Director's Status Review of the Large Synoptic Survey Telescope (LSST) Project

Close-Out Briefing

August 8, 2019 SLAC National Accelerator Laboratory

Committee Membership

(* = subcommittee chair)

Co-Chairs: B. Barish (Caltech), J. Tapia (SLAC)

SC-1: Data Management Alex Szalay (JHU)*, Richard Dubois (SLAC)

SC-2: Camera John Matthews (U of Utah)*, Brenna Flaugher (FNAL)

SC-3: Telescope and Site David Sawyer (Lowell)*, Warren Skidmore (TMT)

SC-4: Project Management Jeff Hoy (retired DOE)*, Lowell Klaisner (retired SLAC)

Committee Membership

(* = subcommittee chair)

SC-5: Cost and Schedule Michael Barry (LBNL)*, David Sala (SLAC)

SC-6: ES&H David Carroll (LBTO)*, Ian Evans (SLAC)

SC-7: Education and Public Outreach William Garnier (SKA)*

1. <u>**Project Scope:**</u> Is the LSST project progressing as planned, and are they making appropriate plans for future construction and commissioning work?

Are all activities consistent with the baseline project objectives as described in the Project Execution Plan? Is there adequate progress and planning across all Work Breakdown Structure (WBS) elements, including both in-house efforts and external procurements and contracts? Are there appropriate plans for realizing opportunities and for mitigating risks? Are the plans for assembly, integration, test, and commissioning phases complete, achievable, and well understood by the commissioning team? **(SC-1, 2, 3)**

2. <u>Cost and Schedule:</u> Are the current cost and schedule (C&S) performance and their future trends acceptable?

Are the budgets and contingencies for the full scope of the NSF deliverables and DOE deliverables covered by each agency's funding plans? Do the performance to-date and C&S trends give confidence that the project can complete successfully on time and within budget? Is there adequate reporting for both funding agencies? Have changes to the Project Management Control System (PMCS) been properly incorporated? Is the change control process solid and is it being followed correctly? **(SC-5)**

3. <u>Project Management:</u> Is the project management functioning well?

Are there clear lines of authority and responsibility? Are the interfaces between DOE- and NSF-supported activities managed appropriately? 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? (SC-4)

4. <u>**Transition to Ops:**</u> Is the planning for the transition to operations adequate for this stage of the project?

Will essential materials, including manuals, maintenance plans, test reports, and as-built drawings, be ready when needed? Is planning for the transition of personnel sufficiently developed and being appropriately communicated to staff? (SC-1, 2, 3, 4, & 6)

5. <u>Education and Public Outreach</u>: Are the Education and Public Outreach activities properly planned and executed? Is the EPO team the right size with the right skills? Is it engaged and integrated as appropriate?(SC-7)

6. <u>ES&H:</u> Are Environment, Safety & Health (ES&H) issues managed appropriately? Does the project have an acceptable safety record? Are Integrated Safety Management Principles being followed? (SC-6)

7. <u>Recommendations:</u> Has the project responded satisfactorily to recommendations from previous reviews? (AII)

Subcommittee 1: Data Management

Subcommittee Chair – Alex Szalay (JHU)

Subcommittee Members – Richard Dubois (SLAC)

Observations Issues/Concerns Recommendations Charge Response

- DM'a stated mission is to "Stand up operable, maintainable, quality services to deliver high-quality LSST data products for science, all on time and within reasonable cost.". This makes clear the boundary between DM in construction and in operations, wherein the systems are operated to create the data products.
- DM has 6 departments: Science Pipelines, DAX, LSP, QA, Data Facility and Mountain and Base sites staffed by 65 FTEs, originating from 96 people.
- Primary products are pipelines for Alerts and Data Releases; the DAC & LSP are provided for access to data and analysis. The code base exceeds 1M loc.
- The analysis concept is to bring the code to the data, via the LSP at the DACs. About 10% of the NCSA facility resources will be devoted to users.

- DM is preparing for commissioning and has a well-defined set of required elements needed. They have demonstrated transferring camera test data from Chile to NCSA and making it available in the LSP for analysis.
- Significant progress has been made, including a design for the Alert Filtering Service, several improvements to the camera pipeline (including a new deblender and brighter-fatter corrections). HSC precursor data is routinely reprocessed. The LSP was reviewed in April 2019, and is in use by the Commissioning team. The Qserv database is in use at NCSA and CC-INP3 with 50% capacity demonstrated. Emphasis is being placed on IVOA standards for data access, including TAP/ADQL query service, SODA image cutout service, and AstroPy PyVO Python client library improvements.
- Camera and LATISS test data is being transferred to NCSA and made available via1 the Gen 3 Butler

- NCSA delivered multiple services: Kubernetes, Qserv, HTCondor; authorization & authentication support to LSST in Chile. Demonstrated Workflow on HTCondor and Butler based on an Oracle database running with "Generation 3" DM middleware.
- The Notebook aspect is now the norm in the LSP. InfluxDb has been adopted for tracking metrics, both for requirements performance, and eventually for pipeline performance. InfluxDb also has become the technology for the EFD.
- The sizing model for NCSA dates back to 2013 and was extrapolated from Sloan experience
- CC-IN2P3 will be an operational partner with the Facility, running about half of the DRP processing. It is envisaged that it will be a "slave" facility, with pipeline job dispatch originating from NCSA.

- DM has successfully investigated cloud solutions, for both the LSP and DRP, with Google and AWS. They are continuing to follow pricing and negotiating with these providers. It is entirely possible that price points will end up favouring cloud deployments rather than facility-owned hardware. Again, nimbleness is key.
- Over the scope of the project there may be opportunities to use free HPC resources for the data processing at little or no direct cost. This should not be left unexplored.
- DM has started to identify anticipated similarities and differences among usage patterns for the different data products, and how these would impact the service implementations (relational, object oriented, qserv)

Kudos

- The DM group has shown to be much more cohesive than any time in the past; they are now working towards common goals as a real team.
- Significant progress has been made over the past year
- We thank the DM team for clear presentations and prompt responses to our questions

- The DRP sizing model dates from 2013; should do a refresh at regular intervals as algorithms evolve
- Major processing at scale requires capable tooling to allow diagnosis and recovery from errors as well as excellent overviews of the status. Such tooling also minimizes the person effort involved in operating the workflows. They will need to exercise the system at scale ~1 year before survey starts, including at any remote sites. Having the tooling in place may require determining soon whether an external system exists (or pieces can be patched together) or if custom tooling is needed.

- DM will potentially be stressed by reassignment of roles in the Ops funding rebalancing; they also will need to plan carefully as Ops transitions happen during Commissioning. There could be morale issues as well as problems matching the skill sets to operations roles.
- Science query patterns are still largely unknown. It is notoriously difficult to poll scientists prior to real data analysis on how they would go about it. This may require some nimbleness in design to accommodate a range of patterns from fully relational to full object/file based.

- It is clear that by the end of the survey most of the data and services will be operated on a commercial cloud platform. How and when such a migration will happen is still unclear, and the complexities and know-how of operating in the cloud at scale may be underestimated (moving data in/out on PB scales, different staffing skill-set, underestimated hidden costs). The details of the cloud migration will depend on external factors (pricing of cloud providers), thus during the development phase multiple alternative migration models should be evaluated.
- While not formally required of DM, a goal is to include algorithms from the science community in the areas of photo-Z's and shear maps, and potentially collaborating on blending and PSF algorithms. An issue is that the community needs time to develop these algorithms and needs functionality from DM that may not align with DM's schedule. We do note the LSST Algorithms workshop scheduled for December as a good step interacting with the community.

Recommendations

- We recommend to continue exploring heterogeneous computing resources, as the Facility may be forced by budget pressure to utilize these as they are available. Planning for an elastic deployment capability would provide risk mitigation.
- 2. More effort should be spent on refining diagnosis and recovery from processing errors as this will be critical for operating at scale. This includes automated recovery from errors at multiple levels.

Response to the Charge Questions

- Project Scope:
 - Is the LSST project progressing as planned, and are they making appropriate plans for future construction and commissioning work?

yes.

- Are all activities consistent with the baseline project objectives as described in the Project Execution Plan?

yes.

 Is there adequate progress and planning across all Work Breakdown Structure (WBS) elements, including both in-house efforts and external procurements and contracts?

yes.

Response to the Charge Questions

- Project Scope:
 - Are there appropriate plans for realizing opportunities and for mitigating risks?

yes.

 Are the plans for assembly, integration, test, and commissioning phases complete, achievable, and well understood by the commissioning team?

yes.

Response to the Charge Questions

- Transition to Ops:
 - Is the planning for the transition to operations adequate for this stage of the project?

yes.

 Will essential materials, including manuals, maintenance plans, test reports, and as-built drawings, be ready when needed?

yes.

 Is planning for the transition of personnel sufficiently developed and being appropriately communicated to staff?

Yes, but uncertainties in the Operations funding model makes it impossible for them to finalize the staff transition plan and any communications with $_{21}$ staff.

Response to the Charge Questions

- <u>Response to Previous Reviews:</u>
 - Has the project responded satisfactorily to recommendations from previous reviews??

Yes

Subcommittee 2: Camera

Subcommittee Chair – John Matthews (U of Utah)

Subcommittee Members – Brenna Flaugher (FNAL)

Observations Issues/Concerns Recommendations Charge Response

- The Camera project has made enormous progress in the past year
 - Sensor procurement is complete thus closing the risks and worries of the last review
 - Raft production is complete
 - Several cost accounts are already closed and others are close
 - Ramp down of personnel on the MIE project has begun with some transitions to the commissioning team already in progress
- The optics have made great progress
- One filter was completed in March 2019, but full characterization has been delayed
- Shutter prototype testing is complete, however the production shutter is not yet complete
- Filter exchange mechanism (IN2P3) is well advanced, but is now near the critical 24 path

- Cryostat is nearly complete, although demonstration of cooling and vacuum systems with the full load of rafts remains
- Clogs in the capillary cooling pipes were found and a procedure was developed for avoiding them this has been successful so far
- Integration and testing has begun. Plan to load 9 science rafts and cool down again
- As of this meeting, the corner rafts and 2 science rafts have been installed
- DAQ system is prepared to support a 9 raft test, however issues with scaling up to a full system test remain - the issue should be resolved with an upcoming software update for a problematic commercial switch
- A dedicated raft of sensors was build for ComCam using "almost science quality" sensors. Later, this could be used as a spare
- ComCam has been delivered to Tucson

- In Fall 2018, contamination in the rafts causing ~0.5% dead pixels was observed The project took aggressive action to identify, mitigate future contamination and remove the debris from completed rafts. This work is nearly complete and is well documented. The number of dead pixels has been reduced and the risk of future contamination has been minimized.
- A washer from a connector is missing and may be in the cryostat. After an exhaustive search the project has concluded the risk of it being in the cryostat is very small. They documented their actions and potential future risk before proceeding.
- The Filter Changer is a complicated system with multiple subsystems (carousel, insertion/removal, and changer) with a lot of software and hardware interlocks that are integrated with the camera control system.
- About ¹/₃ of the mass budget has been verified. Less than 100kg of budget remaines

- The Clean and White rooms on the mountain have been prepared and are ready to receive ComCam and Telescope
- Commissioning is being managed as a project with EVMS.
- The plan to ship the camera via chartered aircraft remains the primary option and cost, packing, transporting, etc continue to be optimized
- Plan to ship the test mass to mitigate risks probably by sea
- There exists a good property tracking system which includes customs lists for AURA, photos when the items arrive in LaSerena, and notices at the morning meeting so that equipment gets where it is needed.

Observations

Operations

- Operations team leadership is well engaged in both the MREFC and MIE projects.
- Operations team is considering taking an early look at the operational procedures and technical documentation, in time to provide feedback to construction teams.
- Although funding model for Operations has changed, the scope is the same. International partners might off-set some scope via in-kind contributions.
- Redistribution of effort between AURA/NSF and SLAC/DOE operations roles (from ~ 75-25 to ~ 50-50) is in progress and impacts staff transitions from the projects to Ops.

- The project should be commended for establishing a policy of "Notice to Proceed" reviews before first power and after any substantial change
- The project has developed an effective set of daily tailgate meetings and holds weekly meetings for planning (and replanning as needed) activities for the following weeks.
- Major item procurement for the project is complete. The last major item is a cryostat integration stand which is due this month
- <1% of awards remain to be made, nothing >\$50k
- The remaining cost and schedule contingency is small.

- The project is in a very intense period. Cost and schedule pressure is inevitable but management should take an active and aggressive role to ensure that the teams are proceeding with the utmost care.
- Complete and comprehensive testing, integration and commissioning, while the experts are still available to the project, is critical to the long term success of the survey.
- Project has a comprehensive approach to monitoring and replanning site integration and commissioning activities as events evolve with the TMA and the camera. A strategic approach is used to optimize daily and weekly activities with a view to longer term impacts.

- Although production filters and shutters are not yet complete, the project is on a path for success and should continue to closely monitor progress and float.
- Identified risks (cooling clogs, vac. and cooling with full complement of rafts, scaling DAQ to full complement) have been addressed and documented, but some risk remains. Much will be learned in next few months when the camera is operated with 9 science rafts.
- The capillary de-clog procedure may not work as well when the camera is connected to the full cooling system at the top of the telescope. Tests with LSSTCam on the floor in Chile and with the pathfinder/comcam are important for addressing these risks.

- In the presentations, it was sometimes hard to follow the status and where things are located and plans for future shipments. Shipped to the project could mean at Tucson or on Mt in Chile. E.g ComCam. A high level description of what goes to Tucson and what goes directly to Chile with dates would be helpful in one of the early plenary talks in addition to the later talks.
- In the commissioning status slides it would be helpful to have the total subsystem cost on each slide to put the variances in perspective along with a comment indicating it is recoverable (or not)
- The project has an excellent system for tracking risks as they transfer from MIE to commissioning to Operations.

- The commissioning manager has an excellent understanding of the cost and schedule and is making good use of the EVMS tools
- Camera operations and documentation of performance are making great progress
- The project is doing an excellent job of optimizing the remaining activities.
- Finishing the project with the remaining contingency looks doable, but challenging.
- Project is doing a good job planning for the transition to operations

- The complexity of the filter changer software, hardware, the numerous configurations under which it will be tested, the institutional separation of responsibilities and the safety incident are a concern and merit extra attention.
- Membership of Operations leadership in the CCB is an excellent way to ensure the transition to operations is smooth
- Early evaluation of the project (MREFC and MIE) documentation by the operations team is an excellent way to ensure the documentation will meet the needs of the operations team.
- Delayed definition of NSF/DOE operations scope could impact preparation for the joint operations review which could then impact the ability to get the plan and funding approved before the pre-ops funding is exhausted.

Recommendations

- 1. Continue to work with AURA, NSF, SLAC and DOE on development of the operations roles and funding model
- 2. After delivery to SLAC, perform a formal review of the filter changer system to be assured that the principles of readiness have been evaluated, including hardware, software, and interlocks all function as designed, all configurations for testing and operation have been fully evaluated and documented; staff roles and responsibilities have been defined, required training is defined and complete and all documentation signed off and in place before the start of commissioning
- 3. Perform a similar review for the shutter assembly

Recommendations

- 4. Consider contracting with an experienced transportation company to evaluate and test the camera shipping frame and plans to mitigate the risk in shipping
- 5. The presentations should adjusted for the Joint Status Review to focus the emphasis to present more about future activities and less on the past
- 6. Evaluate the effects of exceeding the mass budget affects performance
Response to the Charge Questions

- Project Scope:
 - Is the LSST project progressing as planned, and are they making appropriate plans for future construction and commissioning work?

yes

 Are all activities consistent with the baseline project objectives as described in the Project Execution Plan?

yes

 Is there adequate progress and planning across all Work Breakdown Structure (WBS) elements, including both in-house efforts and external procurements and contracts?

Response to the Charge Questions

- Project Scope:
 - Are there appropriate plans for realizing opportunities and for mitigating risks?
 - yes although the opportunities for reducing cost and schedule are nearly exhausted
 - Are the plans for assembly, integration, test, and commissioning phases complete, achievable, and well understood by the commissioning team?

yes - however, delays in the TMA are compressing the time (and funding) available for on-telescope commissioning

Response to the Charge Questions

- Transition to Ops:
 - Is the planning for the transition to operations adequate for this stage of the project?

yes

 Will essential materials, including manuals, maintenance plans, test reports, and as-built drawings, be ready when needed?

yes

 Is planning for the transition of personnel sufficiently developed and being appropriately communicated to staff?

Not yet, the uncertainties in NSF/DOE scope are preventing this

Response to the Charge Questions

- <u>Response to Previous Reviews:</u>
 - Has the project responded satisfactorily to recommendations from previous reviews??

yes

Subcommittee 3: Telescope and Site

Subcommittee Chair – David Sawyer (Lowell)

Subcommittee Members – Warren Skidmore (TMT)

Observations Issues/Concerns Recommendations Charge Response

- Significant progress has been made in the last year:
 - M1M3 delivered to the site
 - M2 Hexapod/rotator delivered. M2 successfully coated.
 - Coating plant installed and tested
 - Summit facilities nearly complete
 - Dome steel construction is nearly complete, but this is behind schedule and starting to impact the project schedule. Many deliverables still pending (e.g. overhead crane, light/wind screen, louvers). More in Issues/Concerns..
 - TMA has been shipped from the factory and installation of support systems (e.g. hydrostatic bearing oil and cooling fluid is underway).
 - Auxiliary telescope is functional and ready for spectrograph.

- The OCS appears to be well under control and does not appear to be a critical path concern. This is a significant positive change from a year ago, but was not obvious from the plenary talks. See recommendation #1.
- The AOS development is proceeding well and good plans are in place to conduct simulations and early testing as much as possible.
- The observatory software development appears very comprehensive, all areas being addressed. The software team is actively communicating/collaborating with camera and TMA groups. A TMA simulator is being developed.

- Systems Engineering tools are in place and are being used to track verification testing and compliance. Subsystem performance is exceeding requirements.
- The process of evaluating progress, problems and readjusting the schedule is operating fairly well and the top level LCR process allows for rebaselining the project schedule before end of CY2019 (when Dome and TMA progress are known)
- The efficiency of implementing changes to schedule or staffing resulting from the LCR process needs to be improved. This process needs to happen almost real-time to minimize schedule delays.
- In the SITCom schedule, DOE and NSF funded tasks are separately described in the schedule.

- Integration and Commissioning Replan for SIT-Com is a good approach for integrating the many parallel activities planned. The SIT-Com management and team appear to be well defined.
- All areas of activity key to delivering the science capabilities (dome and TMA assembly, AIV/SITCom, observatory software and data management) have significant levels of staffing comprised of LSST staff, LSST engaged personnel and teams from contractors.
- Mitigating activities and measures that deviate from the baseline plan (e.g. temporary dome drive, tests based around ComCam and M2 off the TMA) do not appear to add any significant burdens that could complicate assembly work, except for the temporary dome crane.

- T&S Cost and Schedule are realistic but very success oriented. Not many descope options remain, but performance margins have room for contingency.
- Safety is clearly a top priority for the team. But the fact that there have been some injury incidents emphasizes the need to remain vigilant about safety especially with the increasing pressures of schedule deadlines and the higher levels of activity on the summit.
- Transition to operations workshops are being conducted for knowledge transfer (e.g. TMA control, Dome control), operations staff are transitioning from the project staff and/or are being integrated into the SIT-Com efforts.
- There is a confident track to keep SLAC personnel engaged with ComCam and LSSTCam tasks through to when LSSTCam is installed on the TMA

- Schedule contingency only 3.5 months
 - 5 months of contingency used in last 18 months for fabrication delays not leaving much contingency for AIV and commissioning unknowns.
 - Dome construction is on the critical path and needs a lot of work completed by October 1, 2019 before it has a direct impact on this remaining contingency. The work needed to be complete by Oct. 1 (cladding, provisional crane installation, louvers, and shutter) seems overly optimistic and will thus will likely require schedule contingency.
 - Factory tests deferred to on-site AIV due to fabrication delays (e.g. TMA control system tests) - adds schedule risk to AIV effort

- Dome construction
 - Vendor and resource issues are being addressed, but timeline is concern.
 - Replacing the temporary dome crane could impact the schedule later and risks associated with the replacement of the provisional dome drive needs better investigation due to potential conflicts of tasks in the same space and risk of damage to the TMA. See recommendation #7
 - The vendor has a good reputation and the LSST team has a good relationship with them. However, due to vendor financial problems, there appears to be some uncertainty in the timeline of receiving incomplete deliverables (e.g. louvers, wind screen).

- T & S Project Management
 - Loss of project manager (B. Gressler) at critical time beginning systems integration
 - Contract issues with dome and TMA contractors aggressive contract oversight of the dome is essential.
 - Tasks re-assigned, but concern of over-committing existing resources or deferring other important tasks
 - There are no documented connections of the staff transitioning from SITCom planning to operations but there is lots of expectation on the part of the LSST team about transfers of staff from SITCom to operations (see Management recommendations)

- SITCom
 - Scheduling for SITCom is realistic and acknowledges the complex process(es) that is(are) commissioning. There is time built in for dealing with the inevitable, but a priori, unknown 'punch-list' items. If there is schedule pressure then there may be pressure to reduce the punch-list schedule allocations. These need to be carefully prioritized to address the most pressing needs.
 - The planning for SITCom is very dynamic as there are a lot of moving parts and uncertain timelines. This will require frequent replanning in order to deal with inevitable setbacks. See recommendation #2

- SITCom
 - The Test Specification and Test Plan and Report documents appear to relatively immature, many tests are not described at this stage and may not reflect the maturity of the SITCom schedule. See recommendation #6.
- Observatory Control System
 - The status of the OCS was not described in the plenary presentations

- Staff turnover is a reality and is having some impact on team organization and schedule. This is being managed, but in some cases could be over-burdening other staff that are assuming more responsibilities (temporarily or permanently).
- Single point failures in the staffing plan is a concern, but the project is taking steps to broaden the knowledge base through cross training, boot camps, etc.

Recommendations

- 1. Since the Observatory Control System was a concern at the last review, we recommend including a more thorough status update in the JSR plenary talks. We don't believe OCS is a risk anymore, but there have been significant changes to the group organization and the OCS has been replanned, so a more detailed explanation would be helpful.
- Develop SITCom contingency plans for various scenarios of construction delays e.g. Dome not closed in by October 1, provisional dome crane not certified, TMA testing delays, etc. Consider various task sequencing options.
- 3. Eliminate TMA pointing verification plans to repeat factory tests. This is a two week effort with questionable value as the dome platform is not stable. Use StarTracker on-sky instead.

Recommendations

- 4. As cost saving measures with no impact on science performance, consider deferring;
 - a. the data backbone and data access center in Chile (\$1.5M),
 - b. plans for remote operations (implement only summit operations),
 - c. summit lodging.
- 5. On the November 2019 timescale, re-evaluate the project schedule with the full LCR process once the dome and TMA progress is better understood.
- 6. The Test Specification and Test Plan and Report documents should be brought to the same level of maturity as the SITCom planning.
- 7. Provisional components in the dome assembly need to be integrated into the SITCom schedule and risk register.

Response to the Charge Questions

- Project Scope:
 - Is the LSST project progressing as planned, and are they making appropriate plans for future construction and commissioning work?

Conditional yes. Some of the decisions being made to minimize schedule delays, such as deferring factory tests of the TMA, have not been well detailed for AIV/Commissioning schedule impact and added risk.

 Are all activities consistent with the baseline project objectives as described in the Project Execution Plan?

Yes.

Response to the Charge Questions

- Project Scope:
 - Is there adequate progress and planning across all Work Breakdown Structure (WBS) elements, including both in-house efforts and external procurements and contracts?
 - Yes.
 - Are there appropriate plans for realizing opportunities and for mitigating risks?

Yes.

Are the plans for assembly, integration, test, and commissioning phases complete, achievable, and well understood by the commissioning team?

Conditional yes. Replanning will be required to adjust for inevitable setbacks, so the plans needs to be re-evaluated often.

Response to the Charge Questions

- <u>Transition to Ops:</u>
 - Is the planning for the transition to operations adequate for this stage of the project?

Yes.

 Will essential materials, including manuals, maintenance plans, test reports, and as-built drawings, be ready when needed?

Conditional yes. These are part of deliverables, but not clear how production delays have impacted their readiness.

 Is planning for the transition of personnel sufficiently developed and being appropriately communicated to staff?

Conditional yes - For this stage of the project.

Response to the Charge Questions

- <u>Response to Previous Reviews:</u>
 - Has the project responded satisfactorily to recommendations from previous reviews?

Yes.

Subcommittee 4: Project Management

Subcommittee Chair – Jeff Hoy (retired DOE)

Subcommittee Members – Lowell Klaisner (retired SLAC)

Observations Issues/Concerns Recommendations Charge Response

- The Project is reported to be 77% complete (as of May 31, 2019), with the DOEfunded Camera MIE at 93% (22% contingency on work-to-go) and the NSF-funded MREFC at 71% (12% contingency on work-to-go).
- Overall, the Project schedule contingency has diminished 5 months (over the past 18 months) to only 3.5 months.
- It was made absolutely clear that the NSF funding cap (\$473M) cannot be exceeded.
- The Project presented a list of descope options for the MREFC that totaled nearly \$30M. There are also a small number of actions that senior management could take to help arrest the decline in cost and schedule contingency.
- The To-Go budget for "System Ready for Observing" is ~\$67M, so there is 26% contingency on that work. It assumes that DM and EPO efforts are frozen at present levels.

Observations

 The Operations funding picture (shared between NSF and DOE) is rather complicated. There have been some recent changes that require a greater emphasis on in-kind contributions from entities desiring access to data acquired during LSST Operations. It is expected that this situation will continue to evolve.

- Over the past year, the Project has made good technical progress and overcome several obstacles under the leadership of a strong and experienced senior management team. However, a few key staff (e.g., Telescope & Site Manager, Systems Engineering Manager, EPO Manager) have been lost for various reasons.
- At first glance, the loss of key staff, vacancy of the Deputy Project Manager position in Chile, and "Acting" status of the LSST Operations Director gave a worrisome impression. Further investigation revealed that the staff losses have been largely compensated by others capably stepping up to fill those roles, and the Project Manager has been able to assume the leadership responsibility in Chile by offloading his other less important duties to AURA staff in Tucson.

Issues/Concerns

 Retention of key staff and preservation of technical expertise into the Operations phase is typically a challenge for projects at this stage. Senior management has addressed this with a "Workplace Advocates" program and a retention bonus program. Only time will tell if these will be sufficiently effective.

- The Camera MIE is close to completion, many risks have been retired, and barring any major surprise or incident, it seems likely to be delivered on time and within the TPC. Delivering the balance of the LSST Project within the firm \$473M cap, however, will be quite difficult. It will require the best efforts of this capable project team, sustained over the next ~3 years (along with some good luck).
- The consumption rates of cost and schedule contingency are clearly unsustainable, as LSST management is fully aware.
- There was a recent change in telescope control system software management and tools. This seems to be OK, but comes late in the project.

- There is a serious issue with completing the Telescope Dome due to the vendor being in a near-default financial situation. This appears to be the largest near-term threat to project's schedule (and cost) baseline. LSST has proactively taken steps (advance payments to fully fund the vendor and direct funding of Dome subcontractors) to keep progress moving.
- The Project foresees that by October 16, 2019, it will know whether steps will need to be taken to exercise descope options to avoid schedule slippage associated with having the Dome ready for TMA installation to proceed.

Issues/Concerns

 The lack of clarity in the Operations funding picture (NSF/DOE/in-kind contributions) has complicated staffing plans for the transition to steady state science operations. Senior management was able to demonstrate how the current staffing plan for the Project morphs into a complete Operations staff.

Recommendations

- 1. For the Joint Agency Review, present the project organization and key staffing picture earlier in the initial plenary talks, making it clear that appropriate steps have been taken to mitigate the impacts of losses and gaps.
- 2. For the Joint Agency Review, improve the presentation of the Project's descoping plan (with watch/decision dates) for actions and other measures needed to meet the overall Project cost and schedule baselines.

Response to the Charge Questions

- <u>Project Management:</u>
 - Is the project management functioning well?

Generally yes, but the management in Chile needs to be strengthened.

– Are there clear lines of authority and responsibility?

Yes

 Are the interfaces between DOE- and NSF-supported activities managed appropriately?

Yes for the construction project but issues remain for commissioning and operations.

Response to the Charge Questions

- Project Management:
 - Are new risks being uncovered and are identified risks being actively mitigated and/or retired?

Yes

– Are there concerns over the distributed nature of the second level WBS teams and how well they are communicating and working together?

No

 Does the systems engineering team monitor progress and performance across the project using proper methodology?

Yes

Response to the Charge Questions

Project Management:

 Is the systems engineering documentation being suitably created and refined as the project progresses?

Yes

Are all necessary written procedures in place, documented, and followed?

Yes

Are contracts and procurements properly monitored?

No, for example, the issues with the dome vendor were not identified promptly.

Response to the Charge Questions

- <u>Project Management:</u>
 - Is the project staffing adequate for the work?

Yes, for now. Retention of key staff through project completion and into Operations is a concern.

Response to the Charge Questions

- Transition to Ops:
 - Is the planning for the transition to operations adequate for this stage of the project?

Yes

- Will essential materials, including manuals, maintenance plans, test reports, and as-built drawings, be ready when needed?
- Yes, provided that plans are realized.
 - Is planning for the transition of personnel sufficiently developed and being appropriately communicated to staff?

Yes, within the constraints of uncertainties surrounding the Operations funding picture.
SC-4: Project Management

Response to the Charge Questions

- <u>Response to Previous Reviews:</u>
 - Has the project responded satisfactorily to recommendations from previous reviews??

Yes.

Subcommittee 5: Cost and Schedule

Subcommittee Chair – Michael Barry (LBNL)

Subcommittee Members – David Sala (SLAC)

Observations Issues/Concerns Recommendations Charge Response

- Technical progress has been excellent.
- The project continues to encounter technical and programmatic challenges

 all are being managed.
- Challenges and Risks:
 - Overall Project Schedule adjusted 5 months in last 18.
 - Now 3.5 months schedule contingency to planned start of survey
 - Telescope Mount (Dome) now on the critical path Camera close
 - Staffing Challenges / Departures / Transitions
 - Contingency Levels

Observations

Project Schedule

- Project (MREFC and MIE combined) is 77% Complete
- Significant impacts this year from Telescope Mount Assembly and Dome vendor deliveries
- Two Change requests processed to stretch baseline 5 months, LCR-1623 and LCR-1725
- Contingency draw of -\$6.14M associated with the two LCRs
- Telescope and Site subsystem is on the Critical Path, specifically the Dome and Telescope Mounting Assembly. Camera is very near the Critical Path

- Contingencies
 - MREFC: \$17.5 M remains 13% on work remaining, Project is forecasted to complete in June 2022
 - Some areas of the project now have a not-to-exceed baseline, which means the areas with the highest risk and work remaining can fully utilize the remaining cost contingency.
 - This approach bumps percentage of contingency on work remaining to 26%
 - Project has 3.5 months of schedule contingency,
 - MIE: \$2.6 M remains, 21% on work remaining. Camera is forecasted to complete in Jan 2021 when factoring 1 month of negative float

LSST Schedule – 3.5 Months Contingency



Observations

	MREFC - NSF	LSSTCam – DOE
% Complete (May 2019)	71	93
SPI	0.98	0.97
CPI	0.98	0.97
Contingency (EAC)	\$17.5 M	\$2.6M
Contingency % Remaining Work (EAC)	13	21

NSF EAC - BAC = \$12.7M : EAC formality increasing but not baselined

LSST Change Control



- CCB is fully functioning
 - 1029 Fully Implemented LCRs
 - 8 Pending LCRs
 - 11 Pending LCRs awaiting approval

LSST Change Control: Recent changes since May to \$4,014K

JL	JLY Baseline	Period:	Jun 2019			Alloc	ation		Running Totals	
Change	Description	NSF Approval	Risk ID	Affected	Schedule Impact	"Puts"	"Takes"	6 Month	Authorized	Total
Control		Date		WBS/Control				Jan - Jun 2019	Balance	Remaining
ID				Account						Balance
Pending LCRs with Potential PMCS Impact										
LCR-1856	Global Interlock System		RM-841	1.04C.12.01		\$0	(\$28,897)	(\$11,406,868)	\$83,439	\$25,610,024
	(GIS) Cabinets									
LCR-1873	Add CIND for NCSA DM		RM-887	1.02C.07		\$0	(\$20,000)	(\$11,426,868)	\$63,439	\$25,590,024
	Accounts									
LCR-1943	Reconcile Outstanding UA		RM-841	1.04C.06.03		\$0	(\$764,398)	(\$12,191,266)	(\$700,959)	\$24,825,626
	and CAID M1M3 Effort									

J	UNE Baseline		Pendin	g LCRs with Potential PMCS Imp	pact	•			
LCR- 1834	TSSW Adding Next Quarterly Scope		1.04C.15	None	\$0	(\$201,435)	(\$8,791,969)	\$2,698,338	\$28,224,923
LCR- 1715	Remove Incomplete EIA Tracking Milestones from Project Baseline		1.06C	None	\$0	\$0	(\$8,791,969)	\$2,698,338	\$28,224,923
LCR- 1725	Early ComCam Integration and Test		1.04C	Schedule impact ~2 months critical path		(\$3,000,000)	(\$11,791,969)	(\$301,662)	\$25,224,923

LSST Contingency Allocations



Scope Options (LPM-72)

- LSST has 41 scope options for total current (1 July 2019) value of \$29.8M
- Eight items are \$1.5M or more and total \$22.6M
- Quarterly updates continue and data now sorts by current value
- DM10 and partial CO1 have already been taken in recent schedule re-plan

		2019-07-
		01
ID	Title	(k)
CO1	Eliminate Early System AI&T with ComCam	5000
CO5	Eliminate Both Science Validation Surveys	4300
DM6	Remove MultiFit Hardware and Test Processing in DR1 and DR2	2800
CO3	Reduce extended observing and Science Pipeline Testing with ComCam	2700
CO4	Reduce Extended Observing and Science Pipeline Testing with LSSTCam	2100
CO6	Eliminate SV Survey for Alert Production	1600
CO7	Eliminate SV Survey for Date Release Processing	1600
	Delete Data Backbone and Data Access Center in Chile: serve data from	
	NCSA only. Only have commissioning cluster and other smaller systems	
DM18	required at Base Data Center for staff	1500

- MREFC Schedule Contingency
 - 3.5 Months of schedule remain for the life of the project (~3 years). With the Dome facing some critical technical and schedule phases in the next 4 months
 - The project has lost at least 5 months of schedule contingency over the last year
 - Remaining LSST scope involves some of the most difficult and risky activities for the project

- MREFC Schedule Contingency (cont.)
 - Key "watch" dates for progress assessment for next 12 months
 - 16 October 2019
 - Dome Conditional Completion for TMA start (BP 15 Sept 2019)
 - TMA Integration Started (BP 1 Oct 2019)
 - 15 April 2020
 - TMA Azimuth Structure complete (BP 28 Feb 2020)
 - Dome Outer Panels complete and Computer control (BP 1 Feb 2020)
 - ComCam full dress rehearsal complete and on site (BP 6 March 2020)
- Camera
 - Has experienced a loss of 118 days of schedule float over the last year
 - Has ~12 weeks of float to the Telescope need by date

- Cost Contingency
 - MREFC
 - MREFC portion of the project has approximately 13% contingency on remaining work. Cost Contingency is currently \$17.5M
 - Currently the difference between the Projects ACWP and BCWP is ~\$7.4M and it is uncertain how much of this variance will be accepted versus mitigated.
 - Descope opportunities of ~\$29M have been identified as of this review
 - Any delay in the Project schedule could cause significant standing army costs, which were estimated at \$1.5M/month on near-term work

- Cost Contingency (continued)
 - MIE
 - The Camera experienced a draw on contingency of ~\$4.7M since the previous JSR, current contingency stands at \$2.6M
 - Contingency is 21% on work remaining and appears to be adequate at this point in time
 - Any delay in the Project schedule could cause significant standing army costs, which were estimated at \$0.5M/month on near-term work

Recommendations

- 1. Immediately incorporate the 10/16/19 and 4/15/20 "watch" points into the schedule as reportable milestones owned by the Project Director
- 2. For the JSR, present each subsystems ETC and EAC to clearly inform the committee of the amount of work remaining and percent of contingency
- 3. Continue to develop mitigation plans and strategy and closely follow key dates for descope decisions
- 4. Ensure that the portion of the CV that can't be mitigated continues to be incorporated into project's ETC and EAC

Response to the Charge Questions

<u>Cost and Schedule:</u>

– Are the current cost and schedule (C&S) performance and their future trends acceptable?

No. Current C&S performance and future trends shows that both Camera and Telescope and Site have had significant draws on cost and schedule contingency since the last Status Review. The camera lost 118 days of schedule float and ~\$2.8M of cost contingency driven by raft contamination and challenges in refrigeration testing. For the telescope and site significant impacts this year resulted from Telescope mount and Dome vendor deliveries resulting in a 5 month loss of schedule contingency and a draw of \$6.14M in cost contingency.

Response to the Charge Questions

- Cost and Schedule:
 - Are the budgets and contingencies for the full scope of the NSF deliverables and DOE deliverables covered by each agency's funding plans?

Yes, but given the issues regarding trends in the previous bullet and the challenges coming in the next 6 months, project must consider all options for maintaining adequate cost and schedule contingency.

Response to the Charge Questions

• Do the performance to-date and C&S trends give confidence that the project can complete successfully on time and within budget?

Camera. **Yes**. Despite the current cost & schedule trends, the camera has a clear path forward for achieving deliverable milestones without impacting the project critical path. Cost and schedule contingency appears to be very tight and will have to be actively managed. Mitigation plans have been developed and progress will have to be monitored closely to allow adequate time to implement these plans. It should be noted that some of these mitigation plans could affect both cost and schedule for MREFC.

Response to the Charge Questions

• Do the performance to-date and C&S trends give confidence that the project can complete successfully on time and within budget?

MREFC. Conditional Yes - The committee has concerns that the remaining 3.5 months of schedule contingency is adequate. However, if the dome is enclosed by October 15th then the project can begin TMA integration. All hardware for the dome enclosure is either on site or in the process of being shipped. If the project misses this date, mitigation plans will have to be initiated including potentially reducing the future science validation activities. Additional key watch date to monitor progress will be in 4/2020 when TMA Azimuth Structure complete, Dome Outer Panels complete and Computer control, ComCam full dress rehearsal complete and on site will be statused. Approximately \$29M dollars of descope opportunities have been identified along with their associated decision date. Both cost and schedule contingency will have to be actively monitored and managed.

Response to the Charge Questions

- <u>Cost and Schedule:</u>
 - Is there adequate reporting for both funding agencies?

YES.

 Have changes to the Project Management Control System (PMCS) been properly incorporated?

YES. MREFC has initiated a more robust ETC process and commissioning activities and performance can be isolated by DOE and NSF funding.

Is the change control process solid and is it being followed correctly?
 YES. The integration between different parts of the project has been implemented including a new LCR process that clearer management of project fund types

Response to the Charge Questions

- <u>Response to Previous Reviews:</u>
 - Has the project responded satisfactorily to recommendations from previous reviews??

YES.

Subcommittee 6: Environment, Safety, and Health

Subcommittee Chair – David Carroll (LBTO)

Subcommittee Members – Ian Evans (SLAC)

Observations Issues/Concerns Recommendations Charge Response

- LSST Management appears to fully support and adequately resource the ES&H initiatives.
- Safety and risk management seem to be integrated into project and functional areas. This was evident in that some plenary talks addressed safety and risk (project overview, camera, telescope and site, etc.).
- The project seems to have well established ES&H programs, processes and procedures.

- The Safety Hazard Assessments have been mostly completed. The quality of the assessments seems to be good overall, but somewhat inconsistent across equipment/areas. Most mitigation items are not yet closed.
- Hazard identification and control seems to be integrated into the daily planning meetings on site, such as Plan of the Day (Chile) and the Work Planning Control (SLAC). Cursory checks of the SLAC and Chile ES&H work plans and job site inspections indicated that they were being utilized by the staff.
- While the OSHA injury rate is relatively low compared to other similar industries, there have been some significant incidents and injuries and a number of minor accidents and close calls.



- There were a series of recommendations from the LSST Camera Filter Exchange Safety Review that occurred in May. Not all have been completed per established due-by dates.
- (SLAC) Management walk-arounds are being routinely performed. This and the quick shut down of activities after the Bell-Jar incident highlights management engagement.
- Not all pertinent documents are signed off. (LSST Camera Environment, Safety, and Health Engagement Plan, LSST Camera Hazard Analysis Report)
- It is unclear that the level and type of qualification of ESH staff in Chile is the same skill set that would be needed for complex installation.(Construction versus Technical Installation)



- We attended a daily tailgate for Camera work. With the principle that no attendance = no work, coupled with strong meeting leadership, we were satisfied that all work is planned and all work is released per SLAC Work Planning and Control Program.
- The use of the e-traveller system for Camera install activities is commendable and has many other uses around SLAC, and perhaps could be implemented in LSST Operations.
- We noted that within the framework of LSST there lacks a QA role that is actively engaged in installation activities.
 - The Area Manager for Camera activities was decisively pushing NCR's which is a good practice.



- There was no plenary ESH talk. For a Project of this complexity and the ESH risks it faces, a talk on integrated (ESH) risk assessment and mitigation would have been beneficial.
- If ESH (safety) is part of the business model of managing LSST, then the Project Director should provide a slide outlining performance to date; the good, bad and ugly.
 - i.e. Injury/Incident rates are low, but we are seeing problem. We investigate all issues and apply lessons learned moving forward.
- Thus far, the ESH transition to operations has been informal and reactive (creating policies and procedures as the need is identified). It was suggested that the ESH transition to operations become a more formalized, proactive initiative with a plan developed.



- The plenary presentations did not address how the mitigation of hazards that were identified in the project Hazard Analysis (per LPM-49) would be implemented, verified, tracked and closed. It was discovered that this will be done in JIRA.
- A holistic view of the contributing factors to accidents on the project has not been presented. Gathering these metrics could help in identifying additional needs and focusing attention and resources when it comes to continual improvement in safety performance.

Recommendations

- 1. The project should provide a plenary ESH talk
- 2. Communicate the plan to track hazard mitigation completion and verification in JIRA.
- 3. Develop the ESH TTO Plan. (Understand risks, compliance standards, define processes and programs that address and develop implementation plan)
- 4. Evaluate ESH skill set required for Technical Installation, Commissioning and Routine Operations. Include in ESH TTO planning.

Response to the Charge Questions

- <u>ES&H:</u>
 - Are Environment, Safety & Health (ES&H) issues managed appropriately?

Yes

– Does the project have an acceptable safety record?

No. There are far too many minor or close call incidents that suggest attention to detail is lacking. (Vehicular, hand injuries...)

Are Integrated Safety Management Principles being followed?
 Yes

Response to the Charge Questions

- Transition to Ops:
 - Is the planning for the transition to operations adequate for this stage of the project?

Yes, but the EH&S transition plan should now be documented.

 Will essential materials, including manuals, maintenance plans, test reports, and as-built drawings, be ready when needed?

Yes, if the documented EH&S transition plan identifies the needs/gaps in the management system and addresses how to meet them.

 Is planning for the transition of personnel sufficiently developed and being appropriately communicated to staff?

Yes, but see recommendation on evaluating skill sets.

Response to the Charge Questions

- <u>Response to Previous Reviews:</u>
 - Has the project responded satisfactorily to recommendations from previous reviews??

Yes, however we are awaiting further confirmation

Subcommittee 7: Education and Public Outreach

Subcommittee Chair – William Garnier (SKA)

Observations Issues/Concerns Recommendations Charge Response

SC-7: Education & Public Outreach

General observations and comments (apply to all)

- Several suggestions made last year to improve presentations were taken on board.
- In a few presentations, slides included charge question(s) of relevance → makes it much easier for the reviewer...
- In some cases, slides summarised project response to actions and recommendations from the previous review: good practice (where applicable).
- On-going high-level discussions on renaming LSST. Despite current uncertainties around it, I was
 expecting to see some mention of that as a reassurance that the Project is <u>cognizant</u> of such
 discussions, conscious about the risks and opportunities inherent to this matter, and is ready to "rapidly
 embrace the change", in particular since it has direct implications on a number of areas, including
 Comms and EPO.
- Similarly, I was expecting a mention of NCOA in the Transition to Ops talk, since such governance evolution will impact a number of aspects, EPO/Comms (activities, staffing) being one of them.
- Lack of diversity in review panel

SC-7: Education & Public Outreach

Observations (on EPO presentation itself)

- Very good presentation overall. Quite dense and comprehensive yet accessible and pleasant to follow due to it being visually appealing.
- Useful explanation of "separation of powers" between the Comms and the EPO functions, and the plan to eventually merge both functions at the project transitions to Ops
- Good overview of key programme elements, deliverables, status and plans.
- Other comments \rightarrow see <u>recommendation 1</u>
Observations (on programme itself)

- Good progress realised over the last year, with a high number of concrete deliverables across all elements of the EPO programme
- Evaluation mechanism seems well in place to assess quality of deliverables (incl. iterative process with future end users)
- Good overall management of risks, with mitigations well identified and defined
- A comfortable remaining EPO budget also allows for using consultants and contracting out relevant activities.
- <u>Positive</u>: very good to see that a strong emphasis is put on Spanish-language aspect of EPO programmes, with a number of initiatives targeting Chilean audience
- <u>Good practice</u>: EPO Head on Senior Management Team and on Ops Exec Council.

Issues/Concerns

- Loss of 3 EPO staff members -incl. PM- in one year is worrying.
 - Good response from EPO Head though and Project Mngt expertise in particular was partly compensated.
 - Gap remains though, on EPO Technical Management and web design/dvpt side of things. Needs to be addressed.

\rightarrow <u>Recommendation 2</u>

- Development of LSST brand policy and guidelines still in limbo due to current brand situation. Although mitigations are in place, impact on EPO/Comms will become more and more apparent (and costly) as things are dragged along. → <u>Recommendation 3</u>
- Citizen science component heavily relies on Zooniverse platform. Risk is low though, since good understanding of it and mitigation/remediation plans in place.

Recommendation 1 (suggestions for EPO presentation at upcoming review)

- Staffing slide: explanation of past and ongoing measures to cope with loss of staff/expertise.
- Acknowledgment of LSST brand situation, incl. risks and opportunities for EPO/Comms
- Mention of how the delivery compares against the plans.

Recommendation 2 (staffing)

• Pursue recruitment effort to recover from loss of personnel and ensure appropriate staffing in the team

Recommendation 3 (Brand)

• In absence of decision on LSST brand, keep focusing on <u>content</u> of deliverables with, as much as possible, minimum effort on brand/look and feel considerations

Response to the Charge Questions

- <u>EPO:</u>
 - Are the Education and Public Outreach activities properly planned and executed?

YES

- EPO keeps delivering at pace and according to plans.
- Plan for next phase looks comprehensive and realistic, in line with current phase of the project.

Response to the Charge Questions

- <u>EPO:</u>
 - Is the EPO team the right size with the right skills?

CONDITIONAL YES

- EPO team suffered some loss in recent past and is slightly understaffed at present in the light of the work ahead.
- Mitigation and recovery plans are in place though. Expectation is to be back on track at the end of the year.

Response to the Charge Questions

- <u>EPO:</u>
 - Is it engaged and integrated as appropriate?

YES

• Good integration of EPO sub-system within overall architecture and good interface with other departments, in particular Communications (1 person shared), DM, Commissioning, Ops Planning

Response to the Charge Questions

- <u>Response to Previous Reviews:</u>
 - Has the project responded satisfactorily to recommendations from previous reviews?

YES

Executive Summary

Technical

- There has been good technical progress across many fronts, and no major outstanding technical issues have been identified
- The Science Requirements are mature and have been in place since 2011 without change. The project is on track to meet these requirements when the long observing run begin.

Schedule

- Overall assessment is that successful baseline delivery remains possible, but if the schedule delays at the site persist, the likelihood of success is diminishing.
 - Dome closure and TMA assembly are pacing items on the critical path
 - Multiple, converging work paths and the ramp up to site integration, testing, and commissioning will introduce additional challenges.

Executive Summary

Cost

• Contingency balances are very tight considering the current project risk profile. Project must monitor the monthly EAC growth and invoke de-scope options as required to meet target TPC.

Management

- The major concern is reaching the finish line on cost and schedule
 - It is not time to panic, but time to develop alternatives to employ as needed as the situation becomes clearer in the next few months
- In anticipation of a Ops Review, project leadership should prepare a cohesive plan for joint agency consideration.

Thanks

- Thanks to the extended project team, the SLAC and AURA supporting organizations and the committee for a productive review
- Draft report to be ready for committee review and project factual accuracy check in ~ a week
- Best wishes for a successful joint DOE / NSF Review!