Large Synoptic Survey Telescope Camera Management Plan	Document # **LCA-276-H**		Status LSST Camera APPROVED Effective Date 18 July 2019
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Document Title **LSST Camera Project Technical Descope Options**			

1. Change History Log

Revision	Effective Date	Description of Change
H	18 July 2019	Updated for FY19. Added crosstalk de-scope. Released per LCN-2511.
G	1 June 2018	Updated status appendix and reflection of FY18. Released per LCN-2121.
F	1 Aug 2017	Updated to reflect FY17 dates and added status appendix
E	26 Sept 2016	Updated the sensor/raft descope option. Added figure showing the available descope option savings versus time. Updated decision dates to be consistent with P6 Presented at Joint NSF-DOE Review August 2016 and subsequently released per LCN-1646.
D	21 Oct 2014	U band filter descope option removed. Release per LCN-1364.
C	18 Sept 2014	Updated per the Performance Baseline established for CD-2
B	20 Sept 2011	Reformatted. Finalized for CD-1.
A	21 Aug 2011	Initial draft release for NSF PDR

2. Contents

3. Applicable Documents

The following documents are applicable:

[1] LCA-398, LSST Camera Auxiliary Units and Overage Plan
[2] LCA-396, LSST Camera Enhancements List

4. Definitions

4.1. Acronyms

ARO	After Receipt of Order
DAQ	Data Acquisition
DC	Diagnostic Cluster
DOE	Department of Energy
I&T	Integration and Test
L1,L2,L3	Camera Lenses 1, 2, 3
LSST	Large Synoptic Survey Telescope
TDS	Two-Day Store

5. Purpose

The LSST project plan includes contingency reserves for budget, schedule and scope. This document presents the LSST technical descope options for the Camera Project. The value of all technical descopes identified here is approximately $6M.

6. Scope Contingency Analysis

As is the case in other areas of the LSST Project, the guiding rationale for proposed Camera scope reductions is to minimize the impact of reductions in light of the LSST system requirements and also to avoid reductions to the construction budget that would lead to substantial inflation in operational costs. The scope for the construction of the LSST Camera can be reduced in two fundamentally different ways: (1) reductions in the scientific or (2) reductions in engineering implementation. This document describes options of both types.

The system requirements for LSST that provide a framework for analysis of reductions in scientific scope are specified in the Science Requirements Document (LPM-17), the LSST System Requirements (LSE-29) and the Observatory System Specifications (LSE-30). The project has identified a number of descope options that result in cost savings but also impact the scientific capability of the LSST.

6.1. Reduce Effective Area of the Focal Plane

The camera Key Performance Parameters contain a number of pixel requirement, with a KPP threshold of 2.6 Gigapixels and an objective KPP of 3.2 Gigapixels. This descope option reduces the number of science rafts by four (and thus the number of CCDs by 36), resulting in a total pixel count of 2.7

Gigapixels (not including guide and wavefront sensors). The spare science raft is one of the 4 raft de-scoped.

If the descope option is exercised early in the construction phase, prior to finalizing CCD procurements the Camera would see approximately ~$4.5M in cost reduction from the sensor procurement alone.

For each raft, this descope includes the sensor procurement, Science Raft processing and I&T processing. No electronics or mechanical part reductions are included. There are several decision points for this option. The CCDs to populate these rafts come from the last production batch on order. For the full descope the decision would need to be made before purchase of the last batch (May, 2017). Other items that can be descoped are the baseplates ($80K in April 2017), raft assembly ($400K from July 2018 to December 2018), and raft integration into the camera ($75K in January 2019 to May 2019). Note that some of the decision points (raft assembly for example) are on a raft by raft basis, so the final descope could range from a single raft up to four rafts and spare.

This de-scope option can also be exercised as a cost saving approach should the vendor yield prove to be inadequate and the number of sensors delivered under the baseline production contract not sufficient, as this would require procuring additional sensors. This de-scope option can also be exercised for performance if some sensors or portion of sensors have non-conformance against requirements.

This impact can be recovered during operations if funds become available to complete the Science Rafts.

The primary schedule issue concerns early notification of the descope option to realize the cost reduction in the Camera subsystem. Otherwise there are little if any schedule interactions with the descope option.

6.2. Reduce the Amount of Spare SiC Ceramic for GRID Construction

The GRID is the rigid 18cm thick Silicon Carbide, ~65cm diameter “picture frame” structure that mechanically supports and maintains the positioning and precision alignment of the Raft Towers and Corner Rafts that make up the focal plane and guide sensor array. Held at the Cryoplate temperature, the GRID also provides in part the uniform thermal environment for the Raft Towers and Corner Rafts, and aids in cryo-pumping the focal plane vacuum.

SiC ceramic is chosen for its large stiffness to weight ratio as well as its excellent thermal properties: a version produced by ECM-Munich known as HB-CeSic, for example, has a density of ~3 g/cm3, has high thermal conductivity (~120W/m ºK) and a low thermal expansion coefficient (dropping from 2.1x 10-6 /ºK at room temperature to below 0.4 x 10-6 /ºK at operating temperatures). HB-CeSic is ideal considering the very large transverse dimensions and thickness of the GRID.

The 18cm thick blocks of carbon fiber felt raw material used to fabricate the GRID is custom manufactured for ECM by a company in Japan. There are other candidate carbon-fiber felt vendors, but the properties of such material would have to be validated upon receipt. ECM prefers to procure all material at once to insure uniformity of its properties (and the final products) and avoid the need to pre-test many distinct batches. The manufacturing lead time is 4 (6) mo for procuring the raw material from their regular (alternate) supplier because it must fit in to their overall production line. This represents significant part of the total GRID manufacturing time which is about 9mo ARO. Given a manufacturing lead time >4 months for procuring the raw material, the GRID development plan calls for the Project to hold enough carbon-fiber felt raw material from the same batch, to manufacture a second GRID. This would be the case if there was a problem during the silicon infusion of the GRID, which is an uncorrectable process.

Reducing the amount to be sufficient for producing only a single GRID could provide a savings of 158K Euro for raw material. ECM has informally proposed their buying back of this material, should it not be necessary to be used.

However, if it is not procured but subsequently required, a delay in delivering the GRID will take place. This will be a combination of the raw material procurement plus its preparation for si-infusion (testing, pyrolization, green machining). Under the current schedule, which calls for 12 months from first article to production unit given sufficient spare material on hand, the delay in delivery would be 5 months.

6.3. Eliminate Off-Line Refrigeration System for Summit Facility

The Camera baseline design calls for a separate, off-line refrigeration system to provide cooling for Camera components in the Cryostat when the Camera is off the Telescope and being maintained in the summit clean rooms. The system is a duplicate of the on-line system that supports the Camera when on the Telescope. The duplicate system is used to maximize the time available for maintaining the Camera during observatory down times.

If the duplicate system were not used, the primary system would need to provide both on-line and off-line capabilities, requiring considerable additional time to pump and purge the lines to the Telescope, adding jumpers and cross-over valves to re-plumb the system to the clean room, then re-charging the system with the new plumbing to the clean room. While there would be additional capital and operating costs associated with this design, the real issue is the added time this would take during the limited down time, which could require adding an extra 16-24 hours to a down time session. Also, additional time would be needed if the refrigeration system itself required servicing.

Budget impact of this option is anticipated to be $150K. There is no schedule impact anticipated to the MIE Project. The cost and schedule impacts during operations need to be quantified.

6.4. Scale Back System-Level Verification Testing

The Camera Project has budgeted for extensive verification testing as part of Camera integration and testing (I&T). This testing has been closely matched to the Camera requirements, including those for Camera mechanical tolerances, focal plane flatness, Camera optical throughput and optical image quality. During the integration of the Camera, verification tests for optical throughput and image quality were planned at the system level, on the complete Camera, using specialized test equipment. This descope omits these system level verification tests. Verification of these requirements will instead be performed via a combination of unit level tests and calculations to match predicted performance against requirements.

We believe that this method for verification will be successful, but it does incur additional risk. With this descope, effectively the first system test of the Camera will occur only when the Camera is installed on the Telescope, meaning a failure of the Camera to meet its requirements would only be known very late in the Project.

Budget impact of this option is anticipated to be approximately $350K. Schedule impact is anticipated to be a reduction of 4 months to the critical path.

6.5. Eliminate the Standby Shutter and spare blades

The off-line Shutter will be used as a standby unit to allow for a quick exchange with the on-line Shutter if the on-line unit fails or in some way is not operating to specifications. The intent is that the two units would be interchanged during the yearly maintenance time, and the unit coming out of service would be fully reconditioned, re-tested, then be in standby for a quick exchange if needed, or for replacing the following year.

Without access to the off-line unit, Camera—and observatory—operations would be exposed to a significant increase in operational risk, since failure of the on-line Shutter would require an immediate cessation of the survey and continued down time until the malfunctioning unit was removed, diagnosed and repaired, re-tested, and re-installed. While the Shutter is designed to operate for a full year between servicing, premature failure of a mechanism is a real possibility. Furthermore, during the yearly maintenance, additional risk would be incurred since the on-line shutter would need to be reconditioned and re-tested during the two week maintenance period. This would add further work to the down time and incur additional risk of delay.

Budget impact of this option is anticipated to be $250K. There is no schedule impact anticipated to the MIE Project. The cost and schedule impacts during operations need to be quantified and will be better understood after shutter reliability testing.

A third set of shutter blades is to be used as a risk mitigation during assembly and during operation refurbishment. Without the third set of blades, there is a low to medium risk increase that fabrication or operation maintenance could be halted due to damage to a set of blade. The budget of this third set is anticipated to be $150K. There is no schedule impact anticipated to the MIE Project.

6.6. Scale Back the Image Diagnostic Capability

The Camera DAQ system design includes a Diagnostic Cluster (DC), a hardware and software system deployed in the summit computer room, whose purpose is to provide a platform for performing arbitrary types of analysis on Camera image data, with visualization being but one example (albeit the most interesting) of an image analysis. Any such data would be confined to the summit "Two-Day Store". The DC is designed to facilitate interactive off-line analysis, as well as providing dedicated "real-time" monitoring of the Camera's image health, with the goal of not only anticipating image-related issues, but once recognized, rapidly diagnosing and repairing those issues. These diagnostics are intended to develop and mature as the Camera itself is developed and matured: the DC is designed from the beginning to be an open environment allowing the entire Camera community to participate in the development of those diagnostics. Finally, the DC was intended to serve as the platform for both Camera's acceptance and regression tests.

Given these functions, eliminating the DC would have the following impact:

- It would increase the risk that a problem would go undetected during the Camera's development. Such a risk could negatively impact schedule.

- During observatory operation, it would increase the "mean-time to repair" of any potential issue. Increased mean-time-to-repair could negatively impact the observatory's uptime.

- It increases the engineering effort required by the observatory team. Observatory systems must perform image diagnostics on arbitrary image data and would likely leverage DC development. Consequently, in the absence of the DC, the observatory would be forced to replicate its functions.

This being said, the impact of this descope option could be mitigated by moving a small, well-identified set of diagnostics into the DAQ readout system. However, the Diagnostic Cluster is designed for accessibility and openness; adding to or changing diagnostics elsewhere in the DAQ would be a much more difficult task than doing so in the context of the DC.

Budget impact of this option is anticipated to be $150K.

6.7. Reduce Summit Data Storage Capacity

The observatory has a requirement to continue to acquire data in the absence of connectivity with or function of the base facility. It must continue in this mode long enough to cover the anticipated mean time to recover service. This is estimated by the observatory at no more than two days. The purpose of the "Two-Day Store" (TDS) is to buffer image data in the eventuality of such an outage. The TDS has two additional functions: first, it provides the Diagnostic Cluster real-time access to its data and second, it provides storage for simulated images to drive the DAQ system when in diagnostic or simulation mode. Note that the DAQ system has an observatory requirement to provide at least one observation night of simulated data. Given these functions, reducing the amount of available buffering would have the following impact:

- It reduces the available time to recover from an outage, which could negatively impact observatory uptime.
- It reduces the coverage available to analysis which could negatively impact the ability to diagnose Camera issues.
- It reduces the abil1ity to deliver one night's worth of simulated data compromising the Camera's ability to meet an observatory requirement.

Note: The proposed architecture of the TDS is modular, meaning that additional storage can be added quickly at no operational cost and, except for the storage media itself, at no additional cost. Therefore, decreasing storage will not affect the schedule development for the TDS.

Budget impact of this option is anticipated to be $25K.

6.8. De-scope crosstalk correction

The camera has a requirement to be able to deliver a crosstalk correction algorithm removing intra CCD crosstalk as the image is delivered through the DAQ. The cross talk correction is implemented at the end of the project and can be added via firmware/software at any time. The DAQ would still deliver hadware with the computing power to implement the correction but juts provide raw data and not provide the option to deliver the data corrected for crosstalk.

Eliminating this capability would have the following impact:

- If crosstalk correction is needed real time, this would impact the alerting time unless commissioning or operation takes on the scope of implementing cross talk correction.

Note: This would not impact any of the key performance parameter requirements and would not impact early commissioning. This de-scope is recoverable at any time via a firmware/software upgrade.

Budget impact of this option is anticipated to be $203K.

7. Scope Contingency Summary

Table 3-1 summarizes the camera level descope options. Figure 1 shows graphically the potential remaining savings over time.

Table 3-1: Summary of Camera Descope Options

Option	Summary	Cost Saving (x $1000)	Target Date	Recoverability
Reduce Effective Area of the Focal Plane by 4 rafts and descope spare raft	Keeps the pixel count above the KPP minimum, with several options for lesser descopes depending on the time frame of the decision	$4987	Feb 2017	Recoverable
Reduce the Amount of Spare SiC Ceramic for GRID Construction	Hold less SiC ceramic on-hand. Exposes GRID construction to schedule risk.	$134	Jul 2017	Not Recoverable
Eliminate Off-Line Refrigeration System for Summit Facility	Eliminate refrigeration system used in summit clean rooms.	$150	Feb 2017	Recoverable
Scale back System-Level Verification Testing	Perform system-level verification tests for optical throughput and image quality "in the field", without dedicated test fixtures, after Camera is shipped and integrated with Telescope.	$350	Mar 2016	Not Recoverable
Eliminating the Standby Shutter and spare blades	Eliminate stand-by Shutter and spare blades.	$400	Nov 2017	Recoverable
Scale Back Image Diagnostics	Eliminate DAQ Diagnostic Cluster system in summit computer room; build smaller set of image diagnostics into other DAQ subsystems.	$150	Aug 2015	Recoverable
Reduce Summit Data Storage Capacity	Reduce hardware capacity for summit data storage.	$25	June 2018	Recoverable
De-scope crosstalk correction	Do not implement and test the cross talk correction firmware in the DAQ	$203	October 2019	Recoverable

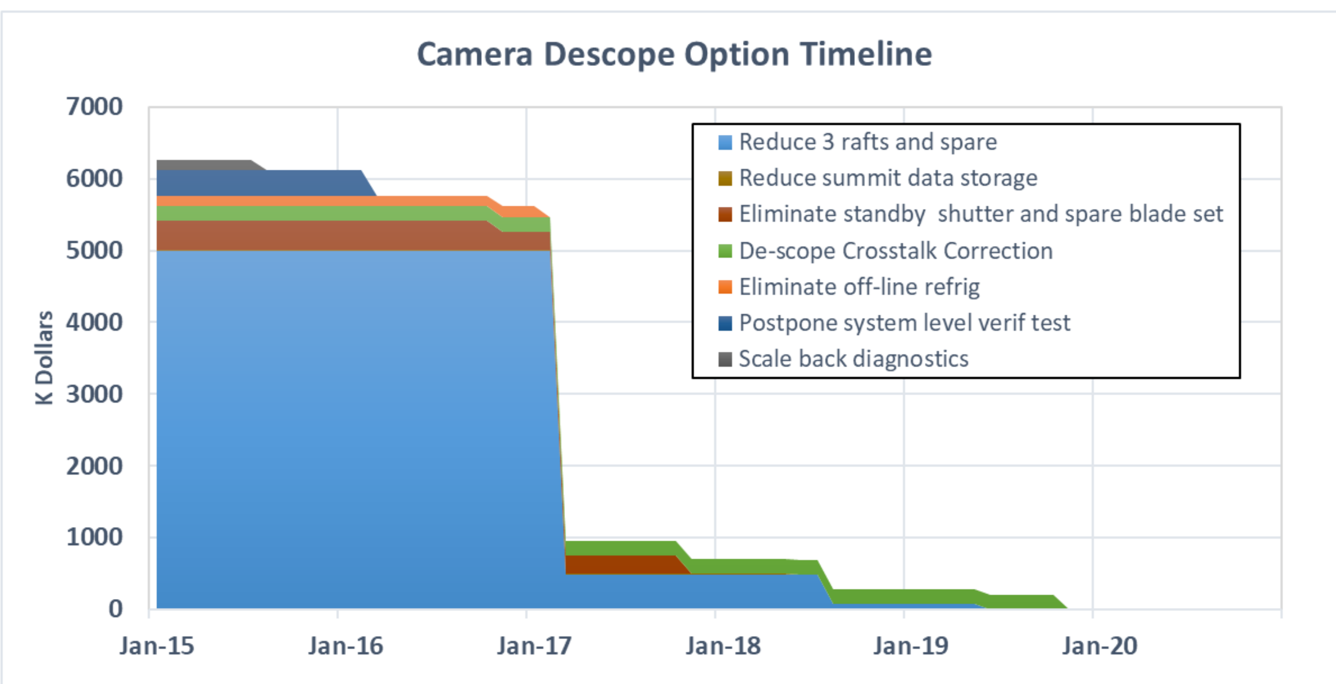

Figure 1. Camera Descope Remaining Savings over Time

8. Appendix – Status as of 6/27/2019

Focal plane area reduction

All sensor baseline procurements have been placed and 100% of the sensors have been received and cannot be de-scoped. The baseplates have been received and cannot be de-scoped. Raft assembly is mostly complete. Raft integration is still available for de-scope, however, some of the sensors exhibited some noise sensitivity causing read noise performance to not be fully met. This descope has been partially taken for performance reason, still possibly requiring all raft to be assembled to reach the threshold KPP number of performing pixels. However, the cost of installing the rafts is less than $10K so there are no advantages in taking the remaining de-scope.

Reduction of Spare CeSiC Ceramic

The grid has been delivered and the spare CeSic was not used. However due to issues with the grid during fabrication causing additional cost on the vendor, the spare CeSic buy back was negotiated to $30K. This de-scope is not available anymore.

Offline refrigeration system elimination

Per the FY17 refrigeration EAC this de-scope has been implemented. The off-line refrigeration system for summit has been de-scoped and the refrigeration system required during integration will be used for maintenance instead , mitigating the risk described and allowing the de-scope.

System-level verification scale back

In April 2015, the system level testing with test rafts was reduced from 210 days to 75 days to accommodate key sub-system delays. In February 2016, in order to accommodate further schedule delays in key components, the system level verification testing was de-scoped from 164 days to 89 days. These were documented in BCR-023. This de-scope is not available anymore.

Standby shutter and spare blade set removal

The spare shutter blade set has been de-scoped in 2016 to accommodate the cost growth of shutter blade anticipated procurement based on prototype work. The standby shutter is still part of the baseline and procurement was awarded in November 2017. This de-scope is not available anymore.

Diagnostic Cluster scale back

The diagnostic cluster effort was not de-scoped in 2015 and this option is no longer available.

Summit data storage capacity scale back

The quantity of boards for camera emulation (storage) has been selected and hardware received in 2019. The decision was made to proceed with the planned capacity and to not de-scope This option is no longer available.

Crosstalk correction de-scope

The work has been pushed to Q1 FY20 and the de-scope is still available.