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Closeout Report

on the

Director's Preliminary Review

of the

Dark Energy Survey Proposal and Design

June 7-8, 2004

REPORT OUTLINE

<u>Appendices</u>

Executive Summary

Technical

We repeat the science finding from the Spring Fermilab Physics Advisory Committee review of the Dark Energy Survey (DES) proposal: " The Committee finds the science of the proposed Dark Energy Survey very exciting and important." The DES team proposal puts forth a good program and it can be carried out.

The DES was proposed as two projects 1) an instrument and 2) the data management. These two projects are proposed to be overseen and guided by a Management Committee.

Instrument

The presentations focused primarily on the instrument and activities at Fermilab in support of instrument construction. The project complete stage proposes delivery of a commissioned CCD camera on the CTIO telescope in the fall of 2008.

A complete Reference Design was presented. We believe this design could do the science program described. However, it is recommended that the following two important steps be taken next. First, state the scientific requirements for the Dark Energy Survey, and then translate these into technical systems requirements for the hardware and software components of the project. These requirements can then guide the collaboration as they further refine the Reference Design and consider several of the design tradeoffs suggested in this report.

Data Management

This effort will be centered at the National Center for Supercomputer Applications (NCSA) at UIUC with participation by Fermilab and the University of Chicago. This is not an extremely difficult task, but there are challenges. Manpower and time to complete the task are the issues. There is concern by the committee that the proposed 8 FTEs at NCSA will not be enough. Furthermore, it is not evident that "grid" computing is required. A cost / benefit analysis of this approach should be done.

Cost

Rather well developed initial cost estimates were presented for the instrument. In FY04$ the base cost for WBS 1.0 was $11.2M. Including a $4.7M contingency brings this to $15.9M. The cost fully loaded with overheads and escalated is $20M.

Some increases in contingency for the CCDs and an allowance / accommodation for "university" efforts which for some reason do not come to fruition should perhaps be made.

Detailed cost estimates for the Data Management were not presented. These will be developed for a proposal to NSF later this year.

Schedule

The proposed schedule is a major concern for the DES project. An aggressive schedule has been proposed so that the scientific survey program can be completed before the LSST project comes on line in 2012. Key areas of concern here are the CCDs and data management. More time than allowed is likely to be required for CCD fabrication and test. Additional manpower and perhaps additional time will likely be required for the data management. The science motivation for the project is robust against slips up to ~2 years, but not any longer.

Funding

Funding requests will be made to the DOE, NSF and private funding sources. Initial plans for these funding requests were presented. The predominant fraction of the instrument costs will be requested from Fermilab. The time required to develop the funding proposals, get them through the review and approval process, and receive the money is problematic given the aggressive schedule.

The schedule put forth at this review was a technically limited schedule with the assumption that funding to support the schedule could be provided. This committee recommends that the DES Collaboration now develop a plan based on a more realistic funding profile.

Management

This is not a large project, but it is large enough that project management discipline will be required. It is felt that a single Project Manager in charge of the entire effort would be more appropriate than the two-project scheme overseen by a Management Committee. The Management Committee can take on the role of Collaboration management and support. It is recommended that a comprehensive, complete and agreed upon set of "systems requirement" be developed.

The reliability / dependability of partners (Fermilab, UIUC [both DAQ and Data Management], LBNL, CTIO, and University of Chicago) to develop quality products in a timely manner is a concern. This can be maximized by having one or more persons at each of the partner institutions who is passionate about the science.

A cost / schedule person will be needed throughout the life of the project. Perhaps not full time, but dedicated to the efforts required.

1.0 Introduction

A Preliminary Director's Review of the Dark Energy Survey (DES) proposal and design was held at Fermilab June 7-8, 2004. The charge for the review is included in this report as Attachment A. The agenda is shown in attachment B. The list of reviewers and their assignments are given in Appendix C and the list of participants is shown in Appendix D.

The Physics Advisory Committee (PAC) at their Aspen meeting in mid June will conduct another more detailed technical review. At that time DES team will provide answers to a list of questions given them by the PAC at their spring meeting when the DES proposal was first presented.

This report is structured in two sections: Section 2.0 addresses findings, comments, and recommendations by component. Section 3.0 gives answers to the PAC questions as they were presented during this review.

2.0 Technical

2.1 Science

Findings

- Recent astronomical evidence implying that the expansion of the Universe is accelerating, rather than decelerating, poses a challenge to our current understanding of quantum field theory, general relativity, or both. Further exploration of this phenomenon is of fundamental interest to particle physics.
- Progress may come from deriving better constraints on the dynamics of dark energy, as characterized by its equation of state parameter: $w = p/\rho$, and its derivative with respect to cosmic time. At present, these parameters are only well-determined when constraints from several different techniques are combined in a single analysis.
- A wide field visible survey of the sky can yield constraints on w and w' by a variety of complementary techniques: cluster counting, weak lensing, galaxy clustering, and SN 1a distances.
- Given its location at CTIO, the DES will be uniquely well-positioned to provide timely determination of photometric redshifts for the clusters discovered using the Sunyaev-Zeldovitch effect with the South Pole Telescope.

Comments

- DES is not the ultimate experiment of its kind. PanSTARRS, LSST, and SNAP offer superior capability for similar measurements. The timing of DES is therefor crucial to its scientific impact.
- As proposed, it will see first light in 9/2008. As presently planned, LSST will come on line in 1/2012. If DES is significantly delayed (> 2 years) and LSST holds schedule, DES will be eclipsed by LSST before it can complete its scientific program.
- PanSTARRS will be on-line in a similar time frame to DES. However, PanSTARRS will be sited in Hawaii, and will not be able to follow-up the SPT clusters. *In terms of the complementarity to SPT, DES is unique in the 2008-2012 timeframe*

Recommendations

1. Systematics uncertainties may limit most of the separate analysis programs planned for the DES database. Understanding these systematics will be important to the ultimate determination of dark energy parameters.

2. The team is currently engaged in a number of simulation efforts to characterize the implications of systematics. This work looks promising, but has not been especially well coordinated. A detailed systematics error budget should be constructed for each of the DE analyses planned.
3. For the supernova program, a plan should be developed for the serendipitous SNe discovered via repeat observations of the main survey fields.
4. For weak lensing, the optical performance of the telescope and camera should to be modeled as a system, including the effects of environmental factors such as windshake.

2.2 Instrument

2.2.1 Prime Focus Cage, Infrastructure, Integration, Cost
2.2.2 Optical Design

Findings (Prime Focus Cage and Optical Design)

- The scientific requirements for the optical corrector have not been well defined but have evolved over time. They should be clearly stated. Optical design has proceeded but some well-intended guidelines have evolved into requirements: 2.2 degree field, <0.64 arc-sec images, 18 micron pixels, etc.
- Alignment and final testing of a 1.0 meter class optical system at the Laboratory is a major and heroic undertaking, given that no significant optical system have been assembled here. There appears to be insufficient plans for a null test both at Fermilab and at CTIO during commissioning.
- The prime focus cage includes a 5-element corrector lens for the four meter Blanco telescope, four interchangeable spectral filters, a fast shutter and a tip/tilt/focus/lateral adjustment for the corrector lens. The last lens is a vacuum barrier just before the flat CCD mosaic array. The cage design is fairly mature. It is a good design that meets all of the design requirements, but the committee has comments on a number of issues.

Comments (Prime Focus Cage)

- Vacuum barrier: Condensation, because the detector is cooled, will be a problem if ambient air is allowed to contact the window. Provision should be made to fill the volume between the vacuum barrier and lens C4 with dry nitrogen. Alternately, a flow of dry nitrogen along with a small heat load could be used if a sealed environment interferes with the fast shutter.
- The optical system and the camera are mounted to the tip/tilt mechanism and the corrector assembly will move and deform as the telescope is slewed toward the horizon.

- Adjustments of individual lenses are planned during the assembly/alignment procedure in Fermilab or elsewhere. The committee strongly feels that lens adjustments and maybe even a complete alignment will be required at CTIO for a number of reasons:
    - The optical prescription for the Blanco primary mirror may not be known with adequate precision. The Blanco primary is 40 years old, has suffered some damage and the optical prescription and optical quality was not well measured even before this damage.
    - Lenses may have shifted positions in the shipping of a completed cage assembly or because of assembly errors during reassembly of smaller modules at CTIO. Although analysis has been done to show that the expected errors will be acceptable, prudence and experience indicate that procedures should be in place for making the required adjustments in the observatory. For example, damage to even one lens would require realignment of the replacement lens.
- The shutter concept appears to be a practical solution to a large shutter in limited space. Exposure time precision and uniformity across the field should be required to have negligible effect on the photometry, so that the time and effort for this calibration task is limited. The goal should be to make the precision adequate for all observing programs and not just the Dark Energy Survey itself. A suitable benchmark is probably the SOAR Optical Imager which exceeded its goal of 1% peak error for a 1 second exposure. The achieved timing error was 500 μs. (While the shortest exposure time for the survey may be 100 seconds, the shutter error will determine how early in twilight sky flats can be observed. This together with the readout time will be the primary determinants of how many calibration flats can be obtained each night. Accurate short exposures will also allow bright standard stars to be observed.) The exposure time error is determined by how well the position vs. time profile for the closure motion matches that of the opening motion. (It is not necessary that the shutter blade move at constant velocity, just that the shutter accelerates and decelerates the same.) The use of a single "blade-with-aperture" rather than a dual blade shutter helps with this profile matching since the same motor and masses are moving for both motions. The penalty of this arrangement is that the minimum exposure time is determined by the time for one edge of the shutter to transit the focal plane. As the project team noted, a shorter exposure could be achieved by scanning a slit.

Comments (Optical Design)

- The current design covering a field of 2.2 degrees meets a specification of collecting 80% of the diffracted light in any spectral band across the diameter of the detector of 0.64 arc-secs. That seems large given that the seeing at CTIO is about 1.0 arc-sec. The estimated degradation due to fabrication and alignment errors introduces an additional 0.24 arc-sec blur.

- It would be desirable to have the images more uniform over the field and across spectral bands. Presented analysis of the current five lens design shows that the image sizes varies from 0.11 to 0.41 arc-secs in the r- and i-bands, and from 0.31 to 0.59 in the g- and z-bands. In addition to refocusing for each spectral band, translating lenses C2 or C4 and/or adjusting the individual thicknesses of filters may result in more uniform images across spectral bands. Current designs for the LSST project use this technique to good advantage, although it is realized that these techniques may not yield sufficient image size reductions to warrant the complexity.
- Ghosting has been examined to some extent, but a stray light analysis should be performed to determine placement of baffles at appropriate places in the corrector lenses.
- There is some concern in using sol-gel coatings for the lenses because of potential lifetime and the fact that they are so easy to damage.
- Finally, there is an additional blurring due to atmospheric dispersion that is dependent on spectral band and angle from zenith and which is uncompensated that should be addressed in the scientific requirements.
- Fermilab expects to hire an experienced optical designer to handle finalizing the optical design. Much progress has been made in this design in terms of achieving a build able system. An equally important task for the optical designer/optical engineer should be designing a null test or series of null tests that certifies the completed assembly. It is ambitious and aggressive to consider building a facility from scratch to assemble and test a one-meter class telescope corrector without having significant in house experience. The goal of the designer should be to determine the practicality of performing the alignment and null test of the completed assembly. He should be expected to assess the advantages and disadvantages of various options for the assembly and alignment and to make recommendations for implementing any facility.

Recommendations

1. The design team should separate scientific requirement and mechanical constraints from engineering goals and guidelines, in an effort to firm up and clarify the strict scientific requirements. After a solid scientific requirements document is agreed upon, trade studies of field size vs. image size should be repeated since 2.2 degrees has evolved as a requirement. A reasonable balance between field size, image size and tolerances at a reasonable cost should be the goal. It would be desirable to have the images more uniform over the field and across spectral bands.
2. The design team should address the issue of characterizing the 4-meter Blanco primary mirror (deduced specifications and figure errors) since errors could be significant compared to the seeing limit at CTIO. The corrector design should use this deduced prescription. One surface of a lens could be aspherized to partially compensate for low-order figure errors.

3. The design team should address costs for spare blanks or lenses in case of damage or breakage; i.e., extra costs vs. schedule slip, to be presented to management. The design team should address issues on handling the lenses during alignment and shipping to CTIO to minimize risks. The planned mounting scheme leaves the convex first surface exposed to damage because it projects beyond the mount.
4. A statement of work should be prepared for the optical expert to include optical design, optical null testing, optical alignment and verification of the completed assembly and alignment at CTIO. The optical expert must be engaged from project start to final commissioning The goal of the designer should be to determine the practicality, cost impacts and schedule impacts of performing the alignment and null test of the completed assembly, both at Fermilab and at CTIO if necessary. The design team should design the assembly testing to uncover and recover from any significant errors in fabrication and assembly over tolerances. Even well planned projects have errors creep in due to misunderstanding or carelessness.
5. The design team should address condensation on the vacuum barrier and look at alternatives ways to use a dry nitrogen environment. The design team should address ghosting, sol-gel or hard coatings and condensation prevention as an interconnected problem.
6. An FEA analysis should be performed on the adjust mechanism for the corrector lenses to determine static and dynamic deformation that will result in image tilt and settling time between slews. These affects are zenith-angle dependent and design adjustments should be made to minimize them.
7. The design team should make its preference known to management that the preferred units are millimeters.

2.2.3 CCDs

2.2.4 CCD Packaging, Focal Plane

Findings

- The LBL fully depleted devices are an excellent match to the science requirements of the DES project.
- The CCD packaging effort appears compatible with previous SiDet experiences and should not present be a major risk to the project.
- The metrology required for packaging evaluation exists at SiDet. This is suitable for focal plane alignment as well.

Comments

- A major risk to the project is the LBL device availability, due to both schedule requirements and technical risks.

- A new mask set for the LBL devices does present new risks in process optimizations.
- 20% contingency for LBL device processing is too low, given the technical issues of CCD processing.
- 25% yield is considerably too optimistic a yield estimate given the limited statistics of the process so far. DC shorts yield from DALSA can be expected to be 50%, and 50% of those unshorted devices are unlikely to be working astronomical quality after packaging and final device testing.
- There are no clear science-driven cosmetic specifications for the CCDs.
- A simple JFET amplifier in the CCD package might eliminate all other electronics inside the cryostat and is compatible with previous SiDet efforts. This method is in common use for astronomical CCDs
- MONSOON is not developed yet for CCD mosaics, so more time and effort than has been planned may be required before it is acceptable to the DES project.
- The device testing plan is technically feasible and reasonable, but the schedule does not allow sufficiently time for "problem" devices. It is unlikely that three test cameras and 1-2 operators can test a device a day during the course of the project, at least in the early stages.
- Software support for device testing algorithms, hardware interactions and optimizations is critical for rapid testing and not clearly defined.
- New mask failures (design or processing) might occur, requiring Phase B to be repeated. An alternative schedule should be developed for this scenario.

Recommendations

1. The project should quantify the cost and schedule impact for the possibility that the LBL devices are not available when required.
2. The project should consider alternative devices, at least as a fallback, at least to the level of obtaining quotes from E2V, MIT/LL, Semiconductor Technology Associates, and/or Hamamatsu. Other vendors might also be contacted to determine their interest in deep depleted devices.
3. The minimum acceptable red QE (minimum thickness of the devices) should be determined so that other CCD vendors can be considered. This information is required before contacting other vendors.
4. The contingency cost for CCD production should be increased.
5. The yield estimate should be decreased to perhaps 10%. A contingency run at the end of the procurement process may not be as useful as splitting a run (12+12 wafers) early in the process to make sure the new mask design is acceptable.

6. A clear set of science-driven CCD specifications should be developed and used for device screening. Include cosmetics, read noise, CTE, flatness, QE, etc.
7. Developing a small mosaic test system (perhaps 4 CCDs) as soon as possible using MONSOON would be very beneficial for the project in order to learn to operate the software, controller, and devices in a mosaic configuration. Cross talk issues must be studied in such a manner.
8. Consider allowing two full time technicians and a full time scientist for device devices, at least in the early stages while the first 20 devices are being processed.
9. A full-time software person should be allocated for testing development activities.

2.2.5 Camera Vessel

Findings

- The cryostat design appears to contain the relevant features. An analysis of the worst-case radiative load with the current thermal strap layout shows that there will be a radial temperature gradient of 3K on the flat plate, which carries the detectors.

Comments

- Although the cable layout was shown, the procedure for installing the detectors and forest of cables was not presented. Since the ability to easily access and engage the connectors, install CCDs safely was not highlighted we must presume that this has not yet been reviewed in detail. However these details can and should drive the design.
- The proposed 4 side buttable CCD package does not protect the edges of the CCDs from touching so they must be handled even more carefully than conventional buttable CCDs whose base-plate extends slightly beyond the silicon.
- In private conversation, a member of the team suggested that second getter, which warms up more slowly than the focal plane, might be included to capture materials outgassing during warm up. This would be a good solution to a common problem, which can compromise CCDs.
- The attention the team has give to outgassing is well placed since the CCDs will be cold for long periods and their AR coating performance is altered by thin films cryopumping onto their surface. This can becomes a serious problem when the detectors are kept cold for months at a time unless care is taken with vacuum cleanliness. For example, excess vacuum grease on O-rings has caused problems of this kind.

Recommendations

1. Review the cabling connector accessibility and mechanical layout, to determine that the CCDs and cables can be installed safely from both a mechanical and electrical (Electrostatic Discharge). Identify any fixtures that may be required. Ensure that nothing can (or is likely to) be dropped on the detectors, that cable swill not be stressed, that all fasteners can be easily seen and accessed, and that tool slippage will not result in harm to the detectors. Take care that at no point the focal plan could slip and fall face down.
2. Review the method used by E2V for mounting CCDs into a 4 side buttable mosaic array.
3. Present a step-by-step disassembly procedure, to reviewers not involved in the design, using 3D CAD models and possibly simple mock ups. Include the transfer of the CCDs to/from their storage containers, bearing in mind that this must occur in clean room conditions.
4. Conduct an analysis of tolerances required to guarantee clearances between CCDs during handling & installation.
5. Use finite element analysis to determine whether an unacceptable deviation from focal plane flatness is induced by the projected thermal gradient in the detector carrier plate.

2.2.6 Cooling System, Thermal Controls

Findings

- A cooling system is proposed which consists of a nitrogen liquefaction plant off-telescope, evacuated nitrogen delivery and return lines to/form prime focus and a pump to circulate the nitrogen. The total cost of WBS 1.2.7 is shown as $543K.
- Benefits of this system are low vibration, low condensation risk and no contamination in the event of a leak.
- Pulse Tubes were considered but would require several and these suffer from efficiency variations with orientation.

Comments

- The liquid Nitrogen reticulation system is an elegant solution but its high cost and lack of a spare are a concern.
- CCDs are resistant to microphonics due to their relatively low output impedance and so the vibration is only a problem from the point of view of image degradation. Many modern astronomical telescopes achieve excellent image quality while using closed cycle helium refrigerators, mounted directly

on the instruments. Vibration is often mitigated by using compliant couplings between the Closed Cycle Refrigerator (CCR) and the instrument. In larger systems, a pair is some times synchronized to produce horizontally opposed motions. 350 W Gifford-McMahon cold heads are commercially available.

- A worst-case test could be devised by moving a voice coil actuated mass at the required frequency and amplitude while rigidly coupled to the Blanco prime focus, and then to determine image degradation for the existing mosaic in good seeing conditions. It may be found that the vibration is of less consequence when in the axial direction than in the radial direction, for example.

- The option exists to minimize the thermal load so that smaller lighter CCRs can be employed. Reducing the peak load to 90W or somewhat less appears to be feasible by:
  - Using thinner traces in flex circuits: less than 50mW/CCD, should be possible for 3W total instead of 20W. Trace resistance can be quite high (tens of ohms) for most signals.
  - Don't thermally ground the cable to 77K: smaller delta T = less conduction.
  - Can use higher voltage to lower current for detector heater traces, so higher resistance is possible without excessive self-heating.
  - Move most electronics outside cryostat (save 20W)
  - Reduce radiative load by gold plating; use multiple floating shields. Bring shield close to edge of focal plane.
  - Make dewar smaller now that liquid nitrogen reservoir has been eliminated
  - Determine radiative load from window more accurately. Measure the radiative transfer from window to a LBL CCD in a well shielded test dewar.
  - Allow for the lower equilibrium temperature of the larger DEScam window. Radiative transfer goes as T^4 so a drop from 300K to 285K is worth 19%.

- Bear in mind that the goal is to keep surface temperatures close to ambient (+-0.5K?) to prevent formation of convection cells, and that excessive cooling is similar in effect to excessive heating. (This probably precludes an open liquid nitrogen system.) It is acceptable to dissipate heat from the electronics or motors into the structure in an amount equally to the radiation into the cryostat provided that the thermal gradients can be kept small enough. If surface temperatures deviate significantly from ambient an enclosure might be required.
- Heat extraction from the prime focus may be unavoidable since, even if the Front end electronics were inside the cryostat and the Monsoon electronics were moved off telescope, heat must still be removed from A/D converters,

fiber links, motors and motor controllers. Would this cooling be provided by the recirculating liquid nitrogen, or would a split cycle air-conditioning system, or liquid refrigerant such as water/alcohol be used?

Recommendations

1. Re-examine the feasibility and cost savings from reducing the thermal load then using a closed cycle refrigerator *on the instrument*.
2. Evaluate how the elimination of the nitrogen tank simplifies assembling and/or cable routing. Does it allow external electronics to be relocated close behind the detectors for shorter cable lengths.
3. Consult with major observatories achieving high image quality (Gemini, ESO, Keck, NOAO) to determine the efficacy of their measures to mitigate CCR vibration on IR instruments.
4. Determine how (much more?) stringent the vibration specification is at prime focus, by testing.
5. Determine whether it will be necessary to provide for heat extraction for the electronics and motors, and if so how.
6. Determine whether some form of enclosure is needed to contain convection cells produced by local surface temperature deviations. Compare these projected deviations with typical thermal lag of the telescope structure during the night.

2.2.7 CCD Electronics and Testing

Findings

- The reference design for the CCD electronics is viable but poses some challenges due to operation in vacuum and at low temperature. It locates significant control circuitry close to the CCD package, places the ADCs on the outside of the cryostat and relays data to and clock timing signals from a stripped down Monsoon chassis off-telescope.
  Attractive features of this arrangement were identified as:
  - Reduced noise pickup
  - Avoidance of long paths for CCD clock currents
  - Reduction of power dissipation at the prime focus.

  The team did not discount using warm Front end Electronics but this was not the reference design used for the cost estimate. The cost (for the cold front end option) is shown as $1189K for WBS 1.2.3 less $204K for WBS 1.2.3.7.
- The team acknowledged being lured into the adoption of cold electronics by the possibility of using LBL's CCD Readout IC (CRIC), which has subsequently proven to be available only in versions with partial capability on the time scale required.

- The specifications for the electronics are:

  Noise < 5e-

  Non-Linearity < 0.25%

  16 bit conversion at 250 kpix/sec/ch for ~128 channels.

  20 sec readout time

- The project has taken an aggressive approach towards preparing a setup to test and readout a CCD with a Monsoon system.
- The project has allocated one physicist, ¼ of an electronics engineer and 0.75 of an electronics tech to testing CCD's.
- Testing of the CCD's will take place with the current Monsoon system, whereas the Monsoon system is planned to be modified for the final system. The latest generation of LBL devices have not yet been readout with the current Monsoon system.

Comments

- Although the testing is being planned, acceptance criteria have not yet been specified, neither has grading criteria.

- The specifications for the CCD's seem to be rather loose in view of the science requirements for an astronomical CCD camera. Though DES does not require low read noise, other programs may do so and reducing the electronic noise to <1.2e- is generally not a problem, for CCDs with sensitivity of ~2uV/e-, overall inverse gain ~ 1e-/ADU, and dual slope integration times of 5+5μs, at which rate the CCD will probably deliver <4e-. A spec of 2e- noise under these conditions (with 300 ohm input impedance) would be a goal, which would keep all users happy without impact on cost.

- Resources allocated to the testing seem rather thin. Moreover, we are also concerned that the development of new electronics will draw on the same pool of expertise, which is to be directed towards testing and optimizing a large number of detectors. Even if the expertise is not limited, those funds are probably better applied to CCD characterization and integration and test.

- The committee is worried that the QA and testing of the CCD's will be carried out with the old Monsoon system

- Experience elsewhere indicates that front-end electronics are not required to be located at the CCD's to achieve required noise and crosstalk.

- Development of this front-end electronics is a significant unnecessary expense and risk.

- Cold electronics, however good, do have the serious drawback to limit diagnostics. The lack of access to the CCD pins can make diagnostics very difficult or impossible particularly when problems are intermittent.
- Are cold electronics necessary? Experience with CFHT Megacam, MMT Megacam, NOAO Mosaics, and others indicate that the cable length encountered will not cause noise pickup or degrade clock performance. While good grounding and shielding practices are important, acceptable immunity to interference is generally achieved by ensuring that all sources of interference within the shield and grounding system are strictly synchronous such that the interference is identical on each pixel and thus causes an offset which is calibrated out during the overscan subtraction.
- The read rate of the camera seems rather low and it would be wasteful of an expensive camera if the readout time was not hidden within the filter or telescope motions, given that the read rate can be increased somewhat without increasing the read noise above the shot noise of the sky. Other programs using the instrument would benefit from a higher read rate, and the overhead for taking short exposures on sky flats and on bright standard stars would be reduced. The down side may be an increase in power consumption of the faster A/D converters required.
- Although the inclusion of substantial amounts of electronics is not being recommended, a good compromise is to hybridize a low noise source follower FET to buffer the CCD output. Including this in the CCD package eliminates microphonics, and the reduction in output impedance from 5-7kohm to a few hundred ohms will reduce settling time for the video signal due to cable capacitance, while also reducing crosstalk due to capacitive coupling in the cabling.
- The logic of moving the Monsoon off the telescope was difficult to follow. Once the signal chains, clock and bias generation had been moved into the dewar, all that was left in the Monsoon crate was the timing generator and fiber optic link. To move the Monsoon crate off-telescope, an additional fiber optic communication link has to be added between the Front End (the cryostat) and the remote (gutted) monsoon crate. While the committee did not have (or find) the specific numbers in the report, the savings in power consumption cannot be large, while the overall cost and complexity has been increased by such an arrangement. Some reduction in power delivered to the telescope environment is achieved by placing the front-end electronics within the dewar but this is an expensive way of removing heat.
- The argument that locating the clock drivers close to the detector to avoid large currents from circulating over extended paths is of dubious merit. Placing the clock switches close to the CCD only localizes the current if the power supply capacitors are also local to the CCD. These large current transients are at sufficiently low frequencies that induced transients are dominated by ground bounce effects in the substrate and ground return wiring impedance. These effects are synchronous with the data acquisition and thus produce only offsets which are easily calibrated out.

- The use of flex circuits to make the connection between CCDs and external electronics is strongly endorsed since these will provide optimal thermal isolation for a given resistance and minimal cable capacitance, while minimizing capacitive and inductive coupling by maintaining large separations. At the same time they impose order upon the massive interconnects.
- The economics of the proposed vacuum feedthrough is dubious when commercial hermetic connectors cost less than 10% of the projected cost for this component of DEScam. The elimination of the cryogen tank proposed elsewhere in this review may open up some interesting possibilities to simplify the cable routing and connector mounting.

Recommendations

1. The committee recommends that the collaboration expedites assembly of the test setup for CCD testing and that the laboratory support this effort.
2. Because CCD's are at the heart of the project, the project should identify a person(s) as soon as possible who will assume responsibility for the CCD testing and characterization for the duration of the project.
3. We suggest that the collaboration revisit the specifications for the CCD's and evaluate if they can be tightened to benefit the science goals.
4. We recommend that that the scope of the general testing be increased and include cryo-cycling and that the resources for general testing of CCD's be increased to at least 3 FTE's.
5. We recommend that final stage testing, QA and calibration be carried out with a DAQ system identical to the system employed during the operation phase.
6. The committee recommends that a system test of 3 to 4 CCD's be part of the baseline program and that additional resources be allocated for this testing. With such a 'vertical integration' test not only electrical issues, such as noise, cross-talk, etc. can be studied, but will also push and exercise the software needed for the commissioning and operation of the instrument.
7. It should be evaluated if a separate smaller focal plane should be pursued or if populating the final focal plane is an option for this test. We recommend that additional resources be allocated for this testing.
8. Examine in detail what other "Megacams" have done, particularly with regard to packaging, connectors, cable routing and assembly procedure.
9. Revert to external Monsoon electronics
    a. on cryostat with JFET buffer hybridized to CCD output, but no other cold electronics.
    b. to upgrade Monsoon (only) where necessary, e.g. new ADCs with lower power and/or faster.
    c. to eliminate the fiber link between ADCs and "remote Monsoon" bringing the Monsoon (back) into the prime focus cage

d. Study heat removal from prime focus (to also deal with mechanisms).

2.2.8 Data Acquisition

Findings

- Proponents are basing the design of the DAQ on the established Monsoon system. Power considerations at the camera prohibit an "Out of the Box" application of Monsoon ADCs on the camera, which has motivated a lower power ADC front-end local to the camera to minimize readout noise.
- The UIUC group does have the necessary experience to deliver the DAQ system, and the M&S and Labor estimates are reasonable for a project at this stage.

Comments

- The use of existing MONSOON infrastucture is commended, with enhancements as needed.

Recommendations

1. Establish MONSOON Test-stand with engineering grade CCDs ASAP.

2.3 Survey Strategy, Calibration and Simulations

Findings

- A science requirements flowdown has been developed to map the science goals into a concrete observing strategy.
- Three prime survey regions have been defined: a 4000 squ deg region coincident with the SPT field, a 250 squ deg SDSS stripe, and 700 squ deg region "overhead" in Chile.
- Weather data for the CTIO sight have been collected to estimate expected fractions of usable nights.
- The team has adopted a hexagonal tiling pattern to cover the sky. The plan is to cover the entire 5000 squ degs in the first year, and follow-up with repeat observations of the same fields in later years. At maximum efficiency, 8 tilings per year are possible.The proposed calibration program involves a full-system lab measurement at Fermilab, followed by extensive relative and absolute photometry calibrations using standard stars on the sky.
- Multiple exposures of a given field coupled with overlapping tilings will indeed enable a relative photometric calibration and allow reduction of systematics.
- The astrometric calibration program was not described, although a requirement of 0.1 arc sec absolute was provided.
- An extensive simulation program is underway to understand the uncertainties in photometric redshifts and their impacts on science requirements

Comments

- At present, it is still unclear how the 1/3 time committed to the DES will be allocated within the year. This may affect the survey strategy, and the system efficiency.
- The observation overhead seems unreasonably large for a survey of this size: 28% in g, r, and 14% in i, z. Consideration of ways to improve the slew time, and/or incorporate faster readout might be warranted.
- The decision to cover the entire survey field first, without repeat observations may be problematic, since multiple exposures of the same fields are very useful for identifying artifacts and systematics.
- A concise definition of science requirements is still lacking.
- The observations strategy optimization is still at a preliminary stage.
- The full-system calibration effort must be better defined and costed. A figure of $75K in M&S costs was quoted for this facility, which seems quite low.

Technician and engineering support might also be required to get this system operational at the required accuracy.

- The on-sky photometric calibration has received the most attention, and appears to be in-hand.
- The astrometric calibration pipeline needs better definition.
- The simulation effort is a real strength of the project, but could use a higher level of coordination.

Recommendations

1. A detailed observation simulator should be developed to investigate problems likely to be encountered in trying to tile the full 5000 squ deg survey field in 4 colors. The simulator should take account of weather patterns at the site, seeing variations, the effect of bright time on different filters, and the likely assignment of time from the facility.
2. The details of the time allocation need to be worked out with NOAO. The team appears to have made optimistic assumptions about how their time will be distributed.
3. Ways to improve the observing efficiency should be investigated
4. A complete end-to-end calibration plan, from testing of individual sensors through integrated system testing at Fermilab, and on through sky calibration should be developed, with requirements on sampling and accuracy at each level. The integrated system testing facility should be designed and costed.
5. A plan for astrometric calibration and reduction plan must be defined, and validated with the assumed opto-mechanical tolerances on the camera.
6. A management plan should be developed for the simulation activities to assure that the investigations being performed are well coordinated and directly impact the systematics error budgets for the various analyses.

2.4 Data Management

Findings

- Will receive data from the DAQ and ultimately deliver data to science teams and the community
- There is approximately 300 GB of data in a full night of imaging
- Automation is desired where ever possible for reduction and QA.
- Plans include reuse of existing code and use of common grid tools whenever possible (to provide a common environment)
- Effort requirement for the build phase (2004-2008) is 8 FTE's years
    - 1-2 persons from NSF funding
    - 1 person from UIUC funding likely
- The NSF funding for effort will be in the proposal stage later this year
- Most of the effort will be located at UIUC
- UIUC has grid experience
- FTE needs will be revaluated as the design progresses
- Pipeline processing does not need grid resources
- Reprocessing will have massive processing needs
    - Will need a grid based approach
- Monitoring requirements are not complete or contained in the FTE estimate
- Bandwidth requirements to ship data from La Serena to UIUC are not clear
- Bandwidth from La Serena to UIUC may be upgraded by CTIO
- There is no requirement to reduce a night's data within a short timescale (e.g. 24 hours) once off of the mountain

Comments

- Data rates are manageable by current standards and technology
- Estimate of 8 FTE years effort required is not enough
- The funding for the manpower from NSF is not guaranteed
- Grid development will increase Data Management task length, more integration and communication required throughout project
- Grid integration may require “development” on “reused” code

- Not clear how much is gained by using grid tools for data pipelines given tight manpower and time
    - Common environments can be attained without the grid

Recommendations

- Expand the FTE estimate. This will become more clear as the design is solidified.
- Firm up commitment from UIUC to provide a person
- Identify and procure funding for additional manpower (NSF proposal is not certain)
- Investigate sharing development (esp. grid framework) with the simulations effort
- Develop a procedure for “management” within the DM task
    - May need “local” managers offsite of UIUC in order to help coordinate effort and priorities
- Expand thinking for monitoring at the mountain and generate an FTE estimate
- Improve bandwidth from mountain to La Serena
- Encourage improvement of bandwidth from La Serena to UIUC

3.0 Cost

Findings

- This project is at a very early stage. Camera total cost (WBS 1.0) is **$20.3M(TY).** Data Management (WBS 2.0): **8+ FTE**. There is a core group of excellent project managers that are working hard to further develop the cost and schedule.
- We were shown elements of a Resource Loaded Schedule for WBS 1.0. We are told that a WBS structure exists for 2.0, but we have not had the time to go through it.
- **~$500K** in FY04 and **$5M** in FY05 required to stay on technically driven schedule which delivers first light in 2008.
- **$1M** required in FY05 to stay on track and to accommodate a delayed schedule.
- The funding model assumes that the WBS 1.0 M&S funding and labor will predominantly be provided by Fermilab.
- The funding model assumes that essentially all of WBS 2.0 be provided by resources outside of Fermilab (UIUC and NCSA).

Contingency Comments

- Mean WBS 1.0 mean contingency is 43%. Since much of the design remains pre-conceptual or conceptual, we cannot ratify this estimate at this early stage. The CCD contingency of 20% is of particular concern given the early stage of that effort.
- The BTeV project for scale, which has received years of engineering and enjoyed the benefit of many reviews effort has a mean contingency of 36%.

Comments from Sampling the WBS 1.0 Resource loaded cost and schedule.

- Costing and procurement of spares is not uniformly treated.
- Work elements appear to be highly fractioned, with 5% fractions commonplace.
- Resources for a full system test of the camera at Fermilab were not accounted for. The period for this activity is also considered as float.

RLS Sampling continued, have the most cost effective solution been chosen?
Costs *can* go done too:
Examples include:

- PCB cryostat feed-through $228K. M&S. Are there not cheaper alternatives?
- In-cryostat electronics. Is it worth the cost? Warm electronics have achieved around 3e-.
- See written comments for more details.
- Comments on Cost Dependence on Schedule
- As noted previously, the project schedule is problematic. The project cost will likely grow as the funding profile becomes more realistic. The scale of this growth is difficult to estimate at this point.

Recommendation

1. Continue what you are doing. Proponents are working hard to develop a realistic Cost and Schedule. Work to develop a cost based on plausible cost profiles from funding sources.

4.0 Schedule

Findings

- A resource loaded MSP schedule for WBS 1.0 exists and was available at the review. Schedule goes down to level 6 and has 483 lines of activities.
- A list of Critical Path Milestones for WBS 1.0 was shown.
- The contents of the current WBS 1.0 schedule contains prototyping, preproduction and production activities with work starting in 2004 and going through 2008.
- Data Management Project WBS 2.0 has developed a high level WBS. An Excel version of the Data Management Project WBS 2.0 schedule is in existence but not presented at this review.

Comments

- The schedule for WBS 1.0 is a good start, but is optimistic and aggressive especially technical risk and without any solid funding.
- The schedule for accomplishing WBS 2.0 could not be assessed since a resource-loaded schedule was not available for review.

Recommendations

1. The WBS 1.0 project Schedule needs to be revised to include dates based on a sensible estimate on the availability of funding. Also, a more detailed risk assessment should be performed and where schedule impact is identified schedule contingency should be incorporated into the schedule.
2. A detailed WBS and resource-loaded schedule should be developed for WBS 2.0 with an appropriate project scheduling tool. This will assist in further WBS development and improve the FTE and cost estimates.

5.0 Management

Findings

- The Dark Energy Survey is divided into two projects – the Survey Instrument and Data Management - each with a separate management structure. A management committee provides overall coordination of the DES. A management structure and WBS has been developed for the Survey Instrument. The Data Management project is just now being organized.

Comments

- The Dark Energy Survey team has assembled an outstanding group of experienced scientists and engineers to lead the project.
- The task breakdown for the Survey Instrument Project is well conceived. The Data Management task is just now getting organized. As a result we were not able to comment meaningfully on its management structure.
- The DES is a schedule driven project that requires a strong and agile management structure with clear lines of authority and responsibility. The upper management structure that has been presented is probably adequate, although it appears to the review panel that the DES would be better served by a single overall project manager.
- There is clearly a need for a governing body to raise funds, provide science and fiscal oversight and speak for the collaboration. At the same time some of the responsibilities of the Management Committee might be more appropriately assigned to the project manager. Among these are:
    - The agreements with participating institutions regarding deliverables, delivery schedules and participation, however, relate to resources that the project manager needs to carry out construction responsibilities.
    - Technical, cost and schedule presentations to funding agencies may also more appropriately be the province of the project manager.
    - It also seems to us that the project contingency should be in the hands of the project manager as well.
- In order to effectively carry out his/her responsibilities, the project manager should have the help of a full time cost and schedule person and perhaps a project engineer. This is particularly important to a project on such a tight schedule.
- Although the DES is not a large project by today's standards, the use of disciplined management techniques will help ensure the success of the project.
    - The WBS is the single most important management tool, especially at this stage of a project. The development of the DES WBS, though well along, needs to be more comprehensive with a detailed cost and schedule

contingency analysis. The exercise of applying contingency to all levels provides a better feel for cost exposures. Allocation of a funding or in-kind source to each WBS element would be a valuable addition.

- A detailed set of requirements – both science and the technical – need to be developed, reviewed and approved by the collaboration in a timely way. Given the schedule pressure, the project may wish to review a subset of the requirements now so that work in some areas can confidently proceed. Where work is already under way, preliminary design reviews organized by the project manager will ensure that designs meet the requirements, are within cost estimates and can be delivered on schedule.

Recommendations

1. The project would benefit from the addition of a full time cost and schedule person to assist the project manager.
2. The collaboration should consider setting aside some time to pull together the project definition starting with the science and technical requirements

6.0 Response to PAC Questions

6.1 What is the funding model? If the funding cannot be secured in the time frame needed, what is the plan?

Funding requests will be made to the DOE, NSF and private funding sources. Initial plans for these funding requests were presented. A substantial fraction of the instrument costs will be requested from Fermilab. The time required to develop the funding proposals, get them through the review and approval process, and receive the money is problematic given the aggressive schedule that was presented. However, it appears that the project could slip somewhat without compromising the science objectives of the survey.

6.2 Given the expected tests of CCD packaging done by the end of 2004, how would the project proceed if the tests were not successful?

Fermilab expertise in silicon packaging appears to be sufficient that it is unlikely the packaging effort will fail. It is more likely that devices will not be available or resources for testing and gaining CCD expertise will delay schedule.

6.3 What is the fully loaded schedule and budget; and what is the Fermilab commitment required for this project?

In FY04$ the base cost for WBS 1.0 was $11.2M. Including a $4.7M contingency brings this to $15.9M. The cost fully loaded with overheads and escalated is $20M. Some increases in contingency for the CCDs and an allowance / accommodation for "university" efforts which for some reason do not come to fruition should perhaps be made. Detailed cost estimates for the Data Management were not presented. These will be developed for the proposal to NSF later this year.

6.4 Does the collaboration have enough manpower to carry out the construction?

At this time the construction side of the collaboration is 2.5 FTE scientists. The project estimates a peak need of 7.5. It seems likely that the collaboration will be able to attract some additional scientists, but clearly the ramp up of the scientific staff affects the technical development of the project, and this needs to be accounted for in the planning. The sense of the committee is that there are opportunities for scientist contribution beyond the 7.5 FTEs identified in the project plan.

6.5 Does the collaboration have enough manpower for data handling, especially given that the survey is four times as big as the Sloan Digital Sky Survey?

Given current start-up for operations is 2008, the estimate of 8 FTEs is not enough. A more accurate estimate needs more detailed design and evaluation of "reused" packages within the proposed grid environment

6.6 How robust is the science case if there are delays?

The DES is projected to see first light in September 2008. LSST is projected to come on line in January 2012, with enhanced capability for similar science investigations. PanSTARRS, which also has similar capabilities, will be online in the same timeframe as DES, but will not be in the Southern hemisphere. Therefore, the DES science case is robust against delays ~ 2 years, but not much longer. Potential delays in LSST will probably not be identified until DES is well underway.

6.7 Is there enough expertise at the Laboratory for handling the procurement of the optics?

An optical designer should be contracted to handle the design, optical component specifications and drawings since that expertise is not available in the Laboratory. This person or firm should additionally be tasked with designing the null optics for any aspheric lenses, the alignment procedure for the optical corrector assembly and the verification procedure for the completed assembly. He should be asked to estimate what facilities the Laboratory will need to do this in house.

Appendix A

Charge for the Preliminary Director's Review
Dark Energy Survey Proposal and Design
June 7-8, 2004

A collaboration of particle physicists, astrophysicists, and astronomers has submitted a proposal to build and operate a CCD camera on the Cerro Tololo telescope to conduct a Dark Energy Survey (DES). The proposal was presented to the Fermilab Physics Advisory Committee (PAC). The PAC found "the science of the proposed Dark Energy Survey very exciting and important." The Fermilab Directorate charges this committee to conduct a review of the Dark Energy Survey proposal and Preliminary Design.

The charge for this preliminary review is to conduct a technical, cost, schedule, and management review of the Dark Energy Survey proposal and design. The emphasis of the review should be to assess the validity of the cost estimate and the veracity of the schedule at this early stage of the project. To do this an assessment of the completeness of the scope and appropriateness and adequacy of the proposed management arrangements will also be needed.

A written update from the DES Collaboration has been requested for the June Aspen meeting that responds to the seven questions listed below. This Director's Review Committee is asked to assess the Collaboration's responses to these questions as given during this Preliminary Director's Review. The questions are:

1. What is the funding model? If the funding cannot be secured in the time frame needed, what is the plan?

2. Given the expected tests of CCD packaging done by the end of 2004, how would the project proceed if the tests were not successful?

3. What is the fully loaded budget and schedule: and what is the Fermilab commitment required for this project?

4. Does the collaboration have enough manpower to carry out the construction?

5. Does the collaboration have enough manpower for data handling, especially given that the survey is four times as big as the Sloan Digital Sky Survey?

6. How robust is the science case if there are delays?

7. Is there enough expertise at the Laboratory for handling the procurement of the optics?

The Director's Review Committee is asked to present findings, comments, and recommendations in a closeout session with the DES Collaboration and Fermilab Management at the end of the review and in a written report soon thereafter.

Appendix B

Agenda for the Preliminary Director's Review
Dark Energy Survey Proposal and Design
June 7-8, 2004

Monday, June 7, 2004 – Hornet Nest 8th Floor Crossover

8:00 – 8:45 am	Executive Session	E. Temple
8:45 – 9:15 am	Science	J. Frieman
9:15 – 10:15 am	Project Overview, Management, Organization, Cost, Schedule (L2)	B. Flaugher
10:15 – 10:30 am	Break	
10:30 – 10:50 am	Prime Focus Cage, Infrastructure, Integration, Costs	F. Leger
10:50 – 11:10 am	Instrument – Optical Design	S. Kent
11:10 – 11:30 am	Instrument - CCDs	C. Bebek
11:30 – 11:45 am	Instrument - CCD Packaging, Focal plane	Greg Derylo
11:45 – 12:00 am	Instrument – Camera Vessel	H. Cease
12:00 – 12:15 pm	Instrument - Cooling system, Thermal controls	D. Allspach
12:15 – 1:15 pm	LUNCH – 2nd Floor Crossover	
1:15 – 1:35 pm	Instrument, CCD FE Electronics and Testing	W. Wester
1:35 – 1:55 am	Instrument, Data Acquisition	J. Thaler
1:55 – 2:15 pm	Survey Strategy and Calibration	J. Annis
2:15 – 2:35pm	Survey Simulations	H. Lin
2:35 – 3:05 pm	Overview of DES Data Management	J. Mohr
3:05 – 3:20 pm	BREAK	
3:20 –3:50 pm	Processing and Archiving Framework for DES Data Management	R. Plante
3:50 – 4:10 pm	Review and funding process (NSF, DOE, external)	J. Peoples
4:15 pm	Executive Session (report writing) - Comitium	

Tuesday, June 8, 2004

8:00 – 9:00 am	Project Management Breakout – Black Hole 2nd Floor NW	B. Flaugher /J. Peoples /J. Mohr /T. Abbott
9:00 – 10:30 am	Camera Breakout – 1 North - CCD procurement plans - Front end electronics CCD testing and packaging factory - Focal plate, cooling, dewar design - DAQ	C. Bebek (LBNL) / B. Flaugher W. Wester G.Derylo/ H.Cease/ D.Allspach/ R.Silva J.Thaler
	Optics and Prime focus cage and integration at CTIO Breakout – Snake Pit 2nd Floor NE	F. Leger, T. Abbott, S. Kent, M. Gladders, P.Limon
	Data Management and Survey Strategy Breakout – Racetrack 7th Floor Crossover	J. Mohr, R. Plante, J.Annis

10:30 am	Report Writing -Comitium	
12:00 noon	LUNCH – 2nd Floor Crossover	
1:00 pm	Dry Run Closeout - Comitium	
3:00 pm	Closeout – Curia II	

Appendix C

Review Committee for the Director's Preliminary Review
of the
Dark Energy Survey Proposal and Design
June 7-8, 2004

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Appendix C

Reviewer Assignments

Executive Summary	Temple
1.0 Introduction	Temple
2.0 Technical	
2.1 Science	Kahn
2.2 Instrument	
2.2.1 Prime Focus Cage, Infrastructure, Integration, Cost	Seppala
2.2.2 Optical Design	Seppala
2.2.3 CCDs	Lesser/Smith/Crisler
2.2.4 CCD Packaging, Focal Plane	Lesser
2.2.5 Camera Vessel	Smith
2.2.6 Cooling System, Thermal Controls	Smith/Lesser
2.2.7 CCD Electronics & Testing	Demarteau /Crisler
2.2.8 Data Acquisition	Tschirhart
2.3 Survey Strategy, Calibration and Simulations	Kahn
2.4 Data Management	Berman
3.0 Cost	Tschirhart
4.0 Schedule	Hoffer
5.0 Management	Mantsch
6.0 Response to PAC Questions	
6.1 What is the funding model? If the funding cannot be secured in the time frame needed, what is the plan?	Mantsch
6.2 Given the expected tests of CCD packaging done by the end of 2004, how would the project proceed if the tests were not successful?	Smith
6.3 What is the fully loaded budget and schedule: and what is the Fermilab commitment required for this project?	Tschirhart
6.4 Does the collaboration have enough manpower to carry out the construction?	Crisler
6.5 Does the collaboration have enough manpower for data handling, especially given that the survey is four times as big as the Sloan Digital Sky Survey?	Berman
6.6 How robust is the science case if there are delays?	Kahn
6.7 Is there enough expertise at the Laboratory for handling the procurement of the optics?	Seppala

Appendix D

Review Participants

Firstname	**Lastname**	**Affiliation**
Mike	Gladders	Carnegie Observatories
Tim	Abbott	CERRO TOLOLO INTER-AMERICAN OBSERVATORY
Tom	Droege	Dark Energy Survey
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Steve	Holmes	Directorate
Hugh	Montgomery	Directorate
Ken	Stanfield	Directorate
Michael	Witherell	Directorate
Del	Allspach	FNAL
Jim	Annis	FNAL
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John	Peoples	FNAL
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Chris	Stoughton	FNAL
Doug	Tucker	FNAL
William	Wester	FNAL
Chris	Bebek	LBL
John	Cooper	Observer
Roger	Dixon	Observer
Bob	Kephart	Observer
John	Tapia	Observer
Vicky	White	Observer
Eileen	Berman	Review Committee
Mike	Crisler	Review Committee
Marcel	Demarteau	Review Committee
Dean	Hoffer	Review Committee
Steve	Kahn	Review Committee
Michael	Lesser	Review Committee
Paul	Mantsch	Review Committee
Lynn	Seppala	Review Committee
Roger	Smith	Review Committee
Ed	Temple	Review Committee
Bob	Tschirhart	Review Committee

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Joe	Mohr	U of I Champaign/Urbana
Ray	Plante	U of I Champaign/Urbana
Jon	Thaler	U of I Champaign/Urbana