1. NAME OF INITIATIVE: The Dark Energy Survey

List of major collaborating institutions (including non-US partners).

The Dark Energy Survey (Fermilab E-939) is aimed at understanding one of the fundamental questions of our time, the nature of Dark Energy. The Collaborating Institutions are Fermilab, University of Illinois, University of Chicago, LBNL, and the Cerro Tololo Inter-American Observatory. The DES Collaboration proposes to build a prime focus instrument (corrector optics and 500-megapixel CCD camera) for the Blanco 4m telescope at CTIO in Chile in response to an Announcement of Opportunity from the National Optical Astronomy Organization (NOAO) which offers up to 30% of the observing time over 5 yrs in return for a new instrument.

We are open to additional US partners, provided that they can bring needed skills and funds to the project. We have begun discussions with several groups in the UK and Spain. Non-US partners will be asked to contribute cash or to make in-kind contributions that would reduce the M&S costs to the US agencies supporting the project.

2. SCIENTIFIC JUSTIFICATION:

Physics goals. How does it fit into the global physics goals for the entire field.

Unraveling the nature of the Dark Energy has been recognized as one of the critical goals for fundamental physics by reports from the National Academy of Science, OSTP, and HEPAP. Connecting Quarks with the Cosmos (NAS), the Quantum Universe (HEPAP) and the DOE Facilities report all recognized pursuit of this problem as a key national priority. The Physics of the Universe (OSTP) report rated it as the highest priority for research. The Dark energy represents either a new form of stress-energy in the Universe or a breakdown of Einstein’s General Relativity on large scales—in either case, the implications for fundamental physics are profound. In order to pin down the nature of the dark energy and decide between the theoretical alternatives, we must probe the dark energy (and measure its equation of state parameter w) with greater precision. This calls for a coherent U.S. Dark Energy program consisting of a sequence of incremental steps of increasing scale, technical complexity, and scientific reach, culminating in what should be definitive measurements and, we expect, a breakthrough to a new paradigm. The Dark Energy Survey is the next key step in that program.

Experimentally, we probe dark energy by studying the impact it has had on the history of the expansion rate of the Universe. Through the expansion rate, the dark energy affects observables such as the apparent brightnesses of standard candles (such as supernovae), the apparent sizes of standard rulers, the volume of space containing `standard structures' such as galaxies and clusters of galaxies, and the rate at which those structures form. In recent years, a number of very promising new methods for probing dark energy have been developed. Since each of them measures different combinations of these observables, with different systematic errors and with different dependences on the cosmological parameters, they are doubly complementary. Because the nature of the dark energy is such an important question, and the measurements technically challenging, the most promising complementary dark energy probes must be pursued in order to form a robust program.

Four techniques appear to hold great promise as probes of dark energy, and the Dark Energy Survey (DES) will implement all 4 of them: (i) the luminosity distance (apparent brightness) of Type Ia supernovae, (ii) weak gravitational lensing of distant galaxies and its dependence on redshift, (iii) the abundance and clustering evolution of galaxy clusters, and (iv) the evolution of the spatial clustering of galaxies, using features in the galaxy power spectrum as standard rulers. In the Dark Energy Survey, each of these methods should deliver statistical constraints on the dark energy equation of state parameter w at the 5-10% level, a substantial improvement over current constraints. Moreover, the DES should yield interesting constraints on the time evolution of w. The key driver of the Dark Energy Survey design is method (iii): the survey is designed to overlap with the Sunyaev-Zel'dovich cluster survey that will be carried out with the South Pole Telescope (SPT). In particular, the DES will measure photometric redshifts for these ~30,000 clusters; in combination, DES and SPT will provide the first high-precision dark energy constraints from the abundance of clusters.
Moreover, DES will be a technical and scientific precursor to the more ambitious dark energy projects of the following decade, LSST and SNAP/JDEM, which aim at few % precision on w and improved constraints on its evolution.

To carry out these science goals, DES will use 30% of the Blanco 4m time over 5 years to carry out a deep imaging survey of 5000 sq. deg. in 4 optical passbands (griz), yielding measurements of approximately 300 million galaxies. Approximately 10 % of the survey time will be devoted to repeat imaging of a 40 sq. deg. region, which will yield ~1900 high-quality Type Ia supernova lightcurves for luminosity distance measurements.

3. VALIDATIONS FOR SCIENTIFIC JUSTIFICATION:

Examples of recommendations and supporting statements from the committees, panels, and the community at large.

As noted above, a number of panels have endorsed vigorous pursuit of the science of dark energy. The work of these panels preceded the development of the Dark Energy Survey. The DES aims to deliver major advances in dark energy precision around the end of the first decade of this century. The project was presented to the Fermilab Physics Advisory Committee (PAC) in March 2004. The PAC has strongly endorsed the project, resulting in Stage 1 approval by the Fermilab Director. In particular, the PAC report states in part:

> ``The Committee finds the science of the proposed Dark Energy Survey very exciting and important. Its strongest point is the redshift measurement of galaxy clusters that can be correlated with the Sunyaev-Zeldovich measurements at the South Pole Telescope…This may be the best possible measurement of the equation of state before LSST and JDEM. The proposed project will also pave the way to future bigger dark-energy programs such as LSST and SNAP. "

A Director's Review of the Dark Energy Survey was held at Fermilab in early June 2004. The final report endorsed the science and added that ``the DES team proposal puts forth a good program and it can be carried out."

4. DESIRED SCHEDULE:

List major milestones (month & year) such as design complete, construction start, construction complete, etc.

The schedule for construction of the Dark Energy Survey Instrument is driven by procurement of the CCDs for the camera focal plane and by funding available for procurement of the optical components for the corrector. We can meet the following schedule if the funding profile that was presented to the PAC (and in response to question 5 below) is realized.

Sept. 04 – Oct. 05: Design and development phase

Sept 04: place a preproduction order for CCDs

March 05: Optical design complete

Aug. 05: verify CCD preproduction order was successful

Oct. 05: place order for production CCDs and the largest optical components

July 06: 1st production CCD packaged and tested

July 07: All CCDs complete and ready for focal plane

Sept. 08: Corrector fully assembled, tested and ready for integration with camera.

Jan. 09: ready to ship fully tested and integrated Dark Survey Instrument to Chile.

June 09: Instrument fully commissioned on the telescope

5. ROUGH ESTIMATE OF COST RANGES:

Whatever the best information available (eg. $M +/-30~50%, $150~250M, etc.). Total cost range including non-DOE funding (if any other funding sources are assumed and if known, state from where and how much. Also indicate remaining R&D cost to go.

The Dark Energy Survey has developed a full WBS for cost and schedule. FY05 costs should be considered R&D.

Table 1: Obligations plan for the DES Instrument (in FY04 $K)

	FY04	FY05	FY06	FY07	FY08	FY09	Total M&S
M&S Base	0	1027	3161	3113	470	60	7830
M&S Contingency	0	123	539	587	1130	440	2820
Total Base M&S	0	1150	3700	3700	1600	500	10650
M&S DOE (Fermilab)	0	1000	2500	2500	600	500	7100
Other funding	30	150	1200	1200	1000	0	3580
Total funding	30	1150	3700	3700	1600	500	10680
DOE fraction		0.87	0.68	0.68	0.38	1.00	0.67

Table 2 Cost of Technical Labor at Fermilab and University of Illinois (FY04 $K)

	FY04	FY05	FY06	FY07	FY08	FY09	Total
Fermilab Labor	578	964	821	983	442	216	4004
UIUC Labor	39	66	110	71	74		370

The corresponding fully loaded costs in then year $ are: $9.7 M for M&S, $3.9M for M&S contingency, $5.7M for labor and $2.8M for labor contingency. Following the DOE tradition, the scientist labor is not included in the cost. The cost of the labor at CTIO has also not been included. The fully loaded and escalated total project cost with this profile is ~ $22M. This was calculated assuming a 2.5% per year escalation on M&S due to inflation plus 16.5% overhead on all M&S costs, and a 4% per year escalation on the labor costs with 30% overhead on the Labor costs.

6. DESIRED NEAR TERM R&D:

Major activities needed to be completed before start construction.

The DES project has chosen proven technologies and thus extensive research is not needed to proceed with the project. However, there are a few steps that must be taken before we can proceed with the start of production. The tasks and associated M&S costs (FY04 $) are listed below:

$255k for a 24-wafer preproduction CCD order followed by processing of 2 wafers at LBNL to establish that the masks and production process will be successful. The existing masks have only 2-CCDs/wafer while the DES masks will have 4 CCDs/wafer in order to reduce the DES cost.

$355k for processing the remaining wafers at LBNL to establish the CCD yield and processing rate. Two CCDs made from the 2-CCD/wafer masks are in use on telescopes, but this small quantity is not enough for a solid estimate of the yield.

$70k to begin to develop the CCD packaging process at Fermilab

$200k to develop and test the design of the Front End Electronics, the CCD testing setup and the Data Acquisition system at Fermilab

$40k to develop the Optical Design of the corrector and perform trade studies to minimize the cost of the corrector elements.

7. BRIEF DESCRIPTION OF LABORATORY'S ANTICIPATED ROLE:

Expected unique capabilities to be provided by lab. Rough estimate of human resources from lab (#FTE in what type labor).

Fermilab is the lead institution in the Dark Energy Survey Collaboration. The role of Fermilab is to provide project management, build the instrument, and provide scientific guidance. This project capitalizes on many of the unique capabilities of Fermilab. Fermilab has extensive experience managing this scale of project. The DES collaboration is organized into two projects, one to build the instrument and one to handle the data. Fermilab will take the lead role in building the instrument and provide oversight to both the instrument project and the data management project. The University of Illinois at Urbana-Champaign and NCSA will lead the data management project.

Building a CCD camera is similar to the construction of a silicon vertex detector. The Fermilab Silicon Facility has developed extensive experience and equipment through the construction of the silicon vertex detectors for CDF, D0 and CMS. This project capitalizes on that investment and advances Fermilab's capabilities in to a new and exciting field.

Fermilab is playing a major role in many aspects of the Sloan Digital Sky Survey, including project management, data management, and telescope engineering and support.

Fermilab plans to continue to support project management and data processing during SDSSII, the extension that will begin in 2005 and end in 2008. The Lab has developed substantial expertise in planning, executing, and analyzing large astronomical surveys through this effort.

The Director of Fermilab recently announced the formation of the Fermilab Center for Particle Astrophysics with the goal of “promoting excellent research at Fermilab in the exciting science at the boundary between particle physics, astrophysics and cosmology”. This center will “build an intellectual center for particle astrophysics at Fermilab” and “integrate particle astrophysics research more completely into the scientific life of the laboratory.” The DES project has already drawn interest from both particle physicists and astrophysicists and represents a first step in the integration of these two fields. The scientists in the Theoretical and Experimental Astrophysics groups, who are currently engaged in the SDSS, plan to take lead roles in science analysis and science management of the DES. Fermilab will be able to contribute to the Data Management of the DES project after SDSSII concludes all operations in FY08. At that time the DES will become the primary astrophysics effort at Fermilab. We do not expect that this shift will detract from the Fermilab effort on SNAP/JDEM. In fact DES will bridge the time gap between SDSS and SNAP/JDEM. As the center develops, Fermilab will become an ideal place for the study of Dark Energy and Dark Matter.

An estimate of the Labor resources needed for the DES Instrument project is given in Table 3; the corresponding costs were given in Table 2. Following the DOE standard, the scientists are included in the project for scheduling purposes, but only the cost of technical labor (engineers, technicians) is included in the labor costs of the project.

Table 3: Estimate of the type of labor needed for the DES Instrument Construction

Labor Type	Total	FY04	FY05	FY06	FY07	FY08	FY09
Scientist	26.0	2.5	7.8	6.5	5.2	4.0	1.7
Technical	45.2	7.9	17.2	9.7	5.8	4.5	1.9