Department of Energy/
National Science Foundation
Review Committee Report

for the

Technical, Cost, Schedule, and
Management Review

of the

DARK ENERGY SURVEY (DES) PROJECT

September 2008

EXECUTIVE SUMMARY

A Department of Energy (DOE) and National Science Foundation (NSF) review of the proposed Dark Energy Survey (DES) project was conducted on September 9-10, 2008 at Fermi National Accelerator Laboratory. The review was conducted at the request of Dr. Dennis Kovar, Associate Director for High Energy Physics, DOE/SC, and Dr. Craig Foltz, Acting Director, Division of Astronomical Sciences, NSF, and was chaired by Mr. Steve Tkaczyk, Office of Project Assessment, DOE Office of Science (SC). For DOE, this review will serve to verify DECam's (DES new camera) readiness for approval of Critical Decision (CD) 3b, Approve Start of Construction. CD-2 approval of the performance baseline was approved for the DECam project on April 29, 2008. CD-3a, for initiating early procurement of long lead items, was approved on May 20, 2008.

For NSF, the review will serve to assess the status of the Cerro-Tololo Inter American Observatory (CTIO) facilities improvements project (CFIP) and a data management system (DESDM) projects.

The Committee recommended approving Critical Decision (CD) 3b (Approve Start of Construction) for DECam, the DOE responsibility.

The DES experiment consists of three fabrication projects: DECam led by Fermilab, CFIP, and DESDM led by the National Center for Supercomputing Applications (NCSA). The camera is to be mounted and operated on the Blanco four-meter telescope in Chile, which is operated by CTIO for the NSF.

The DECam fabrication project is being supported by DOE, along with in-kind contributions. Funding for the DESDM and CFIP is being provided by the NSF and in-kind contributions.

The DECam technical design was found to be sufficiently mature for the project to initiate procurement and fabrication. For those elements that are not finalized, the project showed that there are no major issues that need to be addressed. Some detailed comments and recommendations were made about each subsystem as described below. The Committee found that the DECam project technical design is ready for CD-3b approval.

In the Optics and Opto-Mechanical Systems, it was noted that the filters are particularly challenging and should be monitored closely. The design study of the hexapod system should be completed prior to procuring the full system.

The Charge-Coupled Devices (CCD) production has started and the testing and focal plane integration infrastructure is in place. The Committee recommended that effort be maintained to keep the CCD production running smoothly (not limited by funding) to produce CCDs early, and that full contingency for extra CCD lots be retained. A particular concern by the Committee was LBNL's antiquated vacuum sputtering machine, which caused CCD production to stall for 25 weeks in the last few years, and recommended that LBNL purchase a new one for future needs. Electronics have made very good progress and most are already at the final design stage.

The Committee noted that the DESDM project made significant progress since the January 2008 DOE review but was concerned that some key areas of expertise still reside with individual team members and that standard software practices are not yet widely employed. The Committee recommended that the data challenges start significantly involving the science working groups, that the WBS tasks be derived from the top-level science requirements and data products, and that risk management be put into place. The Committee also recommended increasing the project management effort.

The CFIP projects are all progressing appropriately. The projects have detailed, milestone-rich schedules and are all scheduled to complete at least 12 months before the arrival of DECam in Chile. Plans for integration and installation of DECam and the optics at the Blanco are being developed.

The DECam cost baseline is $35.15 million. This Major Item of Equipment has an adequate contingency of $6.78 million (41 percent of remaining work). The schedule contingency for the CD-4 milestone is twelve months, which was deemed to be adequate.

The DESDM team has a Total Project Cost of $7.6 million using a mix of funding sources. The DESDM cost estimate primarily consists of labor costs supporting a software project. Approximately 20 percent of their costs during the construction phase are not currently funded. They plan a supplemental proposal to NSF in FY 2009 to request additional funding. They are holding to their schedule for 2011 operations.

The CFIP project is estimated at $860K. The project is expected to be funded out of the CTIO operating budget and the Director is committed to CFIP being ready for DECam. The current CTIO funding amount forces deferral of capital expenditures until FY 2009, possibly FY 2010, but without impact to DECam. The schedule performance is meeting expectations.

ES&H aspects are properly addressed with appropriate hazard analyses and safety documentation completed for this stage of the project.

The Committee was pleased to see that the Global Memorandum of Understanding is signed and being actively executed. The DES Project Office has increased its integrating activities and has been responsive to previous review recommendations, though some are still being implemented. The Committee recommended that the DES Project Interface Working Group be initiated as soon as possible.

The Committee found that the DECam project is being effectively managed at a level appropriate for a project of this size and complexity. The DECam project manager provides a strong integrating role for both DECam and DES as a whole. Recommendations from the January 2008 DOE/NSF review were fully responded to and implemented. The Committee recommended that they develop a risk-based procurement timing strategy in response to inevitable extended continuing resolution situation and examine the subcontract/vendor controls/communication to minimize schedule and cost risks.

There were no specific Action Items resulting from the review.

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1. INTRODUCTION

The discovery that the expansion of the universe is accelerating was first announced in 1998. Studying the nature of the “dark energy” causing this expansion has become one of the most important science objectives in physics and astronomy. This mysterious dark energy comprises about 70 percent of the matter-energy contents of the universe. Not much is known about it other than that it exists.

Determining the nature of dark energy is a high priority science objective for the Department of Energy (DOE) Office of Science (SC) Office of High Energy Physics (HEP) and the National Science Foundation (NSF) Division of Astronomical Sciences. The Dark Energy Survey (DES) experiment offers a cost-effective and timely approach to unraveling the mystery of dark energy.

The DES experiment will use the existing Blanco Telescope at the Cerro-Tololo Inter American Observatory (CTIO) in Chile to study the nature of dark energy. The project includes the fabrication of a new camera (DECam) optimized for the study of dark energy, the CTIO facilities improvement project (CFIP) for upgrade to the telescope and CTIO facility, and a data management system (DESDM). The DES project plan calls for funding for the DECam to be provided by the DOE and funding for the DESDM and CFIP by the NSF. Funding for CFIP would be provided through the National Optical Astronomy Observatory (NOAO), CTIO’s parent organization. In addition, funds are expected to be provided from other U.S. and foreign institutions.

The DES collaboration consists of scientists from Fermi National Accelerator Laboratory (Fermilab), Argonne National Laboratory (ANL), Lawrence Berkeley National Laboratory (LBNL), the NOAO, five U.S. universities, and institutions in Brazil, Spain, and the U.K.

In exchange for providing the instrumentation, the DES collaboration will get 30 percent of the Blanco Telescope observing time over a five-year period. DES will provide significant science results using all four methods recommended by the Dark Energy Task Force: supernovae, galaxy clusters, baryon acoustic oscillations, and weak lensing. The main method is the use of galaxy clusters. The Collaboration plans to combine their data with other telescope experiments such as the South Pole Telescope to enhance their results. Their data will improve the figure-of-merit well above the recommended minimum factor for a Stage III experiment.

For DOE, this review served to verify the DECam project's readiness for approval of Critical Decision (CD) 3b, Approve Start of Construction. CD-2, Approval Performance Baseline, was approved for the DECam project on April 29, 2008. CD-3a, Approve Procurement of Long Lead Items, was approved on May 20, 2008.

For NSF, the review served to assess the status of the CFIP and DESDM projects.

2. TECHNICAL

2.1 DECam

2.1.1 DECam Optics and Opto-Mechanical Systems, CFIP

2.1.1.1 Findings

The Optics and Opto-Mechanical subsystem teams have demonstrated significant progress since January 2008. The DECam project has been responsive to the review recommendations and adequately addressed the recommendations from the January 2008 DOE/NSF review leading up to CD-2.

The top-level specifications and technical requirements have been developed. Flow-down requirements in the form of Requirement Specification Documents (RSDs) have been produced for nearly all of the major subsystems.

The procurement of the optical elements is well underway. Corning has successfully fabricated the blanks for lens elements C1 through C5, and these have been shipped safely to England and then to the SESO, to whom the contract for polishing and coating the lenses has been awarded. This retires one of the previously identified sources of risk to the overall project. Polishing of the elements is set to begin in mid-September. The team at University College, London has fabricated a prototype cell (at roughly half the scale of the largest final design cells) and has begun tests on mechanisms to accurately position and hold lens elements in the cells.

At the January 2008 DOE/NSF review, the design of the hexapod assembly had been identified as an area of concern. The recommended design study of the assembly, including the construction of a prototype actuator is underway, with final results available around the end of 2008. Initial results have been encouraging, and the contractor has provided all the required documentation and materials.

Another area of concern in the January 2008 DOE/NSF review report was the vibrational stability of the optical assembly when placed on the Blanco Telescope. A finite element analysis of the upper Blanco structure has now been performed to demonstrate acceptable modal performance of DECam in the telescope and determine stiffness requirements for the hexapod actuators. The lowest (local) modal frequency of DECam supported by its hexapod positioner to the (grounded) top ring assembly is 35 Hz. This is well above characteristic frequencies for turbulent wind disturbance. The FE analysis of the barrel assembly indicates the assembly is sufficiently rigid. Further analyses of lens cells and focal plane deflections are planned.

The January 2008 DOE/NSF review also indicated the heat loss of the DECam electronics ("the plume") as a potential limiting factor in the image quality delivered by DECam. A thermal analysis indicated that the seeing will not be materially degraded for surface temperature differentials up to 3° from ambient. This specification is currently being used the design of the camera assembly.

The original specification for filters turned out to be too stringent; bids were solicited for the design, and no credible response was received. The major issue was the specification on the transmission variation across the thickness of these large filters. The DECam team has gone back and studied the consequences of relaxing the filter uniformity specifications. They have developed a specification based on the principle of calibrating out the non-uniformities rather than not having them. This has relaxed the specifications considerably, and another round of bid procurement is underway. The filters are an expensive item, and the consequence of the continuing resolution budgeting has been to push the filter acquisition until as late as possible.

The project has settled on a cooling design. A prototype of the LN2 cooling system is being assembled. And a local facility at Fermilab has been selected for testing the system with the appropriate vertical offset between the tanks and the dewar. The prototype will be tested on the Telescope Simulator with the MCCDTV imager prototype in the near future, and later with the full range of motion on the Telescope Simulator.

The prototype filter changer mechanism is nearing completion. This allows ample time for reliability testing prior to shipment to CTIO. No changes to the shutter design were presented. This item should be purchased in time to allow off-telescope reliability testing under representative conditions.

A new mechanism for mounting and removing the F/8 secondary mirror via a mounting station where the F/8 secondary can be positioned horizontally and then lifted vertically into place is being developed. This mechanism is a major improvement over the concept presented in January 2008; it addresses operational and safety concerns with the previous design, and should allow for consistent replacing of the F/8 secondary for observing at Cassegrain focus.

The DECam project has a well-defined cost and schedule and appears to be adhering to these. Project management procedures have been tightened. Risks are being tracked, some risks have been retired, and there is an awareness to pay close attention to critical milestones.

Plans for integration and installation of DECam and the optics at the Blanco are being developed. The tight coupling between the engineering work at Fermilab and at CTIO is evident in the plans. The CFIP projects are all progressing appropriately. The projects have detailed, milestone-rich schedules and are all scheduled to complete at least 12 months before the arrival of DECam in Chile. The Telescope Control System (TCS) project is underway, and (through alterations to the work plan) the scheduled completion date has moved forward three months, further reducing the schedule risk to DECam. The primary mirror radial support study is complete; the newly designed radial support H-bars are being machined at CTIO. Installation is planned for spring 2009 during a four-week shutdown.

Although the same budgetary pressures facing DOE also face CTIO, the central projects of CFIP, the ones that are critical to DECam's success, have been given high priority within NOAO to protect them from budgetary pressures.

2.1.1.2 Comments

Although the level of cooperation and responsiveness of the polishing contractor is encouraging, the accurate shaping of the lens elements is still a risk to the project. The DECam team will need to continue to monitor the progress and conduct independent tests of the metrology to supplement the vendor's own tests.

The DECam optics will be tested as a complete system only after assembly at CTIO and installation on the Blanco Telescope. Fabrication errors in the lenses (surface figure, center thickness, etc.) or coatings uncovered at this stage could have serious performance, schedule, and/or cost ramifications. The project has a very detailed plan to mitigate the risk, transferring the lens cells to Fermilab to test the metrology in the barrel before they go back to University College of London (UCL) to have the lenses installed. Nevertheless, the project should monitor this effort closely. Independent methods for testing the lenses and coatings to mitigate the risk are potentially available to the project.

The relaxing of the filter specification appears necessary, but the project needs to study the effect of spatially varying colors carefully. Even with the relaxed filter specifications, procurement may be difficult. The project should monitor this effort closely and independently verify that the delivered filters meet specifications and consider the implications of higher order spatial variations in the filter transmissions. The schedule for acquiring the filters is pretty tight; the Committee was concerned that the filter acquisition not be delayed for budgetary reasons, as there is still the risk of problems with their fabrication. There is still some confusion about how many filters will be acquired and with what budget—for example, the filter was not in the budget shown. This should be resolved soon. The lack of spare filters is a risk to DES science.

Designs for the major optical and opto-mechanical subsystems are sufficiently well advanced to proceed to CD-3b.

2.1.1.3 Recommendations

1. The DECam team should conduct independent measurements of the DECam lens low-order surface figure and thickness during production to reduce program risk. This could be accomplished using separate metrology (test plates?) provided by the supplier in tests witnessed by the project. Scrutinize the primary tests closely.

2. Measure the transmission curves for the lens AR coatings (using witness samples) and filter functions to verify compliance with specifications. Utilize the facility being developed at the University of Michigan to make these measurements.

3. Complete the design study of the hexapod system and prototyping of an actuator prior to procuring the full system. Verify the prototype meets the positioning and stiffness specifications.

4. Proceed immediately to CD-3b.

2.1.2 DECam CCDs, SISPI, Electronics

2.1.2.1 Findings

Charge-Coupled Devices (CCD)

As recommended at the January 2008 DOE/NSF review, CCD production was started immediately after CD-3a, in advance of the main fabrication (CD-3b), to mitigate risk of yield problems causing schedule delays. CCD production, test, and focal plane integration infrastructure are in place along with plans to gain early experience integrating both hardware and software.

The project is on track to have 40 percent of the required CCDs in hand, passing wafer probe tests (not packaged CCDs), by the end of FY 2008.

With sound electrostatic discharge (ESD) practices, it appears that CCD losses due to ESD event are insignificant at Fermilab. The abnormal ESD sensitivity observed for the LBNL CCDs would appear to be an infant mortality effect that may impact manufacturing yield but does not appear to pose a serious risk later in integration and operations phases provided that ESD mitigation measures are rigorously followed.

Front-End Electronics (FEE)

All recommendations from the January 2008 DOE/NSF review have been addressed. Very good progress has been made on finalizing the design of readout electronics.

With the exception of one board, the Master Control Board being laid out in Spain, all pre-production versions are now being tested. Final versions are expected unless new issues arise during system testing.

A visit was made to CTIO to investigate the present state of grounding as recommended in the January review. This proved to be very fruitful confirming the soundness of the initial scheme for DECam, but also indicated that more work is needed at CTIO to resolve present grounding issues.

The plans for integration tests from October 2008 through February 2009 are very impressive and should do much to wring out both hardware and software issues.

Survey Image System Process Integration (SISPI)

Good progress has been made on software development since the January 2008 DOE/NSF review. A detailed list of functional milestones with a high level of granularity has been created to closely monitor software development. This should facilitate project tracking, which is always difficult for software development, and will hopefully avoid schedule slips going unseen until late in the project.

The real SISPI software in its present state of development will be used for the hardware integration tests starting in October 2008 Testing of the final/complete version is scheduled for fall 2009. This early deployment is an excellent idea, and will allow the software to be tested in a timely fashion.

Most SISPI software development effort is funded as an in-kind contribution to the project.

2.1.2.2 Comments

Charge-Coupled Devices (CCD)

Crosstalk between readout channels can be accurately characterized and will need to be corrected. This can be done without read noise penalty since the crosstalk is small; however, it is only possible if the source intensity is known. Crosstalk correction is important since there will be many bright stars in the field of view and many potential crosstalk paths. This correction is only possible if all CCDs bloom prior to ADC (analog to digital converter) saturation.

It is very encouraging that wafer probe yield-to-date has been 27 percent (for wafers, not yet for packaged CCDs).

The claim that the "standard deviation of the yield is 6%" is potentially misleading since CCD yield statistics are prone to change due to new process problems or equipment failures occurring. Such effects are not reflected in the relatively small data sets and short time frame on which the above yield estimates are based. Whole lots have already been lost and for the remaining lots the yield ranged from 5 to 29 devices.

A particular concern is that LBNL's MicroSystems Laboratory (MSL), in common with most other low volume R&D laboratories making CCDs, uses some old equipment and in many cases has only one instance of critical pieces of equipment. The vacuum sputtering machine is a prime example. It was "used equipment" when purchased in 1993, relies on very old electronic vacuum tubes and has had to be revived sometimes by cleaning edge connectors with pencil erasers. This machine has been down for 25 weeks in the last few years. This resulted in CCD production being halted since this machine is required for depositing both the frontside metal, and the SiO_2 and Indium Tin Oxide coatings on the back surface.

This is a risk for which LBNL takes responsibility, but to eliminate risk of delays to DECam and other projects (e.g., SNAP, BOSS), a new machine needs to be brought on-line and qualified before the current machine fails again. Diversion of DECam wafers to a new machine is not advocated while the current machine is working. Instead the safest route would be to procure and qualify the new machine with bare silicon wafers then alternative CCDs.

Front-End Electronics (FEE)

There was not much performance data shown nor was there a list of what changes to the design had been made from earlier versions. This would have been helpful to the Committee and is something that should be provided at future reviews.

Atmopheric Dispersion Corrector (ADC) Differential Non-Linearity (DNL), the variation in the voltage range at the input of the ADC represented by a given output code, is probably the performance parameter which is the most susceptible to degradation whether through component variation, PCB layout, power supply quality, supply bypassing, or noise/interference on supplies or reference voltages. It is therefore important that it be measured carefully when boards are tested and again after the system is integrated. DNL is measured statistically. A slow (say 10Hz) triangle wave is DC coupled to the ADC. If injected via the video chain, the Correlated Double Sampling must be inhibited. To measure bin widths to X-percent accuracy for an N bit converter, 2^N*$(100/x)^2$ samples are acquired and a histogram is then formed. The relative number of counts in each bin is proportional to the relative width of the bin.

For example, for the 18 bit ADCs used by DECam acquiring data at the normal 3.5us/pixel, two percent bin width accuracy will be achieved in 38 minutes of data acquisition. While a large amount of data must be acquired, only the histogram needs to be stored, so a real time histogramming routine might be contemplated.

A histogram of the histogram (!) is a good way to present the distribution of the ADC errors.

It is also possible to make DNL histograms over a substantial fraction of the ADC input range using flat field illumination in place of a triangle wave from a function generator. A shutter control mode is required wherein the shutter is opened during readout instead of during the exposure so that flat illumination generates a linear ramp. Multiple exposures would be required to build up enough data to make a histogram of sufficient precision. (A ramp illumination mode like this can serve as a useful diagnostic providing a quick check for well capacity and the mean-variance relation.)

Survey Image System Process Integration (SISPI)

The Committee remained concerned about security of ongoing budgetary support for this vital component of DECam, given that most development resources for SISPI are in-kind.

Software execution or communication delays not only impact observing efficiency but can greatly magnify the amount of observing time lost in the event that a software restart is required. This can significantly impede debugging.

2.1.2.3 Recommendations

1. Maintain the intensity of efforts to keep CCD production running smoothly (not limited by funding) to produce CCDs early, not withstanding the encouraging initial results.

2. Retain the full contingency for extra CCD lots.

3. Set the electronic gain such that the ADC saturation exceeds the maximum blooming level, or adjust the parallel clock rails for CCDs, which show unusually high well capacity to reduce the blooming level to lie within the digitized signal range.

4. Include measurements of ADC DNL in the standard test suite.

5. Implement a “single slope” video processing option to support measurement of the input DC level and to allow ADC testing. (The normal Correlated Double Sampling employs dual slope integration to form the analog difference of two samples of the video before and after the charge dump.)

6. Incorporate a test for ADC noise (and offset) by implementing a “no-slope” option for the integrator wherein pixel timing and integrator reset would be unchanged but time delays would replace the pulses, which enable the integrations.

7. Identify how all LEDs in DECam will be disabled prior to commissioning. (Perhaps single pin sockets could be inserted into the current printed circuit boards (PCB) where the light emitting diode (LED) leads were to be soldered directly, so that the LEDs can be removed, yet be easily replaced when required for diagnostics?)

8. Develop communication and execution time requirements for all SISPI software components and the hardware on which it runs. The requirements on individual software modules and communication paths should be derived by the top-down allocation of high-level requirements including but not limited to the following:

- SISPI should not significantly impact efficiency of observing, calibration, or diagnostics. Therefore SISPI must be ready to begin the next exposure "as soon as" CCD readout clocking ends so that the impact of software execution and communication delays have negligible impact on frame rate even for zero length exposures (i.e., software delays must be very much less than readout time for all read modes). Implicit in this requirement is the ability to acquire long sequences of frames at the maximum frame rate without negative consequences such as buffer overruns, or slowing of data acquisition due to filling of disk caches.

- DECam software restart should not impede fault recovery or debugging efficiency. A sensible goal would be for software shutdown and restart to take less time than a CCD readout. The shutdown and restart under discussion includes SISPI and all user and communication interfaces (Linux task termination and respawning, creation of new windows in the desktop manager, etc., closing and opening all file and communication ports.)

9. Minimize Linux reboot time, insofar as this is possible. (For example, there may be memory checks or other diagnostics, which can be performed on demand rather than after every reboot.)

10. Provide a single command to shutdown and restart DECam/SISPI. If practical, consider whether partial restart (e.g., just the CCD controllers) can also be supported as a way of further expediting hardware debugging.

11. Make execution and communication timing part of the standard software testing regimen from the outset.

12. CD-3b approval is recommended for the CCDs, FEE, and SISPI.

2.2 DESDM, Simulations, Calibration

2.2.1 Findings

DESDM has made significant progress since the January 2008 DOE/NSF review. The DESDM project has expanded its WBS to include a science codes element; currently primarily addressing the lensing pipeline. The DESDM team has augmented its staff since February 2008 in response to recommendations. Staff were added at University of Illinois at Urbana-Champaign (UIUC) and Fermilab.

Some key areas of expertise still reside with individual team members (e.g.. database expertise and support for science codes).

Preparations for DC (data challenge) 4 are well underway, and readiness for DC4 is generally high for all of the WBS elements.

Some unit level testing and unit level regression testing has been put in place for several of the WBS development areas.

The project has implemented some standard software practices (e.g., using SVN and JIRA), but these practices are not yet widely employed. Data simulations have progressed well, now including more realistic image artifacts. The strategy of using ever-more sophisticated simulations in conjunction with the Blanco Cosmology Survey (BCS) data to test DESDM is a sound one.

Data challenges to date have not significantly involved the science working groups (SWG). Stress testing of the system by the SWGs is currently only planned for the end of the development phase.

Risk management is not in place, beyond identification of software development priorities as a contingency planning model.

2.2.2 Comments

The DESDM team has made progress in estimating the level of effort required. The Committee noted that this is a difficult-to-impossible task, as individual's software talent and skills vary enormously.

Core data reduction steps (e.g., transient detection) have been brought under DESDM's aegis, but the new steps are as yet very loosely coupled. The needed degree of integration with the data management infrastructure and codes is not yet clearly articulated.

Hardware purchases have been deferred in lieu of supporting additional staff. NSF is expecting and is prepared for a request for supplemental funding. DESDM has un-funded contingency for which they intend to apply to NSF, but there is no other contingency in the budget.

Difference processing might be applied to general catalog data; but no plans for allowing such processing are in place.

The scope of user (DES scientist and general public) access to the DES database was not clear to the reviewers.

In the January 2008 DOE/NSF review, it was stated that all goals were (eventually) met for DC3. But in the DESDM plenary presentation, two DC3 objectives were listed as not met. It was not clear if these goals will be addressed in DC4. In general, it is not clear how the goals of each DC are a prioritized.

There was no time to review the developments in the Data Access Framework, quality assurance/quality control (QA/QC), and the Community Pipeline during the DESDM splinter session. These should be reviewed at the next review.

2.2.3 Recommendations

1. Define the scope of, and requirements on, the science-ready data products. These requirements should be derived from the top-level science requirements, and tracked down to DESDM WBS tasks.

2. Ensure that all science collaborations (including those which are just forming now) have included their requirements in this effort.

3. In descriptions of data challenges, make it clear which of these requirements have been addressed, and the extent to which they have been met.

4. Classify principal risks in severity/likelihood matrix and track them as part of the DES project risk management system.

5. Use data challenges, starting with DC4, to produce realistic estimates of processing hardware requirements for the required throughput.

6. Increase the amount of effort applied to project management.

7. Continue to adopt and embrace standard software practices. In particular, show progress towards consistently using version tracking and bug-tracking systems by the next review.

8. Define the scope of the public and collaboration interfaces to the DES database.

9. Involve SWGs in data challenges (for example, use blind data challenges and require science groups to attempt to discover simulated science phenomena).

3. COST

3.1 Findings

The DECam project received CD-2, Approve Performance Baseline, on April 24, 2008. The Total Project Cost (TPC) is $35.15 million (R&D $11.7 million, MIE $23.45 million). All project costs are estimated costs are in FY 2007 dollars and are fully-burdened and include out-year escalation. Installation and commissioning costs are not included in the DECam project.

The DECam project has reported earned-value since August 2007. For month-ending July 2008, the earned-value is:

- R&D is 87 percent complete, contingency is $.28 million (19 percent on cost to go).
- MIE is three percent complete, contingency is $6.78 million (41 percent on cost to go).
- 11 Baseline Change Requests, totaling approximately $257K have been approved since CD-2.

The DESDM is primarily a software project (dominated by labor costs) supported by NSF and a variety of in-kind contributions. The DESDM cost baseline (as per DESDM Project Execution Plan, revision F) is $8.61 million. The baseline includes approximately 28 percent contingency based upon a risk-based analysis. Of the baseline, $7.02 million has funding identified with $1.59 million currently unfunded.

The DESDM includes software testing and commissioning. DESDM system components have been prioritized to delay/defer lower priority items should funding not become available for the entire baseline scope.

The CFIP cost estimate includes $390K for equipment upgrades and $470K for labor ($860K total). No contingency is included in the CFIP, although the CTIO Director holds contingency for CFIP external to the project.

Lower-than-planned funding levels have required prioritizing the CTIO upgrades as “core”, “stretch”, and “wish list”. All items related to supporting the DECam are identified as “core”.

3.2 Comments

The cost and schedule estimates for the DECam, DECDM, and CFIP are managed as separate projects. DES management is working on an integrated project schedule for overall project coordination. Integration efforts should continue to receive high priority.

DECam cost performance has been good and change orders have been modest to date. The cost plus contingency appear adequate to deliver CD-4 deliverables.

The project established good configuration control and has 12 months of earned-value reporting. DECam management is using the monthly earned-value reports effectively in its decision-making.

The DESDM project effort uses partial FTEs and is distributed over many national and international contributors that require strong management and coordination. Only 0.7 FTE (0.5 Project Director, 0.2 Project Manager) is dedicated to managing the overall DESDM project. The Committee judged that this is not adequate to actively manage the project. No DESDM breakout materials were presented on cost, schedule, or management areas. These topics should be addressed at subsequent reviews.

DESDM management is working with its in-kind contributors to increase support and has identified some partial solutions to the funding shortfall. In addition, DESDM plans to submit a proposal to NSF Astronomy to support 2 FTEs in the FY 2010/FY 2011 timeframe.

Prioritizing the DESDM components is an effective way to ensure the ‘must-haves’ are ready for initial operations. Management intends to make a decision on priority 2 and 3 components after the latest data challenge has been evaluated and after the NSF proposal has been approved or not. This decision date is the end of FY 2009, which appears reasonable.

The CFIP project team is steadily ramping up resources and making good progress. Schedule performance is meeting expectations.

3.3 Recommendation

1. Recommend CD-3b for DECam.

4. SCHEDULE and FUNDING

4.1 Findings

The DECam resource-loaded schedule is captured in a MicroSoft Project file 44 month schedule August 2007-March 2011. The DECam critical path runs through the cooling system, imager and barrel designs and FY 2009 funding. The schedule has one year of schedule contingency to CD-4 (March 2012).

Earned value (Cost Performance Reports) is produced by COBRA, which is integrated with the Fermilab general ledger. COBRA applies burdens, escalation and provides the detailed earned-value data.

The DECam project has a funding constrained schedule with the majority of its procurements planned in FY 2009.

The DESDM schedule follows a series of spiral development cycles. Yearly data challenges are planned with identified milestones. A Community Pipeline test is scheduled for summer 2010 with a ‘stress test’ for fall 2010. Commissioning and acceptance testing is scheduled for spring 2011 with full operations in October 2011.

For CFIP, all new hardware components (encoders, controllers, power drivers) will be installed by the end of September 2008 in time for the October tests of the telescope mount. Software application and project completion dates have been advanced three months. Overall, 12-15 months of schedule contingency is available.

Additional NSF funding is planned via a proposal to support the DESDM project scope.

CFIP infrastructure improvements will be provided using operating funds.

4.2 Comments

DECam, DESDM, and CFIP are managed as separate projects. However, DES management is working to tie the projects together with an integrated project schedule. DES management should continue this effort.

To date, DECam schedule performance is good and schedule contingency is considered adequate to meet its CD-4 commitments.

With the exception of some project office resources, the DECam schedule contingency is not costed. Any schedule delays will draw from contingency and the project team should make every effort to maintain good schedule performance.

An FY 2009 Continuing Resolution (CR) is assumed by the project, which will make executing the full list of procurements problematic. Fermilab management (PMG) is actively engaged and has committed to assisting the project in a funding shortfall due to the CR.

The DECam obligation profile is front-loaded and early use of contingency should be carefully managed. The project should identify on a risk-basis procurements that can be deferred under a limited-funding situation, or advanced should additional funding be available.

In addition, the project should investigate whether forward funding opportunities with its university partners might help in awarding the DECam FY09 procurements.

With full funding, the DESDM project team can commit to delivering the full scope and with approximately nine months of schedule contingency. Without full funding, the priority 2 and 3 items may be dropped from the full scope and schedule contingency is projected to fall to near zero. This is a critical decision for the project and DESDM management should work closely with NSF and all its partners to ensure that the scope is, at all times, well defined and clearly communicated to the project team.

The CFIP is performing well on its baseline schedule and is steadily ramping up resources and making good progress.

4.3 Recommendations

1. DECam should prioritize (according to risk) a list of planned FY 2009 procurements, and a list of late FY 2009 procurements that can be deferred should additional contingency be necessary to address overruns and/or CR.

2. Recommend DECam for CD-3b.

5. MANAGEMENT

5.1 Findings

The DES project consists of three major subprojects, the DECam project, the DESDM project, and the CFIP. A project director oversees the DES Collaboration and Project that currently consists of 12 participating institutions and over 100 individual collaborators. The Office of High Energy Physics within DOE/SC funds the majority of the DECam project. Fermilab is the lead institution for DECam. NCSA at UIUC leads the DESDM project with NSF funding. NOAO leads the CFIP project with funding from the NSF as well. In-kind contributions and no-cost resources and deliverables form substantial and critical contributions in all three projects. In addition to the American collaborating institutions, there are three foreign consortia: United Kingdom-DES, Spain-DES, and Brazil-DES, each with specific in-kind deliverables. Additionally Spain-DES and the UCL have successfully applied for and received explicit funding from their respective funding agencies to participate in the DES project. In several instances, the in-kind or no cost contributions from collaborators include subcontracts to other institutions (for example, University of Michigan subcontracts to Bonn University for the shutter) or vendors (UCL procures the optics from potential multiple suppliers).

A DES Council representing Fermilab, NCSA, and NOAO provides director level oversight of the project. P. Oddone (Fermilab), T. Dunning (NCSA), and D. Silva (NOAO) presently serve as its members. A global Memorandum of Understanding (MOU) was developed and signed (May 14, 2008) concerning the DES Council and its working relationship between the three principal institutions. DOE approved CD-3a immediately following the signing of the global MOU.

Each of the DES collaborating institutions has a MOU; the majority of the MOUs have been signed with most having annually revised statements of work (SOW) associated with them.

The governance of the DES project reflects its collaborative multi-institution and multi-agency aspects. The DES Management Committee represents the interests of the collaboration. The DES Project Director (J. Peoples) chairs this committee with members elected from the collaborating institutions and consortia with the DECam Project Manager (B. Flaugher), the DES DM Project Leader (J. Mohr), and CTIO Director (A. Walker) participating as ex-officio members. The management committee addresses collaboration management and overall DES project coordination.

The DES project has a Science Committee that is tasked with providing the survey science requirements to the DES project as a whole. A Community Needs Working Group has been established by NOAO to review and integrate community needs into the three projects. It is the forum for the integration of the community pipeline into the NOAO/DPP E2E system and the DECam use of the NOAO DTS.

The highest level of integrating systems support within the DES project is provided by the DES Project Director and an executive committee constituted by the project offices of the three subprojects that meets on an approximately monthly basis. Strong communication between the three subprojects and the overarching DES project is in evidence and consequently exerts a strong integrating function. In response to previous recommendations, the DES project has organized a Systems Interface Working Group that is to meet for the first time at the beginning of October 2008. This reflects the increased integrating role that the DES project is now playing in regard to its three subprojects.

The DES project and the DECam project in particular (with regard to DOE requirements) have addressed the five management recommendations from the January 2008 DOE/NSF review. DECam continues to develop its management systems and integration support at the DES project level.

The DECam project has revised and tightened its risk registry and developed three issues logs that are used regularly in the management of the project: ongoing, technical, and integration. Likewise the DECam project continues to exercise the control processes that it has put in place prior to establishing the project baseline (CD-2) and is rigorously managing to that baseline.

The DESDM project at the time of this review had allocated approximately 0.2 FTE of project management in its project.

5.2 Comments

The Committee judged that the state of the project is ready for full construction authorization in both documentation and management systems. The DECam project has adequately prepared all the requirements necessary to meet the requirements for CD-3b, and the committee endorsed DOE approval of CD-3b.

The CFIP project continues to make progress and is managed in a manner that the Committee judged to be adequate. DESDM has a project team in place and acknowledges that their proposed project baseline is not consistent with the scope of work anticipated. The complexity of the DESDM project and the importance of its deliverables (both internally to the DES project and externally to the community) are such that the Committee felt that there is a need for additional project management and software development rigor and that the present level of project management (approximately 0.7 FTE) is inadequate. The DESDM project is also encouraged to be more explicit in its reporting of responses to previous review recommendations. This will facilitate the Committee recognizing its accomplishments and progress.

Configuration management formality, though starting, is not as well established or mature as the Committee would like to see at this point of a project, but progress in this area is accelerating. The project, however, does not appear to be suffering from this nascent activity at present. All three subprojects, and the DECam project in particular, are encouraged to examine and strengthen their progress and approach on configuration management as DES transforms into full construction.

Integration of the three individual projects within DES has greatly improved, but will always remain an area where additional effort will bring substantial returns to the collaboration. An integrated schedule was reported as being under development (as recommended at the January 2008 DOE/NSF review). Milestones, schedules, and risk and issues management that are carefully synchronized and integrated will minimize delays and increased costs stemming from inadequate coordination.

The Committee was pleased to see the increased emphasis on risk, issues management, and integration. All parts of the DES project are encouraged to aggressively pursue risk management as a means of optimizing the project performance and subsequently the scientific output. The telescope simulator is a prime example of the attention being paid to integration risks that will reap dividends when final integration and installation occur at the telescope.

While the quantity and quality of risk management has increased, progress is still possible. Project communication and cross coupling of complex risk issues such as funding profiles and availability are two areas that will benefit from careful examination. For example, there was confusion about the number of filters to be purchased by the project and whether or not spare filters for operations would be solicited at the same time. With the initial quotations for the optical filters being significantly larger than originally estimated, the project must not unduly delay the procurement of optical filters. Such a delay in procurement could lead to significantly increased schedule risk should any technical issues arise during the procurement. This is true for other procurements of higher risk. Care should be exercised to avoid compounding risk in schedule technical areas in an effort to mitigate funding profile risks. It is tempting to delay higher risk procurements using funding profile constraints as a justification in hopes that the higher risks will resolve themselves. This simply does not happen. The delay, while providing some funding profile relief increases the risk in technical, schedule, and subsequently even in cost of these procurements.

Associated with this area of risk management, DECam project should carefully review its subcontract monitoring and management to mitigate potential technical and schedule risk with the suppliers before they become critical issues.

The DES Project Director continues to do a remarkable job in guiding an enthusiastic collaboration and bringing a diverse set of complementary capabilities with significant in-kind contributions together. The DES Collaboration is an enthusiastic competent team and the Project Director's direct efforts continue to increase the likelihood of success of the overall effort while reducing overall risk.

5.3 Recommendations

1. Ensure that nomenclature used throughout the project is consistent and clear to reduce potential miscommunications prior to the next review.

2. Add more resources or at least provide for more project and risk management rigor to the DESDM project (consider adding approximately one FTE) before the next review.

3. Develop a risk-based procurement timing strategy in response to an inevitable extended continuing resolution situation prior to the need to reschedule activities and procurements within the project.

4. Examine the subcontract, vendor controls, and communication to minimize schedule and cost risks prior to the next review.

5. Reexamine both the integration and configuration controls in place throughout the DES project (DECam in particular) to ensure adequacy. This includes initiating the DES Project Interface Working Group as soon as possible.

6. Proceed with obtaining CD-3b for DECam project.

APPENDIX A

CHARGE TO THE COMMITTEE

U.S. Department of Energy

and the

National Science Foundation

July 16, 2008

To: Mr. Daniel Lehman, Director, DOE Office of Project Assessment, SC-28

Subject: Request to Review the Dark Energy Survey project

The Department of Energy (DOE) Office of High Energy Physics (OHEP) and the National Science Foundation (NSF) request that you conduct a review of the Dark Energy Survey (DES) project on September 9 - 10, 2008 at Fermi National Accelerator Laboratory (FNAL).

The DES experiment will utilize the existing Blanco Telescope at the Cerro Tololo Inter American Observatory (CTIO) in Chile to study the nature of dark energy. The project includes the fabrication of a new camera (DECam) optimized for the study of dark energy, the CTIO facilities improvement project (CFIP) for upgrades to the telescope and CTIO facility, and a data management system (DESDM). Funding is being provided by the DOE, NSF and other U.S. and foreign institutions.

For DOE, this review will serve to verify the DECam project's readiness for approval of Critical Decision 3b (Approve Start of Construction). Critical Decision (CD) 2 for approval of the performance baseline was approved for the DECam project on April 29, 2008. CD-3a, for initiating early procurement of long lead items, was approved on May 20, 2008.

For NSF, the review will serve to assess the status of the CFIP and DESDM projects.

In carrying out its charge, the review committee is requested to evaluate the progress and status of all 3 DES projects as well as the coordination between them. For the DECam project, the committee should evaluate whether the final design of DECam is complete and if it's prepared to enter the next stage. In carrying out this charge, the committee should address the following specific items:

1. Technical: Is the final design sufficiently mature so that the project can initiate procurement and fabrication? For those elements that are not finalized, has the project convincingly shown that there are no major issues that need to be addressed and that they have a clear path forward towards final design?
2. Baseline Cost and Schedule: Are the current project cost and schedule projections consistent with the approved baseline? Are the allocations of contingency adequate for the risks?
3. Management: Is the management structure adequate to deliver the proposed final design within specifications, budget and schedule? Has the project responded satisfactorily to recommendations from the previous review?

4. Fabrication: Has there been adequate progress on the fabrication activities approved under CD-3a? Is the project satisfactorily prepared to execute the remaining fabrication activities?
5. Documentation: Is the DECam documentation required by DOE Order 413.3A for CD-3b complete? Have the CD-2 documents been updated to reflect any changes resulting from the final design?

Kathleen Turner is the DOE program manager for the Dark Energy Survey and will serve as the Office of High Energy Physics contact for the review. Nigel Sharp is the NSF program manager for the Dark Energy Survey and will serve as the NSF Division of Astronomical Sciences contact for the review.

We appreciate your assistance in this matter. As you know, these reviews play an important role in our programs. Both agencies look forward to receiving the committee's report within 60 days of the review.

/s/
____
Craig Foltz
Acting Director
Division of Astronomical Sciences
National Science Foundation
Arlington, VA

/s/
____
Dennis Kovar
Associate Director
for High Energy Physics
Office of Science
Department of Energy
Germantown, MD

APPENDIX B

REVIEW PARTICIPANTS

Department of Energy/National Science Foundation Review of the Dark Energy Survey (DES) Project

REVIEW COMMITTEE PARTICIPANTS

Department of Energy

Stephen Tkaczyk, DOE/SC, Chair

Review Committee

Subcommittee 1
Kem Robinson, LBNL*
Mark Reichanadter, SLAC

Subcommittee 2
Roger Smith, CalTech*
Alex Grillo, UCSC

Subcommittee 3
Matt Johns, Carnegie Inst.*
Ian Dell'antonio, Brown

Subcommittee 4
Robert Lupton, Princeton*
Rob Cameron, SLAC

*Lead

Observers

Mike Procario, DOE/SC
Kathy Turner, DOE/SC
Paul Philp, DOE/CH
Nigel Sharp, NSF

APPENDIX C

REVIEW
AGENDA

Department of Energy/National Science Foundation Review of the
Dark Energy Survey (DES) Project

AGENDA

Tuesday, September 9, 2008—Wilson Hall, Comitium (WH2SE)

8:00 am	Executive Session .... Tkaczyk			
8:30 am	Welcome and Laboratory Overview—**Racetrack (WH7XO)**........ P. Oddone			
8:50 am	Fermilab Particle Astrophysics and DES........ C. Hogan			
9:10 am	DES and NOAO........ D. Silva			
9:30 am	DES Status Report .... J. Peoples			
10:00 am	Break			
10:20 am	DECam Project Overview and Status........ B. Flaugher			
11:05 am	CFIP Status Report .... T. Abbott			
11:30 am	DESDM Status Report........ J. Mohr			
12:00 pm	Lunch—**Second Floor Cross Over**			
1:00 pm	Subcommittee Breakout Sessions			
	DECam #3 (management, Q&A)	SC 1	Comitium (WH2SE ...	W. Merritt
	DECam #1 (CCDs, FEE and SISPI)	SC 2	Racetrack (WH7XO)	T. Diehl
	DECam #2 (Optics and Opto-Mech)	SC 3	Snake Pit (WH2NE)..	A. Stefanik
	DESDM #1 (short status reports)	SC 4	Black Hole (WH2NW) ...	J. Mohr
3:30 pm	Break—**Outside of Comitium**			
3:45 pm	Subcommittee Breakout Sessions			
	DECam #3 (management, Q&A)	SC 1	Comitium (WH2SE ...	W. Merritt
	DECam #1 (CCDs, FEE and SISPI)	SC 2	Racetrack (WH7XO)	T. Diehl
	CFIP (Q&A)	SC 3	Snake Pit (WH2NE).....	T. Abbott
	DESDM #2 (management, Q&A)	SC 4	Black Hole (WH2NW)	C. Beldica
4:30 pm	Executive Session—**Comitium (WH2SE)**			
6:00 pm	Adjourn			

Wednesday, September 10, 2008

8:30 am	DES Responses to Questions—**Racetrack (WH7XO)**
9:30 am	Executive Session –Dry Run—**Comitium (WH2SE)**
12:00 pm	Lunch—**Comitium (WH2SE)**
1:00 pm	Closeout Presentation with DES Management—**One West (WH1W)**
2:00 pm	Adjourn

APPENDIX D

COST, SCHEDULE and FUNDING TABLES

DECam Baseline TPC

DARK ENERGY SURVEY

- **Revisions to the TPC following the Jan. Review Recommendations**

Changes to the Base	M$
Travel in FY11	0.16
FEE engineering in FY10 and 11	0.47
Mech. Eng. (FEA analysis) FY09	0.09
Total Base Increase	0.72
Contingency Increase (41% on MIE)	1.58
Total Increase	2.30

- **Incorporated in baseline before CD-2 approval**
- **Baseline Funding Profile (in the DECam PEP)*:**

	FY06	FY07	FY08	FY09	FY10	FY11	Total
R&D Funding	2.28	4.76	3.95	0.71	0.00	0.00	11.70
ME Funding			1.65	8.19	8.61	5.00	23.45
Total Funding	2.28	4.76	5.60	8.90	8.61	5.00	35.15
Integral Funding	2.28	7.04	12.64	21.54	30.15	35.15	

*includes UIUC DOE Base grant funds allocated to DECam

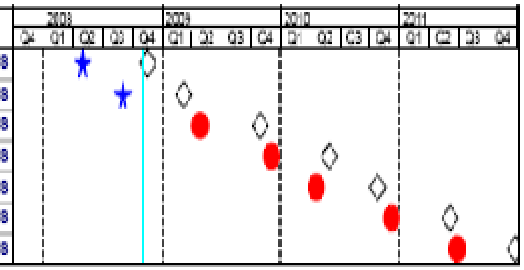
Milestones

DARK ENERGY SURVEY

- Level 1 Milestones: 7 (~ 1 every 6 months)
- Tracked by DOE-OHEP

DECam L1 Milestones
Sorted By Baseline Start Date

ID	WBS	Task Name	Baseline Start	Start	Variance
503	1.4.1.12.8	L1 - All Lens Blanks Complete	8/18/2008	1/31/2008	-27.6 wks
304	1.2.2.10.14	L1 - v2 CCD Processing and Packaging Review Complete	12/8/2008	6/2/2008	-25.8 wks
306	1.2.2.10.16	L1 - CCD's From 30th Production Wafer Delivered To FNAL	7/31/2009	1/26/2009	-26 wks
305	1.2.2.10.15	L1 - 128 CCD's Tested and Graded	3/1/2010	9/3/2009	-23.4 wks
918	1.5.2.12.1.13	L1 - Prime Focus Cage Complete	7/28/2010	1/19/2010	-26.6 wks
945	1.5.2.14.8	L1 - Camera and Telescope Simulator Tests Complete	3/7/2011	9/8/2010	-24.2 wks
94	1.1.6.16	L1 - Acceptance Testing Complete	9/24/2011	3/28/2011	-25.2 wks



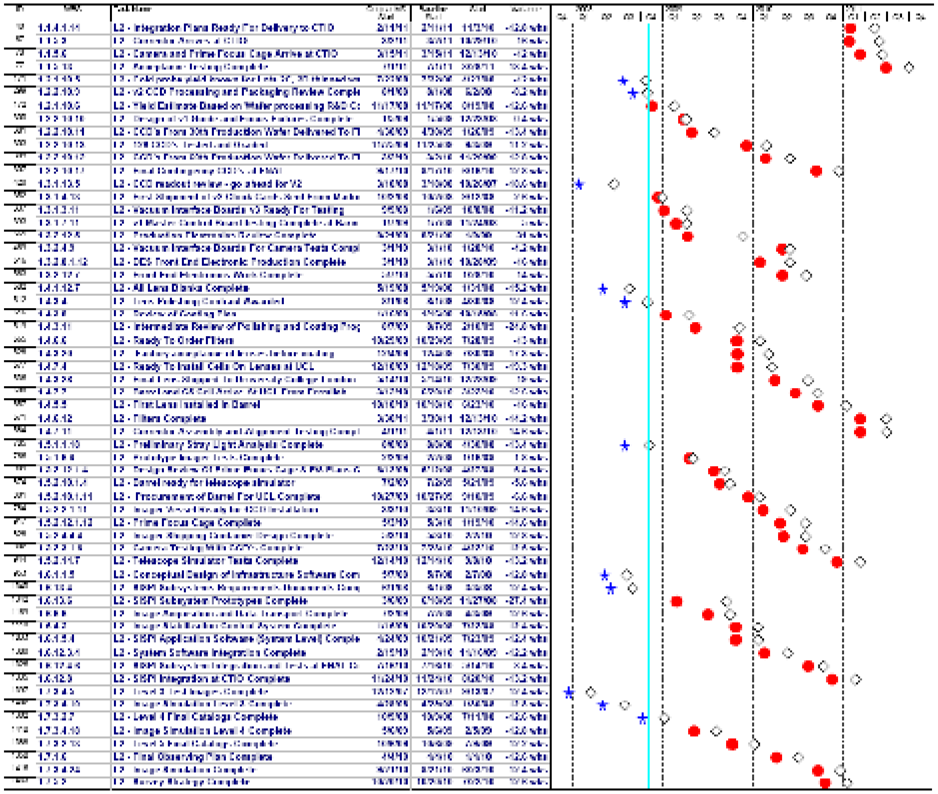
Open Diamond = Baseline MS Date
Solid Red Circle = Forecast MS Date
Blue Star = Completed MS

24

Brenna Flaugher Sept. 9-10, 2008 DOE/NSF review of DES, CD3b Review of DECam

L2 milestones sorted by WBS and baseline date

DARK ENERGY SURVEY



Open Diamond = Baseline MS Date

Solid Red Circle = Forecast MS Date

Blue Star = Completed MS

56 Level 2 milestones over the project

11 completed on or ahead of schedule

Next one “CCD yield estimate based on R&D wafers” has been completed

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Brenna Flaugher Sept. 9-10, 2008 DOE/NSF review of DES, CD3b Review of DECam

APPENDIX E

MANAGEMENT CHART

DES Organization

DARK ENERGY
SURVEY

DECam Project Organization