Department of Energy/
National Science Foundation
Review Committee Report

for the

Technical, Cost, Schedule, and
Management Review

of the

DARK ENERGY SURVEY (DES) PROJECT

July 2009

EXECUTIVE SUMMARY

A Department of Energy (DOE) and National Science Foundation (NSF) review of the proposed Dark Energy Survey (DES) project was conducted on July 8-9, 2009 at the Fermi National Accelerator Laboratory (Fermilab). The review was conducted at the request of Dr. Dennis Kovar, Associate Director for High Energy Physics, DOE Office of Science (SC), and Dr. Craig Foltz, Acting Director, Division of Astronomical Sciences, NSF, and was chaired by Dr. Kathleen Turner, Office of High Energy Physics, DOE/SC.

The DES experiment consists of three fabrication subprojects: a new camera (DECam) led by Fermilab, the Cerro-Tololo Inter American Observatory (CTIO) facilities improvements project (CFIP) and a data management system (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 NSF and in-kind contributions.

For DOE, the review served to assess the status of the DECam project. The DECam project received Critical Decision (CD) 3b, Approve Start of Full Construction, on October 24, 2008 with a Total Project Cost of $35.15 million and a September 2012 completion date. For NSF, the review served to assess the status of the CFIP and DESDM projects.

The DECam optics and opto-mechanical assembly is on track for an on-time and on-schedule delivery. Schedule delays could still occur in a number of areas and close oversight should be maintained. Design work continues on some subsystems, but the time-critical components are now in final design. The barrel delivery is now the critical path item for the optical assembly. The charge-coupled device yield appears to be on track to complete the project with the planned number of wafers and adequate contingency. Good progress has been made on all front-end electronics, with continued testing needed before production in some cases. There are some issues with crosstalk.

Across the DECam project, error budgets and risk analyses should be updated and the configuration controls should be formalized. Delivery, installation, and commissioning plans need to be fleshed out in detail, in coordination with CTIO. Due to inadequate engineering support, the DECam project manager is also the subproject manager for the opto-mechanical system.

The DECam project continues to assess effectively potential Environment, Safety and Health (ES&H) questions. DECam activities at Fermilab are conducted in a manner consistent with Fermilab's Integrated Safety Management Program. The design of the project's technical components incorporates consideration of ES&H related concerns. Fermilab and DOE conduct regular safety inspections of the DECam work at Fermilab and have found that the project incorporates potential ES&H impacts in work planning and execution.

The DECam cost baseline is $35.15 million. This Major Item of Equipment is 27 percent complete and has 30 percent contingency on cost to go. The DECam current costs plus contingency appears adequate to deliver the CD-4 deliverables. DECam delivery to CTIO is forecast for February 2011 with plenty of contingency available until CD-4.

The DESDM project's Data Challenge 4 (DC-4) was largely completed on schedule. There were quite a few concerns about the management since the Principal Investigator (PI) of the DESDM has taken a permanent postion at Ludwig Maximillian University in Munich. The Project Manager was replaced earlier this year and a search for a full-time project manager will be initiated in response to one of the recommendations in this report. The highest identified risk is insufficient staffing. There were also concerns that the change control processes have not been formalized and that the risk assessment and contingency planning need to be refined. The management has submitted a supplemental proposal to NSF for additional funding for staffing.

The DESDM cost estimate of $6.59 million includes work through the commissioning phase. A supplemental proposal of $0.645 million has been submitted to NSF for remaining unfunded work. The schedule is on track for 2011 operations.

The CFIP effort is proceeding at a satisfactory pace and with sufficient schedule contingency to be completed in time for DECam on-site installation. Planning for the transfer of DECam to CTIO and for installation and commissioning is beginning. The management is committed to paying the careful attention required for this effort.

The CFIP costs of $0.86 million are fully funded by CTIO. The project team is making good progress against schedule and all required deliverables will be in place by January 2010.

Overall, the three DES subprojects appear to be progressing adequately and within their cost envelopes. The Committee noted that steps have been taken to improve integration of the three subprojects, but it is still in the development stage and more effort is needed. The work of external teams also needs to be fully incorporated and tracked in the schedule. An overall configuration control system is not in place.

There were some significant leadership issues in DES. The DES Project Director is planning to step down in the next six months, and efforts to identify a successor have not been advancing adequately. The DESDM PI is leaving for a permanent position in Germany and leadership from Europe is not seen as viable. The DECam Project Manager has taken on the additional responsibility of managing Work Breakdown Structure (WBS) 1.5, Opto-Mechanical Assembly. The Committee recommended that leadership vacancies should gain the full attention of the DES Council.

Key Committee Recommendations

1. Appoint local PI-level leadership for DESDM and a single, full time, permanent Project Manager by the end of DC-5.

2. Appoint a new full-time DES Project Director by January to lead DES through the remainder of the construction project and into early science.

3. Appoint a person who reports to the DES Project Director to oversee the overall integration of the three DES projects by August 2009. Recruit a DES systems engineer by October 2009 to track system-wide error budgets, interfaces, and resources, and to maintain configuration control. A DES-level change control board process should be working by April 2010.

4. Identify a project engineer to manage DECam WBS 1.5, Opto-Mechanical Assembly.

Intentionally Blank

CONTENTS

Executive Summary i
1. Introduction 1
2. Technical 3
   2.1 DECam 3
      2.1.1 DECam Optics, Opto-Mechanical Systems, and Integrations 3
      2.1.2 DECam CCDs, SISPI, Electronics 7
   2.2 DESDM, Simulations, and Calibration 13
3. Cost (DECam, DESDM, CFIP). 17
4. Schedule and Funding (DECam, DESDM, CFIP) 19
5. Management 21

Appendices
A. Charge Memorandum
B. Review Participants
C. Review Agenda
D. Cost, Schedule, and Funding Charts
E. Management Chart

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 Office of High Energy Physics (OHEP) in the Department of Energy (DOE) Office of Science (SC) 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 upgrades 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 provided by the NSF. Funding for CFIP will 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), SLAC National Accelerator Laboratory (SLAC), the NOAO, seven 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, the review served to assess the status of the DECam project. The DECam project received CD-3b, Approve Start of Full Construction, on October 24, 2008 with a Total Project Cost of $35.15 million and a September 2012 completion date. 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, Opto-Mechanical Systems, and Integrations

2.1.1.1 Findings

The construction of the optics and fabrication of the opto-mechanical system have made very significant progress since the September 2008 DOE/NSF review. The design of the major opto-mechanical elements is complete, although a few minor elements are still in the design stage. The optical element fabrication is fairly advanced, as all the lens elements have at least reached the fine grinding stage, and multiple elements are at the polishing stage.

SESO has been chosen as the vendor for the element coatings. This reduces the risk of additional shipping, but has necessitated a choice not to coat the C1 element. This has minor consequences for the system throughput and even fewer consequences for scattered light. Recently (July 1 and July 8) damage to optical elements C1 and C2 have been reported at SESO during the grinding stage. The damage to C2 appears to be outside the optical path, and the element is now in the polishing stage, so there is a reasonable expectation that this problem will not have measurable effects. The damage to C1 is inside the optical path but only affects a small part of the surface layer. The project is investigating mitigation measures; one such measure is to grind the defects out by changing the element thickness.

The coating contract with SESO specifies that optical elements are shipped back to University College London (UCL) independently as they are finished. The schedule for the finished (polished) elements will result in them being delivered to UCL by January 2010. The optics invar cell design is finalized, the lessons learned from the fabrication and testing of the test cell have been integrated, and construction of the lens cells is underway. The current schedule is tight, in that the cell fabrication interleaves with the arrival of the optical elements from SESO (the current schedule has cell manufacturing finished by November 2009).

The hexapod design has passed the prototype tests, and the order for the hexapod assembly has been placed. The hexapod assembly no longer appears to be the critical path item for the DECam project. A complete Finite Element Analysis (FEA) has been performed for the barrel, and the results are acceptable. Stress loads appear under control, and the optical design

appears to pass lateral movement tests, although there are some ambiguities as to the extent of the amplification of the forces predicted at the top end of the telescope due to earthquakes.

Both the shutter (which is in fabrication at Bonn) and the filter assembly (being tested at Michigan) are on schedule. Requests for information turned up at least two companies who claim to be able to fabricate the filters. A request for proposals (RFP) for the filter fabrication was sent out July 1, with quotes due by the end of August. The funds for filter acquisition do not become available until October 2009. Because the vendors suggest approximately one year typical delivery time, the filters have a potential to be a schedule driver for the project if there are any delays in delivery.

The project management is very capable, but it is stretched extremely thin. In the past year, the project manager took direct responsibility for managing the WBS 1.5, Opto-Mechanical Assembly. This work is competing for time with other management activities. Tasks where improvement may be needed are in formal configuration control and in expanding the error budget calculations to go beyond image quality metrics. Risk management appears uneven across the DECam project and should integrate risks arising in work being performed by external groups (some of these management issues may have been addressed in the presentations to the management review team).

The management has been effective so far in keeping the project on track. Overall, the costs incurred to date and the cost and schedule projections are consistent with the approved baseline. The project has used up a few months of schedule contingency, but has adequate contingency left for this stage in the construction phase.

The project team has responded satisfactorily to the recommendations of the September 2008 DOE/NSF review. Overall the DECam optics and opto-mechanical assembly are on track for an on-time and on-budget delivery, barring major delays in the delivery of key optical components (noted below).

The projects that comprise the CFIP efforts are proceeding at a satisfactory pace. The radial supports have been installed, and the lateral movement of the Blanco primary mirror in its cell has been reduced by a factor of ten. The effect on the image quality will be tested during the July 2009 shutdown. The Telescope Control System (TCS) upgrade project has also progressed. The TCS test planned for July 2009 has been postponed until September 2009 (the next engineering time block) due to illness of key personnel, but the TCS is nevertheless expected to be ready by January 2010, a full year before the arrival of the camera at CTIO. The installation of the clean room at the Blanco has just begun. However, the schedule for the clean room

delivery is driven by the arrival at CTIO of the NOAO Exteremely Wide Field Infrared Imager Infrared camera in February 2010, leaving ample time in the schedule before the facility is required by DECam.

Work towards integration of DECam and the opto-mechanical assembly in the telescope simulator at Fermilab is progressing. Testing of the electronics with the multi-charge-coupled device (MCCD) test vessel has also progressed strongly. Detailed plans for the installation and commissioning of the telescope are still lacking. There will be a meeting to discuss installation and issues related to installation in La Serena in November 2009. The CTIO director has assigned the task of planning for scientific commissioning to Alistair Walker, who will begin when his sabbatical ends in September 2009.

2.1.1.2 Comments

Progress on the in-kind contributions for the opto-mechanical systems appears to be adequate. The filter mechanism has been assembled at Michigan and is being tested. UCL is paying careful attention to the lens cell manufacture and overseeing the grinding, polishing, and coating of the elements at SESO. The recent problems at SESO notwithstanding, the optical elements are still on schedule. The decision to not coat element C1 appears to be sound risk management; nevertheless, significant schedule and cost risks remain during the finishing, packaging and shipping of the optical elements. The damage incurred to the optical elements C1 and C2 at SESO seems is unlikely to be important; for C1, the most likely solution is to remove the scratches by further grinding, slightly altering the thickness of the lens element. This, however, should not be a problem for DECam because the lens element positions can be re-optimized to account for the decreased thickness of C1. Local treatment of the scratches is another mitigation option, which would result in minimal impact to the project.

The barrel delivery is now near the critical path item for the optical assembly, and the project needs to keep apprised of this order. The assembly metrology (particularly the parallellism) is essential given that a full optical test is not being done before final assembly.

Several major risks were identified that have the potential for causing major schedule delays and additional costs to DES. Examples include:

- Major damage or breakage of a refractive element (particularly C1, which would require at least a year to repair,
- Significantly late delivery of the filters,

- Loss of the z’ filter (the filter that will receive the most use in DES operations), and
- Fabrication and/or assembly errors in the optics that can only be discovered at the telescope during validation and commissioning.

For cost reasons, there are no spares planned for any of the major optical elements of DECam.

Procurement of the filters is just commencing. Because the RFPs from the filter vendors are not due until August, estimates of the delivery dates of the filters are not precise. Since funding to purchase the filters is not available until October 2009, there is still the chance that filter procurement will cause delays to the project, particularly if the vendors have difficulty producing such large filters.

Time constraints limited a full discussion of the cooling system. The system has been successfully prototyped and, based on the materials provided in the review documents, the Committee was comfortable with the design.

The discussion of the F8 assembly was also limited. The assembly is in final design and, based on the review documents, it will satisfy the requirement and be completed on schedule. The Committee noted that the F8 assembly is a risk to the DES only in the sense that acceptance of the camera would fail if the Blanco loses the ability to use instruments at the secondary focus.

The elegant staged development of the prototype MCCD system provides confidence that the production camera will perform according to specifications. The Committee noted that some charge-coupled device (CCD) position tolerances were marginally out of specification but that these were being addressed.

This is the time to flesh out the installation and commissioning plans, particularly as the installation presents non-trivial challenges and there are cost and control implications to problems arising during commissioning. The end of installation and the commissioning will require a tricky transfer of responsibilities between the DECam team and the CTIO staff responsible for commissioning and operations. The DECam project recognizes this fact and has been committed to working with CTIO both before and after the transfer to ensure a smooth transition.

2.1.1.3 Recommendations

1. Maintain close project oversight and risk management of the production, assembly, handling, and shipping of optical elements to mitigate the potential for significant schedule delays and added costs in the production of these elements. This activity should continue through the delivery and installation of the optics in the camera.

2. Update error budgets for image quality, throughput, and ghosting based on the current understanding of error sources and the current optical element designs. A procedure to periodically rebalance the error budget as necessary should be in place by the end of the year.

3. Consolidate and update risk analysis across the DECam project including the external contributors to provide a cross-check of interdependencies between subsystems. This should be performed by the next review.

4. Formalize configuration control procedures, by the next review.

5. CTIO should push forward with planning for the installation of DECam to ensure adequate time for scheduling activities, engineering, and production of fixtures, etc. The preliminary plan should be complete in time for the November 2009 installation meeting in La Serena.

6. Review top-level staffing for WBS 1.5, Opto-Mechanical Assembly, and provide additional help to alleviate overload of the Project Manager. This should be implemented as soon as possible.

2.1.2 DECam CCDs, SISPI, Electronics

2.1.2.1 Findings

DECam CCDs

So far, 27 of the required 72 CCDs have been found to be of full science quality after packaging and testing. The cumulative yield is predicted to be approximately 85 plus/minus 23 once all of Lots 2A to 2F are fully processed. The cumulative yield is predicted to be 101 plus/minus 28 if the entire Lot 3 is fully processed. Wafers are being drawn from all lots for processing to average the lot-to-lot variations and to learn about the quality of each lot.

CCDs fabrication is still 26 weeks off the critical path. If all wafers need to be processed (i.e., contingency has to be invoked), there will be no impact to overall schedule.

A significant number of CCDs have been graded ‘high quality’ but not science grade, and could serve as a fall back in the event of a catastrophe.

Front-End Electronics

Good progress has been made on all electronic boards and cables, which seem to be at revision level ready for production, though in some cases this needs to be verified by testing.

System level tests performed so far are quite impressive and have not shown any big issues as yet, with the exception of crosstalk. The care taken with grounding and shielding is commended. It was reported that electromagnetic interference (EMI) tests were performed to measure emitted radiation and corrective actions taken.

One decision yet to be made is whether to use differential or single-ended signals from pre-amp through the Vacuum Interface Board (VIB) to the 12 Channel Transition Board. The differential version shows negligible crosstalk, while crosstalk for single-ended transmission is clearly detectable, but might still be acceptable in the final configuration since the strength of the crosstalk decreases as more channels are added.

The project proposed to only test examples of the Analog to Digital Converters (ADC) for differential nonlinearity (DNL), rather than follow the previous recommendation to measure DNL for every channel, due to the perceived difficulty of the measurement.

Survey Image System Process Integration (SISPI)

System level tests indicate that the project is in good shape.

The longstanding concern about manpower has been mitigated by addition of new institutions (SLAC/Stanford/University of California at Santa Cruz, UCSC).

Restart and command execution times, which were raised as a concern at the September 2008 DOE/NSF review, appear to be well under control.

2.1.2.1 Comments

DECam CCDs

Yield contingency appears to be adequate.

It was difficult to understand the yield numbers as presented, so considerable discussion was required. Greater clarity would be an aid to management, stakeholders, and future reviewers.

Front-End Electronics

The Committee judged that the crosstalk requirements (implied, not defined, in the presentations) were rather weak. Being significantly better than the current poor performance of the NOAO eight K Mosaics is not sufficient. In such a high channel count system as DECam, the scientists will appreciate keeping the magnitude of the crosstalk (and thus the required accuracy of the calibration and correction) low. Better than 1:10,000 is probably possible and desirable. The Committee suggested a requirement that is no weaker than 1:5000.

The fact that the cross talk decreases as more channels are included may indicate that the crosstalk is caused or aggravated by floating traces on the VIB; it might also be masking other sources of cross talk, which could increase as the full channel count is connected. Another possibility is that the addition of more channels provides more ground return paths in parallel so that the ground return impedance and thus ground modulation by signal is reduced.

The Committee did not see an attempt to deduce an electrical model (a circuit diagram with component values) to explain the crosstalk and encouraged the project team to attempt this level of understanding, in order to build confidence in the solution. The reviewers would be available to examine such a model along with a schematic for the transmission circuit even prior to the next formal review if the designers think they would profit from such feedback.

The safer choice would be the differential option but the single-ended option is preferred since it simplifies the transmission circuitry. Adopting the single-ended option without the tests recommended below (and the circuit model above) would run the risk that uncontrolled current returns could affect receiver or transmitter circuits as the full complement of channels is added.

The VIB protruding through the dewar wall is protected by a frame designed to resist forces applied when mating connectors in the VIB but not the loads such as a person’s weight or collision of the instrument with an immovable object during instrument handling. If the VIB is

broken this would be expensive and time consuming to replace. Covers to protect cables from being snagged and to divert electrostatic discharge (ESD) from the cables and VIB would also reduce electrical and mechanical risks.

This is a key performance parameter, which is vulnerable to board construction or component failure, and thus needs to be 100 percent tested.

The 18-bit resolution of the ADCs is overkill. With 200,000 e-well capacity and >7 e-noise, and a requirement for >2 analog-to-digital unit (ADU) noise to avoid quantization, then 16 bits is sufficient resolution.

SISPI

The guider test results from trials at CTIO in April 2009 are encouraging and the team is aware of system tradeoffs between signal quality and update rate, and the practical limitations of Region of Interest readout for synchronized readout of multiple CCDs.

Given that automated CCD tests in 'cubes' mostly use flat illumination, the projection of star-like images in the MCCD Test Vessel (TV) is especially important to catch any odd effects. It also has great value by facilitating and encouraging more realistic testing of software.

2.1.2.2 Recommendations

DECam CCDs

1. Develop a tabular and/or graphic format for showing points yield loss in the production process, causes of loss, and evolution of these over time. Make clear what is in the denominator when expressing yield as a fraction, and be consistent. Present plots of cumulative CCDs produced in each grade vs CCDs ordered from DALSA, in addition to the 'number of science CCDs vs time' that was presented. The reviewers may be contacted for additional information.

Front-End Electronics

2. Illuminate many more pixels (e.g., shine laser spot during readout to produce bright signal in entire column) to achieve better signal to noise (S/N) and thus characterize crosstalk down to weaker levels.

3. Measure crosstalk with the present VIB with single-ended signals for the video and the current number of CCDs, but with unused signal lines grounded instead of floating to determine how crosstalk changes.

4. Measure crosstalk with all signals in one VIB being driven (single ended video transmission) before ruling out an upgrade to differential video transmission.

5. Strengthen and brace the frame around the VIB so that it is strong enough not only to resist forces when connecting cables, but to survive a person's weight or accidental blows that might occur during instrument handling.

6. Add covers to protect the cables from the VIB to electronics box from being snagged or accidentally pulled and to protect cables and VIB from ESD.

7. Inject noise on AC power lines and shields to measure the effectiveness of the grounding and shielding scheme, over a range of frequencies including those in the bandpass of the front-end electronics.

8. Check maximum surface temperature of integrated circuits (ICs) to make sure there are no hot spots that might accelerate component ageing.

9. Truncate the 18-bit ADC output to 16 bits when observing. Increase electronic gain to ensure that rms noise maps to > 2 ADU (preferably 3 ADU). Use the highest gain, which will not saturate the ADC on any CCD.

10. Construct a CCD simulator circuit, for support of DNL testing, to convert a function generator output into a waveform with 'reset' and 'signal' levels during each pixel time. Reviewer may be contacted for additional design information.

11. Measure DNL for *all* ADCs with triangle wave input for all channels concurrently using the proposed readout waveforms, with >200 samples per ADC output code. Make histogram (e.g., with the imhist task in Image Reduction and Analysis Facility (IRAF)) with binwidth=1 and again with binwidth=4 to provide a statistical measure of ADC code widths for the full 18-bit resolution and for truncation to 16 bits. Normalize the histogram (so mean counts per bin is scaled to unity). Present the results as a histogram of code widths, i.e. a histogram of the histogram.

SISPI

12. Continue to improve the multi-spot projection optics so that projected spots will more closely approximate stellar point spread functions (PSFs) to allow experience to be gained with astro-realistic illumination during both the present test phase with the MCCD/TV, and during integration and testing (I&T).

2.2 DESDM, Simulations, and Calibration

2.2.1 Findings

The DESDM PI/Project Scientist Joe Mohr has taken a permanent position in Munich.

DESDM has a new (half time) Project Manager, Mike Freemon, who may be moving to another project.

DESDM is taking steps to add team members with additional funding request to NSF for two full-time equivalents (FTEs), including an additional 0.5 FTE for a Project Manager.

A Data Challenge Coordinator (Brian Yanny) was appointed (25 percent time) to help coordinate the Science Working Groups (SWGs) and DESDM.

A Systems Interface Working Group (SIWG) is being implemented, to address cross-project interfaces and issues.

DESDM Commissioning Planning is just getting underway.

Astronomy codes seem to be progressing well, although the new functionality implemented in SExtractor (psf-convolved models, psf-matched coadds) were not run as part of routine Data Challenge 4 (DC4) processing

'Gold Night' data processing and analysis with DESDM and SWGs is planned as a precursor to start of the remaining DCs in order to get feedback before committing to the full processing runs.

DC4 was very largely completed on schedule. DC4 had some involvement of SWGs, and provided useful feedback to DESDM on data access issues. DC5 will take place between

October 2009 and January 2010. DC6a will focus on the Community Pipeline. DC6b is expected to be the first 'blind' test for SWGs, with simulated cosmological effects not revealed until the end of the test.

Real Blanco Cosmology Survey (BCS) data have been analyzed using DESDM.

DES Community Pipeline will re-use some of the processing and science code developed for DESDM.

The Brazilian team led by da Costa has moved effort from providing quality assurance (QA) framework and portal to providing a mountain-top quick reduction system for observer/ operation feedback. A new QA system is being developed at NCSA, and was used in DC4.

Risk identification and tracking within DESDM is being implemented as previously recommended; highest identified risk is insufficient staffing.

JIRA issue tracking has been successfully implemented and become a useful tool (Freemon: 'a cultural change') within DESDM.

There is no apparent formal change control process in place.

DESDM intends to keep all derived image products, and to use lossy compression to keep the disk usage under control. They will be asking NSF to fund the required hardware within the next six months.

Current production computing plan is baselined on using Blue Waters, which is scheduled to come online in 2011, and is based on currently unspecified technology.

There are plans to implement an application programming interface (API) for data access.

2.2.2 Comments

The Committee was concerned that both top-level DESDM roles (Project Scientist and Project Manager) are changing two years before the start of commissioning. The Committee realized the difficulty of finding a suitable local candidate to replace Joe Mohr, or augment his function. But, a person with strong science skills needs to be proficient by the time of DECam commissioning and the start of the science observing program, to be fully available to support these activities. The DESDM Project Manager (PM) has changed since September 2008

DOE/SC review, from Cristina Beldica to Mike Freemon, but a stable and full time, long-term DESDM PM is needed. Since DC6 is the final critical test of the DESDM system before commissioning, it is important to have both these positions filled by then. The Committee also suggested a follow-up independent review of the readiness for DC6.

The Committee agreed that the supplemental funding request to NSF, for two additional FTEs for the remainder of the project, is at about the right level of needed additional support. But, the Committee did not feel the DESDM group had demonstrated that their requested 1.5 extra FTEs (beyond the additional 0.5 of a PM) were filling the most critical needs in the NCSA group.

Appointing a DC Coordinator is a good idea, but 25 percent time may not be sufficient. The corresponding job during commissioning certainly requires at least 100 percent time.

The SIWG led by Rich Kron was mentioned, but no presentation was made on the specifics of work completed so far.

Who is really going to lead photons-to-science DES Commissioning? The separation of DESDM from SWG responsibilities makes careful coordination and sharing of experience especially important.

While the Committee agreed that processing a suitable subset of the data should precede the complete DC processing, the Committee was not so sure that a 'Golden Night' is the correct subset (e.g., would a set of multiband exposures of the same field be more valuable?)

Database schema and table structures are to be revised in 2009 as a result of SWG feedback from DC4—is this an indicator of future extra unplanned work for DESDM stimulated by SWGs?

The Committee had some concern about timescales for DC6 (particularly 6b): Jim Annis states that six months lead-up may be needed to fully prepare blind simulation dataset that suits SWG needs, and that SWGs may need several months post-DC6b to fully analyze data and close the loop with DESDM. These periods of time preceding and succeeding the DC6b may not agree with the DESDM schedule.

The processing of real data (BCS) has not been as successful as that of the simulated data. This is hardly surprising, but it underlines the fact that success in simulated DCs does not obviate the need for potentially extensive commissioning and debugging on the sky. If possible, it may be of use to try and at least partially process test data from the real DECam focal plane populated with flight CCDs, taken during DECam construction.

An important function for the Project Scientist is tracking and assessing the combined performance of the DESDM and SWG codes, working in collaboration with the Data Challenge Coordinator (DCC). This will help prepare the project for scientific commissioning

The Committee did not understand the connection between the Quick Look Pipeline and DESDM/Community Pipeline efforts. DESDM reviewers missed the presentations on Simulations and Quick Look Reductions due to splinter meeting agendas. The Committee appreciated the fact that more care should be given to scheduling the splinter sessions in future reviews, to ensure that the single review team can together assess the three topics of DESDM, simulations, and calibrations.

Risk assessment currently only considers individual WBS elements.

Change control processes are not uniformly applied across the DES projects. No formal change control process is yet in place for DESDM, which will become especially important as SWGs increase their involvement in Data Challenges.

Saving all images with lossy compression needs cost-benefit analysis vs. recalculation as needed.

Over the lifetime of DES, the computer hardware and middleware that the DESDM depends upon will inevitably evolve, but the Committee saw no contingency plans for addressing the changes to the data management systems that such evolution will inevitably impose.

The grid middleware has already had to be re-implemented in a new scripting language (OgreScript), and elements of DC4 postponed due to the unavailability of the anticipated Oracle RAC hardware. Of particular present concern is the assumed reliance on the Blue Waters machine, whose detailed specifications are currently unknown.

New QA processes and outputs are being developed that will track/show QA information on processed data. The Committee was not clear if this includes monitoring of computer systems. There seems to be no specific tracking of processing failure rates (e.g., number/fraction of failed processing jobs) during the DCs, to be able to measure how far short they are of 100 percent processing success, and how they improve their success rate with time. Monitoring and managing failed jobs in the operational phase could be major staffing issue if a large number of failed processing jobs must be debugged and/or completed by hand.

2.2.3 Recommendations

1. Recommend local PI-level leadership for DESDM. At least a transition plan should be in place by the beginning of DC5, but definitely no later than the end of DC5. The DESDM lead needs to be fully up-to-speed in September 2011 to support commissioning on the sky. In order to attract a candidate of the required calibre, the Committee judged that this position should have full responsibility for DESDM, rather than just being the previous incumbent's deputy. Joe Mohr should be encouraged to remain involved in the project.

2. Recommend a single, full-time, permanent DESDM PM who should be in place by the beginning of DC5, but definitely no later than the end of DC5.

3. Put a Change Control process (e.g., a Change Control Board) in place by DC6, either at DESDM- or DES-level.

4. Refine risk assessment and contingency planning to include DESDM system-wide risks that cross WBS element boundaries, needed by DC5.

5. Hold a follow-up review of DESDM and the scientific codes being produced by the SWGs before DC6.

3. COST

3.1 Findings

The DECam project cost baseline is unchanged since receiving CD-2, Approve Performance Baseline, in April 2008.

- The Total Project Cost (TPC) is $35.15 million (R&D $11.7 million, Major Item of Equipment (MIE) $23.45 million).
- All project costs estimated costs are in fiscal year (FY) 2007 dollars and are fully-burdened and include out-year escalation. Since the September 2008 DOE/NSF review, some estimates have been updated using the change control process.
- Installation and commissioning costs are not included in the DECam project.

The DECam project has been reporting earned-value since August 2007. For the month-ending May 2009, DECam earned-value is:

- R&D is 100 percent complete.
- MIE is 27 percent complete. Contingency is $4.3 million (30 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, rev. F) is $6.592 million (607.1 man-months). The baseline includes contingency based upon a risk-based analysis. Of the baseline funding, $6.01 million has been approved with $0.58 million currently unfunded. A proposal has been submitted to NSF for $645K to fund remaining work. Progress on the overall project is measured via milestones (data challenges).

CFIP cost estimate includes $390K for equipment upgrades and $470K for labor $860K total. This information has not changed since September 2008 review. No contingency is included in the CFIP costs, although the CTIO Director holds contingency for CFIP external to the project. Progress is measured via milestones (included in the CFIP Project Execution Plan).

3.2 Comments

To date, the DECam cost performance has been good. There have been 21 months of earned-value reporting and the management team appears to be effectively using earned-value metrics in its decision-making.

The current DECam cost estimate plus contingency appears adequate to deliver CD-4 deliverables. Baseline change processes are in place, and change orders to date, although numerous, have been modest in scale and documented.

The DECam cost estimate has been updated regularly, using change control, when new cost information became available. However, there has not been a comprehensive cost estimate of all remaining work since April 2007. The project team should consider updating remaining work prior to the start of FY 2010. An updated comprehensive cost estimate will provide a higher confidence of available contingency as the project enters the last two years of the MIE.

The DESDM project effort utilizes many fractions of FTEs and work is distributed over many national and international contributors, which will require strong management and coordination. The Committee continues to have concerns that insufficient attention is paid to proactively managing the project. This concern will only increase with the Scientific Leadership moving to Europe.

The CFIP project is primarily an upgrade to an operating facility. Funding is provided by CTIO and the project is making good progress. Schedule performance is meeting expectations and should be ready well in advance of the DECam arrival.

3.3 Recommendation

1. Perform a bottoms-up cost estimated on remaining work for the DECam project by October 2009.

4. SCHEDULE and FUNDING

4.1 Findings

The DECam resource-loaded schedule is captured in a resource-loaded Microsoft Project file which is used to track overall DECam progress. DECam delivery to CTIO is forecast for February 2011 and early finish milestone (DECam ready for installation on the telescope) is forecast for May 2011. The schedule has 16 months of schedule contingency to CD-4 (September 2012).

DECam earned value (Cost Performance Reports) are produced by COBRA, which is integrated with the Fermilab general ledger. COBRA applies burdens, escalation, and provides the detailed earned-value data. Through May 2009 cost and schedule performance indices are approximately 0.97 and 0.98, respectively.

The DECam project is well advanced. R&D is complete and CCDs (WBS 1.2) and Front-End Electronics (WBS 1.3) are in production. The largest portions of remaining work are in WBS 1.4: Lens fabrication (Science and Technology Facilities Council (STFC) funding), filters (yet to be procured), and WBS 1.5, Opto-Mechanical Assembly (integration).

The DESDM schedule follows a series of DCs with milestones. To date, DESCM has conducted four of six DCs. A Community Pipeline test is scheduled for summer 2010 with a 'stress test' in the fall 2010. Commissioning and acceptance testing are scheduled for the spring 2011 with full operations in October 2011. Additional NSF funding is planned via a proposal to support the remaining DESDM project scope.

For CFIP, all new hardware components (encoders, controllers, power drivers) have been purchased. The April 2009 engineering run demonstrated the full and stable open-loop control of the telescope and subsidiary systems. Full production tests are scheduled for December 2009 in advance of commissioning in January-February 2010. Overall, CFIP is anticipated to be ready for DECam installation, and 12-15 months of schedule contingency is available.

4.2 Comments

Overall, each of the three DES projects have made good progress since the September 2008 DOE/SC review. However, DECam, DESDM, and CFIP still appear to be managed as separate projects without a summary level integration schedule or interface

milestones. DES management is working to tie the projects together with an integrated schedule but this work should take on more importance as the three subprojects approach systems commissioning and early science.

To date, DECam schedule performance is good and schedule contingency is considered adequate to meet its CD-4 commitments. This is particularly good news given last year's budget difficulties and the DECam project team should be commended for its diligence.

With most large procurements under contract, the impact of an FY 2010 Continuing Resolution (CR) is not a major issue. Fermilab management is actively engaged and has committed to assisting the project should a shortfall due to the CR be realized.

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 two or three 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 DESDM project is 4.75 years into a seven-year development project. The first four DCs have been deployed and tested. There has been some schedule degradation and not all DC requirements have been achieved. The project team did not identify any schedule contingency but is 'holding to schedule for 2011 operations'.

For CFIP, while there have been some delays, the project team has made good progress against its baseline schedule. The largest remaining deliverable required to be in place prior to the DECam arrival is the clean room, which is scheduled to be complete in September 2009. It is highly likely that all required CFIP deliverables to support DECam will be in place by January 2010.

4.3 Recommendation

1. Develop and distribute a summary schedule identifying key interfaces, milestones, and dependencies for the three DES subprojects to the Joint Oversight Group (JOG) by October 2009. Regular updates to the summary schedule should be made at the monthly JOG meeting (see also management recommendations).

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 is responsible for the integration of the three subprojects into the DES project. The DES Collaboration has added member teams in the United Kingdon and at SLAC/UCSC/Stanford for specific functions, and now stands at 13 participating institutions and over 100 participants.

OHEP, within DOE/SC, funds the majority of the DECam project. The NCSA at the University of Illinois at Urbana-Champaign (UIUC) leads the DESDM, primarily with funding from NSF. NOAO leads CFIP 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. A JOG consisting of funding agency representation from DOE/SC and NSF provides overall DES project oversight.

The DES Project Director reports to the DES Council representing Fermilab, NCSA, and NOAO, which provides director level oversight of the project. P. Garbincius (Fermilab), C. Hogan (Fermilab), D. Crutcher (NCSA), and D. Silva (NOAO) presently serve as its members. A global Memorandum of Understanding (MOU) has been developed and signed (May 14, 2008) concerning the DES Council and its working relationship between the three principal institutions.

In response to previous recommendations, the DES project has organized a SIWG that coordinates interfaces between DECam, DESDM, CFIP and the science committee. This reflects the increasing role that the DES Project Office is now playing in regard to integration of its three subprojects. Other actions consistent with an increased emphasis on integration are; a DECam shipping plan has been drafted by DES and NOAO; a draft property transfer DOE-NSF MOU has been drafted by DOE; a first draft of the integrated schedule has been prepared by DES; a DC Coordinator (B. Yanny) was appointed to develop a plan to more closely involve the SWGs in the remaining DCs, and coordinate the use of the archive by the SWGs with the DESDM team and the science committee.

The DECam project is actively managing risk through the use of a registry and has reduced the number of active risks to provide a better focus on the major risks to the project. 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.

At this review, some significant DES leadership issues were presented. First, the DES Project Director wants to step down from his management role within the next six months, though is willing to stay on in a scientific capacity. Second, the DESDM Project Scientist is leaving the U.S. for a permanent position in Germany, but wishes to retain his position on DES, while the DESDM is also seeking a full-time project manager, and finally, the DECam Project Manager has taken on the additional responsibility of managing WBS 1.5, Opto-Mechanical Assembly.

5.2 Comments

In general, the three DES subprojects appear to be progressing adequately and within their cost envelopes. The Committee found the DECam project to be well managed though staffing is thin in some areas. Project control processes are in place, fully functional and being used to manage the project. The DESDM project has progressed through four DCs with most deliverables achieved, though management communication and rigor still needs improvement. The CFIP project has most deliverables in place in preparation of the DECam next year. All DES subprojects have been generally responsive to previous review recommendations.

The steps taken on improving integration in preparation of science are improving, however, each subsystem project manager is focused on completing their subsystem deliverables with less consideration on integration into the overall DES system. Integrating the three subprojects remains an area where additional effort will bring substantial returns to the collaboration. An integrated schedule, as recommended at the September 2008 DOE/NSF review, is still in the development stage and this effort should be increased. Interface milestones, integrated schedules, and risk management that are used in making DES management decisions and transmitted across the collaboration will minimize delays and increase readiness for commissioning and early science.

There does not seem to be a vigorous configuration control system in place, nor are processes uniformly applied across three DES projects. This will become more important as SWGs increase their involvement in the DCs.

A large number of documents have been developed but there seems to be a lot of overlap and no overall organization. Key documents are difficult to find, and overall project communication and coordination would be well-served by a logical, flow-down document tree structure.

The leadership vacancies within DES should gain the full attention of the DES Council and support of the JOG. John Peoples, the founding DES Project Director, has performed exceptionally in guiding the project teams and the broader collaboration to this exciting point in the project. With two years until early DES science, this is an ideal time to bring in a successor who can lead the project through the final construction phase and into commissioning and early science. The DES Management Committee has appointed a committee to seek names for a successor for the DES Project Director and this committee has worked closely with the Council to define the job description of the DES Project Director. The Council has charged the Management Committee to provide a ranked list of three names from which it will appoint the successor. The Council plans to make the appointment by January of next year. This effort must continue to receive a high priority.

In addition, Joe Mohr, DESDM Scientific Director, has taken a faculty position in Germany. Completion of the development of the DESDM and leading the integration of DESDM into early science comprise a significant effort, and the Committee judged that management of the DESDM by a part time person in Europe, while the bulk of the work is done, in the U.S. is not a viable plan. DESDM needs a local, full-time leader to continuously monitor data system development.

5.3 Recommendations

1. Recruit local PI-level leadership for DESDM. A transition plan should be in place by the beginning of DC5, but definitely no later than the end of DC5.

2. Recruit, by January 2010, a full-time DES Project Director to lead DES through the remainder of the construction project and into early science.

3. Identify, by August 2009, a person who reports to the DES Project Director to oversee the overall integration of the three DES projects. This person should be included in the monthly JOG meetings and present a detailed status of the overall DES construction, testing and commissioning schedule.

4. Recruit, by October 2009, a DES systems engineer to track system wide error budgets, interfaces, and resources, and to maintain configuration control. A DES-level change control board process should be working by April 2010.

5. A project engineer should be identified to manage DECam WBS 1.5, Opto-Mechanical Assembly.

Intentionally Blank

APPENDIX A

CHARGE TO THE COMMITTEE

U.S. Department of Energy
and the
National Science Foundation

JUN 2 2009

To: 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 status of the Dark Energy Survey (DES) project on July 8 - 9, 2009 at Fermi National Accelerator Laboratory (FNAL). The most recent DOE/NSF review of this project was held September 9 – 10, 2008 at 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 three main parts: 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 assess the status of the DECam project. The DECam project received CD-3b, Approve Start of Full Construction, on October 24, 2008 with a Total Project Cost of $35.15 million and a September 2012 completion date. 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 parts of the DES project as well as the coordination between them. The committee should address the following specific items:

1. Technical Scope: Are the accomplishments to date and planned future activities consistent with the baseline objectives and is the project progressing adequately? Are the focal plane detectors, electronics, optics and opto-mechanical systems progressing sufficiently? Are the data management and telescope facility upgrade projects progressing sufficiently? Have the final designs of all major systems been finalized?

2. Cost, Schedule, and Risks: Are the current cost and schedule projections consistent with the approved baseline for all the projects? Are the allocations of cost and schedule contingency adequate? Have most major risks been identified and are they being addressed effectively?

3. Management: Is the management structure adequate to successfully execute the projects within specifications, budget and schedule? Is the management approach effective? Are there opportunities for improvement?

4. ES&H: Are ES&H aspects being properly addressed? Are Integrated Safety Management Principles being followed?

5. Prior Reviews: Has the project responded satisfactorily to recommendations from the previous review?

6. Preliminary Planning for Transition to Operations: Are the preliminary plans for the delivery of the systems, transition to operations and for the operations phase appropriate for this stage of the project?

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.

for CBF
2 JUNE 2009

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

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
July 8-9, 2009

REVIEW COMMITTEE PARTICIPANTS

Department of Energy

Kathy Turner, DOE/SC

Review Committee

SC 1—DECam Optics, Opto-Mech, CFIP
Matt Johns, Carnegie Inst.*
Ian Dell'antonio, Brown

SC 2—DECam CCDs, SISPI, Electronics
Roger Smith, CalTech*
Alex Grillo, UCSC

SC 3—DESDM, Simulations and Calibrations
Robert Lupton, Princeton*
Julian Borrill, LBNL
Rob Cameron, SLAC

SC 4—Cost, Schedule, and Management
Mark Reichanadter, SLAC
Henry Heetderks, LBNL

*Lead

Observers

Theodore Lavine, 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
July 8-9, 2009

AGENDA

Wednesday, July 8, 2009—Wilson Hall, Hornets' Nest (WH8XO)

8:00 am	Executive Session		K. Turner
8:45 am	Welcome and Laboratory Overview		TBD
9:00 am	DES Status Report		J. Peoples
9:20 am	DECam Project Overview and Status		B. Flaugher
10:00 am	CFIP Status Report		T. Abbott
10:20 am	Break —**Outside of Hornets' Nest**		
10:40 am	DESDM Status Report		J. Mohr
11:20 am	Community Pipeline		M. Gower
11:30 am	Data Challenge Coordination with Working Groups		B. Yanny
11:45 am	Lunch—Second floor crossover is available		
12:45 pm	Subcommittee Breakout Sessions		
	DECam Optics and Opto-Mech	SG 1	Dark Side (WH6W) B. Flaugher
	DECam CCDs & FEE	SG 2	Hornets' Nest (WH8XO) T. Diehl
	DESDM short reports and Q&A	SG 3	Theory 3NE (WH3NE) J. Mohr
	DES Management Issues	SG 4	Req Room (WH4NW) J. Peoples
3:00 pm	Break—**Outside of Hornets' Nest**		
3:20 pm	Subcommittee Breakout Sessions		
	CFIP and DECam Integration	SG 1	Dark Side (WH6W) T. Abbott
	DECam SISPI and Simulations	SG 2	Hornets' Nest (WH8XO) K Honscheid
	DESDM Management Issues	SG 3	Theory 3NE (WH3NE) M. Freemon
	DECam cost, schedule & mgmt	SG 4	Req Room (WH4NW) W. Merritt
4:30 pm	Executive Session—**Hornets Nest (WH8XO)**		
6:30 pm	Adjourn		

Thursday, July 9, 2008

8:30 am	DES Responses to Questions—**Hornets' Nest**
9:30 am	Executive Session and Dry Run—**Hornets' Nest**
12:00 pm	Executive Session/Lunch—**Hornets' Nest**
1:00 pm	Closeout Presentation with DES Team—**Curia II (WH2W)**
2:00 pm	Adjourn

APPENDIX D

COST, SCHEDULE, and FUNDING TABLES

DECam Funding and Obligations Tables (overhead included, then yr $)

DARK ENERGY SURVEY

Total Funding (table from the PEP April 2008)

	FY06	FY07	FY08	FY09	FY10	FY11	Total
R&D Funding	2.28	4.76	3.95	0.71	0.00	0.00	11.70
MIE 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	

- FY07 Funding includes $0.77M of carry-over from the R&D proposal and funds spent before Aug.1 (EVMS reporting started)
- FY08 Funding is $5.5M from FNAL, 0.1M from UIUC Base Grant
- FY09 - FY11 have $0.2M each year from UIUC Base Grant

Status as of May 2009 :

	FY06	*FY07*	*FY08*	*FY09*	*FY10*	*FY11*
Integral Obligations Thru May09	2.28	6.17	12.02	17.63		
Integral BCWS Thru May 09	2.28	6.20	11.47	16.79		
Integral BCWP Thru May 09	2.28	6.20	11.29	16.61		
Integral Actual Costs Thru May 09	2.28	6.16	11.31	16.94		
Integral Scheduled Obligations	2.28	6.20	11.47	21.01	28.26	30.81
Integral Funding	2.28	7.04	12.64	21.54	30.15	35.15
Integral Carry-over/contingency	0.00	0.87	0.62	0.53	1.89	4.34

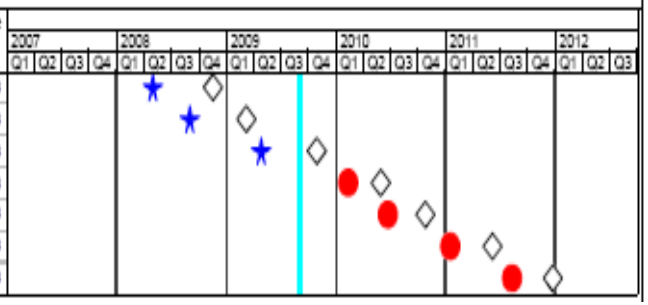
DECam Milestones

DARK ENERGY SURVEY

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

DECam L1 Milestones
Sorted By Baseline Start Date

WBS	Task Name	Baseline Start	Start	Baseline Variance
1.4.1.12.8	L1 - All Lens Blanks Complete	8/18/2008	1/31/2008	-27.6 wks
1.2.2.10.14	L1 - v2 CCD Processing and Packaging Review Complete	12/8/2008	6/2/2008	-25.8 wks
1.2.2.10.16	L1 - CCD's From 30th Production Wafer Delivered To FNAL	7/31/2009	1/26/2009	-26 wks
1.2.2.10.15	L1 - 128 CCD's Tested and Graded	3/1/2010	11/12/2009	-13.8 wks
1.5.2.12.1.13	L1 - Prime Focus Cage Complete	7/28/2010	3/24/2010	-17.4 wks
1.5.2.14.8	L1 - Camera and Telescope Simulator Tests Complete	3/7/2011	10/18/2010	-18.6 wks
1.1.6.16	L1 - Acceptance Testing Complete	9/24/2011	5/12/2011	-18.6 wks



Three completed on or ahead of Schedule. On track to complete the next one.

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

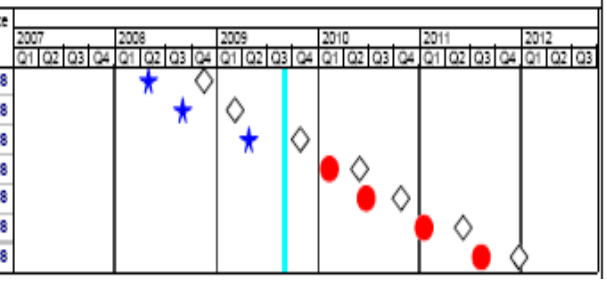
DECam Milestones

DARK ENERGY SURVEY

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

DECam L1 Milestones
Sorted By Baseline Start Date

WBS	Task Name	Baseline Start	Start	Baseline Variance
1.4.1.12.8	L1 - All Lens Blanks Complete	8/18/2008	1/31/2008	-27.6 wks
1.2.2.10.14	L1 - v2 CCD Processing and Packaging Review Complete	12/8/2008	6/2/2008	-25.8 wks
1.2.2.10.16	L1 - CCD's From 30th Production Wafer Delivered To FNAL	7/31/2009	1/26/2009	-26 wks
1.2.2.10.15	L1 - 128 CCD's Tested and Graded	3/1/2010	11/12/2009	-13.8 wks
1.5.2.12.1.13	L1 - Prime Focus Cage Complete	7/28/2010	3/24/2010	-17.4 wks
1.5.2.14.8	L1 - Camera and Telescope Simulator Tests Complete	3/7/2011	10/18/2010	-18.6 wks
1.1.6.16	L1 - Acceptance Testing Complete	9/24/2011	5/12/2011	-18.6 wks



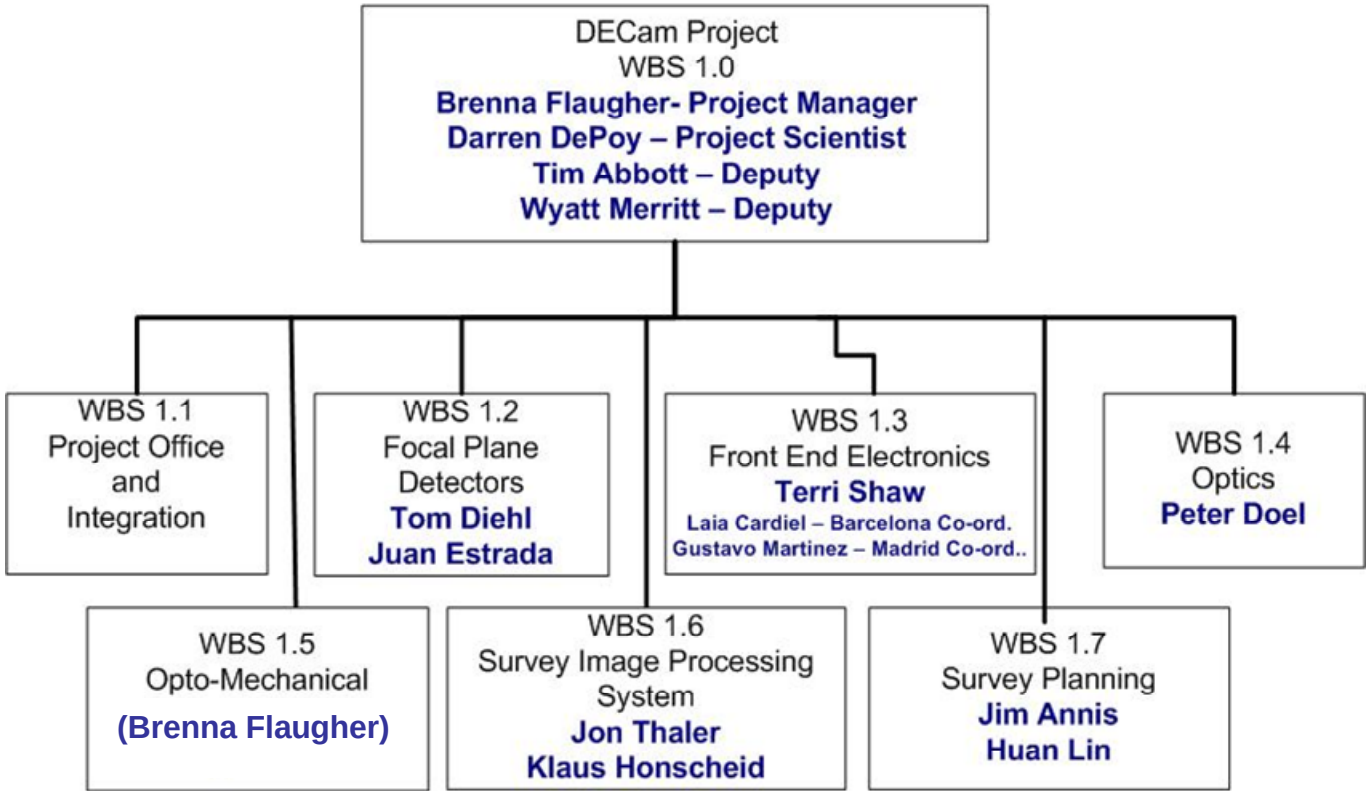
Three completed on or ahead of Schedule. On track to complete the next one.

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

APPENDIX E

MANAGEMENT CHART

DES Organization

DARK ENERGY SURVEY

DECam Project Organization