document.

2.3 Cost and schedule. *Have appropriate cost and schedule estimates been developed for the Commissioning Phase?* **Yes**, there are detailed BOE documents for each phase.
Are the full scope costs and contingencies covered by the combination of DOE and NSF funding? **Yes,** the team showed some of these for camera activities.
Is there a clear understanding and justification for the breakdown of costs that will be supported by separate DOE and NSF funding lines? **Yes.** *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?* **Yes,** the project management brought up detailed files and demonstrated them to us. *Is the schedule consistent and coordinated with the ongoing construction effort and planned onset of Full Operations?* **Yes**, however, the integration and

testing schedule is very tight and may use some of the schedule contingency that might be needed for commissioning.

2.6 Previous Reviews. *Has the Project responded satisfactorily to recommendations from previous reviews that bear on the Commissioning Phase?*
Yes, Recommendations from previous reviews have been addressed.

3.3 Telescope and Site (SC-3)

Observations/Comments.

Construction is nearing completion for many subsystems. Logistical needs are being addressed. The TMA assembly in Spain successful and requirements are being retired. The calibration telescope is on track to be ready as needed and used for DM testing. Dome Assembly is currently taking place on site and moving along well.

Staffing, particularly in Chile, is ramping up appropriately.

The global interlock system was referenced in talks, but was not presented. Through sidebar discussions It appears that the system is covered. However, it would be helpful if the design philosophy, interfaces, and plans for integration and certification were presented. For instance, when is the global interlock system integrated at the site and how are sub-assemblies tested without the system in place?

Verification as early as possible is a sound approach. However, some tests are not planned (or possible to test) early and may take longer than expected. The schedule contingency should be reviewed for verification tests that may be on the critical path - e.g. dome/TMA vibration coupling, M1/M3 thermal control.

Present the commissioning workflow following the approach done by Assembly, Integration and Verification (AIV). Good chemistry exists between System Engineering and AIV, procedures are well developed and tools are being used appropriately.

Issues/Concerns.

M1M3 is on the critical path; the project is aware of this and is increasing resources accordingly. Concerns remain regarding meeting deadlines to access mirror lab on time, so the project should provide the reviewers a plan of the remaining steps to reach completion -- what is the plan if the mirror lab window is missed?

Coating chamber manufacturer spending is not under control and would benefit from more frequent interaction with LSST to prevent additional surprises. This should be a lesson learned and applied to other suppliers.

TMA installation on the mountain has several options regarding use of cranes and lift. Procedures laying out all these options should be studied.

Software is catching up on previous delays. TCS development still lags but more resources are being allocated. TCS should be given priority to prepare for the calibration telescope. The project should define responsibility between Telescope and DM groups for the development of Engineering and Facility Data (EFD) tools.

Recommendations.

Show the requirements of subsystems retired at the factory acceptance test and evaluate the benefits to retire additional requirement before shipment (compliance matrix summary). Many sub-systems currently not on the critical path will be shipped to LSST before the end of the year and may benefit from this evaluation.

Show a list of critical spare parts to be delivered with each subsystem and demonstrate the rationale behind their selection, quantities and status. A brief presentation on the failure modes and reliability analyses processes would be helpful. In addition, present the approach for

identifying and developing servicing plans.

Develop a staffing profile for Chilean staff ramp up and demonstrate how the staffing from construction through commissioning will use the new space built at the casino and base facility. Is the size of the new construction sufficient to support the need of the project? Describe plans for temporary use of other facilities.

Response to Charge Questions Assigned

1.1 Progress and plans. *Is the LSST project progressing as planned, and are they making appropriate plans for the future work?* **Yes.** There are unexpected issues and delays, but they are being dealt with effectively and plans for future work are being adjusted accordingly.

1.3 Management, risks, system engineering and procurements. I*s the project management functioning well?* **Yes**. New risks being identified and mitigated. M1M3 schedule risk is acknowledged by team, but still seems uncertain. Written procedures appear to be in place. FMECA (reliability analysis) not shown.

1.4 Transition to ops. *Is the planning for the transition to operations adequate for this stage of the project?* **Yes**. Servicing plan needs to be shown. Spares are included in the plan but rationale and requirements for them are not clear.

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

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?*
Yes. The scope and requirements seem to be well understood by the commissioning team, but the information was not well articulated to the panel. It would help if the technical scope and requirements were presented in a more concise manner and organized to better match the charge.

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 risk and mitigations been identified?*
Yes. There is a well-defined WBS and an adequate management plan. The interface between DOE and NSF appears to be well managed. Risks appear to be identified and tracked, but a summary of the risks and mitigation status was not shown and would be helpful.

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?
Yes. The plan seems to be well developed.

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

3.4. Project Management/Systems Engineering (SC-4)

Observations/Comments.

The Project is performing well, as is the PM team. The relevant PM tools are in place and functional.

A de-scope plan at a level of 10% of the cost-to-complete is in place.

The leader of the controls software group is leaving the project for another position in AURA. The project has opened a position for a replacement. In the meantime, the group is lead by the deputy with help with help from the head of Data Management.

The controls software effort is being replanned to clarify milestones with more emphasis on near term goals.

All MIE/MREFC major procurements have been awarded. 82% of the MIE procurements have now been completed and the Summit Facility construction contract was completed in March 2018. The open contracts and procurements are being properly monitored and administered during performance delivery. A robust logistics planning and delivery execution process has been developed to support the upcoming push to ship and install a very significant volume of scientific equipment and supporting materials, estimated at 6,000 freight tons and valued in excess of $200M, to the summit in Chile. This is an excellent example of activity-level work planning that should yield positive results.

The Verification and Validation effort is well managed. The tools they have developed are being exercised on early equipment to validate their systems and procedures.

The Project has been diligent in testing early and often. For example, surrogate mirror and ComCam. These activities will reduce risk and provide important early experience.

Recommendations from previous reviews have been addressed.

Observations/Comments - Commissioning

For the DOE scope, there is a commissioning phase from FY18 through FY21 for $23M total funding after which Operations will commence. The FY22 date conforms to the NSF schedule.

The DOE commissioning will be treated as a project. The estimated cost of DOE commissioning increased by $7.9M from the 2017 estimate.

Continuity of key personnel during the commissioning transition will be crucial to the success of LSST. Knowledge transfer and retention will be crucial.

The remaining contingency levels for DOE and NSF are somewhat tight. The remaining levels are comparable to the prior ones, but commissioning is a new phase of work. However, a

scope plan is in place and being carefully watched.

The changes in DM are in place and functioning well. Tight coupling to commissioning activities is needed. Data Quality Monitoring at the summit would provide a short feedback loop for the commissioning teams. In addition, end to end exercise of the DM is also needed.

The remaining contingency levels for DOE commissioning and NSF project are somewhat tight. The remaining levels are comparable to the prior ones, but commissioning is a new phase of work. However, a scope plan is in place and being carefully watched.

There are 3 DOE funding sources during the time of commissioning which occur simultaneously.

A WBS and schedule with a resource loading and BOE for tasks has been created for the commissioning phase of LSST. Milestones for this period have been created. The BOE is detailed and utilizes activity based estimates, engineering estimates, comparison to past work performed and is summarized in a resource loaded roll-up.

The first item for commissioning is the Auxiliary Telescope (AuxTel). LSST has begun to plan a Transition to Operations and presented the present state of that planning. The camera staffing is ramping down, while the commissioning FTE are ramping up. The success of this transition is critical.

This review partly concerned the DOE plan for FY18 – 21 commissioning activities for LSST. Staffing for Commissioning is thought to largely come from the construction project.

Issues/Concerns - Project Progress

The project is responding to changes of management personnel in a timely fashion.

There is an expectation that AURA will enable matrixed personnel similarly to what occurs at national laboratories. This would reduce costs.

All three critical path candidates, M1/M3, the telescope and the LSSTCam should be tracked carefully and schedule risk mitigated to the extent possible.

The change of the LSST Camera Project Manager has been successful and seamless.

For the camera there is not much descope flexibility remaining given that most contracts are let and in the performance/delivery phase.

The AuxTel work in Tucson did not fully test the full capabilities of associated systems. The next chance appears to be on the summit.

The project has 8.5 months schedule float which is tight. Each subsystem manager needs to

avoid allowing the subsystem schedule to slip assuming it could be recovered later (skip tests, etc.).

LSST is moving from subsystem process to integrated system end to end products. This end game period is a change and should be given full attention by the management.

Issues/Concerns - Commissioning

The commissioning phase will put new emphasis of interfaces, procedures, etc.

The fairly new DM PM and SE PM are functioning well. Stability of the management over the transition to commissioning should be maintained if at all possible.

Perhaps scaling to other, comparable scope, telescopes would be a useful crosscheck on Commissioning planning.

During LSST commissioning the Science Validation, System Integration and Technical Coordination functions should be tightly coupled in their work.

The change in the commissioning efforts, treated now as a project, have significantly increased the estimated cost. Details and explanation should be provided at the next review.

Commissioning is of baseline quality in that WBS, BOE, schedule and Milestones, and EVMS are in place and functioning. A DOE commissioning funding profile for FY18, 19, 20 and 21 has been formulated by LSST management and delivered to the DOE.

Risk based contingency, as is usual in projects, is now in place which should reduce the chance that costs will over run.

Recommendations.

Continue to vigorously pursue the placement of key personnel into positions in Commissioning and Pre-operations. The post of Deputy PM at Chile should be filled as soon as possible.

Organize a follow-up review of the controls software effort, budget, schedule, staffing and deliverables before the end of CY2018

Instill a more schedule conscious culture throughout the LSST project organization.

Continue to rigorously plan for Transition to Operations.

Response to Charge Questions Assigned.

1.1 Progress and plans. *Is the LSST project progressing as planned, and are they making*

appropriate plans for the future work? **Conditional Yes**, but both schedule and cost contingencies are marginal and need constant management attention.

1.3 Management, risks, system engineering and procurements. I*s the project management functioning well?* **Yes**.

1.4 Transition to ops. *Is the planning for the transition to operations adequate for this stage of the project?* **Yes**

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

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?* **Yes**. *Is the planned scope complete?* **Conditiona**l **Yes**, the recent cost estimate changes need to be carefully monitored now that there is a full risk based contingency in place.

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

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?* **Yes**

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

3.5. Cost and Schedule (SC-5)

Observation/Comments.

The overall LSST Project cost and schedule baselines are:

- Total Project Cost = $467.8M (not to exceed $473M) for the NSF MREFC + $168M for the DOE MIE
- Project Completion by October 3, 2022

These have remained stable.

The Project Early Finish Date is January 2022 (8.5 months of float; originally 13 months). The Project reported that the remaining cost contingency includes the standing army cost ($1.8M/month) associated with using the remaining 8.5 months of float.

EVMS reporting is done separately for the NSF and DOE funded portions of the Project. As of April 2018, the NSF MREFC is 55% complete with 19% contingency ($39.1M) on remaining work (ETC). SPI = 0.98 CPI = 0.98. The DOE MIE is 81% complete with 28% contingency ($8.1M) on remaining work (ETC). SPI = 0.97 CPI = 0.97. A bottoms-up ETC was completed for the MREFC in April 2018.

The Project critical and near-critical paths are well defined, and the Project was able to communicate that picture in an understandable way. There are no funding issues (neither from NSF or DOE) that threaten the Project baseline.

Recommendations from previous reviews have been addressed.

Both NSF and DOE are contributing funds for the LSST Commissioning Phase during FY 2017-22. The total LSST Commissioning budget, including contingency, is $46.1M ($22.0M from NSF and $23.2M from DOE). It should be noted that the NSF portion of the commissioning budget (including contingency) is already contained in the $473M not-to-exceed cost, whereas the DOE portion is outside the MIE.

The Committee found that it was not possible to completely categorize every WBS activity as either NSF or DOE; some are a mixture using co-mingled funds. It is then not possible to neatly “projectize” the DOE funded portion, so instead, the Commissioning cost estimate and contingency has to be evaluated as an integral unit of scope.

The two parts of the Project maintain two separate sets of schedule (Primavera) & budget (Cobra) databases. One set (P6 & Cobra) contains MREFC/NSF data and the second set (P6 & Cobra) contains MIE/DOE data. Databases are maintained integrated by exchanging updated status information on Interface milestones/activities.

The Commissioning effort is included within the current MREFC/NSF construction schedule and will be maintained with schedule data for both NSF & DOE funded effort. Projects will continue to maintain separate budget (Cobra) databases for Earned Value calculations, forecasting and reporting.

The Project presented:

- Commissioning WBS (part of current WBS 1.06)
- Basis of Estimates
- Primavera schedule
- Earned Value performance reports
- Detail scope, judgments, estimates presented from Confluence tool

The Project is using a non-standard method of calculating Remaining Work which influences the % contingency based on Remaining Work calculation (EAC - ACWP = Remaining Work.) This method is not consistent with SLAC Procedure

Issues/Concerns.

The LSST Project is supported by two Federal funding agencies, who have quite different approaches to handling research facility construction projects through completion, commissioning and transition to operations. This results in a rather complex funding picture that covers construction through research operations. It is a challenge to communicate this picture to external audiences in an easily understood way.

The Commissioning cost estimate and schedule generally appeared to be comprehensive and appropriately detailed. The Basis of Estimate was of baseline-quality. There was a reasonable amount of risk-based and activities-based cost uncertainty contingency included in the DOE estimate (35% of the $23.2M). The Committee believes that the full Commissioning scope can be delivered for the sum of the assumed NSF and DOE annual funding profiles (including contingency).

Contingency on the MREFC element remains tight (similar to a year ago) with almost half of the scope (by value) left to go, and that part arguably involves the most difficult and most risky activities. There are a limited number of descope options, many of which would significantly increase project risk.

The Project uses a non-standard method of calculating Remaining Work. This may cause confusion when presenting % Contingency against Remaining Work

With 8.5 months of remaining float, the overall LSST Project schedule is tight and any of the three controlling schedule paths (M1M3, Camera, and TMA) could easily become the critical path at any time. Management is well aware of this and realistically expects to need all available float to deliver the project.

As these project elements converge into integration/assembly, there are certain risks that are most likely to be realized and will consume float. Management should keep its attention focused on these and thoroughly understand how much cost and schedule contingency use they might require.

At this stage of the Project, there are only a limited number of scope contingency options left available. This is especially true for the Camera.

Recommendations.

For the upcoming joint agency review, consider how to most confidently show that the cost and schedule contingency burn rates will be managed to deliver the project on time within cost.

For the upcoming joint agency review, directly address in the plenary session the fundamental reasons for the large estimate increase (compared to previous 2017 estimate) in the DOE-funded part of LSST Commissioning.

For the upcoming joint agency review, communicate early in the presentations the methodology used to calculate Remaining Work to avoid confusion.

For the upcoming joint agency review, develop a graphic (cartoon) that reflects the architecture of the EVMS databases and how they integrate data while maintaining the required separation.

Response to Charge Questions Assigned.

1.2 Cost & Schedule performance. Are the current cost and schedule performance and their future trends acceptable? **Yes, but management cannot afford to feel comfortable.** 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? **Both cost and schedule contingency must be closely monitored and controlled to be successful.** *Have changes to the Project Management Control System (PMCS) been properly incorporated?* **Yes.** *Is the change control process solid and is it being followed correctly?* **Yes.**

2.3 Cost and schedule. *Have appropriate cost and schedule estimates been developed for the Commissioning Phase?* **Yes.** *Are the full scope costs and contingencies covered by the combination of DOE and NSF funding?* **Yes.** *Is there a clear understanding and justification for the breakdown of costs that will be supported by separate DOE and NSF funding lines?* **Yes.** *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?* **Yes, it is an extension of the existing PMCS.** *Is the schedule consistent and coordinated with the ongoing construction effort and planned onset of Full Operations?* **Yes.**

3.6. Environment, Safety and Health (SC-6)

Observation/comments.
Safety has been given high priority on the LSST project. The structure of the LSST safety program is reflective of DOE's Safety Management System Policy and Integrated Safety Management principles ensuring protection of workers and the project hardware.

Safety receives *continued attention by project senior management* which includes regular field presence with demonstrated focus on safety and support of requests for additional safety support in the form of personnel and emergency response equipment.

The project has *well developed safety documentation* defining personnel safety roles and responsibilities (LPM-18 and R2A2s) and identifying applicable safety standards and project requirements. LSST also has in place a clearly defined Hazard Identification and Mitigation Process (LPM-49).

Effectiveness of the LSST safety program is reflected in its very low *Total Recordable Incident Rate (TRIR),* a measure of occurrence and recordable incidents reflecting the number of injuries per 100 workers over the span of one year.

LSST's TRIR of .37 is 1/11 of the US national average for construction which is 4.0 and *1/4 of that of DOE* construction projects of 1.3.

Accident/ Injury response protocols in Chile have been clearly defined for the LSST.

All safety recommendations from past reviews have been addressed.

Issues/concerns. None.

Recommendations.

Formalize the safety-level review and sign-off of the installation of all telescope, instrumentation, and infrastructure systems to ensure compliance with design, code, and LSST internal safety requirements to document the effort of the individuals already on staff to perform this function.

Response to Charge Questions Assigned.
JOINT DIRECTOR'S Progress REVIEW

Are Environment, Safety & Health issues handled appropriately? **Yes.** *Are Integrated Safety Management Principles being followed?* **Yes.** *Does the project have an acceptable safety record?* **Yes.** *Has the project responded satisfactorily to recommendations from previous reviews?* **Yes.**

REVIEW OF THE COMMISSIONING PHASE

Are the Environment, Safety, and Health aspects of all anticipated work being properly

assessed and managed? **Yes.** *Are Integrated Safety Management Principles being followed?* **Yes.** *Has the Project responded satisfactorily to recommendations from previous reviews that bear on the Commissioning Phase?* **Yes.**

3.7. Education and Public Outreach (SC-7)

Observation/Comments.

The committee formulated a positive overall assessment of EPO sub-system at LSST.

Establishing the Communications function separate from EPO is confusing - since not necessarily intuitive - for someone not intimately familiar with the project. Currently, this confusion is mitigated through a good interaction between the respective Leads and by two individuals who are shared between departments. In the future, the Communications and the EPO functions will merge during Operations, which seems to be the right thing to do.

The EPO sub-system started later, for valid reasons. It is important to note though that the EPO component was considered within the project from the outset, following best practice.

Another notable good practice is that the EPO Head and EPO Project Manager are part of the leadership structure, allowing EPO to be well integrated and part of the decision-making process. It is further noted that an extensive EPO-specific peer review was conducted at the end of 2017 involving education, science centre and science communication specialists. Outcomes were very positive, confirming the reviewer overall impression. Another positive indication consists of a good integration of the Spanish-language and, where applicable, Chile-specific elements into the EPO programme.

As an example of promotional material aimed at a general audience, it might be interesting to generate “LSST by the Numbers”: 8.4 m diameter mirror, so many tons of glass, 3.1 Gpixels, # petaflops compute power, # actuators, etc.

Issues/Concerns.

A “blurry” line between Communications (which sits within Project Office) and EPO (sub-system) activities, including an apparent overlap at times, is an issue, in particular considering the different funding streams and associated scope constraints for those two functions (see recommendation.)

A lack of an LSST brand policy and guidelines at the project level could lead to a misuse of the brand and its derivatives which is a challenge for EPO to develop its policy and interaction with international partners. (See recommendation.)

Based on the information provided to the panel, the evaluation element of the EPO programme seems more qualitative than quantitative. In particular, a list of clear Key Performance Indicators (KPIs) is missing in the review documentation to allow a more thorough analysis of the impact of EPO programme, and recommend some potential readjustment.

(Soft) issues/concerns that relate to presentations in preparation for Joint Agency Review:

a. It is suggested that the LSST Mission Statement be included at the start of the DG’s presentation. This allows to re-state the overarching objective and direction

of travel.

b. Considering that the Communications function sits within the Project Office, it is suggested that a mention of this function and what it actually covers be included in the Project Manager's overview presentation. This would also have the benefit to manage expectations ahead of the EPO talk.
c. The EPO sub-system is poorly featured in Project Execution Plan and would deserved to be fleshed out, in particular including a reference to the EPO Design document.
d. Considering the multiple locations of LSST facilities in Chile, it is suggest that a map be developed and used in presentations where relevant. This would ensure a good understanding of logistics issues -among others- at the site.
e. There are too many acronyms in the presentations and it is suggested to use plain words as much as possible.
f. The EPO peer-review Report following the review undertaken late 2017 should be included in the Reference document pack for upcoming reviews. A reference to such review should also be made in the presentation and highlighted as best practice.
g. It is suggested that more emphasis be put on the evaluation element of the EPO plan in the EPO presentation, highlighting the relevant KPI's being tracked enabling to measure progress and assess what impact/benefits the programme has had and is expected to have.

Recommendations.

1. In partnership with Communications, start developing an overarching Communications Strategy covering the transition from the Construction Project to Operations.

- Such strategy should be fully aligned with and support the objectives of the LSST Project and the LSST governing bodies.
- It should consider the management of the transition of EPO/Comms staff into a single department during Operations.
- It should also be inclusive, considering the needs and aspirations of the LSST partners and providing them clear direction, rules and guidelines under which they are expected to operate. This would allow reinforcing the one-project concept across the partnership while capitalising on expertise and resources at partner institutions.
- Spanish-language and Chile-specific elements should be included in such strategy.

2. Identify a risk that relates to the lack of a timely decision on re-branding.

- The transition from a construction project to a fully-operational world-class instrument provides a key opportunity to evolve the LSST brand to ensure it is fit for purpose and truly reflects the identity (vision, mission, values) of the project.
- A re-branding exercise also offers a real PR opportunity to raise awareness, increase the profile of the project and embed it in the popular culture, with the potential to significantly enlarge the LSST community and expand the number of non-professional users.
- Delaying a decision on a potential re-branding (regardless of the outcome) would have an impact of the development of those short- and mid-term deliverables that will remain post construction and commissioning (examples are the future EPO website, multimedia material, social media, policy documents, etc.), turning what is now an opportunity into a

risk to the EPO programme.

3. Look into partnership opportunities with existing science education programmes whose networks would benefit user testing and future marketing activities.

- A number of astronomy education initiatives have flourished in the recent years targeting audiences of relevance for LSST EPO -examples of well-succeeded practices include Galileo Teachers Training Programme, Global Hands-on Universe, Network for Astronomy School Education, Universe Awareness, etc.
- Partnering with those programmes and leveraging their existing networks would help maximize the diversity of participants in future user testing exercises, and boost the LSST EPO programme and its marketing opportunities under the principle of minimum effort/maximum return.

Response to Charge Questions Assigned.

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?*

Yes. The EPO programme shows an impressive level of maturity considering its stage of development. It seems now well in place and on track against the deliverables. Significant achievements were made in EPO last year, including the completion of several key deliverables and the hiring of 4 FTEs. Another critical recruitment is underway to fill the post of Astronomy Outreach Specialist.

The team seems appropriately skilled, with a clear and thoughtful plan to fill remaining positions. In particular, the hiring of remaining software developers has been put on hold while technical requirements are further refined through EPO prototyping activities. A comfortable EPO budget also allows for using consultants and contracting out relevant activities.

A comprehensive and thoughtful plan going forward was presented to the reviewers, suited to the current phase of the project. The Spanish-language and, where relevant, Chile-specific element is fully embedded in the EPO programme.

The interaction and integration with other subsystems seems to be working well, in particular with DM. This is backed by a continuous reference of EPO requirements and needs in DM-specific presentations and others.

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

Yes. The LSST project even went one step further, organising an EPO-specific review at the end of 2017. This demonstrates a willingness and eagerness to aim at a high-quality EPO programme, informed by experts in the field and embedding best practices. This initiative should be acknowledged.

2.2 Management and organization. *Is an appropriate risk registry maturing and have the*

appropriate risk and mitigations been identified?

Conditional Yes. A risk on a delay in making a decision regarding re-branding should be added (see more details in recommendation #2)

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?*

Response from EPO perspective: Yes. The current EPO strategy covers the period leading up to operations, and its scope is limited to the EPO function. Considering the plan to merge the EPO and Communications function into a single department as the project enters Operations, a strategy addressing the transition and early operations phase and covering the wide corporate/strategic communications, marketing, education and public outreach spectrum should be developed (see recommendation #1). *A plan seems in place to develop this strategy.*

Furthermore, the transfer of staffing from Construction through Commissioning and Operations is well thought through to ensure a seamless continuity of the EPO programme and appropriate knowledge transfer. One-to-one discussions have already happened to identify those individuals to fill the posts needed during Operations.

4.0 Conclusions.

The LSST staff and leadership have made excellent progress since the last joint agency annual review!

Part 1: Overall Progress Review: *Considering the LSST project's performance to date and the execution plan for the future (including the technical scope, cost, schedule, safety and risk management plans)****, can the planned facility be delivered according to the current project plan?***

Conditional Yes. The committee identified heightened schedule risk that exists with multiple, converging controlling work paths and the ramp up to site integration; scope, schedule and budget contingency balances are tight considering the current project risk profile.

Part 2: Review of the commissioning phase: *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?***

Yes.

Appendix A-Review Committee Membership and Contacts

(*= subcommittee chair)

Co-chairs

Fred Gilman (CMU/AMCL)	gilman@andrew.cmu.edu
Carl Strawbridge (SLAC)	cstraw@slac.stanford.edu

SC-1: Data Management

Richard Mount (SLAC) *	rpmount@gmail.com
Tamas Budavari (JHU)	budavari@jhu.edu
Arjun Dey (NOAO)	dey@noao.edu

SC-2: Camera

Brenna Flaugher (FNAL) *	brenna@fnal.gov
Jay Bixler (LLNL)	bixler1@llnl.gov
John Matthews (Utah)	jnm@cosmic.utah.edu

SC-3: Telescope and Site

Tony Travouillon (ANU) *	tony.travouillon@anu.edu.au
Dave Sawyer(Lowell)	dsawyer@lowell.edu
David Carroll (LBTO)	dcarroll@lbto.org

SC-4: Project Management/Systems Engineering

Dan Green (FNAL) *	dgreen@fnal.gov
Lowell Klaisner (Consultant)	lowell@klaisner.com
Greg Wray (SLAC)	wraygb@outlook.com

SC-5: Cost and Schedule

Jeff Hoy (SLAC) *	chipsvienna@gmail.com
Felix Fernandez (SLAC)	fbf@slac.stanford.edu
Julia Chaffin (SLAC)	jchaffin@slac.stanford.edu

SC-6: Environment, Safety and Health

Richard Hislop (Consultant) *	richard.hislop@gmail.com
David Carroll (LBTO)	dcarroll@lbto.org

SC-7: Education and Public Outreach

William Garnier (SKA)	W.Garnier@skatelescope.org

Appendix B-Review Charge

SLAC NATIONAL ACCELERATOR LABORATORY

OFFICE OF THE DIRECTOR

TO: Norbert Holtkamp, SLAC Deputy Director

FROM: Chi-Chang Kao, SLAC Director

CC: Julia Chaffin, Steven Kahn, Vincent Riot, Carl Strawbridge

DATE: May 17, 2018

SUBJECT: LSST Director's Status Review

I request that your Office organize and conduct a Director's Review of the Large Synoptic Survey Telescope (LSST) project at the SLAC National Accelerator Laboratory on June 25-29, 2018. The purpose of this review is to access the project's readiness for the DOE Independent Project Review, July 30- August 3, 2018.

The purpose of this review is to assess the current status of the project, to evaluate plans for the future with emphasis on the next year of construction, and to assess the project's commissioning plans in depth. The review will be conducted to conform to both NSF and DOE requirements for annual progress reviews. Construction of the LSST Project is jointly supported by NSF and DOE. 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 $473 million. The DOE-deliverable portion of the LSST Project is the imaging camera system with a total project cost of $168 million funded as a Major Item of Equipment project. With private support of $39 million, the full construction cost is $680 million.

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 and operations activities and their funding are part of a separate planning exercise.

The LSST Project is organized by Work Breakdown Structure (WBS) under the headings "1. Project Management Office," "2. Data Management," "3. Camera," "4. Telescope and Site," "5. Education and Public Outreach," and "6. Systems Engineering and Commissioning." The Project is a unified, single project but with complex organization and support from two separate federal agencies with different policies and procedures. The panel is asked to consider throughout this technical, cost, and schedule review, how well integrated the project actually

is, especially regarding Project Management, and to draw attention to any interface issues they may identify.

The LSST Project will share all necessary documentation with the review panel through a web-based repository, available approximately a week before the review starts. This will include the Project Execution Plan, which contains the performance baseline against which success is to be measured. We expect that pre-review communications with the panel by both the LSST Project and the Agencies will be by email.

The review panel is requested to prepare a closeout presentation for the project, containing their major recommendations, which will be given on the last day.

Charge to the Panel for the Progress and Commissioning Review

Part 1. Considering the LSST Project's performance to date, and the execution plan for the future, including technical scope, cost, schedule, 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?

In carrying out its charge, the review committee should respond to the following questions:

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

the 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?

Carl Strawbridge and Fred Gilman will serve as the co-chairs for this review. I would appreciate receiving your committee's report within 30 days of the review's conclusion.