NOAO Observing Proposal *Survey proposal* **Panel:** *For office use.*
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The Dark Energy Survey

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CoI: DES collaboration **Status:** __ **Affil.:** various

Abstract of Scientific Justification *(will be made publicly available for accepted proposals)***:**
The Nobel Prize in Physics for 2011 was awarded for the discovery of the accelerating expansion of the Universe. The primary scientific objective of the Dark Energy Survey (DES) is to address the question: why is the expansion of the Universe speeding up? Is cosmic acceleration due to dark energy or does it require a modification of General Relativity? If dark energy, is it the energy density of the vacuum (Einstein's cosmological constant) or something else? DES will address these questions by measuring the properties of dark energy with unprecedented precision, using four complementary techniques: galaxy clusters, large-scale galaxy clustering (including baryon acoustic oscillations), weak gravitational lensing, and type Ia supernovae. To achieve the requisite precision, we will conduct two optimally interleaved surveys over 525 nights: a wide-area $grizY$ survey covering 5000 sq. deg. to $\sim$ 24th mag and a deeper time-domain $griz$ survey with $\sim$ 5-day cadence covering 30 sq. deg. In response to an NOAO AO in 2003, the DES collaboration was formed and has built the Dark Energy Camera (DECam), a 570-megapixel, red-sensitive imager with 2.2 degree field of view, five uniform, high-throughput filters, a five-element optical corrector, and a hexapod system for active focus and alignment. We have constructed and will operate a data management system to process and serve DES survey data and a Community Pipeline for NOAO to process community data. The DES data products will provide a rich legacy for the astronomy community, and DECam will be an extraordinary asset as a facility instrument on the Blanco Telescope.

Summary of observing runs requested for this project

Run	Telescope	Instrument	No. Nights	Moon	Optimal months	Accept. months
1	CT-4m	DECam	525		Sept-Jan	Aug 23-Feb 25
2						
3						
4						
5						
6						

Scheduling constraints and non-usable dates *(up to four lines).*

This proposal requests 105 nights in 2013B. All nights in January are requested to be first-half nights. Gaps of more than 3-4 nights adversely impact the supernova survey. Given the DES footprint coordinates, we request a start after the late-August full moon, with two second-half nights. By February, the survey footprint is increasingly inaccessable for the majority of the night. More detailed schedule constraints are described below.

Scientific Justification *Be sure to include overall significance to astronomy. For standard proposals limit text to one page with figures, captions and references on no more than two additional pages.*

The importance of understanding the origin of cosmic acceleration and the nature of dark energy has been highlighted by a number of national reports, most recently the Astro2010 Decadal Survey report *New Worlds, New Horizons*. The DES will enable measurements of the dark energy and dark matter densities and of the dark energy equation of state parameter through four independent methods: galaxy clusters, weak lensing, galaxy angular clustering, and supernovae. These methods are complementary in their ability to constrain cosmological parameters and in their systematic errors. By exploiting this multiplicity in a single project, the DES will make a substantial and robust advance in the precision of dark energy measurements at the level envisioned for a "Stage III" experiment by the Dark Energy Task Force (DETF, Albrecht, et al 2006).

The DES comprises two multi-band imaging surveys, a wide-area survey and a narrow time-domain survey for supernovae. The wide-area survey covers 5000 deg^2 in the south Galactic cap. The design of the Dark Energy Camera and the depth ($\sim 24^{th}$ magnitude) and filter coverage ($grizY$) of the wide-area survey were chosen primarily to achieve accurate galaxy photometric redshift (photo-z) and shape measurements to redshifts $z \sim 1.3$. The wide-area survey will detect over 100,000 galaxy clusters and will measure shapes, photo-z's, and positions for ~ 200 million galaxies with $S/N \gtrsim 10$. The DES Supernova (SN) Survey (Bernstein et al 2011) comprises *griz* imaging of 10 DECam fields (2 deep, 8 shallow, of 3 sq. deg. each) with a cadence of ~ 5 visits per lunation and will discover and measure good-quality light curves for ~ 3500 type Ia supernovae to redshift $z \sim 1$. DES will collaborate with the ESO Vista Hemisphere Survey, which will provide deep JHK imaging over the same sky area, improving photo-z precision at redshifts $z \gtrsim 1$, and with the ESO VIDEO Survey, which will provide coincident NIR measurements for a subsample of DES supernovae.

Counts of galaxy clusters and measurement of the cluster spatial correlation function vs. redshift probe cosmology through the volume-redshift relation and through the growth of structure. We will control the limiting systematic in this technique—uncertainty in the relation between dark halo mass and cluster observable—via statistical (stacked) cluster weak lensing measurements, improved cluster richness estimators, spectroscopic follow-up of a cluster subsample for velocity dispersion measurements, and by collaborating with the South Pole Telescope (SPT, which has carried out a Sunyaev-Zel'dovich (SZ) survey over 2500 sq. deg. of the DES footprint) and other projects that will provide measurements of complementary cluster observables for a subsample of DES clusters. Weak lensing involves cross-correlating shear estimates and galaxy positions (shear-shear and galaxy-shear correlations) in photo-z bins and also probes both geometry and growth of structure. DECam was designed to have low distortion across its large field of view, and a hexapod system dynamically corrects for focus changes and optical misalignment; combined with upgrades to the Blanco recently carried out as part of the CTIO Facilities Improvement Project, these features will enable precise galaxy shape measurements to the depth of the survey. The wide-area survey, optimized for cluster and weak lensing studies, will also deliver measurement of galaxy angular clustering in photo-z bins, which is sensitive on large scales to the angular-diameter redshift relation via the baryon acoustic oscillation (BAO) feature. The time-domain survey area, cadence, and depth have been optimized through detailed simulations to produce the sample of 3500 SNe Ia over a broad redshift range to $z \sim 1$ (Bernstein et al 2011). All of these measurements take advantage of the very high quantum efficiency of the DECam CCDs in the redder passbands.

Table 1 shows a Fisher matrix forecast of the Dark Energy Task Force figure of merit (FoM) that we expect to achieve through these four techniques, where the redshift evolution of the dark energy equation of state is parameterized by $w(a) = w_0 + w_a(1 - a)$, $a(t) = 1/(1 + z)$ is the cosmic scale factor, and z_p is the pivot redshift at which the uncertainty in $w(a_p) = w_p$ for a given technique is minimized. These forecasts assume a spatially flat Universe and a Planck prior for the CMB, as adopted by the DETF; they should be taken as notional, since all such forecasts make uncertain assumptions about systematic errors. For reference, the DETF "Stage II" FoM, which describes the expected precision of then-ongoing projects, is about 60; we therefore expect DES to achieve a factor $3-5$ gain in FoM. For more discussion of DES science and the basis for these estimates, see https://www.darkenergysurvey.org/reports/proposal-standalone.pdf.

Table 1. Forecast DETF FoM for DES

	$\sigma(\Omega_{DE})$	$\sigma(w_0)$	$\sigma(w_a)$	z_p	$\sigma(w_p)$	$[\sigma(w_a)\sigma(w_p)]^{-1}$
BAO	0.010	0.097	0.408	0.29	0.034	72.8
Clusters	0.006	0.083	0.287	0.38	0.023	152.4
Weak Lensing	0.007	0.077	0.252	0.40	0.025	155.8
Supernovae	0.008	0.094	0.401	0.29	0.023	107.5
Combined DES	0.004	0.061	0.217	0.37	0.018	263.7

The precision and accuracy of photo-z estimates underlies all four dark energy probes. Detailed simulations for DES+VHS indicate that training-set based galaxy photo-z estimators should achieve mean 1-σ photo-z errors of about 0.1 over $0.4 \leq z \leq 1.3$ and substantially smaller errors for rich clusters (Oyaizu et al 2008, Abdalla et al 2008, Banerji et al 2008, Lima et al 2008). These error estimates have been validated using DES Science Verification data taken in late 2012. An issue for all deep photometric surveys is the completeness of spectroscopic samples for photo-z training and error estimation. Deep spectroscopic samples such as DEEP2 and VVDS are particularly useful in this regard, and we have an ancillary spectroscopic program to extend the completeness of the VVDS sample. The DES Spectroscopic Task Force is coordinating applications for follow-up spectroscopy for this purpose as well as for direct science goals (e.g., SNe, SN host galaxies, clusters, etc). We are also implementing angular cross-correlations with spectroscopic samples as a means to determine the redshift distribution function (e.g., Matthews and Newman 2010).

As a major multi-band photometric survey intermediate in scope between SDSS and LSST, DES data will enable a broad array of astronomical studies. Within the DES collaboration, in addition to working groups focused on the four dark energy probes and how to combine them, we have working groups focused on QSOs, the structure of the Milky Way, strong gravitational lensing, galaxy evolution, simulations, and photo-z's. The DES time-domain survey will enable study of a broad array of transient phenomena beyond type Ia supernovae, and we plan to make publicly available information on new transients as soon as they are discovered in our data processing system. Based on the SDSS history, we expect that the DES public database will spawn a large variety of astronomical research programs.

With regard to ancillary benefits, the DES collaboration includes a large number of graduate students from institutions in the US (U. Chicago, Ohio State University, University of Pennsylvania, University of Michigan, Texas A&M, UC Berkeley, Stanford, UC Santa Cruz), Spain, the United Kingdom, Brazil, Germany, and Switzerland, plus postdoctoral researchers drawn from the 27 DES institutions. Many of these students will derive PhD theses in whole or in part from DES data, and DES data analysis will be the core activity of many postdocs in the next several years. DES data will be made public in a timely manner, and we expect additional theses to derive from these public DES data. With regard to transfer of survey experience, the DES Data Management (DESDM) system, the set of pipelines that will be used by the collaboration to process the survey data, has been adapted and modified by the DESDM development team to form the DECam Community Pipeline, which is being run by NOAO on all DECam data (both DES and community), with the outputs served to the public after the usual proprietary periods.

Experimental Design *Describe the survey experimental design and the observations planned in detail. Justify choice of telescope, instrument, and sensitivity goals in terms of the survey science goals. A key part of the survey proposal process is to justify the total duration of the program both in terms of the number of nights and the number and distribution of observing runs required. Please show explicitly how on-target exposure time, setup, and calibration requirements determine these parameters. Please do not include any allowance for bad weather. Based on a clear understanding of your observational strategy as outlined in this section, we will evaluate the need for augmenting the allocation to allow for bad weather.*

In order to implement the four dark energy probes, the survey must cover a large spatial volume, hence large sky area, must reach to redshifts $z \gtrsim 1$ to have optimal sensitivity to the dark energy equation of state and its possible evolution, must achieve a small, nearly round, and stable PSF for weak lensing shape measurements, must achieve a high enough areal density of source galaxies to minimize Poisson errors in galaxy clustering and weak lensing, and must span several optical passbands in order to provide color measurements for photometric redshift estimates.

We have quantified these desiderata in jointly designing the Dark Energy Camera and the Dark Energy Survey strategy. The considerations above led us to a 570-megapixel imager (519 megapixels in the primary CCDs, plus guide and focus/wavefront chips, with 0.26" pixels) with superior QE in the red passbands, fast, low-noise readout, a 3 sq. deg. unvignetted FOV, 5 filters ($grizY$), and active control of focus and alignment. The current survey plan assumes 525 nights of observing with the CTIO-4m as per the NOAO AO of 2003, spread over 5 seasons.

Table 2. Expected Cumulative Wide-Area Survey Depths and Median Delivered PSF

filter	exp (sec)	mean-PSF 5σ m_{lim}	mean-galaxy 10σ m_{lim}	90%-tile bright m_{lim}	95%-tile bright m_{lim}	median PSF(arcsec)
g	900	26.5	25.2 ± 0.12	25.03	24.99	0.83 ± 0.05
r	900	26.0	24.8 ± 0.11	24.61	24.58	0.79 ± 0.05
i	900	25.3	24.0 ± 0.10	23.90	23.86	0.79 ± 0.05
z	900	24.7	23.4 ± 0.08	23.34	23.30	0.78 ± 0.04
y	450	23.0	21.7 ± 0.08	21.61	21.56	0.77 ± 0.04

$n_{eff} = 11.2/\text{arcmin}^2$ for weak lensing; survey area = 4944 deg^2; $N_{gals} = 200 \times 10^6$.
PSF $\equiv$ 1.0*FWHM aperture mag; galaxy mag $\equiv$ 1.6*FWHM aperture mag
4^{th} & 7^{th} column errors denote variations across the survey area

The survey strategy has been designed using detailed simulations of the instrument and telescope performance and using multi-year weather conditions from the site, including the effects of survey strategy, moon, airmass, and seeing variations[1]. The simulations indicate that we can cover approximately 5000 sq. deg. to the depths given in Table 2 in the wide-field survey (which assumes a median-weather year), while simultaneously achieving the requirements of the 30 sq. deg. supernova time-domain survey. The cumulative depths for the SN fields will be substantially greater due to the large number of revisits: for the 2 deep (8 less deep) SN fields, the 5σ point-source limiting magnitudes are estimated to be $g, r, i, z = 27.9(27.6), 28.1(26.4), 27.8(26.7), 27.6(26.5)$ (Bernstein et al 2011). The throughput numbers for DECam in the simulation have been taken to be conservative, while the PSF numbers in the last column may be slightly optimistic: the DECam technical requirements allow the camera to contribute $0.55''$ to the PSF budget, whereas the simulations assume the DECam *design* contribution of $0.45''$ (the largest contribution to this is CCD charge diffusion). Using the technical requirement instead would make the median delivered PSF expected

[1]LSST has adopted a PSF magnitude using an aperture of 1.42*FWHM. Adopting this definition, the stellar (PSF) limiting magnitudes in column 3 of Table 2 would be brighter by ~ 0.4 magnitudes.

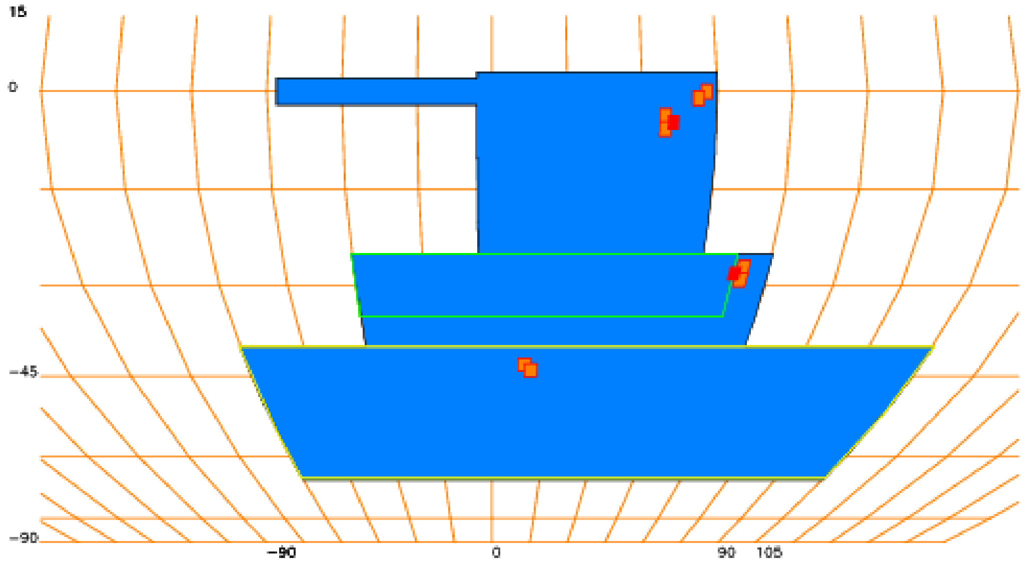

Figure 1: DES 5-year (blue) footprints in a Putnins IV equal area projection. RA increases to the right. Red (orange) squares are deep (less deep) SN fields. Also shown are the SPT SZE survey area (yellow) and the Viking VISTA survey area (green).

to be no worse than 0.9" for the wide-area survey, and the forecasts in Table 1 assume median 0.9" PSF. The standard deviations in m_{lim} in the 4th column of the table reflect the field to field variation in the final coadd. A good survey strategy achieves a homogeneity metric of $\sigma_m \lesssim 0.1$, and poor survey strategies yield $\sigma_m \gtrsim 0.2$.

The survey footprint (discussed below) indicates that the survey should be almost wholly carried out within the B semesters, and we are currently planning on 105-night seasons. In each season, we plan to cover the entire wide-area survey footprint twice in each bandpass, building up depth (a total of ten exposures in each filter) as we coadd data from succeeding seasons. The typical individual exposure times in the wide-area survey will be 90 seconds (see Technical Description section for details).

Survey Footprint

For the survey area of DES, we have selected the south galactic cap region, as it encompasses the SPT SZ survey and a number of other surveys of interest (including SDSS stripe 82 for calibration and other purposes and a number of deep spectroscopic redshift survey fields for photo-z calibration), has suitably low Galactic extinction, and is accessible at low air-mass during the Sep-Jan time frame, when the weather and site seeing at CTIO are good. Fig. 1 shows the current planned 5000 sq. deg. survey footprint. There are also two deep SN fields (shown in red) and eight shallower SN fields (in orange) within the wide-area footprint (Bernstein, et al 2011) that will be targeted following our standard survey strategy. The footprint bounding coordinates are given in Table 3.

Table 3. DES Wide-area Footprint

	RA			Dec		
SPT	-60	$\leq \alpha \leq$	105	-65	$\leq \delta \leq$	-40
Viking	-30	$\leq \alpha \leq$	60	-40	$\leq \delta \leq$	-25
Round 82	-3	$\leq \alpha \leq$	45	-25	$\leq \delta \leq$	-3
Stripe 82	-43	$\leq \alpha \leq$	-3	-2	$\leq \delta \leq$	2

The footprint of a single DECam exposure on the sky is a 3 sq. deg. region that is approximately hexagonal. The 5000 sq. deg. survey area can thus be tiled with 1660 roughly non-overlapping exposures in each filter; each of these single coverings of the entire survey area in one filter is called a tiling. Modulo gaps, inefficiencies, and wildly non-average weather, a given point in the wide-area survey will be covered by 10 tilings in each filter when the survey is completed, with two tilings carried out over the entire survey area in each nominal season. In order to calibrate the photometry across the survey area, the field centers of succeeding tilings are offset from each other by a fraction of the size of the DECam FOV, as described in Table 4 in the Technical Description. This ties the photometry together and reduces systematics by having each sky region sampled from multiple points of the DECam focal plane.

The above survey plan (2 tilings per filter over the entire survey area each season) has been extensively simulated and is the current default observing plan for the survey. Our survey strategy and science working groups are continuing to consider whether alternative plans might be more optimal in terms of science return for the early years of the survey without sacrificing survey completeness, homogeneity, and depth over the long term. One such alternative would be to cover 2500 sq. deg. four times in each filter in each season, alternating the area covered from year to year and again filling out 5000 sq. deg. with 10 tilings by the end of the survey. This has potential benefits for image processing and photometric calibration precision and greater survey depth in the early years of the survey. Prior to the start of the survey, we will only change the survey strategy from the default if the alternative is clearly demonstrated by detailed simulations to be more optimal and executable.

Survey Execution, Simulation, and Optimization

An optimal 105-night schedule for the 2013-14 DES season is shown in Fig. 2. This schedule satisfies a number of simultaneous constraints: total number of nights needed to cover the footprint area to sufficient depth; time of year to access the wide-area footprint at suitably low air-mass; comparable fractions of dark and bright time; gaps of at most 3-4 nights so as not to disrupt the cadence of the SN survey; enables NOAO to schedule up to 7 nights of community time each month; covers a broad enough timeline so that "edge effects" for high-redshift supernova light-curve sampling are acceptable; makes use of months when median site-seeing at CTIO is suitable for weak lensing shape measurements. The combination of those constraints leaves relatively little flexibility in the schedule without sacrificing the goals and efficiency of the survey. For example, if the survey were spread out over a longer timeline, running between Sept. 1 and Feb. 28, the reduction in efficiency would correspond to a loss of 10 nights of time over the five seasons of the survey. As another example, having longer community blocks would degrade the SN light-curve quality and therefore the SN photometric classification performance, leading to larger core-collapse contamination of the photometric SN Ia cosmology sample and larger systematic errors in dark energy parameters.

During DES operations, the ObsTac program will automatically queue up the next set of exposures (filter, pointing, exposure time) and will switch between wide-area and SN observations using a

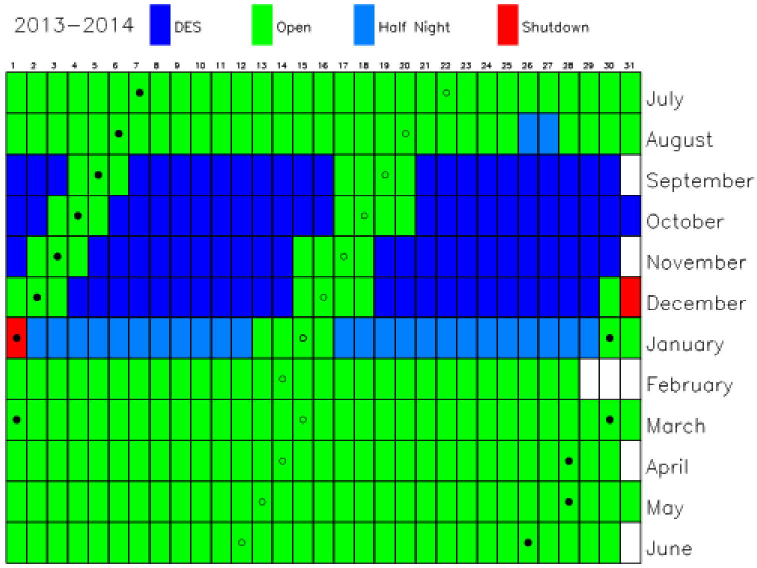

Figure 2: Optimal DES schedule for 2013B. The two half-nights in August are second-half nights for the SN fields, and the half-nights in January are first-half nights, when the wide-area footprint is still accessible.

decision tree that takes into account current observing conditions (photometricity, PSF, moon and sky brightness), time of night and of season, and what sky areas have been previously observed with survey quality in a given tiling. We have used this program and a separate stand-alone program to simulate survey operations, incorporating spherical astronomy, slew/readout overheads, a sky brightness model descended from the Krisciunas et al (1987) model, 35 years of astronomer-reported weather data from CTIO, and 5 years of CTIO site-seeing data reported in Els et. al. 2009. These simulations show that we can place tight constraints upon data quality and still expect to complete the 5000 deg^2 survey to requisite depth in 525 nights. As an example of the constraints imposed, we do not allow an observation in a given filter if the night-sky brightness at observation is higher than 1 magnitude above zenith dark-sky brightness. In practice, that means that g and r are not used when the moon is up, and i is not used if it is within 3 days of full moon. As another example, we impose an airmass limit of 1.5, and our simulations show median airmass = 1.25.

The majority of the DES observing time goes to the wide-area survey. In our current plan, if the delivered PSF, as measured by the automated DECam Image Health online analysis, becomes worse than 1.1", then ObsTac switches to the SN survey. If it is better than 1.1", we perform the wide-area survey, unless there are SN fields that have not been observed in the past 7 days, in which case we observe them. The precise value of this cut will be determined by the distribution of the delivered PSF during the survey. An alternative would be to trigger SN observations when conditions become non-photometric according to the RASICAM infrared all-sky monitor built by the DES collaboration. However, the simulations show that the number of galaxies useful for weak lensing measurements, the wide-area survey depth, and the wide-area survey median PSF are all substantially improved with the PSF (as opposed to the non-photometricity) trigger, while the resulting data still supports the supernova science goals, and the tiling and calibration algorithms ensure that the inclusion of fractional amounts of non-photometric data in the wide-area survey does not significantly degrade the photometric calibration precision of the data.

The primary variable determining completeness is not weather but the statistics of the seeing, which change monthly but for which later in the season is better; our schedule shown above makes almost optimal use of this.

Lessons learned from DES Science Verification

From Nov. 2012 to mid-Feb. 2013, following DECam commissioning, the DES collaboration carried out Science Verification (SV) observations with DECam. These observations, along with engineering and other test observations, enabled substantial improvements in the performance of the system to be made over time, particularly with regard to guiding, tracking, and pointing. These improvements in turn led to improvements in DECam image quality, necessary for weak lensing and other measurements. The SV period also enabled testing and improvement of on-mountain software systems. During much of the SV period, a portion of the nightly operations were carried out using DES survey protocols and procedures, including using obsTac to fill out small subsets of the wide-area survey, and enabling improvements in survey operational efficiency. These SV data have been and are being analyzed in detail to characterize the system and diagnose issues.

During the bulk of the SV time, due to a variety of issues a relatively small fraction of the data taken met the survey data quality requirements, and the operaitonal efficiency was correspondingly low. However, as noted above, a number of significant improvements have been made to the system over the last several months. As of this writing, the system appears to be delivering survey-quality data of order 80% of the time, and it appears that the overhead for telescope slew and settle time can be reduced by perhaps 5 sec from the current 30+ seconds. The telescope pointing accuracy has also recently improved, getting closer to what is needed for the SN survey to maintain high efficiency. With pointing worse than ~ 10", the SN survey efficiency suffers due to either loss of SN candidates at the edges of the fields or increased overhead to take offset pointings.

During the SV period we collected wide-area data in three selected sky regions: one on/near SDSS stripe 82, one in the western part of the SPT footprint (RA$\sim$ 23hr), and one in the eastern part of the SPT footprint (RA $\sim$ 5hr). Details of the cumulative data sets are listed in Table 4 and shown in Fig. 3, showing area and typical number of tilings per filter for data taken with FWHM ≤ 1.3" and image ellipticity $e \leq 0.1$. Preliminary analyses have been carried out on selected areas, and full data processing and analysis is on-going. The SN survey fields received on average a visit per week for 10 weeks, detected hundreds of SN candidates, and spectroscopically confirmed several candidates.

Table 4. DES Science Verification Data

Field	Exposures	Deg^2	Tilings	Notes
Stripe 82	244	≈ 30	≈ 3	Inhomogeneous, poor IQ
SPT-W	322	≈ 60	≈ 3	Inhomogeneous, mostly izY
SPT-E	2537	≈ 157	10	Homogeneous

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                Observing Runs Requested for this Project

Semester    Telescope   Instrument  # of Nights  Moon  Acceptable Months
-------------------------------------------------------------------------
2013B       CTIO-4m     DECam            105              Aug 23 - Feb 25
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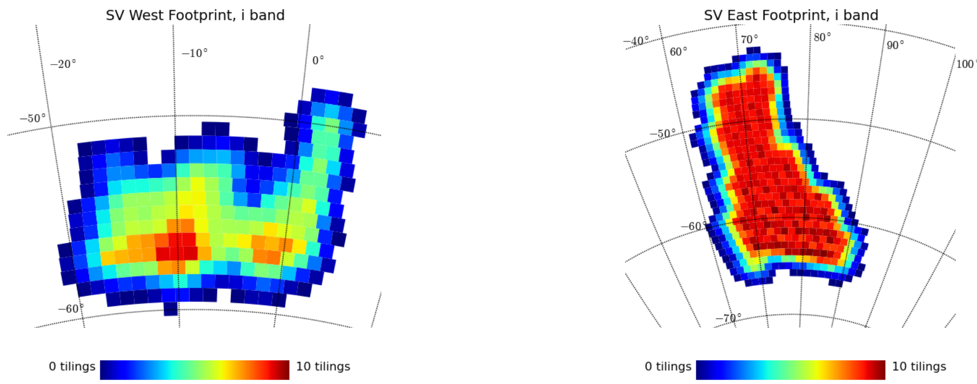

Figure 3: Data collected during DES Science Verification in the SPT-W (left) and SPT-E (right) fields. These are i-band coverage maps, after data quality cuts described in the text. The SPT-E field has more nearly homogeneous coverage in all 5 bandpasses.

Management Plan *Describe the overall organizational plan for conducting the proposed survey, including data reduction and analysis, preparation of survey deliverables, and staffing requirements. List the roles and responsibilities of the Co-Is with their anticipated time commitments directed to achieving the goals of the survey. You may also wish to detail external sources of support that will be used in the program. Please detail any use of non-NOAO observational facilities that are required to achieve the overall goals of the survey program.*

The organization and management of the Dark Energy Survey are described in the *Memorandum of Understanding for the Dark Energy Survey* (see https://www.darkenergysurvey.org/reports/) between Fermilab, NCSA, and NOAO. The PI of this proposal, Joshua Frieman (Fermilab/U. Chicago), currently serves as DES Project Director and Spokesperson and chairs the DES Management Committee, whose members represent the DES collaborating institutions and who advise the Director in managing the affairs of the collaboration. The DES Director has overall responsibility for carrying out the DES. He reports to the DES Council, which represents the Directors of the 3 MOU institutions and which provides oversight of the project. The DES Director also reports to the DOE-NSF Joint Oversight Group for DES, which monitors progress on behalf of the US agencies that have contributed to construction and to survey operations. Substantial support for DES construction has also come from funding agencies in the UK, Spain, Brazil, and Germany, and from the participating institutions. DES Operations are managed by the DES Executive Committee, which the Director chairs. Richard Kron (U. Chicago/Fermilab) serves as the DES Deputy Director, Jim Annis (Fermilab) serves as Project Scientist, with overall responsibility for survey strategy and planning, and Tom Diehl (Fermilab) serves as DES Operations Manager and Operations Systems Scientist. DES operations, including staffing for roughly 70% of the observing runs, is being supported by the DOE through Fermilab. The rest of the observing runs will be supported by the DES institutions. Ofer Lahav (University College London) serves as Chair of the DES Science Committee, which comprises the co-coordinators of the ten DES Science Working Groups and the coordinators of the DES Spectroscopic Task Force. The Science Committee sets the overall scientific direction of the project, and the working groups have primary responsibility for testing data quality and for organizing and carrying out science analyses with the DES Data Management-produced data products, following the guidelines set down in the DES Science Committee Charter and in the DES Publication Policy. Don Petravick (NCSA) serves as Principle Investigator for the DES Data

Management system, with overall responsibility for completing the development of and operating the data management system that will reduce the data, producing corrected single-epoch and co-add images and catalogs and archiving and serving these data products to the collaboration. DES Data Management development and operations are primarily supported by NSF AST at NCSA. Brian Yanny (Fermilab) serves as DES Data Management Project Scientist. The DES project works closely with CTIO scientific staff, several of whom are also members of the collaboration, including Alistair Walker (DECam Instrument Scientist). The DES collaboration currently has roughly 200 members, including students and postdocs. These scientists will work collaboratively within the Working Groups to carry out and publish science analyses of the DES data products, and they will also collectively staff the DES observing runs.

Use of Other Facilities or Resources *(1) Describe how the proposed observations complement data from non-NOAO facilities. For each of these other facilities, indicate the nature of the observations (yours or those of others), and describe the importance of the observations proposed here in the context of the entire program. (2) Do you currently have a grant that would provide resources to support the data processing, analysis, and publication of the observations proposed here?"*

(1) A deep, wide-area survey such as DES naturally complements a wide array of existing and planned data. Since the DES cluster mass threshold is well below that of SPT, our full SPT SZ survey coverage will allow investigations of clusters below the SZ S/N threshold via cluster stacking techniques as well as a new probe of CMB lensing. The VISTA Hemisphere Survey will cover the DES survey footprint in JHK more deeply than in the rest of the southern hemisphere; combined with the DES Y-band, it provides detections of high-redshift quasars. We are exploring possible connections with proposed large redshift surveys such as MS-DESI, eBOSS, and OzDES, each of which would benefit from the deep, uniform photometry of DES for spectroscopic target selection and for cross-correlation of redshift distortion measurements with DES weak lensing measurements. We are also engaging in discussions with the ESA space-based NIR imaging survey Euclid, which requires ground-based multi-band optical imaging for photo-z measurements.

(2) The DOE is currently supporting DES survey operations. Data management operations are supported by a 5-year NSF AST grant to NCSA. Many of the collaboration members (Co-I's on this proposal) have individual and group support from US and foreign funding agencies for DES activities.

Release of Data *Describe the data products (reduced observations, single or stacked images, spectra, object catalogues, and so on) to be releases, as well as the timeline and mechanism of their release to the community. Please differentiate between intermediate products developed during the execution of the survey versus the final products likely to be produced after the full observations have been obtained.*

The raw DES data are released to the public after one year via the NOAO Science Archive. NOAO can process those single-epoch data through the DES-supplied Community Pipeline and make those data products available as well. The DES collaboration plans to make fully calibrated catalogs and corrected-image, co-add data releases several years into the survey and after the survey ends. The DES has constructed and tested through a series of simulation data challenges and using DES SV data a Data Management system for reducing the DES data and will release data products in standard formats. Details of the DES data release policy are described in the DES MOU between Fermilab, NCSA, and NOAO.

Previous Use of NOAO Facilities *List allocations of telescope time on facilities available through NOAO to the PI during the last 2 years for regular proposals, and at any time in the past for survey proposals (including participation of the PI as a Co-I on previous NOAO surveys), together with the current status of the data (cite publications where appropriate). Mark with an asterisk those allocations of time related to the current proposal. Please include original proposal semesters and ID numbers when available.*

The number of nights allocated to DES Science Verification observations are given in Table 5. Details on those data are provided earlier in this proposal. All raw SV data were made immediately public, with no proprietary period. Full processing of the SV data through the DES Data Management system is on-going.

Table 5. DES Science Verification Nights Awarded

Proposal	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Season	Total	
2012B	0	0	0	12	21	11.5	-	44.5	44.5	Science Verification
2013A	-	-	-	-	-	-	7	7	51.5	Science Verification

Observing Run Details for Run 1: CT-4m/DECam

Technical Description *Describe the observations to be made during this observing run. Justify the specific telescope, the number of nights, the instrument, and the lunar phase. List objects, coordinates, and magnitudes (or surface brightness, if appropriate) in the Target Tables section below (required for queue and Gemini runs).*

The Dark Energy Camera and Survey have been designed specifically for the CTIO 4-m, taking advantage of its unique capabilities and excellent site characteristics. The request is for 105 nights during 2013B using DECam on the CTIO 4-m to carry out the first season of the Dark Energy Survey, as described above in the Experimental Design section.

Calibration

Our photometric calibration plan (see Tucker et al 2013 for details) relies on a combination of existing standards and global relative calibration:

- we have deployed a system-response measuring system (DECal) that measures throughput vs. wavelength of the CCDs+filters for each CCD
- standards such as Stripe 82 and Southern ugriz Standards will be observed during astronomical twilight
- SDSS stripe 82, the SDSS-III southern footprint, and the DES PreCam data allow during-the-night extinction estimates
- initial star flats and pupil ghosts have been measured during Science Verification and will be updated as new data are gathered
- the maximally overlapping tilings provide a uniform CCD to CCD pairing plot ensuring that global relative calibration can be used to provide both zeropoints and star flat correction tables
- the RASICAM all-sky monitor built by the DES collaboration provides cloud cover/photometricity measurements
- a GPS system purchased by the DES collaboration has been deployed to CTIO (mounted on the CTIO 1.5m dome) to monitor precipitable water vapor and improve z-band calibration
- a robotic, five-band imager to monitor several atmospheric transmission components in real time has been prototyped and is being explored for possible long-term deployment to CTIO by the DES collaboration

Likewise astrometric calibration will be done with a standards catalog, NOMAD in this case, and then refined with a global relative calibration.

Global Calibration

The data taken in the first season will use the standard DES hexagonal field centers and offsets. This is important for the use of global relative calibration methods (ubercal techniques; e.g. Padmanabhan et al 2008) for photometric and astrometric calibration. As the current plan is to use

Table 6. DES Survey Tiling Offsets

Tile #	Δ RA (degrees)	Δ Dec (degrees)
0	0.0000	0.0000
1	-0.5257	0.7222
2	1.0581	0.0829
3	0.3805	0.7886
4	0.1291	0.6891
5	0.7193	0.4403
6	0.6709	-0.3905
7	-1.1388	0.0166
8	0.0484	-0.6725
9	-0.9452	0.3740

seeing to trigger SN observations instead of the presence of non-photometric conditions, some wide-area survey observations will be taken when conditions are non-photometric. These will be brought onto the same photometric system as the rest of the data via global relative calibration.

The full survey will have 10 passes of the tiling pattern, with 2 passes for each filter planned for each nominal season. Both the photometric and astrometric calibrations are optimized if these passes have large and varied relative offsets with respect to each other. Ideally each location in the focal plane should connect to many other locations in the focal plane via pairs of overlapping exposures in order to best constrain camera-specific properties of the photometric and astrometric variations. Our current set of tiling offsets that do a fairly good job at this are listed in Table 6.

Instrument Configuration

Filters: grizY
Grating/grism:
Order:
Cross disperser:

Slit:
Multislit:
λ_{start}:
λ_{end}:

Fiber cable:
Corrector:
Collimator:
Atmos. disp. corr.:

R.A. range of principal targets (hours): 22 to 7

Dec. range of principal targets (degrees): -65 to 5

Target Table for Supernova Fields

Obj ID	Object	α	δ	Epoch	Mag.	Filter	Exp. time	# of exp.	Lunar days	Sky	Seeing	Comment
100	E1	7.8744	-43.0096	J2000		g,r,i,z	175,150,200,200	1,1,1,2				E1 Shallow SN field
101	E2	9.5000	-43.9980	J2000		g,r,i,z	175,150,200,200	1,1,1,2				E2 Shallow SN field
102	S1	42.8200	0.0000	J2000		g,r,i,z	175,150,200,200	1,1,1,2				S1 Shallow SN field
103	S2	41.1944	-0.9884	J2000		g,r,i,z	175,150,200,200	1,1,1,2				S2 Shallow SN field
104	C1	54.2743	-27.116	J2000		g,r,i,z	175,150,200,200	1,1,1,2				C1 Shallow SN field
105	C2	54.2743	-29.0884	J2000		g,r,i,z	175,150,200,200	1,1,1,2				C2 Shallow SN field
106	X1	34.4757	-4.9295	J2000		g,r,i,z	175,150,200,200	1,1,1,2				X1 Shallow SN field
107	X2	35.6645	-6.4121	J2000		g,r,i,z	175,150,200,200	1,1,1,2				X2 Shallow SN field
108	X3	36.4500	-4.6000	J2000		g,r,i,z	200,400,360,327	3,3,5,11				X3 Deep SN field
109	C3	52.6484	-28.1000	J2000		g,r,i,z	200,400,360,327	3,3,5,11				C3 Deep SN field

Special Instrument Requirements *Describe briefly any special or non-standard usage of instrumentation.*