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Fermilab

Final Report

Director's CD-1 Review of the DES-DECam Project

July 25 – 27, 2006

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Table of Contents

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Executive Summary

Technical

The science of DES directly addresses Dark Energy properties and will lead to significant advances in this emerging and important field. The scientific requirements have been formulated, and the DECam instrument, as operated on the Blanco Telescope, is fully capable of providing the data needed to undertake the science. The technical team is excellent. The project is aggressively moving ahead on several R&D fronts. Areas of cost and schedule risk are already well known to the DECam team and are being addressed. The cost range seems reasonable based on the cost of other large focal plane arrays. The schedule could be paced by the delivery, characterization and testing of working CCD's. For several reasons, we urge that the project continue to place a high priority on 2010 for commissioning DECam on the Blanco Telescope. We expect that our recommendations will help the team with a successful CD-1 review.

Focal-Plane Detectors

Sixty-two large CCD's are to be processed at LBNL and packaged and tested at Fermilab and used in the focal plane; additional packaged devices will serve as spares. These are fully-depleted devices with high QE at 1 micron, which allows meeting the key DES goals of detecting galaxies at high redshift. Several engineering-grade devices have been produced, packaged, and tested, exercising most of the steps in the production. The LBNL infrastructure for DES is largely shared with that related to the SNAP project. Excellent progress has been made at Fermilab to set up the packaging and testing systems in the R&D phase. The general approach appears to be sound, but the CCD's are on the critical path and there are very few of these devices working in an astronomical environment. The eventual yield is uncertain; the project plan allows for a 19% yield. It would be prudent to include an additional lot of wafers in the baseline, with yet another lot held in the contingency. The testing of the engineering CCD's is proceeding well, but additional FTE will be required to handle the full production rate of packaged devices.

Front-End Electronics

The CCD control and read-out system will be a modified version of Monsoon to enable higher density (more channels per board), to drive more clocks, and to provide for an S-Link optical connection. The front-end electronics have been separately reviewed and we agree that Monsoon, and the proposed upgrades, comprise a sensible path. An equivalent system will be used for testing the detectors prior to the assembly of the focal plane. The boards will be fabricated in Spain as part of an in-kind contribution to the project, substantially reducing the MIE costs. The group in Spain has already been deeply involved in the R&D effort.

Optics

The optical design achieves the scientific requirements and has already been separately reviewed. Partners have been added to DES since the June 2004 review who have greatly enhanced the depth of experience in working with optics of this kind, and who have also brought resources for the purchase of the optics. The fabrication of the optics is on the critical path, but there do not appear to be major technical risks. The filters are large but several vendors appear to be willing to bid. The costs are well constrained by comparable fabrication projects. The committee supports proceeding with selecting vendors for the lens material as soon as possible.

Opto-Mechanical System

The opto-mechanical system includes the structure that connects the prime-focus optics to the telescope top-end, and the camera with its cooling system. It also includes the shutter, the filter exchange mechanism, the guiding system, and the active optical alignment system. The prime focus cage carries the f/8 secondary mirror and thus the opto-mechanical system must provide for any attitude. The stiffness inherent in the design appears to be very good. The hexapod concept provides the needed control to align the prime-focus optics with the primary mirror. Combined with the sensing system, the hexapod appears to be a sensible path to pursue, but we note that the combination of required precision of control and moving mass is beyond what has been done so far in astronomical telescopes. Construction of a prototype camera vessel to test multi-CCD performance also allows several mechanical tests and is overall an excellent step to take. The procurement of parts for the prototype camera vessel has helped in the cost estimation for the camera itself. This WBS element contains many sub-systems. The baseline of $4.1M appears to be generally reasonable. More engineering manpower may be needed to meet the schedule.

Survey Image System Process Integration

The SISPI task combines the control of the DECam (filters, shutter, monitoring) with the data acquisition, and with the telescope control system (guiding and active optics) and with other ancillary systems. It includes provision for substantial computing on the mountain, a novel facility for CTIO. The SISPI task includes interfaces between all three parts of the DES project (DECam, the Data Management system, and CTIO infrastructure). SISPI is still in a rudimentary stage of design. The project has determined that several FTE's are required for the design and construction, but so far the resources to hire these individuals have not been identified. The skill mix needs to include several Computing Professionals in addition to postdocs and graduate students. The baseline includes $126k for hardware. We do not have enough information to comment on schedule.

Survey Planning

The scientific goals lead in a natural way to a general plan for how the observations are conducted, leaving what appears to be significant latitude for tuning. The team has substantial experience with the conduct of the SDSS and is well equipped to undertake the task of deriving a detailed observing strategy from the scientific requirements, given the performance of the instrument, both as planned and as operating. In some instances the reasons for choosing between certain trade-offs were not clear to the committee. This may be partly because the scientific and technical requirements need to be refined and tightened. For example, one of the technical specifications is that no less than 5% of the focal plane should be inactive. However, if the choice were between not observing and observing with some inoperative detectors, we assume the latter option would be adopted. Moreover, if sub-standard detectors were used in the focal plane, in principle this could mitigate schedule risk and lead to scientific returns sooner, albeit with some compromise. Decisions made along these lines cannot be easily derived from the current state of the written scientific requirements.

<u>CTIO Integration</u>

A working DECam is to be delivered to CTIO, installed at the prime focus while maintaining the f/8 capability, and tested with on-the –sky observations. Subsequently, CTIO will assume responsibility for operations, but it is understood that the DES collaboration will provide continuing support. Such support during the operations phase includes processing and otherwise handling of the data on the mountain by general users. The details of the integration and the specifics of the respective responsibilities are to be spelled out in a MOU that is currently in draft form. The MOU needs to anticipate a variety of circumstances that could arise regarding impact on CTIO operations (e.g. down-time for the telescope for major DECam maintenance) and regarding continuing resources needed from the DES collaboration (e.g. technical support). Without a careful understanding of the MOU, the reviewers cannot assess whether this task is properly scoped for budget and schedule.

Cost

A Work Breakdown Structure and WBS Dictionary have been created for the DES. Detailed Bases of Estimates (BOE) have been prepared and compiled to support the project cost estimate. The DECam team presented a point estimate of $23.6M. The committee feels that there are some areas where the estimate is possibly high especially in the multiple passes planned for some of the tasks. Conversely, some areas specifically for example the number of CCD wafer orders were felt to be underestimated. The process for assigning contingency was quite broad and should be improved including a risk analysis basis before the CD-2 stage. We were not shown that the point estimate flows smoothly from the base estimate to the burdened estimate with contingency and escalation. In summary the committee feels that about $3M should be added to the point estimate and that perhaps some amount should be added to the upper end of the stated range of $20.4M to $29.5M.

Schedule

A nearly 1000 line schedule based on the WBS has been prepared in MS Project. This schedule has been resource loaded and is said to fit within the funding profile guidance provided by Fermilab management. Major Item of Equipment (MIE) funding from DOE is assumed beginning in FY2008. The schedule completion range is given as March 2010 to March 2011. The committee feels that a scientifically productive instrument can be fielded in this timeframe. However, the committee feels that being ready for a March 2007 CD-2 Review will require focus.

Management

Organization charts were shown for the Dark Energy Survey and for the DECam Project. The DECam Project Manager, members of the DECam Project Office and Level 2 WBS Managers have been named. The Project Team presented the Conceptual Design, Cost and Schedule in a coordinated manner during this review. With some additional staff (notably a full-time Project Engineer, Systems Engineer, and Computer Professionals) the committee feels the team can move DECam to the CD-2 stage.

1.0 Introduction

A Director's CD-1 Review of the Dark Energy Survey DECam Project was held on July 25-27, 2006. The charge included a list of topics to be addressed as part of the review. The assessment of the Review Committee is documented in the body of this report.

Each section in the report is generally organized by Findings, Comments and Recommendations. Findings are statements of fact that summarize noteworthy information presented during the review. The Comments are judgment statements about the facts presented during the review and are based on reviewers' experience and expertise. The comments are to be evaluated by the project team and actions taken as deemed appropriate. Recommendations are statements of actions that should be addressed by the project team. A response to recommendation(s) is expected and actions taken will begin to be reported by the project within two months from the review closeout during the Directorate's DES-DECam Working Group Meeting with a complete set of responses to be provided at the next Director's Review.

Reference materials for this review are contained in the Appendices. Appendix A is DECam's project cost estimate with contingency spreadsheet. The Charge for this review is shown in Appendix B. The review was conducted per the agenda shown in Appendix C. The Reviewer's assignments are noted in Appendix D and E, and their contact information is listed in Appendix F. The Review Participants are listed in Appendix G. Appendix H is a table that contains all the recommendations included in the body of this report.

2.0 Technical

2.1 Science Requirements

Findings

- The DES Collaboration has laid out a scientific program designed to constrain dark energy parameters using four principal techniques: (1) measurement of the number density and distribution of clusters of galaxies as a function of redshift; (2) measurement of the cosmic shear power spectra and various cross-spectra as functions of redshift; (3) detection of baryon acoustic peaks in the large-scale distribution of galaxies; and (4) measurement of multi-color lightcurves for a large sample of Type 1a supernovae.

- DES measurements of the clusters will support and strongly benefit the interpretation of Sunyaev-Zeldovich measurements of clusters that will be performed by the South Pole Telescope. No other planned near-term project can fully meet this need.

- The anticipated data sample that will be returned from the DES will reduce the area of the w-w_a contour by roughly a factor 3 – 5, assuming that the design specs for the camera and the survey itself are met.

- A set of science requirements has been drafted based on the four science themes indicated above. In some cases, there has been a clear flow-down to technical requirements, however some important technical requirements cannot be easily traced back to these science requirements.

- After it is delivered, it is planned for the DECam instrument to be made available to the general astronomical community at CTIO when it is not being used for the survey (roughly 70% of the time). A provision for up to four additional filters has been made to support non-DES science applications of the camera. In addition, the camera has been designed to be operational in the U-band. No other explicit science requirements pertaining to the camera for general observer use were identified.

Comments

- The science case for the DES is quite strong, and it is well-matched to the capabilities enunciated for Stage III projects in the DETF report. The team has done a very careful job in studying the science performance of the project using detailed simulations of all anticipated technical and systematic effects.

- While some flow down from science performance to technical requirements has been identified, the Committee felt that further clarification of this flow down would be helpful to the project. Most of the science performance metrics are sensitive to global figures of merit, like $A\Omega T$. A number of different technical trades can be envisioned, which leave these global figures of merit unchanged, but could reduce cost and technical risk. It is unclear whether the design has been fully optimized in this regard, or whether further trades would be beneficial.

- The project identifies two levels of science requirements, but it is unclear how these different levels will be utilized in the definition of the "success" of the program in its subsequent reviews. Which level of requirements is being used to define acceptance criteria for individual components? Which criteria are relevant to success at CD-4?

- While it is apparent that considerable work has been devoted to understanding the photometric calibration procedures, it was still unclear to the committee whether a detailed calibration error budget has been constructed. With the present tiling strategy, it seems likely that a non-negligible fraction of the proposed survey region will obtain less than 3 visits in individual colors. We were not presented with a clear picture of how this would affect the photometric redshift determinations and the end science analysis. We are especially concerned about the z-band, where the water bands at the red end can lead to photometric errors unless they are properly monitored.

- An adequate study of the potential trade-offs between more or fewer exposures and how they are distributed over time was not presented. There may be important effects associated with cosmic ray removal, time-variable PSF effects, etc., which might be mitigated by an optimized plan.

- While the DES project does offer some unique capabilities in the near-term, the robustness of the science case for the project will decrease significantly with time, both because other near-term programs will be making similar measurements, and because the Stage IV projects will eventually offer much greater capability. We therefore believe that it is critical for DECam to hold schedule, achieving first light by early 2011, at the latest.

- The science requirements for general observer use of DECam must become better understood in the near-term, while critical design decisions are still being made. In addition, there should be a definition of what data products should be available at the telescope immediately following the CCD readout. Some such products will be needed for commissioning and testing the camera in any case, but there should be some well thought-out specifications (FITS image, a quick display tool, etc) that would ensure that this comes out in a form that would also fill the needs of general observers.

Recommendations

1. A clear connection should be made between the two levels of science requirements and the subsequent decision-making process of the project as it proceeds into development. Is achievement of "substantial success" sufficient for the project or not?

2. A more detailed calibration error budget should be developed for CD-2. This should include explicit simulations that demonstrate the required photometric precision can be achieved at all points in the survey region. If the photometric precision will be heterogeneous over the survey region, the science implications should be addressed.

3. A set of more extensive science trades should be performed for technical choices that leave global performance unchanged – e.g. total field versus packing efficiency, versus efficiency in the use of observing time, quantum efficiency in the various bands, etc. Each technical requirement should have a clear science rationale.

4. The MOU with NOAO should include a detailed discussion of science requirements for the use of the DECam by the general user community. These requirements should be identified and enunciated very soon to ensure that they can be met by the present design.

2.2 Focal Plane Detectors and CCD Camera (WBS 1.2 and 1.5.2)

WBS 1.2 – Focal Plane Detectors

Findings

- Obtaining an adequate number of scientific grade CCDs for DECam is identified as one of the highest risk items in the project. The fully-depleted LBNL CCDs offer the best hope of achieving the NIR z-band sensitivity required to achieve the science goals of the experiment. The project assumes an overall yield of 0.25 to acquire the devices needed.

Comments

- This procurement, along with a similar development by the SNAP project, is the first large production run of p-channel, fully-depleted CCDs at DALSA attempted by LBNL. Therefore, yields are far too uncertain to inspire confidence. Some losses of wafers and devices occur in steps at LBNL and by outside vendors (for wafer mechanical thinning and dicing) that were not accounted for in the yield estimates. Experience with other large CCD foundry procurements shows that the expected yield of 0.25 can easily drop to 0.10 if things go wrong (and things DO go wrong).

Recommendations

5. The project should add an additional lot of CCDs to their baseline program, including all the steps needed to make these CCDs ready for deployment into the camera (wafer production at DALSA, processing at LBNL, packaging and testing at FNAL).

Findings

- The NIR 1-micron QE of the fully-depleted LBNL CCDs is the chief driver for their adoption for this project. Yet no justification is given for the choice of device thickness of 250-microns (why not thicker?).

Comments

- Additional NIR QE can be achieved by making the devices slightly thicker (say 300 or 350 microns with the large required backside bias voltage), and by operating the devices warmer that the planned operating temperature of -100C.

Recommendations

6. The team should justify its choice of 250-microns for the CCD thickness (as compared to thicker) and should indicate that it plans to investigate the trade in NIR-QE vs. dark current that can be had at a warmer operating temperature of, say, -80C.

Findings

- The project is faced with a critical decision in the near term before going ahead with their first lot: to go with the new polybackseal wafers or to stick with the Wacker wafers.

Comments

- The new polybackseal wafers offer the hope that the recent occurrence of bright, catastrophic defects can be eliminated. However these new wafers are from a different wafer vendor than that used by LBNL for their earlier p-channel fully-depleted process. Experience shows that changing the silicon vendor can sometimes lead to subtle problems with the new devices (e.g. charge traps). On the other hand, staying with the existing Wacker material requires that these wafers go out for re-polishing after gettering before subsequent processing at DALSA and LBNL to eliminate the catastrophic bright defects (associated with contaminants on the wafer surface). It was not clear that this re-polishing actually solves this problem.

Recommendations

7. The project needs to carefully consider their decision on whether to go with the re-polished Wacker material or the new wafers with polybackseal. This decision should be made after extensive test data are available for the new polybackseal devices (e.g. 1 or 2 working devices does not constitute an extensive set of test data). Similarly, test data need to be acquired for the re-polished Wacker devices. After reviewing the specification for wafer repolishing, we also recommend that a minimum amount of material to be removed be called out in the spec (e.g. the spec currently calls out only a maximum amount of 10 microns to be removed but does not call out a minimum amount that must be removed).

Findings

- The project appeared to underestimate the effort required to screen, test, characterize, and optimize the large numbers of CCDs needed to get approximately 70 of these for use in the DECam focalplane. A clear plan for CCD optimization was not presented, and adequate personnel resources were not identified.

Comments

- CCD characterization and optimization is crucial for the project to achieve its science goals. This becomes even more important when one considers that little astronomical data has been acquired and analyzed using LBNL CCDs. While the team clearly plans to acquire an extensive set of test data on these devices, the overall plan for how these data will be used to characterize and optimize the devices was not clear at all.

- The Fe55 x-ray technique offers a superior way to measure and optimize CCD performance, especially with regard to device gain, CTE, and charge diffusion. To probe the region near the back surface of the device, low energy x-rays can be used by fluorescing targets (C, O, Al) with the 5.9 keV Fe55 x-rays.

Recommendations

8. Adequate resources (primarily experienced personnel) need to be provided to carry out CCD testing, characterization and optimization. This process can be divided into two distinct areas: 1) R&D testing to explore and understand the performance of the LBNL CCDs over a wide range of operating parameters, 2) production testing which is an automated set of tasks that generates a large data set of images that are analyzed to select the best CCDs with their optimal operating parameters. These two areas are coupled, with the first needing to be carried out before one can design and implement the best automated production testing plan. The team should prepare a detailed test plan showing what data will be collected, and how these data will be used to determine the device properties and to converge on an optimal set of operating parameters for each device.

9. The DECam team should include Fe55 x-ray testing as one of the core techniques used to characterize the CCDs. A complete set of Fe55 data should be collected and analyzed for each detector. It would be essential to further characterize a subset of devices using lower-energy x-rays, or UV/blue photons to probe the back surface and insure a field-free region does not exist.

Findings

- The CCD packaging scheme looks sound. However, with this packaging scheme, a damaged connector on the package cannot be repaired, and loss of this connector means the loss of the entire CCD. With the amount of testing needed on these devices, it is likely that these connectors will undergo numerous mating and unmating cycles.

Comments

- Extensive experience with Nanonics connectors has shown that they are fussy, delicate and can be easily damaged. Furthermore, this connector appears to be surface-mount soldered onto the ALN board with no obvious means of strain relief. This makes this particular joint even more vulnerable to damage from handling.

Recommendations

10. A means should be identified to strain relieve the surface-mounted Nanonics connector on the ALN board. Metalized traces on ceramic are much more delicate than copper traces on FR-4 or polyimide, and it will be quite easy to pull this connector right off the ALN if any shear force is encountered during mating and unmating, or by pulling on the mating flexcable. Therefore, we recommend that the number of mating and unmating cycles of this joint should be minimized. This can be achieved by using a connector saver at all times on the device package for all device testing. The connector saver should only be removed for the final installation in the camera focalplane. The mating and unmating cycles can also be

minimized if the team decides to attach the long flexcable to the package and leave it there at all times for device testing and handling. This approach, however, may complicate the device handling and storage and focalplane loading process. The Nanonics connector should also be strain relieved, perhaps by potting the base of the connector into the invar block. This does not preclude using a connector saver, as damage to the connector itself is also a risk (as opposed to damage to the surface-mount joint), but it at least minimizes one of the risk areas.

Findings

- Many of the key components of the CCD packages, focalplane and camera included as many as 4 design iterations in the budget and schedule.

Recommendations

11. We recommend that in most cases, the 3^{rd} or 4^{th} design iteration was unlikely to be needed and should be considered to be part of the contingency.

WBS 1.5.2 – CCD Camera

Findings

- We were not presented with a list of metrology specifications for the camera regarding package and focalplane mosaic planarity, gap size, CCD-to-CCD alignment, etc.

Comments

- It became obvious during the breakout sessions that the team was designing with certain technical specifications in mind, but those specifications and their motivation need to be clearly listed.

Recommendations

12. A list of focalplane metrology specifications needs to be prepared.

Findings

- The approach for the design of the focalplane appeared to be fine. However we were not shown any results of thermal and mechanical modeling (which we were told had been carried out) showing that there were no thermal or mechanical distortions that could warp or otherwise affect the flatness of the mosaic focalplane.

Comments

- It became obvious during the breakout sessions that the team had carried out this modeling.

Recommendations

13. Results of thermal modeling and FEA analysis should be presented to show that the camera focalplane meets spec.

2.3 Readout Electronics and Survey Image System Process Integration (SISPI) (WBS 1.3 and 1.6)

WBS 1.3 – Front End Electronics

Findings

- The continued use of NOAO's CCD Controller, Monsoon, was advocated in preference to the "Leach controller " (Astronomical Research Cameras Inc), due Monsoon's open architecture, considerable software (open source), extensibility, superior packaging, extended features such as telemetry, and the existence of high density boards. The decision to use Monsoon was based on a review of options by an internal DES committee.

- Arguments were presented for modifying the designs of all of the boards:

    - Replace the Systran fiberlink interface (daughter card) with an Slink card familiar to the HEP community, due to failing support(?) and doubtful supply of the Systran in future.

    - Upgrade the Clock/Bias board: more clocks, no biases (etc) for better match to this application.

    - Upgrade video board from 8 to 12 channels to the keep crates within desired size and layout for ease of fit and cooling layout.

- Three (more) design cycles of each component are scheduled over the next two years.

- Cost estimates for the major electronics components are based on costs of the existing Monsoon boards. Engineering costs are based on past experience with similar complexity boards.

Comments

- We fully endorse the rationale and decision to use Monsoon. The group has done a thorough evaluation of the options in making this decision.

- We were persuaded, by a narrow margin, that the benefits justify the considerable expense and risk of the board redesigns.

- The M&S costs for constructing the boards are reasonable. The contingency assigned is reasonable considering the basis of estimate and the fact that there are already three design cycles planned. The labor cost for board design and testing are reasonable and consistent with the engineering effort currently working on the project. The planned number of spare modules at the telescope is appropriate given the need to support the system far from the designer and builders.

Recommendations

14. Gain as much experience as possible, as early as possible in the project, with the electronics and associated software, by using these for CCD characterization etc. Configurations as close as possible to that of the final instrument should be used in qualification tests.

15. Aim to produce the final design in the first iteration with the second PCB design cycle fixing problems found. The third cycle should be retained as *contingency* only. This will maximize experience with boards during CCD, software, and system testing, while minimizing the risk of introducing new faults during the final cycle(s). This may also lead to a cost saving by eliminating the 3rd iterations.

16. Create a clear set of acceptance testing criteria for each stage of board development, which includes all components to be included. Design reviews between steps should include comparison of results with these criteria and provide branch points such as eliminating design iterations or implementing fallback solutions.

17. In addition to the 135 clocks, include several sequencer outputs (digital levels only) on front panel connectors to be used for such things as triggering oscilloscopes (eg Frame Start), or operating a shutter in the lab, unless these features already exist.

18. Test clocks and biases for noise performance by looping back directly into the video preamp (AC coupling, stopped at high then low level). Acceptable noise is defined as being much less than that of the CCD output after the clock in question has been attenuated by the clock feed-through ratio. (This needs to be determined empirically.) An analog multiplexor can be used to scan through all clock outputs automatically. Notes:

    - While technically a sufficient test, simply accepting a clock board because CCD performance appears not to be degraded, gives little information on noise margin.

    - Furthermore the test with the CCD works only when the test system and CCD have already demonstrated low noise, and only tests a subset of the clocks

    - It is preferable to use the video signal path to monitor clock and bias quality since digital interference within the controller is invisible, since it is synchronous. Furthermore, the video chain has better resolution, noise and dynamic range than most lab instruments

19. Verify the efficacy of the multi-controller synchronization mechanisms, which must be employed to prevent degradation of noise performance when multiple master control boards are used together. This should be done during the testing of the first PCB versions in case the problem requires a design modification. As a

baseline, search for beat frequencies by Fourier transforming the data stream from the CCD. (If significant sources of interference are found, the test can be repeated in the bias/clock loop-back configurations and with shorted video input to identify the coupling path.) The test must then be repeated with *multiple* controllers (backplanes) operated in sync in the same crate, to see if new harmonics appear.

Findings

- The project presented the design of the Front End electronics in the Conceptual Design Report and presentations to the review committee in both plenary and breakout sessions.

Comments

- The description of the design in the CDR focused heavily on the process of deciding on the design rather than the chosen design. The CDR and review presentations would benefit from a more top down approach to the presentation.

Recommendations

20. Revise the text of the CDR to focus on the baseline design then describe the justification for the choice of Monsoon and for redesigning boards.

Findings

- The project team expressed the hope that a preamplifier in closer proximity to the CCD would help achieve detector limited noise performance.

Comments

- In fully synchronous systems, with clean clocks, and appropriate grounding and shielding, this reviewer (Roger Smith) has not found preamplification to be necessary for good noise performance. However, reducing the output impedance at the CCD has other major benefits, such as decreasing the settling time on the video lines, reducing crosstalk and reducing susceptibility to current noise in the input to the external electronics.

- The inclusion of a source follower made with a low noise JFET on the CCD package is a *simple* and compact solution, which is commonly employed, eg E2V and MITLL use an n-channel J309 which will have an output impedance of ~100 ohm compared to ~7000 ohm for a typical single stage CCD output.

- Lack of gain greater than one is generally not a problem since the noise density (uV/√Hz) at the CCD output is typically greater than at the input referred noise density of the video chain.

Recommendations

21. Incorporate load resistor for CCD source follower and a low noise p-channel JFET source follower and its load resistor into the CCD package or on the CCD end flex cable (stiffener).

Guiders, alignment and focus CCDs

Findings

- The team has no prior experience developing *astronomical* guider software, though it draws on experience in a similar application.

- The statement was made that guiders differ from the science CCDs in requiring a faster frame rate, and having less demanding noise requirements.

Comments

- The stated difference in requirements relative to the science CCDs is not quite right: while exposure times are indeed 10 to 100 times shorter this reduces the shot noise due to sky and thus makes the noise requirement *more* demanding. At the same time the pixel read rate can be *lower* since, for region of interest readout, the frame time is dominated by parallel and serial shifts rather than the pixel reads.

- The guider interface significantly affects both telescope operator and non-survey users of the instrument.

- This is a topic, which has seen much refinement for decades and is a largely solved problem. It is thus likely that the team can learn from existing experts and can substantially adopt/adapt an existing software package that represents the state of the art.

- The read time for the science CCDs may be short enough to use a science CCD for guiding even in full frame mode. Even if only a region of interest is read out (to increase the frame rate) the surrounding pixels which are lost in this case are likely to have been contaminated by scattering/ghosts anyway.

- The large increase in guide star search area increases the likelihood of finding a bright enough star when narrowband or short wavelength filters are used (for non DE Survey). Choices made now in allocation of CCDs to controller backplanes will determine the impact on the shape of the science field in this mode.

Recommendations

22. Consult with Rolando Cantarutti at CTIO who is an established expert. He will be able to offer examples of well developed guider software (as used on SOAR and Blanco telescopes)..

23. Be aware that guider sensitivity is an issue, which is likely to arise in discussions of non-DES programs where narrower band filters are likely to be used.

    - Consider full frame cross correlation of the guider CCDs to achieve higher precision and/or eliminate the need for automatic guide star selection.

- Allow for the possibility of using a subset of the science field for guiding in the event that brighter guide stars (or cross correlation of larger area) are needed for narrow filters: allocate CCDs to "controllers" to optimize the shape of the residual science field.

- Consider what would be needed to support the selection of a single science CCD (or a group of three) anywhere in the field for guiding.

Findings

- Focus/alignment CCDs are allocated to the same Master Controller Boards (and backplane segments) as science CCDs and thus can't be operated independently.

Recommendations

24. Allocate all focus/alignment CCDs to the same controller (changing cable layout accordingly) to protect against the case where a different readout cadence is required

WBS 1.6 – Survey Image System Process Integration (SISPI)

Findings

- The proponents presented a pre-conceptual design of the data acquisition (DAQ) and control system (SISPI) for the DES experiment. The science requirements can likely be met with an achievable application of modern commodity computing hardware and software engineering.

Comments

- The resources required to design, develop and deliver the acquisition and control system are predominantly the effort to produce the required software. The plan is to utilize in-kind contribution of students, postdoctoral researchers, and part-time scientist contributions. The proponents are working with funding agencies to secure off-project support for about 18 FTE-years of student and postdoc effort. To date only a small fraction of this effort has been secured. While it is laudable for the experiment to exploit the talent of the collaboration to produce the DAQ and control software it is likely that significant computing professional effort will be required to deliver a robust and reliable system.

- Much remains to be done to define the requirements of the software suite. System bandwidth, response time, security concerns, local caching, coordination with other infrastructure control software, etc, remain open issues. Further there may be issues of operating a relatively large amount of commodity hardware at the CTIO site. Examples include the altitude and humidity environment of CTIO. The experience of the IceCube collaboration which is deploying a comparable computing plant in a challenging altitude and humidity environment could be informative here.

Recommendations

25. Analyze the need for computing professional developers to advance the design of the data acquisition and control system. In our estimation the project will require 1-2 Computing Professional FTEs for 3 years to design and develop the required software systems..

Findings

- The SISPI team has informal support in the design of the SISPI system from those who will be users of the system for the DES program but has not clearly integrated them in their design and development process.

- The SISPI team has not identified informal or formal support in the design, development and testing of SISPI from the NOAO community that will be using and supporting the instrument for general observer use.

- There does not appear to be a clear set of written requirements and defined interfaces at the appropriate level for this stage of development for the SISPI system (see also recommendation 13 above), flowing down from the science and operations requirements and coordinating with the tasks of the Data Management System..

Comments

- It is critical for the development of a real-time operations system like SISPI that the design of the system, the trades taken along the way, and the testing and validation process, have active involvement from a dedicated user group which includes (1) observational astronomers who will be working directly with the system to acquire data and (2) instrument and telescope support personnel who will be directly supporting the system's real time use..

- There does not appear to be a requirements document provided to the SISPI project specifying the scope of the user interfaces. These requirements should be set by the users, both within DES and the outer user community (e.g. through NOAO).

Recommendations

26. We recommend that the SISPI Project clearly identify internal DES project science and operations members (including astronomical observers and those with telescope operations expertise) who will constitute the necessary user group to support the development of requirements, design, testing, and deployment of the SISPI System.

27. We recommend that the SISPI project work closely with NOAO to identify a User Advisory Group for the SISPI project with whom they work closely in the design, development, and testing of the system to assure it integrates within the telescope environment and supports the needs of the general user community.

28. We recommend that the SISPI project develop a clear set of requirements from which the high level design will flow, working in conjunction with the internal and external user advisors as noted in recommendations 26 and 27 above. We note that as the schedule shows the development of the high level design of SISPI by December 2006, it is critical that the system requirements be developed *before* the initiation of the design work.

Findings

- No specifications exist for command execution speed.

Comments

- Full initialization from a cold start should be very fast since this can have an enormous impact on debugging, commissioning and maintenance activities where the system may need to be restarted frequently.

Recommendations

29. Develop software execution speed budget, broken down by task. These requirements must ensure that neither survey nor calibration speed (eg twilight sky flats) are not significantly impacted.

30. Ensure that system initialization time, including return to prior setup, are short enough (<20sec?) to have minimal impact on system testing and debugging.

31. Designate a person to be responsible for hardware software initialization/configuration.

MOU topics

Comments

- At only 7000' altitude, Cerro Tololo is a relatively benign environment, except for prolonged very low humidity.

Recommendations

32. Ensure that robust humidity control is provided both in the CTIO computer room and adjoining control room.

33. Specify the networking and security requirements (firewall, access management).

34. Define (limits on) software support for non-DES use of the instrument, both during development and operations phase.

2.4 Optics, Opto - Mechanics, Survey Planning and Integration (WBS 1.4, 1.5, 1.7, and 1.8)

WBS 1.4 – Optics

Findings

- The optics design appears well developed and converging. It has completed a design review in February of 2006. A preliminary sensitivity analysis has been completed.
- Filter bandpass homogeneity is not specified in the science requirements.

Comments

- None

Recommendations

35. Define the required filter bandpass and throughput homogeneity over the camera field of view and incorporate that into the filer procurement process.

WBS 1.5 – Opto-Mechanical System

Findings

- Instrument integration and inter-divisional interfaces are handled informally.
- A conceptual solid model (mechanical) of the DECam system exists. The scientific and engineering staff understand the need for a fully integrated design.

Comments

- The mechanism for L2 managers to interact and control interfaces is not clear to the L2 managers. A more formal procedure for discussions between subsystem leaders is needed.
- More formal lines of communication will need to be developed such that design choices can be understood and made. The choice of the proper cryogenic system is an example where having the correct people (especially from CTIO, in this case) available for discussions is needed.
- For opto-mechanics, the mechanical lead (Andy) holds the solid model for the optics and optics mounts and acts as the opto-mechanical integrator, but no management mechanism visible.
- Analyses (mechanical, thermal, vibration, ...) will need to include not just the camera, but the camera integrated with the rest of the telescope. The required design loads (shipping, seismic) need to be documented.

- Procedures for lifting (weight, swing, and hoisting points), door sizes, elevator weight limits, rough walkways, hose paths, ST vs. SMA, etc., should be understood early to allow smart design decisions to be built-in rather than retrofitted.

Recommendations

36. A full-time instrument scientist or systems engineer should be identified (hired, if necessary). This person should take responsibility for high-level requirements and engineering interfaces of all L2 subsystems with the goal of coordinating interface control, managing changes, and monitoring scientific requirements in the context of engineering compromises.

37. Create an interface control document with procedures for changing and adding to it. Interface documents between components and organizations should be a high priority. This is a job for the instrument scientist/systems engineer.

Findings

- Final assembly and test is done at CTIO under the heading of “commissioning.”

- Final assembly and test is listed as taking 6 weeks at CTIO.

Comments

- Final assembly and testing should be done in a familiar environment where resources are readily available on short notice. Assembly and testing at a remote site is more difficult and requires considerable planning and extra equipment. Having subsystems meet for the first time at the observatory adds uncontrollable and unfamiliar environmental effects (electrical noise, temperature/humidity, power problems, etc.) making initial shakeout difficult.

- It is good to have baseline performance characteristics of the integrated system to compare with performance at the telescope. Getting the subsystems to work together and fine-tuning the control software is easier in your home lab; worrying about all of these things with the problem of adding telescope control and commissioning work in the same trip sounds daunting.

- We would expect the final assembly and testing to take at least 3 months, twice as long as currently allocated.

Recommendations

38. The committee believes a full assembly and test at Fermilab (without corrector lenses but with appropriate masses) before shipment to CTIO should be considered. If final assembly at CTIO remains the baseline, careful and thorough planning of sub-system acceptance testing must be completed.

39. Develop a high-level final assembly and test plan sufficient to call out specific goals (read out the detectors and move the hexapods at the same time, e.g.) and make reasonable schedule estimates.

Findings

- The "commissioning" task currently includes final assembly and testing at the observatory.

Comments

- Commissioning at the 4-m should begin with a fully tested instrument and consists of the tasks needed to mount the instrument, validate science performance, and develop observing procedures.

- The commissioning team should worry about starlight on the detectors. They should not have to debug problems such as shutter interactions with the readout electronics.

Recommendations

40. "Commissioning" should not include the final assembly and test phase (although a re-assembly is probably needed). Assembly and test should be a separate task.

Findings

- Drivers and requirements for the choice of CCD cooling system are not known.

Comments

- A variety of cooling systems were presented but there was no path to choosing the optimum one. What drives the decision? Cost? Vibration? Operations efficiency (stop to fill dewars)? Weight? Power? Heat dissipation?

- The GM choice will inject a strong 2.4 Hz (or thereabouts) signal into the telescope top end. Will this excite vibrational modes in the telescope secondary support structure (these might be in the 5 Hz range?).

- Mechanical design at many levels is stalled until a decision is made on the cooling system.

Recommendations

41. After determining that you've done everything you can to reduce the heat load, bring the appropriate people together, including the CTIO team (who will maintain and operate it), to pare the list of potential cooling systems.

Findings

- Dewar window settles at -10C on the outside, -20C on the inside.

Comments

- Icing of the window is guaranteed if something is not done to prevent this. A dry nitrogen purge is planned but what if it runs out?

Recommendations

42. Think seriously about how to avoid icing the window. Dewpoint sensors, window heaters, or hermetically seal the space between C4 and C5, silica gel canisters, etc.

43. There's an effect, probably minor, on the refractive index of the window. Showing this is not a problem is worth doing.

44. Make sure your coatings are water-resistant.

Findings

- In the straw-man design for the hexapod system, the six legs are attached to six separate attachment points at each end, rather than having pairs of legs come to a common attachment point so that there is a kinematic mount with only three attachments in all at each end.

- Manufacturer suggests that this is not a problem; that the control system handles the situation properly.

Comments

- This looks a lot like an overconstrained system, with potential for warping the rings that the hexapod legs attach to, or otherwise not being well behaved. We were told that the control system would prevent this, and that such systems are routinely used. However, real-life experiences show that overconstrained systems should always be a cause for worry.

- The suggested mechanical configuration allows the hexapod to bend the rings/plates to which it attaches.

Recommendations

45. The hexapod design should be very carefully checked for possible problems due to the proposed attachment scheme. This is not necessarily a bad choice but be sure you understand the issues (what bad things can happen if the control system fails) and have a way to avoid serious damage (breakaway systems, etc.) if you decide to go this route.

46. A three-point scheme would be preferable if it is practical.

Findings

- A spot check of costs for several large ticket items was done. Reasonable base costs have been found through communication with experienced vendors and in some places were compared with similar existing devices. All contingencies were applied top down, at the standard rates.

- A logically linked schedule exists, though complete understanding of the interplay and completeness of those links remains to be developed. Schedule float was based on vendor experience, and included on each individual line.

Comments

- The design as presented is good for this stage of the project. The integration of the thermal, mechanical, vibrational, and optical aspects of the design as it progresses over the next year will require a large effort that should become more formal.

- The cost estimate and schedule should be scrubbed.

WBS 1.7 – Survey Planning

Findings

- The observing plan is based around the Blanco Telescope's current optical performance.

Comments

- There are high hopes that the alignment and dome seeing will be improved by the features designed into DECam. However, an important component of the case made in the current write-ups is that the science goals can be reached with the current performance of the telescope. That argument should be retained in the documentation, as it is a good selling point to skeptics.

WBS 1.8 – CTIO Integration

Findings

- The hexapod is a good approach for providing the motions of the camera required to compensate for telescope flexure and primary de-centering.

Comments

- Throughout their 30-year history, both the Blanco Telescope and its twin, the Mayall Telescope, have had problems with lateral supports breaking their glue bonds onto the primary mirror. This leads to excessive lateral motions of the primary mirror in its cell. The Blanco Telescope showed a promising improvement in performance after recent modifications and adjustments to the lateral supports on its primary mirror. This was the result of an intensive engineering effort by CTIO that led (for the first time) to a specific idea about what the error was in the original design. However, one of the (unmodified) lateral supports did immediately pull loose. It has been the case in the past that it was thought that this problem was under control, only to find out that over a period of a year or so several supports pulled loose. The best-case situation probably is the current performance, with the position of the prime focus shifting laterally relative to the primary mirror by about 1.2mm as the telescope moves around the sky, repeatable to about 0.1mm (Slide 17 of the Tim Abbott's ppt presentation at the breakout session). However, it is too soon to be sure that the telescope will not slip back to its previous performance, with about 1.5 mm shifts and much poorer repeatability (Abbott slide 14). The tolerance is 0.2mm.

Recommendations

47. The project should provide the capability to deal with a worst-case situation in which the primary mirror shifts around by the amount that it did before the recent work on the support system. The donut images from the focus CCDs should be used to measure coma as well as de-focus, and there should be a means of feeding the coma signal as well as the focus signal to the hexapod for closed-loop corrections. Astigmatism should also be measured from the focus images; this signal could in principal be used (very easily) to drive closed-loop astigmatism correction with the existing active optics system on the primary mirror, but at minimum can be used to continuously improve the lookup table that is used by that system.

Findings

- The telescope polar alignment was not discussed.

Comments

- If the telescope is mis-aligned (and even if it isn't: true or refracted pole?), then the imaging field will rotate. This might be a problem for weak lensing.

Recommendations

48. Understand the impact of a mis-aligned telescope. What are the combinations, if any, of Dec and exposure time that affect the weak lensing analysis. Determine the polar alignment requirement.

3.0 Project Management (WBS 1.1)

3.1 Cost

Findings

- The team presented to the committee their cost estimates for each subtask and a level 2 WBS rollup. Presentations were given from each subtask based on their own work scope. The total project cost estimate including contingencies, escalation, and burdens is $23,645,783.30, not including in kind contributions from other countries and US institutions. The team also presented a cost range. For the upper bound of the range, $29.5M, the team assumed that all project costs incurred in FY09 will be repeated. For the lower bound, $20.4M, the team assumed that only half of the project contingency would be needed.

- Costs presented by individual subtasks were unburdened and unescalated. These factors were, however, included in the WBS Level 2 rollup.

- Default contingencies of 50% on labor and 40% on M&S were used unless vendor information or direct experience was available, in which case a contingency of 20% was usually applied.

- The team presented a Basis of Estimate binder including past purchase requisitions, vendor quotes, and catalog information.

Comments

- The committee felt that the project team has the technical and management capability to develop an accurate cost estimate.

- The project presented a WBS down to level 6 and the list of activities therein was fairly comprehensive.

- While the total project cost was presented consistently, the lack of consistency in presenting lower level costs caused some difficulty for the reviewers. For example, the WBS Level 2 rollup included contingency on R&D while in the slide presentation this same contingency was included in MIE instead. Also, the individual Level 2 tasks presented costs without escalation or burden.

- Labor in WBS 1.7 did not include costs for computing professionals, though the project acknowledged that computing professionals would be needed for the simulation efforts. The review committee estimated this cost to be around $1M, though this should be further analyzed by the project team. Additional computing professionals will likely be required in SISPI (WBS 1.6), but are not planned to be costed to the project.

- The reviewers studying the CCD fabrication suggested that the project plan for the procurement of an additional lot of wafers and additional resources for CCD testing, characterization and optimization. This would add approximately $500k for fabrication plus $500k for packaging and testing.

- M&S Cost for WBS 1.8, CTIO Integration, was presented as having zero cost. Costs of final assembly will be shared between the project and CTIO, but the exact split of activities is not defined. The review committee suspects that there will be infrastructure costs incurred by the project.

- The committee felt that a systems engineer will be required to ensure successful integration. This will likely add $400k unburdened in total over 4 years, so around $750k fully burdened.

- The methodology of applying contingency factors and determining the overall cost range should be improved such that they are more easily defensible. A bottom up analysis would help to improve the accuracy of these estimates. In general, uncertainties identified in risk analysis should feed into calculation of contingencies. Providing supporting information for determining the cost range is an explicit requirement of DOE CD-1.

- The committee felt that the project could probably be completed within the presented cost range, although significant additional costs for a system engineer, computer professionals for SISPI, and additional CCD lot and personnel will likely increase the base and lower bound cost by around $3M. The upper bound may increase also, depending on the outcome of re-evaluating contingencies based on the risk assessment.

- Section 2.3 of this report recommends that the goal be for 2nd iterations of Front End PCBs to be final versions to minimize introducing the risks associated with late changes. 3rd iterations would then be considered contingency. This same philosophy could be considered for other systems.

- Section 2.4 of this report comments that the final assembly will likely take longer than the planned 6 weeks, probably closer to a 3 month duration.

Recommendations

49. Reassign contingency factors from the bottom up based on understood uncertainties to be developed in a risk assessment.

50. Reconsider methodologies for calculating lower and upper bounds on total project cost to comply with DOE's CD-1 requirement of supporting information for determining cost range.

51. Maintain consistency in presentation of costs between WBS Level 2 presentations, Project Management rollups, and complete WBS cost chart.

52. Consult with Fermilab Directorate on best method for differentiating R&D base and contingency costs from MIE costs.

53. Evaluate and include costs for WBS 1.8 (CTIO Integration) M&S.

54. Allocate 3rd iterations of Front End electronics and possibly other systems as contingency.

55. Revisit travel costs in the Project Management section of the WBS considering reviews, vendor visits, and site visits.

56. Include cost of an additional lot of CCDs as discussed in section on WBS 1.2 in this report.

57. Include costs for a Systems Engineer, Computing Professionals, and additional resources for CCDs.

3.2 Schedule

In summary, DECam has a resource loaded schedule that meets the intent of the CD-1 requirements. Some minor changes are needed to better justify the recommended schedule range to fulfill the CD-1 level readiness. Some additional scrubbing of the schedule and the Bases of Estimate (BOE) needs to be performed from the Bottom-Up and the Top-Down to meet CD-2 level readiness. There is a lot of work to be performed between now and the CD-2 review, which may require additional resources.

Findings

- DECam has developed a WBS down to Level 6.
- DECam presented a schedule range for completion of the project between March 2010 to March 2011 based on funding availability for MIE activities starting November 1, 2007.
- DECam presented a resource loaded schedule in the Microsoft Project (MSP) scheduling tool.
- The DECam schedule consists of 1013 lines with 685 tasks.
- DECam has established 117 milestones contained in the MSP file consisting of 5-L0, 3-L1, 18-L2, 45-L3 and 46-L4 milestones.

Comments

- Schedule contingency and schedule range was not developed using a detailed risk assessment. Schedule contingency needs to based on bottoms-up and top-down risk assessment.
- DECam believes that they have identified the resources needed to complete the work required to achieve baseline approval (CD-2), but not all the required resources are currently available (i.e. Designers, Project Engineer). The committee believes that there is a lot of work to be accomplished and it will require a tight focus to be ready for a March 2007 CD-2 baseline review.
- The committee believes that a scientifically productive instrument can be delivered to meet the project completion in the proposed schedule range of March 2010 to March 2011. The concern is that the camera's technical specifications may need to be refined to meet the minimum scientific requirements in order to achieve the proposed project completion date.
- There are several schedule mechanic issues that need to be addressed in the DECam MSP schedule as noted below:
    - There are some activities that do not have a predecessor assigned. Generally, all activities should have a predecessor and successor.

- The resource names used in the schedule do not follow the Standard Fermilab Resource Naming Convention. The resources in the schedule should be revised to follow the standard convention.

- Review activities are included in the schedule, but not always fully resource loaded. Appropriate resources should be assigned to all review activities.

- The schedule assumes a CD-3 approval on October 08, 2007 and that MIE funding is available to start work on November 1, 2007. DECam is a FY08 new start and MIE funds are not available to spend until the appropriation bill is signed. Normally MIE funds for new starts are not available until December or later. If the date is not adjusted some of the schedule contingency built into the CD-4 completion date will be used at the beginning of construction.

- Out of the 685 total activities in the schedule there are 685 activities that are greater than 8 weeks in duration and 209 of those activities are greater than 16 weeks in duration. Based on the current project cost estimate of over $20M, an Earned Value Management System (EVMS) and reporting will be required. To establish a schedule that will result in quality EVMS data to manage a project, the schedule activities need to be shorter in duration (i.e. 3 months or less) or objective method to measure progress established. The schedule needs to be assessed and updated to assure it is configured for EVMS reporting and give the project management an accurate assessment of project progress.

- Turnover and project closeout activities have not been included in the schedule or in the cost estimate. These activities should be added to the schedule and resource loaded.

Recommendations

58. The DECam project needs to implement their risk management plan as soon as possible to assure that risk mitigation plans have been incorporated into the base schedule and that schedule contingency has been developed based on the risk assessment. A similar recommendation was identified in the prior 2004 Director's Review Report (Section 4.0 – Schedule, Recommendation #1).

59. The committee believes that it will be difficult for DECam to accomplish all the work required to carry the design forward and to be ready for the March 2007 baseline review with the current available resources. DECam needs to define what work is required to meet the baseline requirements and determine what resources are required to accomplish that work. Then work with Lab Management on any resource shortfalls and then determine when the project can be ready for a baseline review.

60. The committee believes that the project can be accomplished in the schedule range between March 2010 and March 2011 as presented during the review. The committee recommends that DECam assure that the reason given to justify the schedule range is better defined with a sound risk basis.

61. The committee recommends that DECam identify the camera's technical specifications needed to meet the minimum scientific requirements to assure an instrument can be delivered and pass the acceptance test no later than the upper schedule range of March 2011.

62. DECam needs to assess and update the project schedule to address the varies schedule mechanic issues discussed in the comment section above.

3.3 Management

Findings

- The project presented high level overviews of DES, science goals, the final environment, and a DECam project overview talk. The project overview talk covered the proposed design at Level 2. It covered cost, the WBS to level 2, and the critical paths. There are 8 level 2 subprojects, including one for Project Management. There are level 2 managers for all L2 subprojects.

- To Summarize;

    - The project has a WBS

    - The project has a resource loaded schedule

    - The upper management team is in place

    - The project has a PPEP, PPMP, and CDR and draft versions of Hazard Analysis, Risk Management, Configuration Management, Value Management and AS.

    - Total cost for Project Management was shown as $.98M which includes 29% contingency.

Comments

- The project is to be commended for their progress in strengthening the Project Management team. The Deputy Project Managers, Scheduler and Budget Officer are experienced and competent, and should have no problems in supporting a project this size. The addition of a Project Engineer, who has been identified, but who is currently a level 2 manager needs to be expedited. The committee feels that a systems engineer is also probably needed. An ES&H person needs to be assigned to the Project office and Quality Assurance and integration oversight responsibilities defined in the PPMP consistent with the plan presented. The reviewers feel that getting these key people in place before the CD-2 review is important. It is good that the L2 manager positions have been filled with competent and experienced people. Answers were available to questions and recommendations from the previous review.

- The Conceptual Design Report is complete. The PPEP and PPMP are near completion, and should be ready for CD-1 with only minor additions. The preliminary Hazards Analysis Report is in good shape and should be adequate for CD-1 review.

- The website that serves documents to the reviewers had direct links to all the documents that they might need to access, which was very helpful. Having the schedule information there in un-zipped format was very useful. The uniformity of slides and presentations among the project team and subproject leaders should be improved before the next review, with templates for cost, schedule, and subproject critical paths using the same rules for all presentations. It would be helpful to have the subproject WBS number, etc., in the footer for each presentation.

Recommendations

63. Recheck the PPEP, PPMP, and CDR and make them consistent before submission to DOE, with thresholds for change control (cost) established, and Level 3 milestones included in the PPMP.

64. Assignment of a Project Engineer and possibly a Systems Engineer to the Project Office should be made soon.

65. Assignment of an ES&H professional to the Project Office should be made soon.

66. The Project Office planning should include staffing for Project closeout through CD-4, and should re-examine the travel requirements for the entire project.

67. Project management should determine if a performance management system is required, and begin to implement a certifiable EVMS if so.

68. A Quality Assurance Plan should be developed, and QA oversight responsibilities assigned.

69. The Project Office should implement the Risk Management Plan well before CD-2, to engage the level 2 managers in identifying and managing project risks, and to develop more accurate cost and schedule contingencies.

70. A one page master schedule showing the high level tasks and the project critical path should be made.

71. The Project should plan to begin monthly reporting by the end of 2006 so that it is a routine, well understood process by the time the CD-2 review happens.

4.0 Charge Questions

Technical

4.1 Are the scientific requirements sound and clearly stated?

The science requirements that have been stated for the project are sound, but added clarification would be helpful. It is not clear that all technical requirements can be cleanly traced back to science requirements. Some technical trades that leave global performance parameters like AΩT unchanged, may be useful (see response to 4.2).

4.2 Have these scientific requirements been translated into appropriate technical specifications that are clearly stated and documented for this stage of the project?

At the highest level, yes: the SPT survey covers 4000 square degrees of southern sky, and the survey for high-redshift clusters demands a large volume. The required image quality and flux limits have been derived from a straightforward logic. These requirements, plus the need for four bandpasses extending into the red, and the constraint on the available observing time, define most of the high-level DES technical specifications. The image quality has been conservatively reckoned as comparable to the current prime focus camera. Very likely DECam will exceed this requirement. The science "reach" is sensitive to the image quality and to some extent better image quality can be traded for observing time. This is a built-in contingency.

At a deeper level of mapping the science requirements onto the technical specifications, more work is needed to enable clear choices between plausible alternatives. For example, if the dark current spec were relaxed, higher QE could be achieved. It is not clear that the adopted technical spec optimizes the net science. Similarly the read-out noise may be too conservative since a higher observing efficiency with a faster read-out may compensate. Still another example concerns the photometric accuracy required in the z band - we were informed that the science goals could tolerate 2.5% photometric accuracy in the z band, which seems relaxed in the context of the criticality of the photometric redshifts. The point is not that this spec is incorrect, but that we could not easily see how it was derived. Yet another example is how the specifications given to the filter vendors (uniformity over the field of the transmission function) flowed down from the science requirements. The design of a number of subsystems is proceeding now using the existing technical specifications, and so some of these points are substantive.

4.3 Can this design be built?

We define this question to mean: "*Are the technical risks to completion on budget, on time and within spec acceptably low?*"

…Not as presented, due to the significant risk that the CCD yield will be lower than the 19% which can be accommodated by the current budget.

We propose that this be addressed by adding one more wafer-lot and increasing contingency to allow for an additional wafer-lot and the associated packaging and testing.

We also advocate considering fall-back scenarios. At what point, if any, will it make sense to begin the survey with a partly populated focal plane while additional CCDs are being made and tested? If this on-time but partial deployment makes sense scientifically, the additional cost of disassembly and upgrading of the instrument needs to be included within the contingency budget.

Rather than a simple pass/fail definition of success, consider the relative impact on survey rate of a partially filled focal plane (never upgraded), or a of a focal plane which is fully filled but includes partially functioning or poorer performing devices. Attempt to determine the relative likelihood of total failure of devices as opposed to performance falling short of the acceptance criteria.

An easy compromise may be to accept the survey speed loss due to reading out via only one amplifier per CCD. This fall back is only useful if failure of output amplifiers or partly blocked serial registers are a significant yield loss mechanisms. Can the software and wiring scheme support individualized serial register clocking direction?

4.4 Does the design meet technical specifications?

Yes. The technical specifications are not particularly challenging for the existing telescope optics and mount and the optical design is up to the task. If the detectors perform as expected, then the instrument will meet the required scientific performance specifications.

4.5 Is it a reasonable design?

Yes, the general design is a reasonable approach to putting the desired number of CCD pixels on the sky. A wide-field prime focus camera clearly is indicated, and completely replacing the prime focus cage makes good sense. The optical design for the camera is sound, and the hexapod positioning system is a good way to deal with the interface to the telescope. The biggest area of concern is how fast the CCDs can be procured.

4.6 Does the conceptual design meet the project's objective (mission need)?

The conceptual design for DES does meet the stated mission need for the ground-based dark energy CD-0 (Option 1), and is consistent with the goals for a Stage III project as enunciated in the DETF report.

Appendices

Project Cost Estimate

Charge

Agenda

Report Outline and Reviewer Writing Assignments

Reviewer Assignments for Breakout Sessions

Reviewers' Contact Information

Participant List

Table of Recommendations

Appendix A

DES-DECam's Project Cost Estimate for the Director's CD-1 Review of the DES-DECam Project July 25 -27, 2006

			DES-DECam's Cost Estimate AY$									
			Base w/Indirects			Contingency $			Contingency %			Total Base w/Indirects and Cont.
	WBS	Items	M&S	Labor	Total	M&S	Labor	Total	M&S	Labor	Total	
MIE	1.1	Management	$ 207,026.3	$ 555,797.4	$ 762,823.7	$42,443	$176,006	$ 218,449.1	21%	32%	29%	$ 981,272.9
	1.2	Focal Plane Detectors	$ 329,641.4	$ 1,015,964.6	$ 1,345,606.0	$1,026,227	$439,515	$ 1,465,742.1	74%	43%	61%	$ 2,811,348.1
		pass through -LBNL	$ 1,052,110.6	$ -	$ 1,052,110.6	$0	$0	$ -	0%	0%	0%	$ 1,052,110.6
	1.3	Front End Electronics	$ 218,716.1	$ 569,728.7	$ 788,444.8	$78,199	$324,843	$ 403,041.5	36%	57%	51%	$ 1,191,486.3
	1.4	Optics	$ 755,901.4	$ 11,823.6	$ 767,724.9	$314,852	$6,394	$ 321,246.3	42%	54%	42%	$ 1,088,971.2
	1.5	Opto-Mechanical System	$ 2,164,567.0	$ 1,903,232.4	$ 4,067,799.4	$789,702	$901,189	$ 1,690,891.3	36%	47%	42%	$ 5,758,690.7
	1.6	Survey Image System Process Integration (SISPI)	$ 126,725.2	$ -	$ 126,725.2	$51,961	$0	$ 51,960.9	41%	0%	41%	$ 178,686.1
	1.7	Survey Planning	$ 149,306.4	$ 22,521.8	$ 171,828.2	$61,736	$12,180	$ 73,915.4	41%	54%	43%	$ 245,743.5
	1.8	CTIO Integration	$ -	$ 222,025.4	$ 222,025.4	$0	$111,013	$ 111,012.7	0%	50%	50%	$ 333,038.0
		Total TEC:	**$ 5,003,994.4**	**$ 4,301,093.7**	**$ 9,305,088.2**	**$ 2,365,119.6**	**$ 1,971,139.6**	**$ 4,336,259.2**	47%	**46%**	**47%**	**$ 13,641,347.4**
OPC	R&D		$ 2,668,716.8	$ 5,263,916.0	$ 7,932,632.8	$443,546	$1,628,257	$ 2,071,803.1	17%	31%	26%	$ 10,004,435.9
		Total OPC:	**$ 2,668,716.8**	**$ 5,263,916.0**	**$ 7,932,632.8**	**$ 443,545.8**	**$ 1,628,257.3**	**$ 2,071,803.1**	**17%**	**31%**	**26%**	**$ 10,004,435.9**
		TPC:	**$ 7,672,711.2**	**$ 9,565,009.7**	**$ 17,237,721.0**	**$ 2,808,665.4**	**$ 3,599,396.9**	**$ 6,408,062.3**	**37%**	**38%**	**37%**	**$ 23,645,783.3**

Notes: The contingency comes from the task by task factors. These factors are on all the tasks, R&D and MIE so I entered them in the table this way.

Appendix B

Charge for the Director's CD-1 Review of the Dark Energy Survey - DECam Project July 25-26, 2006

Project Overview:
The Dark Energy Survey (DES) is a 5000 sq. deg. imaging survey to be conducted using a new camera on the CTIO Blanco 4m telescope. The primary scientific goal of the DES is to constrain dark energy cosmological parameters using multiple techniques.

The DES is divided into two projects. One component covers the construction of the new instrument, DECam, the second covers the management of the data that the instrument will produce. Fermilab is leading the instrument project and NCSA is leading the data management project.

History:
The DES originated in response to an NOAO Announcement of Opportunity (AO) for a partnership with NOAO in which 30% of the telescope time on the CTIO Blanco 4m was offered in exchange for a new instrument. In Dec. 03 the DES collaboration formed and in March 04 DES submitted a proposal to the Fermilab Physics Advisory Committee (PAC). The PAC found the science compelling. A Director's review was held June 7- 8, 2004. Following the June PAC meeting, the Fermilab Director gave DES Stage 1 approval.

In July 04 DES submitted the updated DES proposal to NOAO in response to the AO. A technical committee (the Blanco Instrumentation Review Panel – BIRP) appointed by NOAO reviewed the proposal in Aug. 04 and in Sept. 04 recommended that NOAO accept the proposal. The Director of NOAO approved the proposal and advised DES to develop a Memorandum of Agreement. A draft of this agreement has been prepared and reviewed by the directors of Fermilab, NOAO and NCSA.

Scope:
The scope of this review is DECam. Fermilab is the lead institution on the project to construct DECam and the majority of the project funding will hopefully be provided by DOE. Since the time of the BIRP review DES has been adding collaborators who can make significant cash or in-kind contributions that would reduce the potential DOE project costs, with a goal that approximately one third of the project equipment costs will be funded by non-DOE funds. The current funding plan includes funding from DOE and funding of in-kind contributions by the United Kingdom(PPARC), Spain(CSIC), and several universities from non-DOE funds.

The DECam project as a whole is managed at Fermilab. R&D for the project is proceeding using funds from both DOE and non-DOE sources.

Approval of CD-1 by DOE is based on a Conceptual Design Report (CDR) for the project. The project scope and preliminary baseline range for the cost and schedule are to be defined at this point in the project. The committee should answer the following questions regarding the scope of DECam: Are the scientific requirements sound and clearly stated? Have these scientific requirements been translated into appropriate technical specifications that are clearly stated and documented for this stage of the project? Can the design be built? Does the design meet the technical specifications? Is it a reasonable design? Does the conceptual design meet the project's objective (mission need)?

Some additional documents that support the CD-1 determination are a Preliminary Project Execution Plan (PPEP), a Preliminary Project Management Plan (PPMP), Acquisition Strategy, Preliminary Hazard Analysis (PHP) report and Draft Risk Management Plan. The technical part of the review will focus on the conceptual design of the DECam. It will determine whether these designs meet the requirements and specifications and whether the designs are sound. The cost, schedule and scope ranges are usually based on an initial set of documentation such as the following: WBS – Work Breakdown Structure, WBS Dictionary, BOE – Basis of Estimate documentation, risk and contingency analyses, RLS – Resource Loaded Schedule, and time phased funding and cost profiles. The committee is asked to review each of these items, for quality, completeness, and accuracy. The committee should determine whether appropriate ES&H measures have been and are being taken into account. Furthermore, the committee is asked to review and assess the quality of and comment on the additional formal project management documentation (PPEP, PPMP, PHA and RMP) required for CD-1 approval.

Additionally, the committee is to review and comment on Project's response and actions taken with respect to the recommendations from the Director's Preliminary Review of DECam in June 2004 and from the Blanco Instrumentation Review Panel (BIRP) Review. Constructive comments on presentation content, format, and style are also requested.

Finally, the committee should present findings, comments, and conclusions at a closeout meeting with DECam, Fermilab, NCSA and NOAO management and provide a written report soon after the review.

Expectations for a Successful CD-1 Review Attachment 1

- Completed Conceptual Design Report: It should
  - Document the science requirements to be met,
  - Describe technical solutions that are likely to meet the science requirements,
  - Provide a credible estimate of the cost range and associated supporting information to justify the cost range,
  - Present a credible schedule duration which shows how long it will take to complete design and construction,

- Project team in place: The team should be capable of carrying the design forward to a baseline.
  - A qualified project management team should be in place,
  - The scientists, engineers, and other personnel needed to complete the design have been identified and made available,
  - Project roles and responsibilities are clearly defined,
  - There is a plan to complete the R&D needed for the design and resources to implement the plan have been identified.

- Other required documentation for CD-1:
  - Preliminary Project Execution Plan (PPEP) which addresses all required elements of the PEP at a preliminary level.
    - Details can be completed at CD-2 when the final PEP is approved.
    - A Risk Management Plan that describes the method for managing technical risk, budget risk, and schedule risk,
    - An Acquisition Plan that identifies procurement strategies, including critical make vs. buy decisions that have been evaluated in conjunction with scope definition,
    - If a Preliminary Project Management Plan (PPMP) will be used to supplement the PEP then a draft should also exist at a similar level of detail.
  - Preliminary Hazard Analysis Report which identifies major safety issues and conceptual solutions to mitigate these issues.

Appendix C

Agenda
for the CD-1 Director's Review
Dark Energy Survey Instrument – DECam Project
July 25-27, 2006

Tuesday, July 25, 2004 – Location

8:00–9:00 AM	Executive Session (Comitium - WH2SE)	Ed Temple Rich Kron
9:00–9:10 AM	Introduction (Curia II – WH2SW)	Hugh Montgomery
9:10–9:25 AM	DES Project overview	John Peoples
9:25–9:50 AM	DES in the context of the Dark Energy Task Force Rpt	Josh Frieman
9:50–10:15 AM	DES Science goals and requirements	Jim Annis
10:15–10:40 AM	Break	
10:40–11:05 AM	AO, CTIO site, telescope environment, user community, DECam and CTIO	Alistair Walker
11:05–12:05 PM	DECam Project Overview, Management, Organization, Cost, Schedule	Brenna Flaugher
12:05–12:30 PM	Data Management	Joe Mohr
12:30–1:30 PM	Lunch (2^{nd} Floor Crossover)	
1:30–1:55 PM	CCD characterization, yield	Juan Estrada
1:55 - 2:20 PM	CCD readout electronics	Terri Shaw
2:20–2:45 PM	Optics: design, procurement assembly and testing plans	Peter Doel
2:45–3:10 PM	Mechanical Overview (camera, barrel, cage, hexapod...)	Andy Stefanik
3:10–3:35 PM	Simulations and Photo-z's	Huan Lin
3:35–4:00 PM	BREAK	
4:00–5:00 PM	Breakouts Sessions (Sessions 2, 3 and 4 only) See Breakout Detail Section for Room Assignments	
5:00–6:30 PM	Executive Session (Comitium WH2SE)	Ed Temple

Wednesday, July 26, 2006

8:00–8:45 AM	Cost and Schedule Executive Session (Comitium WH2SE)	Ed Temple
8:45 – 12:45	Breakouts Sessions (BREAK at 10:15 outside of Comitium)	
	1) Management, Cost and Schedule (Comitium - WH2SE) WBS 1.1 - Management	Brenna Flaugher, Wyatt Merrit,
	2) Focal Plane Detectors and CCD Camera (Snake Pit – WH2NE) WBS 1.2 - Focal Plane Detectors WBS 1.5.2 – CCD Camera	Tom Diehl, Herman Cease
	3) CCD Readout Electronics and SISPI (Racetrack – WH7X) WBS 1.3 - Front End Electronics WBS 1.6 - Survey Image System Process Integration (SISPI)	Jon Thaler, Terri Shaw
	4) Optics, Opto-Mechanics, Survey Planning, Integration (Black Hole – WH2NW) WBS 1.4 - Optics WBS 1.5 - Opto-Mechanical System WBS 1.7 - Survey Planning WBS 1.8 - CTIO Integration	Peter Doel, Andy Stefanik,
12:45–1:45 PM	LUNCH (2nd Floor Crossover)	
1:45–2:45 PM	DES Respond to Committee Questions from 1st Day and Additional Questions from Breakouts (Comitium, WH2SE)	Brenna Flaugher, Wyatt Merritt, John Peoples
2::45 PM-6:30+ (Break at 3:45)	Executive Session and Report Writing (Comitium, WH2SE)	Ed Temple

Thursday July 27th

8:30–2:00 PM	Closeout Dry Run with working lunch (Comitium - WH2SE) Breaks taken as necessary.
2:00 PM	Closeout (Curia II - WH2SW)

Breakouts Details with possible talks identified

	1) Management (WBS 1.1) (Comitium - WH2SE)	
20 min	Milestones, Critical paths, Procurements	Brenna Flaugher
20 min	CD-1 Documents	Wyatt Merritt
	2) Focal Plane Detectors (WBS 1.2) and CCD Camera (WBS 1.5.2) (Snake Pit – WH2NE)	Tom Diehl, Herman Cease
20 min	CCD testing rate, production plans	Juan Estrada
20 min	CCD packaging and testing infrastructure	Tom Diehl
20 min	CCD reports and analysis	Julia Campa*
20 min	Computing support for CCD testing	Liz Buckley-Geer
20 min	Prime Focus Camera	Herman Cease
	3) CCD readout Electronics (WBS 1.3) and SISPI (WBS 1.6) (Racetrack – WH7X)	Jon Thaler, Terri Shaw
20 min	Clock Transition cards and MCB	Manel Martinez*
20 min	Clock Board Design	Juan de Vicente*
20 min	12 Channel Acquisition Card	Dave Huffman
20 min	SISPI	Jon Thaler
20 min	CCD readout Crates	Vaidas Simaitis
20 min	Guiding	Francisco Castander
	4) Optics (WBS 1.4), Opto-Mechanics (WBS 1.5), Survey Planning (WBS 1.7) Integration (WBS(1.8) (Black Hole – WH2NW)	Peter Doel, Andy Stefanik
20 min	Optical Design and optimization	Rebecca Bernstein
20 min	Optical Testing	David Brooks
20 min	Photoz-s and filter definition	Huan Lin
20 min	Focus and alignment	Steve Kent
20 min	Hexapods	French Leger
20 min	Camera Cooling Plant	Rich Schmitt
20 min	Integration at CTIO	Tim Abbott*

* Indicates attending via video conference.

Appendix D

Report Outline and Reviewer Writing Assignments for the Director's CD-1 Review of the Dark Energy Survey - DECam Project July 25-27, 2006

Executive Summary Technical Project Management	 Rich Kron Ed Temple
1.0 Introduction	Dean Hoffer
2.0 Technical	
2.1 Science Requirements	Steve Kahn, Stefi Baum, Jack Baldwin, Rich Kron
2.2 Focal Plane Detectors and CCD Camera WBS 1.2 - Focal Plane Detectors WBS 1.5.2 – CCD Camera	Gerry Luppino Chris Damerell Steve Kahn Rich Kron
2.3 Readout Electronics and SISPI WBS 1.3 - Front End Electronics WBS 1.6 - Survey Image System Process Integration (SISPI)	Roger Smith Stefi Baum Peter Wilson Bob Tschirhart
2.4 Optics, Opto-Mechanics, Survey Planning, Integration WBS 1.4 - Optics WBS 1.5 - Opto-Mechanical System WBS 1.7 - Survey Planning WBS 1.8 - CTIO Integration	Alan Uomoto Jack Baldwin Jim Kerby
3.0 Project Management - WBS 1.1 - Management	
3.1 Cost	Marc Kaducak Mike Lindgren Dean Hoffer
3.2 Schedule	Dean Hoffer Marc Kaducak Mike Lindgren
3.3 Management	Mike Lindgren Ed Temple
4.0 Charge Questions	
4.1 Are the scientific requirements sound and clearly stated?	Steve Kahn
4.2 Have these scientific requirements been translated into appropriate technical specifications that are clearly stated and documented for this stage of the project?	Rich Kron
4.3 Can the design be built?	Roger Smith
4.4 Does the design meet the technical specifications?	Alan Uomoto
4.5 Is it a reasonable design?	Jack Baldwin
4.6 Does the conceptual design meet the project's objective (mission need)?	Steve Kahn

* Note underlined names are the primary writer.

Appendix E

Reviewer Assignments for Breakout Sessions
For Director's CD-1 Review
of the
Dark Energy Survey – DECam Project
July 25-27, 2006

1) Management, Cost and Schedule (Comitium - WH2SE) WBS 1.1 - Management	Marc Kaducak Mike Lindgren Dean Hoffer Ed Temple
2) Focal Plane Detectors and CCD Camera (Snake Pit – WH2NE) WBS 1.2 - Focal Plane Detectors WBS 1.5.2 – CCD Camera	Chris Damerell Steve Kahn Rich Kron Gerry Luppino
3) CCD Readout Electronics and SISPI (Black Hole – WH2NW) WBS 1.3 - Front End Electronics WBS 1.6 - Survey Image System Process Integration (SISPI)	Stefi Baum Roger Smith Peter Wilson Bob Tschirhart
4) Optics, Opto-Mechanics, Survey Planning, Integration (Racetrack – WH7X) WBS 1.4 - Optics WBS 1.5 - Opto-Mechanical System WBS 1.7 - Survey Planning WBS 1.8 - CTIO Integration	Jack Baldwin Jim Kerby Alan Uomoto

Appendix F

Reviewers' Contact Information
for the Director's CD-1 Review of DES-DECam Project
July 25-27, 2006

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Appendix G

Participant List
for the Director's CD-1 Review of the DES-DECam Project
July 25-27, 2006

Role	Last Name	First Name	Affiliation
Reviewers	Baldwin	Jack	Michigan State University
	Baum	Stephanie	Rochester Institute of Technology
	Damerell	Chris	Rutherford Appleton Laboratory, UK
	Hoffer	Dean	FNAL
	Kaducak	Marc	FNAL
	Kahn	Steve	SLAC
	Kerby	Jim	FNAL
	Kron	Richard	University of Chicago
	Lindgren	Mike	FNAL
	Luppino	Gerard	University of Hawaii, Institute for Astronomy
	Smith	Roger	Cal Tech Optical Observatory
	Temple	Ed	FNAL
	Tschirhart	Bob	FNAL
	Uomoto	Alan	The Observatories of the Carnegie Institute of Washington
	Wilson	Peter	FNAL
Presenters	Abbott *	Tim	Cerro Tololo Inter-American Observatory
	Annis	Jim	FNAL
	Bernstein	Rebecca	U Michigan
	Brooks	David	University College London
	Buckley-Geer	Liz	Fermilab
	Campa *	Julia	Universidad Autonoma de Madrid
	Castander *	Francisco	IEEE
	Cease	Herman	FNAL
	de Vicente *	Juan	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT) Madrid, Spain
	Diehl	Tom	FNAL
	Doel *	Peter	UCL
	Estrada	Juan	FNAL
	Flaugher	Brenna	FNAL
	Frieman	Josh	FNAL/Uchicago
	Huffman	Dave	Fermilab
	Kent	Steve	FNAL
	Leger	French	FNAL
	Lin	Huan	FNAL
	Martinez *	Manel	Institut de Fisica d'Altes Energies (IFAE)
	Merritt	Wyatt	FNAL
	Mohr	Joe	U of I Champaign/Urbana
	Peoples	John	FNAL
	Schmitt	Richard	FNAL
	Shaw	Terri	FNAL
	Simaitis	Vaidas	U of I Champaign/Urbana
	Stefanik	Andy	FNAL
	Thaler	Jon	U of I Champaign/Urbana
	Walker	Alistair	CTIO/NOAO - DIR

Role	Last Name	First Name	Affiliation
DOE	Livengood	Joanna	DOE SO
	Lutha	Ron	DOE SO
	Philps	Paul	DOE SO
Directorate	Kim	Young-Kee	FNAL
	Montgomery	Hugh	FNAL
	Oddone	Pier	FNAL
Other Participants	Beldica	Cristina	U of I Champaign/Urbana
	Bock	Greg	FNAL/PPD
	Boroson	Todd	NOAO - Directorate
	Cardiel *	Laia	IFAE
	Donahue	Megan	Michigan State University
	Dunning	Thom	NLSA Director
	Gerdes *	David	U Michigan
	Gladders *	Mike	Carnegie Observatories
	Honscheid	Klaus	Ohio State University
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	Scarpine	Vic	FNAL
	Stoughton	Chris	FNAL
	Strait	Jim	FNAL/PPD
	Tucker	Doug	FNAL
	White	Vicky	FNAL/CD
	Worswick	Sue	University College London

* Indicates attended by video conference.

Appendix H

Table of Recommendations
for the Director's CD-1 Review of the DES-DECam Project
July 25-27, 2006

#	Recommendation	Assigned To	Status/ Action	Date
	Science Requirements			
1	A clear connection should be made between the two levels of science requirements and the subsequent decision-making process of the project as it proceeds into development. Is achievement of "substantial success" sufficient for the project or not?			
2	A more detailed calibration error budget should be developed for CD-2. This should include explicit simulations that demonstrate the required photometric precision can be achieved at all points in the survey region. If the photometric precision will be heterogeneous over the survey region, the science implications should be addressed.			
3	A set of more extensive science trades should be performed for technical choices that leave global performance unchanged – e.g. total field versus packing efficiency, versus efficiency in the use of observing time, quantum efficiency in the various bands, etc. Each technical requirement should have a clear science rationale.			
4	The MOU with NOAO should include a detailed discussion of science requirements for the use of the DECam by the general user community. These requirements should be identified and enunciated very soon to ensure that they can be met by the present design.			
	WBS 1.2 – Focal Plane Detectors			
5	The project should add an additional lot of CCDs to their baseline program, including all the steps needed to make these CCDs ready for deployment into the camera (wafer production at DALSA, processing at LBNL, packaging and testing at FNAL).			

#	Recommendation	Assigned To	Status/ Action	Date
6	The team should justify its choice of 250-microns for the CCD thickness (as compared to thicker) and should indicate that it plans to investigate the trade in NIR-QE vs. dark current that can be had at a warmer operating temperature of, say, -80C.			
7	The project needs to carefully consider their decision on whether to go with the re-polished Wacker material or the new wafers with polybackseal. This decision should be made after extensive test data are available for the new polybackseal devices (e.g. 1 or 2 working devices does not constitute an extensive set of test data). Similarly, test data need to be acquired for the re-polished Wacker devices. After reviewing the specification for wafer repolishing, we also recommend that a minimum amount of material to be removed be called out in the spec (e.g. the spec currently calls out only a maximum amount of 10 microns to be removed but does not call out a minimum amount that must be removed).			
8	Adequate resources (primarily experienced personnel) need to be provided to carry out CCD testing, characterization and optimization. This process can be divided into two distinct areas: 1) R&D testing to explore and understand the performance of the LBNL CCDs over a wide range of operating parameters, 2) production testing which is an automated set of tasks that generates a large data set of images that are analyzed to select the best CCDs with their optimal operating parameters. These two areas are coupled, with the first needing to be carried out before one can design and implement the best automated production testing plan. The team should prepare a detailed test plan showing what data will be collected, and how these data will be used to determine the device properties and to converge on an optimal set of operating parameters for each device.			

#	Recommendation	Assigned To	Status/ Action	Date
9	The DECam team should include Fe55 x-ray testing as one of the core techniques used to characterize the CCDs. A complete set of Fe55 data should be collected and analyzed for each detector. It would be essential to further characterize a subset of devices using lower-energy x-rays, or UV/blue photons to probe the back surface and insure a field-free region does not exist.			
10	A means should be identified to strain relieve the surface-mounted Nanonics connector on the ALN board. Metalized traces on ceramic are much more delicate than copper traces on FR-4 or polyimide, and it will be quite easy to pull this connector right off the ALN if any shear force is encountered during mating and unmating, or by pulling on the mating flexcable. Therefore, we recommend that the number of mating and unmating cycles of this joint should be minimized. This can be achieved by using a connector saver at all times on the device package for all device testing. The connector saver should only be removed for the final installation in the camera focalplane. The mating and unmating cycles can also be minimized if the team decides to attach the long flexcable to the package and leave it there at all times for device testing and handling. This approach, however, may complicate the device handling and storage and focalplane loading process. The Nanonics connector should also be strain relieved, perhaps by potting the base of the connector into the invar block. This does not preclude using a connector saver, as damage to the connector itself is also a risk (as opposed to damage to the surface-mount joint), but it at least minimizes one of the risk areas.			
11	We recommend that in most cases, the 3rd or 4th design iteration was unlikely to be needed and should be considered to be part of the contingency.			
	WBS 1.5.2 CCD Camera			
12	A list of focalplane metrology specifications needs to be prepared.			

#	Recommendation	Assigned To	Status/ Action	Date
13	Results of thermal modeling and FEA analysis should be presented to show that the camera focalplane meets spec.			
	WBS 1.3 Front End Electronics			
14	Gain as much experience as possible, as early as possible in the project, with the electronics and associated software, by using these for CCD characterization etc. Configurations as close as possible to that of the final instrument should be used in qualification tests.			
15	Aim to produce the final design in the first iteration with the second PCB design cycle fixing problems found. The third cycle should be retained as *contingency* only. This will maximize experience with boards during CCD, software, and system testing, while minimizing the risk of introducing new faults during the final cycle(s). This may also lead to a cost saving by eliminating the 3rd iterations.			
16	Create a clear set of acceptance testing criteria for each stage of board development, which includes all components to be included. Design reviews between steps should include comparison of results with these criteria and provide branch points such as eliminating design iterations or implementing fallback solutions.			
17	In addition to the 135 clocks, include several sequencer outputs (digital levels only) on front panel connectors to be used for such things as triggering oscilloscopes (eg Frame Start), or operating a shutter in the lab, unless these features already exist.			

#	Recommendation	Assigned To	Status/ Action	Date
18	Test clocks and biases for noise performance by looping back directly into the video preamp (AC coupling, stopped at high then low level). Acceptable noise is defined as being much less than that of the CCD output after the clock in question has been attenuated by the clock feed-through ratio. (This needs to be determined empirically.) An analog multiplexor can be used to scan through all clock outputs automatically. Notes: • While technically a sufficient test, simply accepting a clock board because CCD performance appears not to be degraded, gives little information on noise margin. • Furthermore the test with the CCD works only when the test system and CCD have already demonstrated low noise, and only tests a subset of the clocks • It is preferable to use the video signal path to monitor clock and bias quality since digital interference within the controller is invisible, since it is synchronous. Furthermore, the video chain has better resolution, noise and dynamic range than most lab instruments.			

#	Recommendation	Assigned To	Status/ Action	Date
19	Verify the efficacy of the multi-controller synchronization mechanisms, which must be employed to prevent degradation of noise performance when multiple master control boards are used together. This should be done during the testing of the first PCB versions in case the problem requires a design modification. As a baseline, search for beat frequencies by Fourier transforming the data stream from the CCD. (If significant sources of interference are found, the test can be repeated in the bias/clock loop-back configurations and with shorted video input to identify the coupling path.) The test must then be repeated with *multiple* controllers (backplanes) operated in sync in the same crate, to see if new harmonics appear.			
20	Revise the text of the CDR to focus on the baseline design then describe the justification for the choice of Monsoon and for redesigning boards.			
21	Incorporate load resistor for CCD source follower and a low noise p-channel JFET source follower and its load resistor into the CCD package or on the CCD end flex cable (stiffener).			
	Gliders, Alignment and Focus CCDs			
22	Consult with Rolando Cantarutti at CTIO who is an established expert. He will be able to offer examples of well developed guider software (as used on SOAR and Blanco telescopes)..			

#	Recommendation	Assigned To	Status/ Action	Date
23	Be aware that guider sensitivity is an issue, which is likely to arise in discussions of non-DES programs where narrower band filters are likely to be used. o Consider full frame cross correlation of the guider CCDs to achieve higher precision and/or eliminate the need for automatic guide star selection. o Allow for the possibility of using a subset of the science field for guiding in the event that brighter guide stars (or cross correlation of larger area) are needed for narrow filters: allocate CCDs to "controllers" to optimize the shape of the residual science field. o Consider what would be needed to support the selection of a single science CCD (or a group of three) anywhere in the field for guiding.			
24	Allocate all focus/alignment CCDs to the same controller (changing cable layout accordingly) to protect against the case where a different readout cadence is required			
	WBS 1.6 Survey Image System Process Integration (SISPI)			
25	Analyze the need for computing professional developers to advance the design of the data acquisition and control system. In our estimation the project will require 1-2 Computing Professional FTEs for 3 years to design and develop the required software systems.			

#	Recommendation	Assigned To	Status/ Action	Date
26	We recommend that the SISPI Project clearly identify internal DES project science and operations members (including astronomical observers and those with telescope operations expertise) who will constitute the necessary user group to support the development of requirements, design, testing, and deployment of the SISPI System.			
27	We recommend that the SISPI project work closely with NOAO to identify a User Advisory Group for the SISPI project with whom they work closely in the design, development, and testing of the system to assure it integrates within the telescope environment and supports the needs of the general user community.			
28	We recommend that the SISPI project develop a clear set of requirements from which the high level design will flow, working in conjunction with the internal and external user advisors as noted in recommendations 26 and 27 above. We note that as the schedule shows the development of the high level design of SISPI by December 2006, it is critical that the system requirements be developed *before* the initiation of the design work.			
29	Develop software execution speed budget, broken down by task. These requirements must ensure that neither survey nor calibration speed (eg twilight sky flats) are not significantly impacted.			
30	Ensure that system initialization time, including return to prior setup, are short enough (<20sec?) to have minimal impact on system testing and debugging.			
31	Designate a person to be responsible for hardware software initialization/configuration.			
	MOU Topics			
32	Ensure that robust humidity control is provided both in the CTIO computer room and adjoining control room.			
33	Specify the networking and security requirements (firewall, access management).			

#	Recommendation	Assigned To	Status/ Action	Date
34	Define (limits on) software support for non-DES use of the instrument, both during development and during operations phase.			
	WBS 1.4 - Optics			
35	Define the required filter bandpass and throughput homogeneity over the camera field of view and incorporate that into the filer procurement process.			
	WBS 1.5 – Opto Mechanical System			
36	A full-time instrument scientist or systems engineer should be identified (hired, if necessary). This person should take responsibility for high-level requirements and engineering interfaces of all L2 subsystems with the goal of coordinating interface control, managing changes, and monitoring scientific requirements in the context of engineering compromises.			
37	Create an interface control document with procedures for changing and adding to it. Interface documents between components and organizations should be a high priority. This is a job for the instrument scientist/systems engineer.			
38	The committee believes a full assembly and test at Fermilab (without corrector lenses but with appropriate masses) before shipment to CTIO should be considered. If final assembly at CTIO remains the baseline, careful and thorough planning of sub-system acceptance testing must be completed.			
39	Develop a high-level final assembly and test plan sufficient to call out specific goals (read out the detectors and move the hexapods at the same time, e.g.) and make reasonable schedule estimates.			
40	“Commissioning” should not include the final assembly and test phase (although a re-assembly is probably needed). Assembly and test should be a separate task.			
41	After determining that you’ve done everything you can to reduce the heat load, bring the appropriate people together, including the CTIO team (who will maintain and operate it), to pare the list of potential cooling systems.			

#	Recommendation	Assigned To	Status/ Action	Date
42	Think seriously about how to avoid icing the window. Dewpoint sensors, window heaters, or hermetically seal the space between C4 and C5, silica gel canisters, etc.			
43	There's an effect, probably minor, on the refractive index of the window. Showing this is not a problem is worth doing.			
44	Make sure your coatings are water-resistant.			
45	The hexapod design should be very carefully checked for possible problems due to the proposed attachment scheme. This is not necessarily a bad choice but be sure you understand the issues (what bad things can happen if the control system fails) and have a way to avoid serious damage (breakaway systems, etc.) if you decide to go this route.			
46	A three-point scheme would be preferable if it is practical.			
	WBS 1.8 – CTIO Integration			
47	The project should provide the capability to deal with a worst-case situation in which the primary mirror shifts around by the amount that it did before the recent work on the support system. The donut images from the focus CCDs should be used to measure coma as well as de-focus, and there should be a means of feeding the coma signal as well as the focus signal to the hexapod for closed-loop corrections. Astigmatism should also be measured from the focus images; this signal could in principal be used (very easily) to drive closed-loop astigmatism correction with the existing active optics system on the primary mirror, but at minimum can be used to continuously improve the lookup table that is used by that system.			
48	Understand the impact of a mis-aligned telescope. What are the combinations, if any, of Dec and exposure time that affect the weak lensing analysis. Determine the polar alignment requirement.			

#	Recommendation	Assigned To	Status/ Action	Date
	WBS 1.1 Project Management - Cost			
49	Reassign contingency factors from the bottom up based on understood uncertainties to be developed in a risk assessment.			
50	Reconsider methodologies for calculating lower and upper bounds on total project cost to comply with DOE's CD-1 requirement of supporting information for determining cost range.			
51	Maintain consistency in presentation of costs between WBS Level 2 presentations, Project Management rollups, and complete WBS cost chart.			
52	Consult with Fermilab Directorate on best method for differentiating R&D base and contingency costs from MIE costs.			
53	Evaluate and include costs for WBS 1.8 (CTIO Integration) M&S.			
54	Allocate 3rd iterations of Front End electronics and possibly other systems as contingency.			
55	Revisit travel costs in the Project Management section of the WBS considering reviews, vendor visits, and site visits.			
56	Include cost of an additional lot of CCDs as discussed in section on WBS 1.2 in this report.			
57	Include costs for a Systems Engineer, Computing Professionals, and additional resources for CCDs.			
	WBS 1.1 Project Management - Schedule			
58	The DECam project needs to implement their risk management plan as soon as possible to assure that risk mitigation plans have been incorporated into the base schedule and that schedule contingency has been developed based on the risk assessment. A similar recommendation was identified in the prior 2004 Director's Review.			

#	Recommendation	Assigned To	Status/ Action	Date
59	The committee believes that it will be difficult for DECam to accomplish all the work required to carry the design forward and to be ready for the March 2007 baseline review with the current available resources. DECam needs to define what work is required to meet the baseline requirements and determine what resources are required to accomplish that work. Then work with Lab Management on any resource shortfalls and then determine when the project can be ready for a baseline review.			
60	The committee believes that the project can be accomplished in the schedule range between March 2010 and March 2011 as presented during the review. The committee recommends that DECam assure that the reason given to justify the schedule range is better defined with a sound risk basis.			
61	The committee recommends that DECam identify the camera's technical specifications needed to meet the minimum scientific requirements to assure an instrument can be delivered and pass the acceptance test no later than the upper schedule range of March 2011.			
62	DECam needs to assess and update the project schedule to address the varies schedule mechanic issues discussed in the comment section above.			
	WBS 1.1 Project Management - Management			
63	Recheck the PPEP, PPMP, and CDR and make them consistent before submission to DOE, with thresholds for change control (cost) established, and Level 3 milestones included in the PPMP.			
64	Assignment of a Project Engineer and possibly a Systems Engineer to the Project Office should be made soon.			
65	Assignment of an ES&H professional to the Project Office should be made soon.			
66	The Project Office planning should include staffing for Project closeout through CD-4, and should re-examine the travel requirements for the entire project.			

#	Recommendation	Assigned To	Status/ Action	Date
67	Project management should determine if a performance management system is required, and begin to implement a certifiable EVMS if so.			
68	A Quality Assurance Plan should be developed, and QA oversight responsibilities assigned.			
69	The Project Office should implement the Risk Management Plan well before CD-2, to engage the level 2 managers in identifying and managing project risks, and to develop more accurate cost and schedule contingencies.			
70	A one page master schedule showing the high level tasks and the project critical path should be made.			
71	The Project should plan to begin monthly reporting by the end of 2006 so that it is a routine, well understood process by the time the CD-2 review happens.			