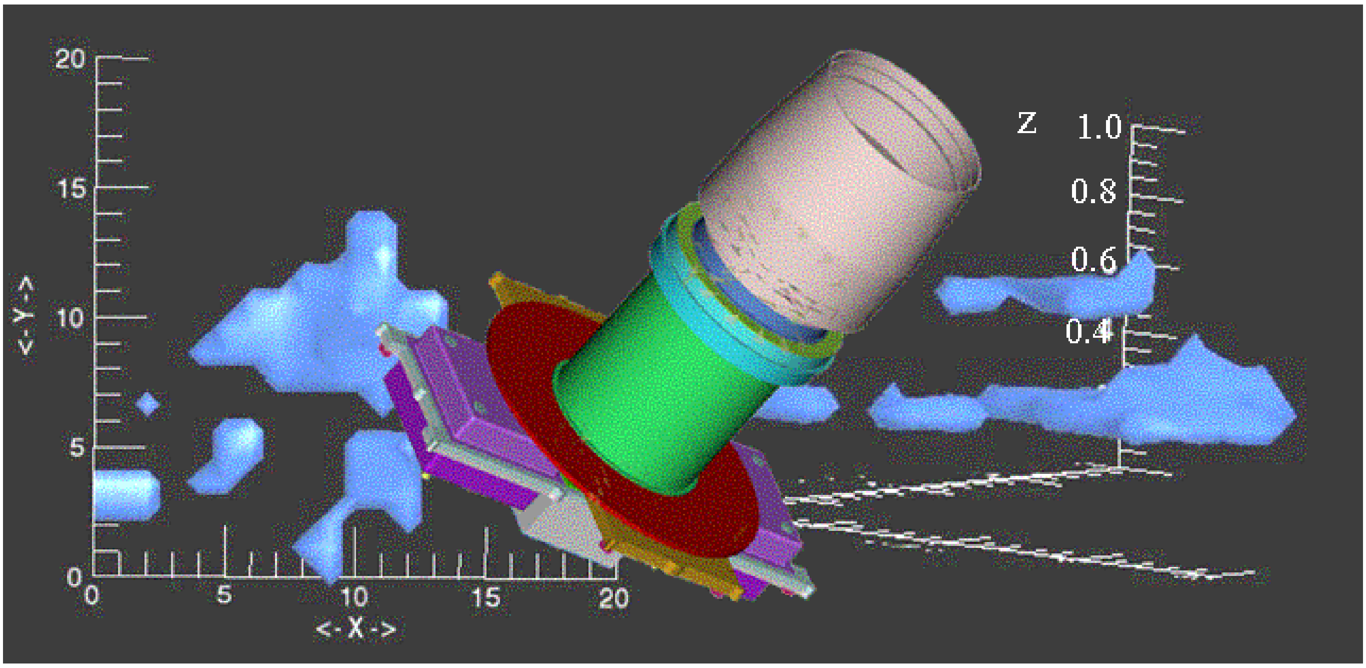
darkCAM

A DARK ENERGY CAMERA FOR VISTA

CASE FOR SUPPORT



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2dFGRS:	Two-degree Field Galaxy Redshift Survey
ADC:	Atmospheric Dispersion Corrector
AIT:	Assembly, Integration and Testing
CASU:	Cambridge Astronomical Survey Unit
CFHT:	Canada France Hawaii Telescope
CMB:	Cosmic Microwave Background
COMBO-17:	Classification of Multi-Band Observations in 17-bands
CTIO:	Cerro Tololo Inter-American Observatory
DES:	Dark Energy Survey
ESO:	European Southern Observatories
FDR:	Final Design Review
FIERA:	Fast Imager Electronic Readout Assembly
HOCS:	High Order Curvature Sensor
HOWFS:	High-Order Wave-Front Sensor
IRACE:	Infrared Array Control Electronics
LCU:	Local Control Unit
LOWFS:	Low-Order Wave-Front Sensor
LSST:	Large Synoptic Survey Telescope
Pan-STARRS:	Panoramic Survey Telescope and Rapid Response System
PDR:	Preliminary Design Review
PSF:	Point Spread Function
PMP:	Project Management Plan
QMUL:	Queen Mary, University of London
QUaD:	QUEST (Q & U Extragalactic Survey Telescope) and DASI (Degree Anisotropy Survey Interferometer)
RAL:	Rutherford Appleton Laboratories
RRA:	Risk Reduction Actions
SDSS:	Sloan Digital Sky Survey
SNAP:	Supernova Acceleration Probe
SPT:	South Pole Telescope
SZ:	Sunyaev-Zel'dovich
UKATC:	UK Astronomy Technology Centre
VDFS:	VISTA Data Flow System
VISTA:	Visible and Infrared Survey Telescope for Astronomy
VLT:	Very Large Telescope
VO:	Virtual Observatory
VSA:	Very Small Array
VST:	VLT Survey Telescope
WBS:	Work Breakdown Structure
WFAU:	Wide Field Astronomy Unit
WFS:	Wave-Front Sensor
WMAP:	Wilkinson Microwave Anisotropy Probe
WP:	Work Package

1. Executive Summary

Recent major advances in our understanding of the state and content of the Universe have led to a major shift in the main goals of Cosmology. The high priority issues are now to understand the nature of Dark Energy and Dark Matter. We propose to map the three-dimensional lensing shear pattern of the Universe with a 10,000 square degree 5-band (g',V,r',i',z') photometric redshift survey to z=0.7, and analyse it to measure the distribution of Dark Matter. With this we will pin down the equation of state of Dark Energy to an accuracy of 1.9% and determine if it is a cosmological constant or a dynamic vacuum energy. This will be achieved by building darkCAM, a 2 square-degree field-of-view visible camera with 50 red-optimised CCDs for ESO's VISTA (Visible and Infrared Survey Telescope for Astronomy) telescope. With darkCAM on VISTA the UK and ESO will have a world-leading facility designed to have superb image quality over a wide field of view, providing a window of opportunity to be the first to measure the Dark Energy properties accurately, well ahead of the proposed LSST and SNAP experiments. 3-D weak lensing is the most effective technique to pursue this goal, as 3-D lensing observables have high sensitivity to the properties of Dark Energy, and these observables can be calculated robustly a priori from theory. The success of Cosmic Microwave Background (CMB) studies, culminating with the Wilkinson Microwave Anisotropy Probe (WMAP) and Planck, was built on similar principles.

UK scientists are the pioneers in 3-D weak lensing theory and application, and ESO's VISTA telescope has been designed in the UK to be suitable for a weak lensing survey, so intellectual and technical leadership is assured. The science is timely: the cosmological concordance model has recently been firmly established so the goals of understanding the Dark Energy and Dark Matter are paramount; the new 3-D weak lensing analysis methods are powerful and robust; and the darkCAM conceptual design for VISTA exists and can achieve the new goals.

The proposed timescale for darkCAM overlaps with the Planck CMB satellite, in which UK/European scientists are playing a leading role. The power of darkCAM alone to study the Dark Energy will be excellent, but in combination with Planck the case is more compelling still. The combined surveys will also be ideal for tackling a wider set of the most important questions in Cosmology, such as probing the dynamics of Inflation in the Early Universe and more exotic phenomena such as searching for observational signatures of string theory.

darkCAM is a survey camera, using the Visible Camera conceptual design developed in 2001 for the VISTA telescope, situated at ESO's Cerro Paranal Observatory in Chile. A baseline conceptual design has been developed for which the total construction, Assembly, Integration and Testing (AIT) and commissioning costs, excluding contingency, are estimated at £8.96M for hardware and 57.5 staff-years of effort over a period of 4 years. Subject to funding approval we could start as early as September 2005. It is expected that when darkCAM is commissioned and accepted by ESO, ESO will provide the darkCAM consortium with guaranteed nights with darkCAM on VISTA whose value is equivalent to the manpower and hardware expended on darkCAM, in accordance with normal procedures. We expect that, subject to negotiations with ESO, ~600 nights over 4 years will be awarded to complete the darkCAM survey.

2. Introduction

The last few years have seen a revolution in our understanding of the Universe. The huge scientific impact of the UK/Australian 2dF Galaxy Redshift Survey (2dFGRS), the Sloan Digital Sky Survey (SDSS), observations of Supernova Type 1a and, of course, CMB experiments such as WMAP have been the main drivers behind this revolution. These high-precision datasets have settled long-standing issues in Cosmology such as the spatial curvature, age and composition of our Universe. Following these surveys it is almost impossible to argue against the Universe being composed of a few percent radiation and baryons, a much larger fraction of Cold Dark Matter, and a mysterious and dominant 'Dark Energy' component, with a negative-pressure equation of state $P = w \rho c^2$, with $w \sim -1$.

These results have initiated the era of 'precision Cosmology', and the major unsolved questions have shifted from quantifying the abundance of the Universe's constituents to understanding their nature. Right now, we do not know if the Dark Energy is dynamical, in which case it may be associated with vacuum energy described by an evolving scalar field, or if it is Einstein's Cosmological Constant. Nor do we know what the Dark Matter is made of. While the nature of the Dark Matter may be settled by the detection of the lightest supersymmetric particle at the TeV-scale Large-Hadron Collider, due in 2007, or the next generation of Dark Matter particle detectors, the effects of the Dark Energy are too weak to be measured in the laboratory and can only be seen on cosmological scales. As Dark Energy is dominant at low redshifts, the CMB has limited sensitivity to its properties, setting the rather weak limit of $w < -0.8$. Determining the nature of Dark Energy is a major scientific goal. darkCAM and VISTA are world-leading instruments which offer a window of opportunity to be the first to do this by measuring w and its redshift evolution, to within a few percent. A deviation from a constant $w=-1$ would signal new physics associated with the vacuum itself, otherwise the Universe is to all intents and purposes dominated by Einstein's Cosmological Constant which presents us with a mysterious new constant of nature.

This Case for Support presents an overview of the primary scientific drivers for darkCAM and a management plan and costs for activities based on the current baseline design for the instrument. It also discusses the routes taken by the consortium to limit technical and schedule risk.

3. Scientific Objectives and Deliverables

Scientific Objectives:

The main objectives of darkCAM are to:

- Robustly measure the dynamics of Dark Energy from its equation of state as a function of redshift to 1.9% precision via 3-D weak lensing.
- Determine if the Dark Energy could be Einstein's Cosmological Constant or a hitherto unknown field.
- Determine the 3-D mass power spectrum of Dark Matter via 3-D Dark Matter mapping and establish the detailed nonlinear clustering and its evolution to determine the nature of Dark Matter.
- Establish the dynamics of the inflationary epoch via accurate measurement of the primordial scalar fluctuation spectrum.
- Probe the dark sector of the Universe by exploring whether there is any coupling between Dark Energy and Dark Matter.

Deliverables:

The principal science deliverables of the main survey will be a high precision determination of the equation of state of the Dark Energy and its time evolution. In particular, for models with simple forms of w evolution, we expect to determine w to an accuracy of 1.9 percent, and its time derivative to 8% accuracy. With this precision, it is clear that competing theoretical models of Dark Energy with varying w can be experimentally tested against observational data.

The baseline darkCAM survey design is for a 5-band photometric imaging survey over 10,000 square degrees, to a depth of r'=24 giving a median galaxy redshift of z=0.7. Such a survey, with exquisite image quality, would be a tremendous legacy for a host of other science programmes, some of which are outlined later in this document.

3.1 Extent of the UK's leadership and influence

The UK lensing community can certainly lay claim to world leadership in 3-D weak lensing analysis techniques. Indeed they have pioneered these methods and the UK also hosts experts in optimized statistical analysis techniques which have previously exploited the CMB and Galaxy Redshift Surveys.

The applicants have been able to show that 3-D weak lensing is the most precise known way to hunt Dark Energy. In addition, the UK weak lensing community is experienced in the analysis of large lensing datasets and have published the first studies of 3-D lensing, and the first analysis with contaminating physical effects removed.

From a technical point-of-view, the existing Phase A design of the visible camera for VISTA, undertaken for the VISTA consortium at the UK Astronomy Technology Centre (UKATC), Edinburgh, is a remarkably effective design, providing an excellent Point Spread Function (PSF) over a wide field of view – perfect for a weak lensing survey. For data handling the UK VISTA Data Flow System (VDFS) project has considerable expertise in pipeline construction, centred at the Cambridge Astronomical Survey Unit (CASU, IoA Cambridge) and in database-driven archiving centred at the Wide Field Astronomy Unit (WFAU, Edinburgh) for the VISTA IR camera data.

3.2 User base in the UK distinct from the proposers, and its size and international standing

The focus of this proposal is weak lensing, but the applications of a multicolour deep photometric survey with exquisite image quality are many, as listed in Section 4.5 below. Most astrophysics departments in the UK would have interests in the areas potentially covered by darkCAM output. The UK has a very high international standing, especially, though not confined to, weak lensing and Cosmology.

3.3 Timeliness

The timeliness of this proposal is built on three factors:

- With the recent establishment of the Cosmological Concordance Model by surveys such as 2dFGRS and WMAP, the main goals of cosmology have moved from measuring the amounts of the 'missing' constituents of the Universe to unravelling their nature.
- The statistical power of weak lensing analysis in 3-D has recently been demonstrated, especially for measuring Dark Energy properties and for 3-D Dark Matter mapping.
- The existence of a new, integrated telescope and camera design with excellent image quality over a wide field, specifically optimized for weak lensing surveys.

4. Main Science Case

4.1 Overview: Dark Energy and Dark Matter

3-D weak lensing, where weak gravitational lensing is combined with angular positions and photometric redshift distances to each galaxy, is the most promising way to study the spatial distribution of Dark Matter and the equation of state of the Dark Energy. In gravitational lensing the images of distant galaxies are distorted, or sheared, by the deflection of light by the gravitational field of intervening matter as it travels across the Universe. Gravitational lensing probes the mass distribution directly, and is independent of the dynamical and thermodynamic state of the lensing material. Most importantly the gravitational physics behind lensing is well understood, so the methodology is robust. There are other methods for constraining Dark Energy properties, and these should be pursued, but one should recognise that in all cases there are uncertainties in the physics which may make the interpretation difficult. For example, galaxy surveys may be used to trace the Dark Matter, but they are biased in a way which, by the standards aimed for here, is only approximately known (~10%). Other probes of Dark Matter and Dark Energy such as galaxy clusters are generally not in equilibrium and have complicated physics, while the physics of Supernova Type Ia may be affected by poorly-constrained evolution and/or environmental effects, and possibly grey dust. Baryon oscillations, traced by galaxy clustering, are promising, but suffer from the galaxy bias uncertainty, and more work is required to see if nonlinearities erase the oscillations sufficiently to lead to large errors in estimates of the Dark Energy properties.

The lensing community is well placed to conduct and exploit a darkCAM lensing survey, having pioneered powerful new techniques to probe Dark Energy (Jain & Taylor 2003, Heavens 2003, Taylor et al 2004, Heavens & Kitching 2005, Castro et al 2005), and 3-D Dark Matter mapping (Taylor 2001, Taylor et al 2004). We have led the field in developing methods to probe the Dark Matter and Dark Energy from 3-D gravitational lensing, by mapping the full 3-dimensional Dark Matter distribution (Taylor et al 2004), measuring the Cosmic Shear power spectrum (Brown et al 2003), and detecting the cosmic evolution of Dark Matter perturbations (Bacon et al 2004). A gravitational lensing survey with darkCAM on VISTA alone would map out the 3D Dark Matter distribution to $z \sim 1$ over ten thousand square degrees, pinning down the Dark Matter properties (i.e. the amplitude of matter clustering, σ_8, and primordial scale dependence of matter clustering, n_s, etc) to 2%.

The Dark Energy affects both the growth of the potential field and the global geometry, and so the lensing of photons is a direct probe of Dark Energy. We emphasize that accurate knowledge of Dark Energy can be achieved because the physics of gravitational lensing is both simple and well understood. Specifically, we can probe the Dark Energy in two complementary ways, via;

- The 3-D shear power spectrum analysis (Heavens 2003), which correlates lensed galaxy distortions separated in both angle and redshift.
- The 3-D geometric Dark Energy test (Jain & Taylor 2003), which uses the lensing geometry to measure the affect of dark energy.

These methods, which exploit different and complementary aspects of the lensing effect, can, on their own, reach about 1.9 percent accuracy (marginalising over other parameters) on the measurement of w, and its time evolution. This would be enough to determine if w, for all practical purposes, is a Cosmological Constant, perhaps motivated by the Landscape picture of M-theory, or a more dynamical entity such as Quintessence, Chaplygin gas, K-essence, tachyon fields or modified gravity.

However by timing a darkCAM lensing survey to coincide with Planck, further goals are achievable, and we should be able to match and exceed the scientific impact of the 2dFGRS and WMAP. Specifically, a darkCAM lensing survey and Planck could be used to tackle the following fundamental problems:

- To establish the dynamics of the Inflationary epoch via accurate measurements of the primordial scalar fluctuation spectrum. This is essential if we are to understand the physics of Inflation, which may well be related to physics at the string scale.
- To probe the dark sector of the Universe by exploring whether there is any coupling between the Dark Matter and Dark Energy and to determine the neutrino mass.
- To measure precisely the evolution of fluctuations over the range z~1000 to 0, fixing precisely the formation epochs of all structures, from the first generation of stars to rich clusters of galaxies.

Given these major scientific goals, we feel it would be a huge wasted opportunity not to build darkCAM.

4.2 A Dark Energy Survey with darkCAM

Dark Energy alters gravitational lensing in two ways, Firstly it changes the evolution history of the Universe making it look younger than it is. This affects the comoving distances, which become bigger than expected for a given redshift, since the Universe has had more time to expand. Hence the geometry between observers, lenses and background is distorted by Dark Energy. The second effect is on the evolution of structure in the universe. The accelerated expansion slows the gravitational collapse of structure, while the increase in the age of the universe gives more time for structure to collapse. The combined effect is to slow down the formation of structure. As light travels through the matter distribution of the universe, gravitational lensing provides us with an integrated history of the growth of structure with cosmic time.

We can use the effects in two ways. The first is to model both effects in the observed lens shear field, γ, with redshift and calculate them through the 3-D shear power spectrum. The second way is to isolate the geometric effect and measure the geometry of the Universe as a probe of Dark Energy. We begin with the 3D shear power spectrum.

4.2.1 The 3D shear power spectrum

All current and future cosmic shear surveys will have photometric redshifts for the source galaxies. Each source carries with it an estimate of the shear due to lensing, so the surveys constitute a set of estimates of the shear field in three dimensions. Previously cosmic shear surveys were analyzed in projection on the sky, although now the prospects of lensing in redshift slices ('tomography') have being discussed (Hu 2002). Genuine 3-D analysis techniques have been pioneered in the UK (Taylor 2001, Heavens 2003, Heavens & Kitching 2005, Castro et al 2005), for optimal cosmological parameter estimation and optimized survey design.

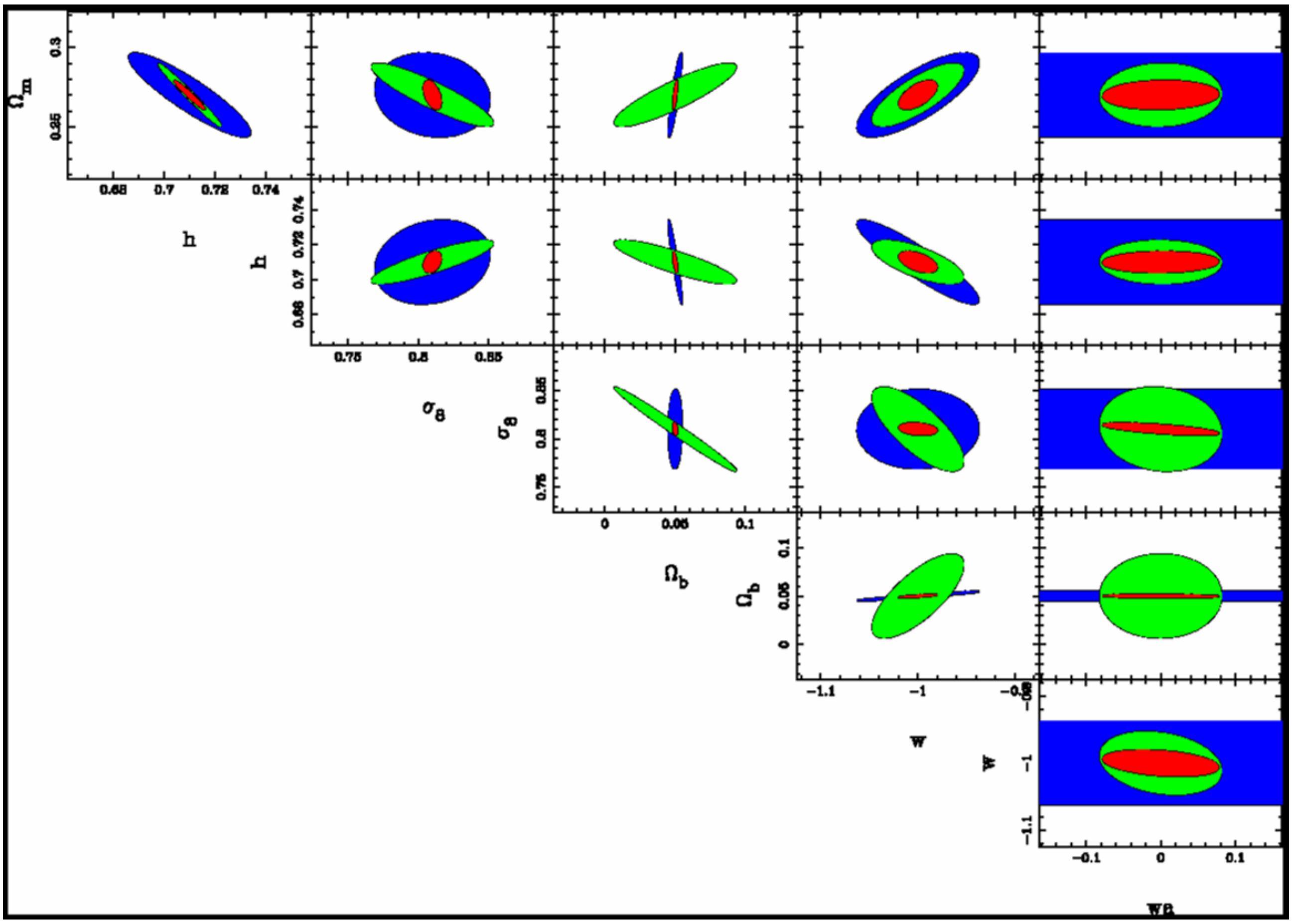

Figure 1: Expected cosmological parameter accuracies from 3-D shear power spectrum.

The expected accuracy of the cosmological parameters Ω_m, h, σ_8, Ω_b, w and w_a for a 5-band darkCAM survey covering 10,000 square degrees to a median redshift of $z=0.7$. Green shows darkCAM only, blue is a Planck prior, and red is the combined accuracy. All contours are one-parameter one-sigma. Marginalising over all other parameters we find a 1-sigma accuracy on w of Δw=0.02. A flat cosmology is assumed.

There are compelling reasons why power spectrum techniques are powerful for parameter estimation. These centre around the calculable covariance properties; large-scale structure and CMB analyses are done this way. For a large-angle survey, the sensible basis in which to expand the 3D shear field is a combination of angular spin-weight 2 spherical harmonics and radial spherical Bessel functions. The resulting (3D) coefficients are labelled by a radial wavenumber, k, and two 'quantum numbers', l and m. Most importantly, the coefficients can be related to the matter distribution, δ=δρ/ρ where ρ is the matter density, through (this shows one component of the shear)

$$\gamma_2(k,l) \propto -l_x l_y H_0^2 \Omega_m \int_0^\infty dz dz_p\, p(z_p \mid z) n(z_p) j_l(kr) \int_0^r dr \tfrac{r'-r}{rr'}(1+z') \int dk'\, j_l(k'r')\delta(k',l,r').$$

This demonstrates that the observables can be related theoretically to cosmological parameters through the dependence of the matter power spectrum shape and growth rate, and on the distance-redshift, $r(z)$, relation. It also includes effects of arbitrary photometric redshift (z_p) errors via the $p(z_p|z)$ term.

The nonlinear small-scale matter power spectrum is uncertain, due to the finite resolution of N-body simulations and nonlinear effects of the baryons in forming galaxies. This uncertainty can be avoided by analyzing only lensing modes with negligible contributions from the uncertain high-k regime. The effects of intrinsic alignments of galaxies (Brown et al 2000, Heavens et al 2000), which mimic the effects of lensing, can be removed by excluding pairs of galaxies with similar photometric redshifts (Heymans & Heavens 2003).

Fig. 1 shows what can be achieved with a darkCAM 5-broadband survey covering 10,000 square degrees to a median redshift of $z=0.7$, combined with the expected Planck results. The contours show the one-sigma errors on cosmological parameters in pairs, marginalised over the remaining parameters, for a flat universe. The parameters which are varied are the Dark Matter density parameter Ω_m, the Hubble constant h, the amplitude of mass fluctuations characterized by σ_8, the baryon density parameter Ω_b, the equation of state parameter w and its redshift dependence. The equation of state as a function of scale factor $a=1/(1+z)$ can be arbitrary, but is modelled for the purpose of survey design as

$$w(a) = w + w_a(1-a),$$

where $w_a=dw/da$ is the change in the equation of state with scale factor.

From lensing alone the parameter accuracies are comparable, but orthogonal to Planck. Of most interest are the errors on w and w_a, which are 1.9% and 8% for this survey design, after properly marginalising over all other parameters.

4.2.2 The geometric dark energy test

As well as using both the geometry of the universe and the evolution of Dark Matter clustering as a probe of Dark Energy, we can also isolate the effect of the Dark Energy on the geometry of the Universe with 3-D lensing (Jain & Taylor 2003, Taylor et al 2005). The amplitude of the induced tangential shear distortion behind galaxy clusters grows as

$$\gamma_t(z) = \gamma_{t,\infty}\, S_k[r(z) - r(z_l)]/S_k[r(z)],$$

where $\gamma_{t,\infty}$ is the tangential shear induced on a galaxy at infinite redshift, z_l is the cluster redshift, $r(z)$ is a comoving distance, and, relaxing the assumption of spatial flatness, $S_k(r)=r$, $\sin(r)$ or $\sinh(r)$ for a spatially flat, closed or open universe. If we take the ratio of shear values at different background redshifts, z_i and z_j, we find

$$R_{ij} = \frac{\gamma_t(z_i)}{\gamma_t(z_j)} = \frac{S_k[r(z_j)]S_k[r(z_i) - r(z_l)]}{S_k[r(z_i)]S_k[r(z_j) - r(z_l)]},$$

where in the last term the mass and structure of the cluster has dropped out. The shear ratios depend purely in the geometry of the Universe through the comoving distances, $r(z)$, and so only on the Dark Energy parameters Ω_v, w, and w_a and the matter density parameter Ω_m. The advantage of this is that the test is purely geometrical and has the minimal of assumptions – we need know nothing about the structure doing the lensing. This means that we can probe the stronger lensing regime around galaxy clusters, where the lens signal is higher and need not worry about accurate modelling of nonlinear density distributions and its evolution, or the relationship between galaxies and dark matter.

Fig. 2 shows the expected accuracy on the geometric parameters, Ω_m, Ω_v, and w from the Dark Energy geometric test with a 5-band photometric darkCAM survey of 10,000 square degrees to a median redshift of $z=0.7$, combined with the expected four-year WMAP parameter accuracies. The geometric test error ellipse forms a thin disc in parameter space, orthogonal to that from the CMB. With these conservative assumptions we find w can be measured to an accuracy of 3% after marginalising over the

other parameters and no assumption of spatial flatness. Here we have assumed only statistical errors, including photometric redshift errors for a 5-band optical survey.
Note that the expected results from the Planck survey will reduce the error on the combination of $\Omega_m+\Omega_V$, but will not, on its own, improve those on w. However, combined with the darkCAM weak lensing survey the constraints on w are even stronger.

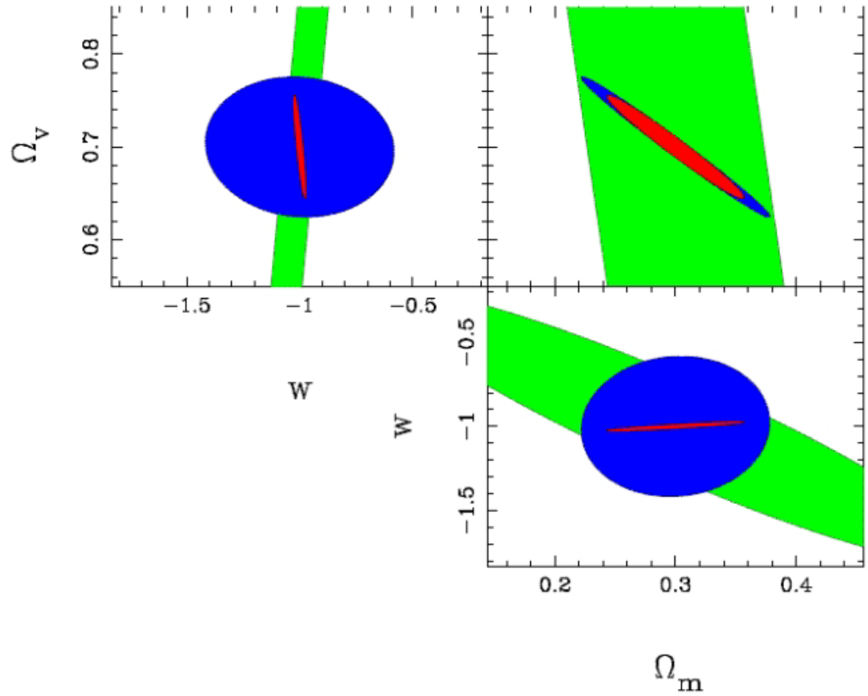

Figure 2: Expected cosmological parameter accuracies for 3-D dark energy geometric test.

The expected accuracy of the cosmological parameters, Ω_m, Ω_v, and w, *for an arbitrary Robertson-Walker cosmology from the darkCAM survey. The green regions are the results from the darkCAM survey, while the red regions show these conservatively combined with the expected four-year WMAP results (blue regions). Contours are one-sigma one-parameter confidence regions. The marginalised one-parameter one-sigma errors are* $\Delta w=0.03$.

The 3-D shear power spectrum and the geometric test are independent and complementary, in that the former probes the weak, linear lensing regime, where the shear signal is ~1%, while the geometric test probes the stronger, nonlinear lensing where the shear signal is ~10%. Hence the two methods can be applied to the same survey, independently probing the Dark Energy and providing a powerful test of systematic effects.

4.2.3 Controlling image quality

To realize a 1.9% measurement of w not only do we need a large enough survey, but we must also be able to control the systematics in the measurement of lens shear to $\Delta\gamma \sim 10^{-5}$. The current generation of lensing surveys, with telescopes not designed for lensing, induce 10% distortions, which can be corrected down to 0.01% with current technology ($\Delta\gamma \sim 10^{-4}$; Heymans et al 2005). The darkCAM team have been involved with the design of the visible camera since 2001, and both VISTA and darkCAM have been designed as a single unit to minimize these distortions. Ray-tracing simulations of darkCAM on VISTA, with active optics and an Atmospheric Dispersion Corrector (ADC), show that we can expect a maximum induced distortion of <2% over the entire field of view and any zenith angle (see Figure 3). Active optics allows control of time-dependent distortions, while the ADC corrects for the differential distortion between galaxies and the different colours stars used to remove these distortions. Even with current weak lensing analysis methods this would be sufficiently accurate to measure w and w_a to an accuracy of 1.9%. In practice, we are developing a new generation of weak shear analysis methods which will improve the correction of telescope-induced distortions by yet another order of magnitude. It is worth noting that systematics in the darkCAM lensing survey can be directly measured and removed by measuring the curl, or B-mode, of the shear signal which cannot be generated by gravitational lensing. Hence, by design, darkCAM and VISTA are well within the specifications required for a 1.9% measurement of w and w_a.

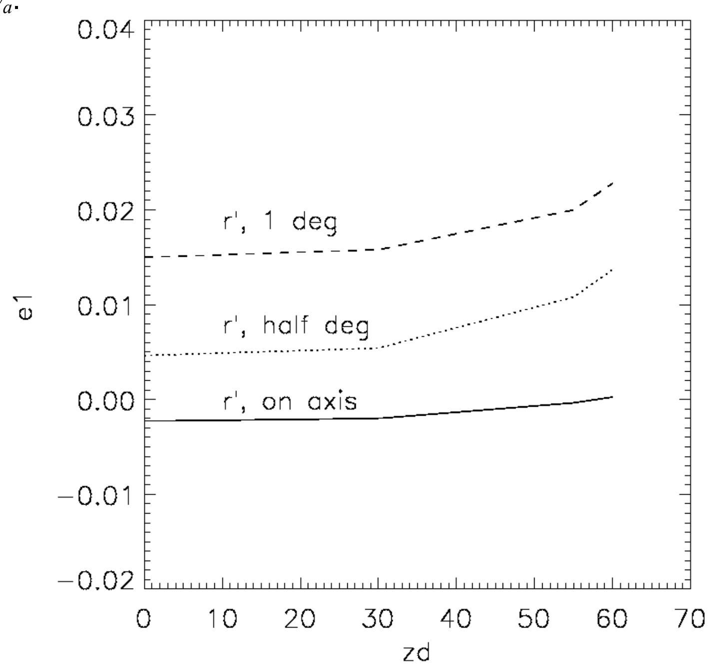

Figure 3: Simulation of the induced distortions in the darkCAM and VISTA system.

Simulation of the optical distortion induced by the darkCAM and VISTA system as a function of angular distance in degrees from the zenith (zd) in the r'-band with an ADC. The solid line is on the focal plane axis, the dotted line for half a degree from the centre of the focal plane, and the dashed line is 1 degree from the centre of the focal plane. The raw darkCAM and VISTA PSF has been convolved with 0.7" seeing and the second moment of the final PSF calculated and converted to an ellipticity, e1, used in a gravitational lensing analysis. At all zenith angles and across the focal plane the induced distortion is less than 2%. Removing the ADC results in the induced distortions increasing by a factor ~10. Active optics on VISTA will allow us to maintain image quality.

4.3 A Dark Matter Survey with darkCAM

4.3.1 A 3-D dark matter map

In addition to measuring Dark Energy, a darkCAM weak lensing survey can be used to construct a large-scale 3-dimensional map of the Dark Matter distribution (Taylor 2001, Bacon & Taylor 2003, Taylor et al 2004). This has already been demonstrated on the COMBO-17 survey (Figure 4). A 10,000 square degree survey would allow a huge volume of the Dark Matter distribution to be reconstructed in 3-D. With a 3-D lensing map, one can accurately and directly measure the Dark Matter power spectrum, independently of any assumptions of how galaxies trace the Dark Matter. The detailed shape of the Dark Matter power spectrum yields direct information about the nature of the Dark Matter, whether it is self-interacting, couples with baryons or the Dark Energy, or once had a significant velocity dispersion. In addition the shape of the matter power spectrum will yield information on the absolute mass of neutrinos, complementing laboratory measurements of the mass-squared differences. Measurement of the 3-D Dark Matter power spectrum will also pin down the amplitude of Dark Matter clustering (and how it changes as function of scale, parameterized by σ_8 and n_s, to a few percent. These are poorly measured by the CMB and are important for constraining models of cosmological Inflation.

With a 3-D Dark Matter map one can make a detailed comparison of the galaxy and Dark Matter distributions, including the occupation distribution of galaxies in Dark Matter haloes, and compare with

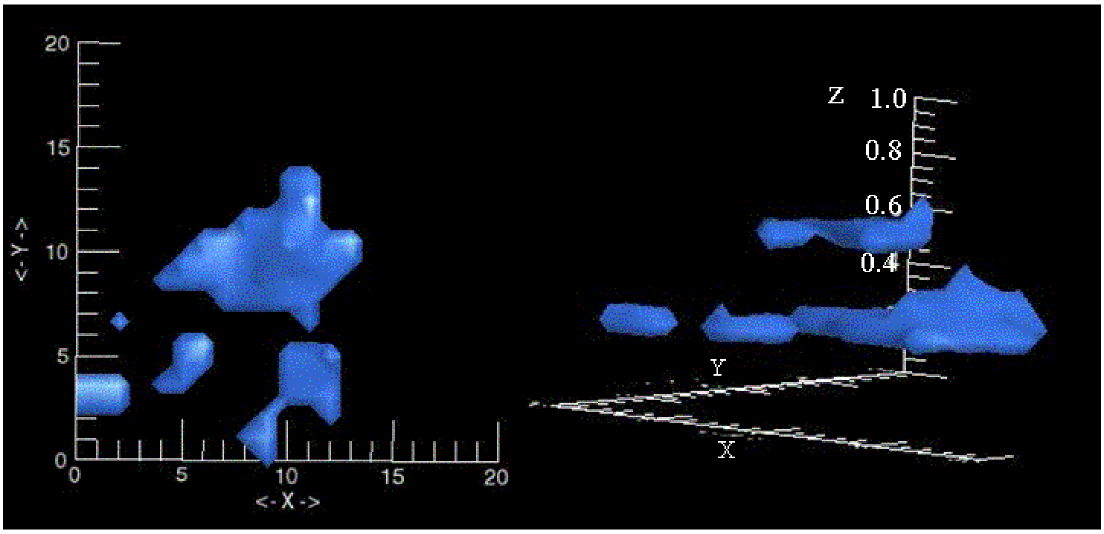

Figure 4: Three dimensional iso-surfaces of the Dark Matter distribution

Three-dimensional iso-potential surface plots of the dark matter distribution for the supercluster Abell 901/2 in the COMBO-17 survey. The coordinates of the map are (x,y,z)=(θ_x,θ_y,z), which distorts the map geometry. Note that the x-y axes are in pixel units, where $\Delta x = \Delta y = 1.5$ arcmins and redshift bins are $\Delta z = 0.05$. The plots are filtered on the scale of the pixels. LHS: The dark matter field, seen from high-redshift looking back to z=0 and RHS: at an oblique angle. The supercluster A901/2 is seen as a sheet in the lower part of the RHS map. A new cluster, CB1, is clearly seen as an isolated structure behind A902 at z=0.48.

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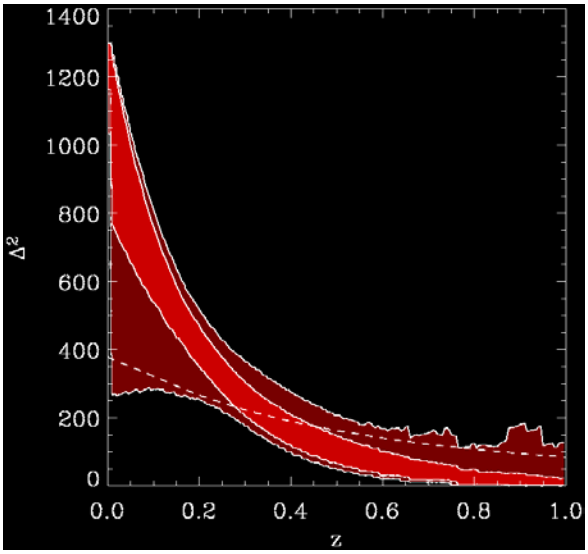

Figure 5: Evolution of the Dark Matter power spectrum.

The measured evolution of the matter perturbation power spectrum, $\Delta^2(k)$, at fixed wavenumber, k, as a function of cosmological redshift, z, from COMBO-17. The lighter (red) shading is the 1-sigma confidence region, while the darker (red) shading shows the 2-sigma confidence region. The evolution of the matter power spectrum has been achieved by analysis of the change in the cosmic shear signal with redshift. The dotted line is the expected Dark Matter clustering evolution.

semi-analytic models of galaxy formation. In addition, by selecting peaks in the matter distribution a mass-selected cluster survey can be constructed in 3-D, removing the main source of contamination due to mass projection in 2-D cluster lensing surveys. Such a mass-selected cluster survey would have a large number of applications such as the detailed evolution of the Dark Matter halo abundance, $n_H(M,z)$, which will allow tests of the currently popular halo model, as well as directly probe the galaxy halo occupation number for a range of halo masses.

4.3.2 The evolution of Dark Matter clustering

A fundamental calculation of Cosmology is of the evolution of matter perturbations due to gravitational instability. While this can be inferred from the evolution of cluster abundances, or by comparing the amplitude of galaxy or mass clustering in the local universe with the high-redshift universe probed by the CMB, this is indirect and dependent on the assumed nature of the Dark Matter. However, the gravitational lensing shear signal can be inverted to measure the evolution of Dark Matter clustering directly. This has been carried out with the COMBO-17 survey (see Fig. 5 from Bacon et al 2004) which seems in line with expectation, but which assumes the WMAP values for the background cosmology and power spectrum shape. A model-independent analysis of this would marginalize over all cosmological parameters to isolate the evolution of the Dark Matter perturbations and directly test gravitational instability and Einstein gravity

4.3.3 Galaxy formation efficiency and environment

3-D mass-density estimates from lensing may be combined with observations of numbers of galaxies separated into morphological type and colour to give valuable detail on environmental effects on galaxy formation and evolution (Gray et al, 2005). These, in turn, can be used to test semi-analytic models of galaxy formation.

4.3.4 Galaxy-galaxy lensing analysis

In addition to a weak lensing analysis, the darkCAM survey will also be used for galaxy-galaxy lensing, where the statistical effect of gravitational lensing around galaxy dark matter halos can be studied. This can be used to probe the Dark Matter halo profile and shape around galaxies. In addition the UK has pioneered the study of higher-order lensing effects, including the flexion (lens-induced curvature of galaxy images; Bacon et al 2005) which can be used to study the details of the Dark Matter distribution around galaxies and clusters.

4.3.5 3-D bispectrum analysis

Efforts are underway to determine the effectiveness of 3-D, 3-point statistics of weak lensing. In 2-D, 3-point statistics can improve parameter estimation by lifting some partial degeneracies. In 3-D the degeneracies are much less important, but parameter estimation may be improved still further.

4.4 darkCAM and the VISTA-IR survey

So far we have only considered the scientific value of a five-band photometric redshift visible survey with darkCAM. But by 2009 VISTA will have been carrying out infrared surveys (Y, J, H, and K_s) with the VISTA IR camera for 2 years, starting in early 2007. The VISTA IR surveys are likely to include both a narrow and deep survey and a wide shallower survey. The specifications of the wider survey have not yet been fixed, but in principle the VISTA IR survey could have covered 1000 square degrees to z=1. The VST survey will, by this time, be struggling to keep up with VISTA-IR. DarkCAM will be able to match well the VISTA-IR survey in both quality and speed. For a 3-D lensing analysis, this will provide a 9-band photometric galaxy redshift survey (5-band optical in g', V, r', i' and z', and 4-band IR in Y, J, H and K_s) with percent redshift accuracy over the range z=0.1 to z=1 and very significant improvements in the photometric redshift errors for sources beyond redshift z>1. We outline the wider scientific value of a 9-band photometric galaxy redshift survey in Section 4.5.

It is worthwhile noting here that the VISTA-IR camera itself, with Y, J, H and K_s band, would be of limited use for a weak lensing analysis as the brighter sky background in the IR would confuse the detection of fainter sources. In addition the field of view of the IR-detector is a factor of 3 smaller than darkCAM, and the larger pixel size (0.31") of the IR camera means that the Point Spread Function (PSF), required to correct the induced distortions, could not be accurately measured.

Finally, the synergy of darkCAM and the VISTA-IR camera may also enhance the efficiency of the VISTA telescope. With only the IR camera installed on VISTA, if that camera develops an unforeseen problem, VISTA might be idle until it can be repaired. With darkCAM interchangeable on the timescale of a day, darkCAM can swiftly be brought into operation during any time the IR camera is being repaired, and vice-versa.

4.5 Wider scientific value to the UK community

PPARC's science strategy recognises that the unravelling of the nature of the Dark Energy and the Dark Matter in the Universe are its top priorities. 3-D weak lensing addresses both of these issues and promises the most accurate determination of the equation of state of Dark Energy of any method currently known.

A multi-band, wide-area visible survey with good photometric redshifts and exquisite image quality has many cosmological and other astronomical applications. In particular such a Legacy Survey would provide the UK community with an up-to-date large galaxy imaging and photometric redshift survey nearly a decade after the 2dFGRS and SDSS surveys. DarkCAM proprietary data would also be made available to all UK users via an archive for other visible survey programs, including those required in support of the VLT, or to complement VISTA's IR surveys.

Other science programmes include:

- determination of the neutrino mass from the shape of the matter power spectrum
- galaxy cluster masses for comparison with Sunyaev-Zeldovich studies
- the large-area galaxy survey with photometric redshifts to z~1 will be invaluable for studies of
    - evolution of galaxies and their clustering
    - low surface brightness galaxies
    - micro-Jansky radio sources
    - Planck and XMM galaxy clusters
    - submm sources
    - star formation
    - galaxy formation theory, via the evolution of galaxy bias
    - high-redshift quasar detection and evolution.

DarkCAM could also be used to probe local galaxies, QSO monitoring, the Local Group, brown dwarfs, white dwarfs, the outer solar system, radio AGN, space sub-millimeter sources, high-z supernova, microlensing, high-redshift clusters, damped Lyα systems, gravitationally-lensed quasars, exo-planets, globular clusters, halo RR Lyraes, and YSO variability, and to complement Hα surveys.

4.5.1 darkCAM and the Planck Surveyor

Much of the power of WMAP came from its combination with the 2dF Galaxy Redshift Survey. Despite its much greater resolution, a similar situation will also arise with the Planck surveyor, due to intrinsic degeneracies between parameters measured at the surface of last scattering. In our Dark Energy analysis of Section 4.2, we combined the darkCAM lensing survey with the expected four-year WMAP and Planck data. Note that even Planck data alone will not yield tighter constraints on $w(a)$.

However, if darkCAM in mounted on VISTA by 2009, the weak lensing survey would benefit from the Planck Survey, due to begin in 2008. While Planck will reach a much higher resolution of the CMB than WMAP, it will suffer many of the same degeneracies, even with polarization (see below). In particular, the CMB is insensitive to Dark Energy, as it only tells us about the state of the high-redshift universe, although some low-redshift information will leak into the CMB via gravitational lensing due to intervening large-scale structure. As the CMB is the highest redshift image we can see, this is the ultimate lensed background. Although the darkCAM and Planck surveys will be powerful on their own, combined they will be even stronger. For example, as well as enhancing the measurement of $w(z)$, darkCAM and Planck will pin down the amplitude of Dark Matter clustering, σ_8. This amplitude is the limiting degeneracy for measuring not only the optical depth τ and the re-ionization redshift, but also the spectral slope of dark matter clustering, which is predicted by models of Cosmological Inflation. Other studies have shown that the combination of lensing and CMB is also a strong probe of neutrino mass.

4.5.2 darkCAM and CMB Polarization

As well as the Planck survey of fluctuations in the temperature field, attention is beginning to shift to surveys of the CMB polarization field, via surveys such as the groundbased QUaD (starting 2005), BICEP (starting 2005), and CLOVER (starting 2008) surveys, and Planck's own polarization survey. The CMB polarization can be decomposed into two types, the even-parity E-modes and odd-parity B-modes, where the former is generated by the density field, while the latter can only be generated by gravitational lensing turning E-modes into B-modes and, more importantly, primordial gravitational waves generated during a period of Cosmological Inflation. The E and B gravitational lensing signals can be correlated with the darkCAM weak lensing survey, just as the temperature field can be, and will again enhance the measurement of cosmological parameters. But in this case lensing is also a contaminant for the detection of the B-mode gravitational wave signal. The darkCAM weak lensing survey can be used to remove a significant fraction of this lensing contamination of the B-modes, allowing a more accurate search for the primordial gravitational wave signal from Inflation.

4.5.3 The darkCAM Galaxy Photometric Redshift Survey

The darkCAM survey will also yield a large-scale galaxy 5-band photometric redshift survey, covering 10,000 square degrees yielding some 10^9 galaxies with a median redshift of z=0.7. This compares with the Sloan Digital Sky Survey (SDSS) photometric survey of ~10^6 galaxies over 10,000 square degrees and depth z=0.2. With such a survey it becomes possible to measure galaxy clustering evolution, and more excitingly, the acoustic baryon oscillations in the galaxy power spectrum as a function of redshift. This will allow an independent measurement of the Dark Energy from the angular distance between the acoustic oscillations, albeit with lower accuracy than the main 3-D lensing survey.

4.5.4 The darkCAM Galaxy Cluster Survey

The darkCAM photometric redshift survey can also be combined with surveys aimed at detecting the thermal Sunyaev-Zel'dovich (tSZ) effect in the CMB, such as the South Pole Telescope (SPT) SZ survey and Planck. The tSZ results will yield estimates of the cluster masses, which can be compared with those of the cluster lensing survey, while the darkCAM photometric redshifts will provide the redshifts to these clusters. This information will provide a major database for galaxy cluster studies.

4.5.5 Spectroscopic follow-up of darkCAM galaxies

The multicolour darkCAM survey will provide large numbers of colour-selected targets for follow-up, such as with VLT spectroscopy and imaging. Scientific areas are listed at the beginning of this section.

5. Comparison with similar past, present and future experiments

A number of other experiments have similar aims of probing the dark energy of the universe. Here we compare darkCAM with current, future and proposed experiments.

Figure 6 compares the effective Grasp (un-obscured collecting area times the field of view) for darkCAM on VISTA, CFHT, VST, Pan-STARRS, CTIO and the LSST, while Table 1 gives a more detailed breakdown of telescope parameters. If built, darkCAM on VISTA will be the leading weak lensing-quality and visible survey telescope in the world from 2009 until the LSST. Below we describe in detail each survey.

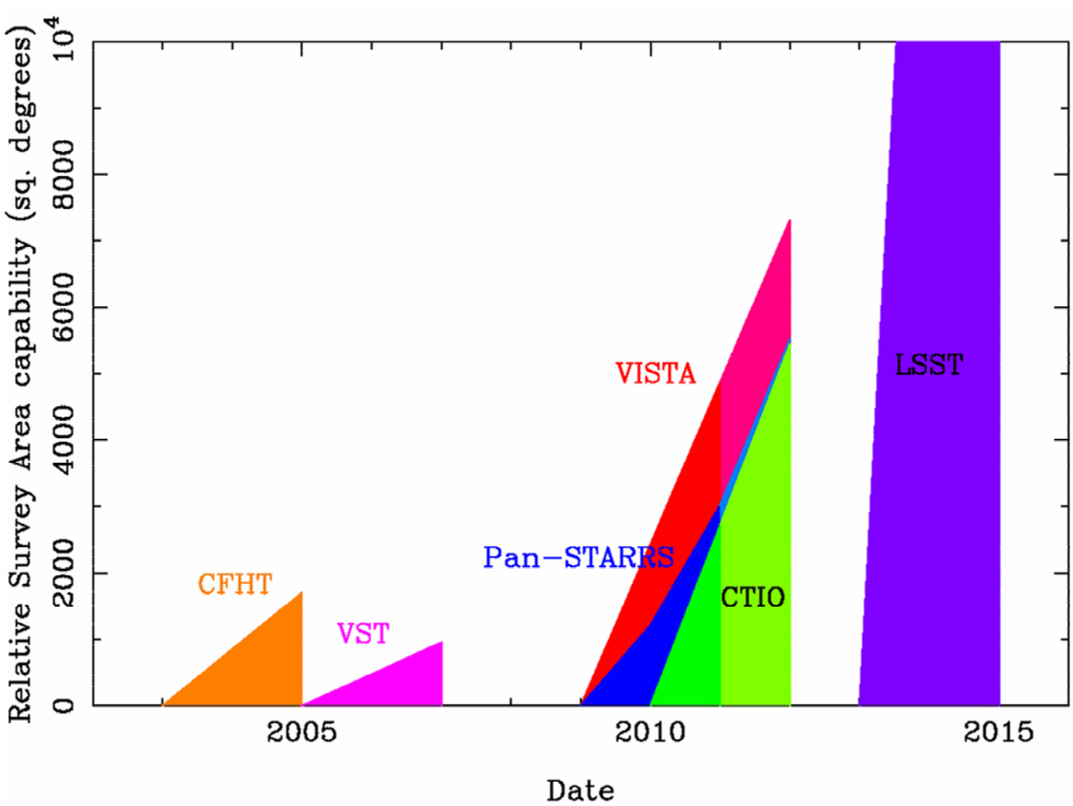

Figure 6: Comparison of telescopes capable of weak lensing surveys.

Wedges show the relative effective increase of area (in sq deg) mapped by each telescope over a two or three year period for the same survey depth, z=0.7. The estimate is based on quoted telescope primary mirror area taking account of central obscuration, field of view and proposed starting date (see Table 1). We have assumed that lensing surveys with darkCAM on VISTA and Pan-STARRS (with initially two telescopes and adding one per year) will start early in 2009, and that CTIO will start in 2010, although the latter two have not yet completed a Phase A study. Note that Pan-STARRS will only devote 30% of its time to a weak lensing survey. We have shown both a 2 year survey (dark shading) and a 3 year survey (light shading) for VISTA, Pan-STARRS and CTIO. Finally, we have assumed LSST will be operational beyond 2012.

Table 1: Table of effective telescope specifications for weak lensing surveys.
Table showing effective telescope diameter including obscuration due to secondary mirrors and baffle (20% for CFHT, 25% for darkCAM on VISTA and DES, and ~35% for Pan-STARRS and LSST), the effective Field of View (FoV) tesselated by CCD's including chip gaps, the Grasp (collecting area=$\pi D^2/4$ times FoV), expected starting time, proposed survey area, depth and number of pass-bands. Bracketed entries are not yet funded. Where detailed telescope specifications are not known we have scaled from similar instruments.

Name	D(m)	Fov (sq deg)	Grasp (AreaxFov)	T (year)	Area (sq deg)	Depth (z)	Photo-z (bands)
VISTA	**3.7**	**2**	**21.5**	**2009**	**10,000**	**0.7**	**5 + 4(IR)**
VST	2.3	1	4.2	2006	1,700	0.7	5
CFHT	3.2	0.93	7.5	2003	170	1.17	5
DES	3.5	2.5	24	2009	5,000	0.7	4
PanS. (1)	1.4	5.5	8.5	2006	10,000?	0.7?	3
(PanS. (2))	1.9	5.5	16	(2009?)	?	?	3?
(PanS. (3))	2.4	5.5	24	(2010?)	?	?	3?
(PanS. (4))	2.8	5.5	33	(2011?)	?	?	3?
(LSST)	6.2	5.5?	166	(2015?)	?	?	?

5.1 Current Weak Lensing Surveys

- **CFHT:** The Canada-France-Hawaii Telescope (CFHT) Legacy Survey is currently underway on a 3.6-metre telescope with a 1 square degree field of view. Its main lensing survey is around 170 square degrees with median redshift z=1.17 in five broad bands, and is due to be completed 2006. However, its 'grasp' (Area x FOV) is 2.5 times less than darkCAM on VISTA and, since the telescope was not designed with lensing in mind, its image quality is poorer. Indeed the CFHT consortium is spending a considerable amount of effort in trying to improve the image quality to a usable standard. Finally, the survey design itself is not optimal for probing dark energy, being too deep and not wide enough for the time allocated. CFHT is the largest lensing survey underway, but cannot get near the accuracy planned with darkCAM.
- **VST:** The VLT (Very Large Telescope) Survey Telescope (VST) is a 2.6-metre telescope with a 1 square degree field of view using blue-optimized CCD's. Its image quality is expected to be excellent. It is planned to operate for 10 years from 2006. Its main survey is proposed to be 1,700 square degrees with median redshift z=0.7 in five broad bands. darkCAM on VISTA will be about 8 times faster than VST, due to the larger collecting area and field of view, and more efficient CCDs. The VST survey will yield a valuable cosmic shear survey, but will only reach an accuracy of 10% on w.

5.2 Competing Weak Lensing Surveys

The major direct competition to the darkCAM on VISTA survey comes from the proposed Dark Energy Survey (DES), and the Hawaiian Pan-STARRS telescopes.

- **DES/CTIO:** The Dark Energy Survey (DES) project is a proposal for an optical camera to be mounted at the prime focus of the 30-year-old Blanco 4-metre Cerro Tololo Inter-American Observatory (CTIO) telescope in Chile. The current camera will be replaced at prime focus with a wide-field camera and corrector with a 3-square degree field of view, due 2009-2015. The main competition to darkCAM is a 5,000 square degree survey in four optical bands (g', r', i' and z') to a median depth of z=0.7, taking around 650 nights. DES's main goal is to probe the Dark Energy by cluster evolution, using mass estimates from the thermal Sunyaev-Zel'dovich (SZ) survey planned for the South Pole Telescope (SPT), with DES supplying the cluster distances from the photometric redshifts. They will use the abundance of rich clusters as a function of redshift as a cosmological test, but this is prone to systematic errors arising from the completeness of cluster samples, cluster evolution and from the complex physics of the intra-cluster medium which is not fully understood in the nearby universe. DES also originally proposed a weak lensing survey, but this no longer seems a high priority due to concerns over the CTIO image quality, following the final instrumental review (see http://decam.fnal.gov/). The DES camera will not have active optics, unlike darkCAM, and so cannot correct for time-dependent distortions induced by the telescope flexing. Also the DES camera will not have an Atmospheric Dispersion Corrector (ADC) and so galaxies and stars, having different colours, will be distorted differently. As stars are used to correct for image distortion, this limits DES for weak lensing. Finally, the photometric redshifts will be optimised for measuring galaxy cluster redshifts and so are expected to be cruder, further limiting a 3-D lensing analysis.
- **Pan-STARRS:** The US Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) is a proposed system of four 1.8 metre telescopes (equivalent to a single 3.6m telescope) each with a 7 square degree field of view. The camera will have five filters (u', g', r', i' and z'). Pan-STARRS' main goal is to monitor the sky for Earth-approaching objects for the US Air Force, and only has 30% of its time for a dedicated lensing survey. Only the first telescope is currently funded (and due in 2006). Thereafter, the US Air Force will review funding subsequent telescopes on completion of its all-sky monitoring surveys. In addition, the proposed weak lensing survey will be only in three filters with no current plans to acquire photometric redshifts and apply a 3-D analysis. This severely restricts the power of Pan-STARRS for Dark Energy studies (see

http://pan-starrs.ifa.hawaii.edu/public/science/cosmology.html). With its single 1.8m telescope, Pan-STARRS could complete a 10,000 square degree survey in 600 nights with a median depth of z=0.7 in 3-band. However such a Pan-STARRS survey will be of limited use for probing Dark Energy unless its science goals are changed. If Pan-STARRS does get further Air Force funding for subsequent telescopes, and changes its survey strategy to match that of the darkCAM survey, it alone will be darkCAM's main competitor.

5.3 Future Surveys

- **LSST**: the Large Synoptic Survey Telescope is an excellent design for probing the dark sector via 3-D weak lensing. However, it will not begin science until >2012, so there is an opportunity for VISTA to achieve the main science goals before LSST.
- **SNAP/DUNE**: the Supernova Acceleration Probe, if funded, could also act as an excellent space-based 3-D weak lensing instrument. Once again, the timescale is long (>2014). The European equivalent (DUNE) is in the same situation.

5.4 Relation to other Probes of Dark Energy

KAOS/KMOS and VIRUS: The KAOS on Gemini, KMOS on the VLT and VIRUS (Visible IFU Replicable Ultracheap Spectrograph) projects propose to measure w from the change in recently measured baryon oscillations in the galaxy power spectrum with redshift. As remarked in Section 4.1, methods to measure w via the imprint of baryon oscillations on the matter power spectrum may be problematic, but this is a useful and complementary way to study Dark Energy. The prospects appear to be less good than 3-D weak lensing (Blake & Bridle 2004), with earlier optimistic estimates requiring a redshift survey around ten times the size of SDSS at z=1 producing an (unmarginalized) error on w alone (not including w_a) of around $\Delta w\sim5\%$.

5.5 Risks of Delay to darkCAM

Pan-STARRS is potentially the most effective weak lensing survey outside darkCAM. At present, they have no plans to analyse in 3-D, but they will have the data to do so, albeit without the accurate photometric redshifts which the VISTA IR will add to darkCAM. It seems inevitable that they will analyse the survey with the 3-D techniques developed in the UK. It is important that darkCAM is funded soon, otherwise there will be no serious UK or European involvement in the most important cosmological studies of the next decade. The UK must be bold in the same way as it was with the 2dFGRS a few years ago, rather than delaying as was the case for the VSA analysis of the CMB.

6. Relationship with ESO

The darkCAM consortium will provide ESO with the darkCAM camera for VISTA. Subject to negotiations with ESO, which are currently in progress, we expect ESO will support darkCAM on VISTA and exchange darkCAM and the VISTA-IR camera when scheduled. In return, subject to negotiation with ESO, we ask ESO for 150 nights per year with darkCAM on VISTA over 4 years for a private weak lensing survey. This is based on our estimate of the value of darkCAM when measured in units of VISTA nights. This number of nights also matches our scientific needs. The data from these nights will be available for the use of the darkCAM lensing consortium and the UK for a proprietary period. Access to the data for other scientific programmes is subject to discussion.

7. Timescales

The conceptual design of the camera was completed during VISTA's Phase A, and darkCAM could be built and installed on VISTA within 4 years, i.e. by end 2009. We envisage a multicolour weak lensing survey to obtain precision imaging and photometric redshifts, requiring around six hundred nights and achievable over 4 years. Such an allocation of nights should be negotiable from ESO in return for darkCAM, following their usual procedures for instruments provided. If approved in the near future, darkCAM could accurately measure the Dark Energy parameters ahead of its competitors, and to higher accuracy.

8. Data Processing

8.1 Data Pipeline and Archive

The darkCAM data calibration can be carried out using the framework of the UK VISTA IR pipeline at the Cambridge Astronomical Survey Unit (CASU, IoA, Cambridge), and the darkCAM archive will be based at Edinburgh's Wide-Field Astronomy Unit (WFAU, Edinburgh), along with the UK VISTA IR archive. At the Edinburgh WFAU Archive the IR and darkCAM catalogues will be data-base driven, pairing and pre-associating objects and providing list-driven photometry, matching detections and upper limits, in different catalogues in different bands. This will also yield a uniform, seamless, mosaiced survey with accurate relative astrometry for proper motion studies. The archive will provide a fast, reliable, user-friendly interface which will become publicly available. This will feed into the Virtual Observatory (VO).

Some development of the existing VISTA IR pipeline will be necessary to handle CCD data rather than IR array data. This is further detailed and costed in Work Package 11 (see Annex A).

8.2 Lensing Pipeline

The UK darkCAM lensing consortium will be responsible for providing the software for reduction of calibrated darkCAM images for a lensing analysis. The default plan is that this will be incorporated into the processing at WFAU, for which funding will be sought through normal grants.

9. Technical Case

The baseline design for darkCAM is a Cassegrain field corrector, similar to that used in other wide field imagers but distinguished by its large size and field of view. The simple optical system gives a high throughput and offers:

- A design which was used to optimize both the existing M1 and M2 VISTA telescope mirrors and to optimize the corrector elements within the instrument for large field of view and excellent resolution. Together with the inclusion of a single aspheric surface this gives darkCAM a 2.1 degree field of view with outstanding spatial resolution.
- A large solid state focal plane with 50 large format (4.6kx2k) charge coupled detectors - a single science image covering 1.96 sq degrees will have approximately 400 million pixels.
- An optical solution with relatively little optical power thus reducing the susceptibility to misalignment.

A summary of the key science parameters that the technical solution needs to meet are given in Table2.

Table 2: Summary of baseline science parameters and values for the darkCAM instrument

Parameter	Baseline Design Value
Throughput	≥ g' 0.4; r' 0.38; i' 0.31; z' 0.2; V 0.41
CCD wavelength coverage	400 to 1000nm
Camera Image Quality B-z' band	50% EED 0.32", 80% EED 0.46" (Telescope System 50% EED is 0.4")
Pixel Scale	0.232" per 13.5 micron science detector pixel
Broad Band Filters	Minimum choice of 10 positions including delivery of: g', r', i', z', V and a blocker
Optical Coverage	Unvignetted field of view ≥ 2.13 deg. 1.96 sq deg sampled by CCDs
Shutter Exposure	Minimum one second (Goal 0.5 seconds) maximum 15 min

Detailed descriptions of the instrument concept are given in the documentation set listed in Table 3. During the initial stages of the Preliminary Design Phase advantage will be taken of the extensive work achieved on the VISTA IR camera to ensure that wherever possible, experience of work already done by the IR camera team is exploited (e.g., Wave-Front Sensors, Telescope Interface definitions, knowledge of ESO software and electronics).

Table 3: List of applicable documents from the VISTA Visible Camera Phase A study*.*

Document No.	Document Title	Authors
VIS-TRE-ATC-07000-0001	Visible Instrument Description	D Henry
VIS-TRE-ATC-00112-0006	Optical Design of VISTA Visible Instrument	S Worswick
VIS-TRE-ATC-00112-0007	Testing and Alignment of IR and Visible Instruments	E Atad & S Worswick
VIS-TRE-ATC-00112-0008	Visible Camera Scattered Light & Ghosts Analysis	B Patterson
VIS-TRE-ATC-00112-0004	Specification of Filter Requirements	B Patterson
VIS-TRE-ATC-00180-0003	Temperature Requirements for the VISTA Cryostats	M Casali
VIS-TRE-ATC-00120-0003	Visible Instrument Conceptual Mechanical Design	K Burch
VIS-TRE-ATC-00120-0005	VISTA Instrument Handling	D Montgomery
VIS-TRE-ATC-00130-0002	VISTA Detector and Controller Conceptual Design Specification	W Sutherland & M Casali
VIS-SPE-RAL-07021-0002	Visible Detectors and Controllers	G Woodhouse & N Waltham
VIS-TRE-ATC-00180-0004	Instrument Mechanism Controllers Conceptual Design	K Laidlaw
VIS-TRE-ATC-00180-0005	Concepts for Guiding Focussing & Wavefront Sensing	M Casali
VIS-TRE-ATC-00112-0003	Report on Curvature Sensing	B Patterson
VIS-TRE-ATC-00150-0001	VISTA Software Architectural Design	M Stewart
VIS-TRE-ATC-00150-0002	VISTA Computer Hardware Architectural Design	M Stewart
VIS-TRE-ATC-00150-0003	Instrument Software Requirements	S Beard, D Kelly, M Stewart

Documents are available to download from http://www.roe.ac.uk/atc/projects/vista/software/darkcam using (username: guest; password: 48darkcam).

The main assemblies of darkCAM are: the front baffle assembly; lens barrel assembly; the filter mechanism assembly; the shutter mechanism assembly; and the focal plane unit assembly. A cross-section of the conceptual design of darkCAM is shown in Figure 7. Note no moving cryogenic mechanisms are employed. The assemblies are described in more detail in the following sections.

9.1 Lens Barrel Assembly

The lens barrel assembly comprises of the Lens 1 sub-assembly, the ADC (Atmospheric Dispersion Compensator) mechanism sub-assembly (Lens 2&3), the main lens barrel of darkCAM and the remaining optical elements of the field corrector (Lens 4 & 5) in their lens mounts. The ADC mechanism comprises the ADC lenses, the housing for mounting the lenses, the motors and the mechanism controller. The ADC lenses are a pair of large doublet lenses with small wedge angles in the lens elements. The lenses counter-rotate around the optical axis to provide the required atmospheric correction. A DC servo motor is used to move the lenses and hold them in position. The angular accuracy to which the ADC lenses have to be aligned is 1°. The optical components required for darkCAM are a fused silica lens (L1), an Atmospheric Dispersion Corrector (ADC), made of 2 cemented doublets of BK7 and N-LLF6 (L2 and L3), two fused silica lenses (L4 and L5), strip filters, and a fused silica cryostat window. Since the original design was completed N-LLF6 has been removed from production. However, the design has been updated using a replacement glass. All the surfaces of the lenses are spherical except the last lens, L5, which is aspheric and located on the concave surface to control the astigmatism in the design. The optical layout in Figure 8 shows the ray-tracing of the on and off-axis rays.

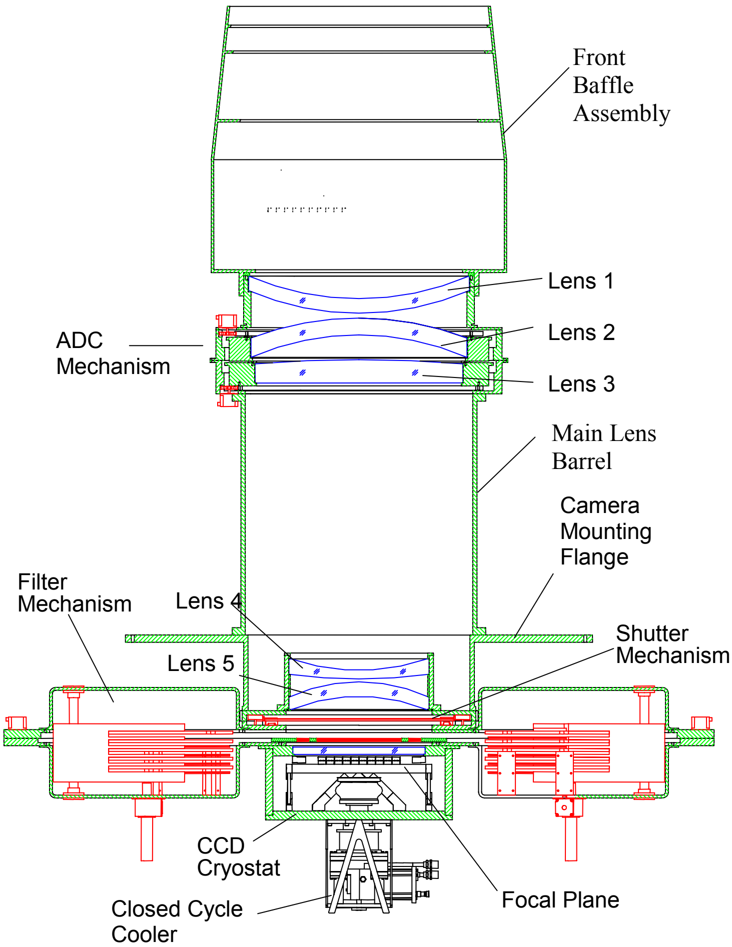

Figure 7: Cross-section view of darkCAM concept.

The Front Baffle Assembly provides control of stray light into darkCAM by means of annular stops and is bolted to the lens assembly on the ADC. The lens barrel also contains internal annular baffles to control stray light. The complete ADC assembly is attached to the lens barrel which in turn connects to the camera mounting flange. The remaining elements of the field corrector (in their housings) are located within this flange.

The camera mounting flange provides the main structural mounting of darkCAM and forms the mechanical interface between the camera and the Cassegrain rotator (which is situated on the telescope). The other main assemblies of darkCAM (shutter mechanism, filter mechanism and focal plane assembly) are mounted below the flange.

9.2 Shutter Mechanism Assembly

A shutter mechanism is used to provide accurate control of the exposure time of the CCD arrays, and to enable the arrays to be blanked off from light. The mechanism consists of two large carbon fibre panels, a pair of linear slideways to support the panels, and two DC servo motors each driving a single panel via a toothed belt. Proximity switches or equivalent devices shall be used to indicate the datum position and end of travel for each panel. The motors provide a constant velocity of each panel across the optical path. The shutters are shaped to allow the autoguider to be exposed without exposing the science arrays to direct illumination.

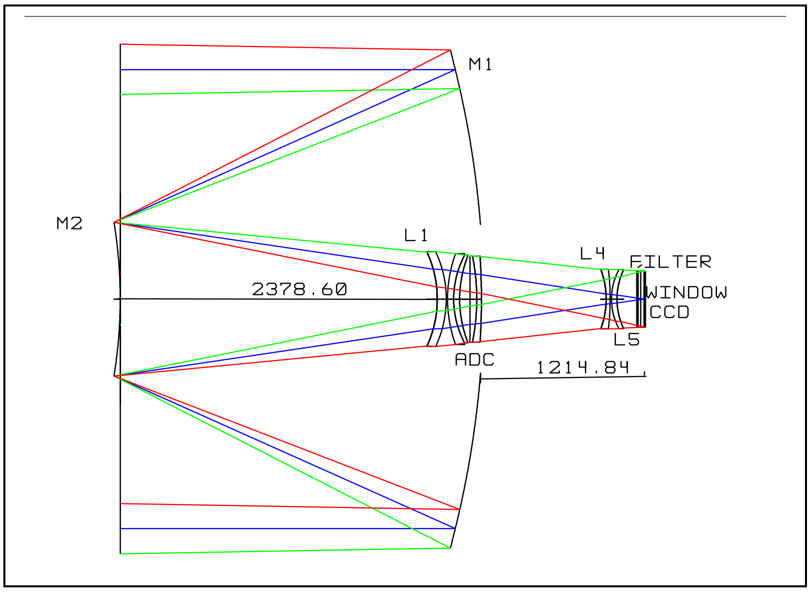

Figure 8: Optical layout of the telescope and darkCAM

9.3 Filter Mechanism Assembly

The filter deployment mechanism consists of two carousel boxes that will be used to deploy a minimum of ten filter positions. Each filter holder includes a unique machine readable identifier. When a filter is selected for an observation, a screw jack moves the appropriate stack of filters vertically until the correct filter is in line with a catchment device. The selected filter is removed from the stack and positioned accurately in the optical path by means of a linear slideway. A proximity switch is used to detect the datum position for both vertical and horizontal movement.

9.4 Filters.

The instrument contains a number of filters. These are mounted in a cassette mechanism which allows deployment of these filters in the optical beam. The baseline filter set is g', r', i', z' and V along with an ND + r' sandwich filter and an opaque "filter". The opaque filter will be housed in a duplicate filter holder and in all physical dimensions conform to the science filter design. In addition, a filter position will be used to position beam splitting optical elements to allow High Order Curvature Sensing (HOCS) to be carried out on the science detector focal plane.

9.5 Focal Plane Unit Assembly

The focal plane unit assembly contains the CCD detectors, the detector controller, the cryostat and window, the detector pre-amps and circuitry, the closed cycle cooler, temperature sensors, cabling and connectors. The focal plane unit also contains all of the hardware (optics, CCD detectors and mechanical mounts) for the autoguider and wavefront sensors. The baseline for the science detectors are E2V CCD42-90 sensors made of red optimized, deep depletion silicon with broadband response.

Figure 9 shows a layout of the conceptual design for the focal plane. The gap between the active areas of the large strips of CCD's is shown as 20mm. This allows separate filters for each strip of CCD's to be used (recent developments may allow larger filters to be used). The unvignetted field of view of the conceptual optical design (2.13 degrees diameter) is shown, together with the total field covered by the CCD's (2.15 degrees).

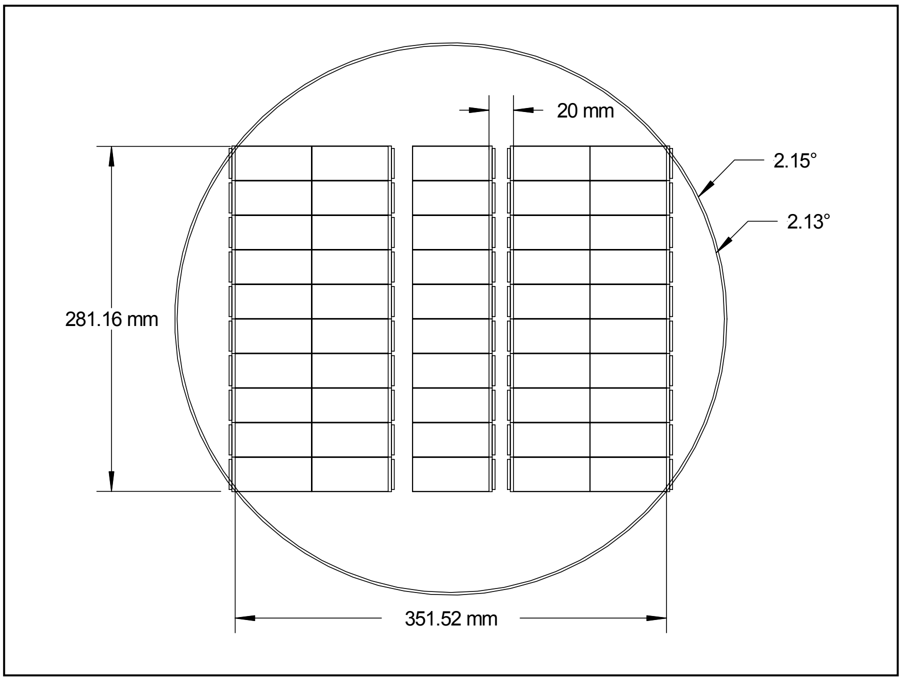

Figure 9 darkCAM – indicative CCD layout

9.6 Detector Cryostat and Window

The detector cryostat provides the mechanical mounting of all the components of the focal plane unit. It includes an optically transparent window to allow light to reach the detectors. The cryostat temperature is maintained at a constant temperature in the range 150-190K by means of a temperature controller (included in the detector controller). A closed cycle cooler provides the necessary cooling power. Temperature sensors are included in the cryostat to provide an input signal to the temperature controller.

9.7 Wavefront Sensors

As with the IR Camera for VISTA, there are three sensor functions required in darkCAM. The instrument contains the hardware necessary for sensing and production of raw data. Processing of raw data into error signals and feedback to the appropriate control mechanism is handled by one of the VISTA sub-systems. The concept for meeting the Wave-Front Sensor (WFS) requirements involves using the space either side of the science arrays to allow light to pass down onto two sets of Low-Order Wave-Front Sensors (LOWFS) and autoguiders. High-Order Wave-Front Sensors (HOWFS), which only needs to be initiated a few times per night, will be achieved by using the science detectors. Where effective, the design solution created for the VISTA IR Camera Wave-Front Sensor solution will be re-utilised.

9.8 Software

In use at the telescope, darkCAM will be a straightforward instrument requiring high-level software control and pipeline data quality analysis. The hierarchies of the IR and darkCAM instruments' software are essentially identical to each other and similar to the telescope control software. Mechanism control is performed by an Local Control Unit (LCU) and associated workstation, operating as a single system as viewed by other systems. Similarly detector control and data acquisition are performed by an LCU/workstation combination. This means that experience gained from working on the IR Camera software for the last three years can be utilised in meeting the darkCAM software design and integration tasks. The main difference between the two cameras is that darkCAM has three warm moving mechanisms rather than one cryogenic mechanism and that Fast Imager Electronic Readout Assembly (FIERA) rather than Infrared Array Control Electronic (IRACE) controllers will be used for controlling the science detectors.

10. New Technology

DarkCAM does not rely upon any new ground-breaking technology to achieve its advantage compared to other instruments in the time frame envisaged for its deployment. It establishes its lead against other instruments because of the foresight in designing VISTA to accept a visible camera. This includes a synergistic approach to the design by combining the optical elements within the telescope as well as the camera to produce a single system with a very large, high imaging quality field in the focal plane which is capable of accommodating a large number of detectors.

11. Industrial Benefits

DarkCAM will outsource several major components to commercial suppliers, not least the need to procure 50 science CCDs along with the five large optical elements required for the conceptual design. Further to the various procurement activities, sub-system integration will take place at the consortium member's sites prior to full system integration at the UK ATC. Table 4 indicates high value items for procurement.

Table 4: darkCAM high value procurement items.

Default Work Package allocation is given, but can be varied to accommodate other partners.

Work Package	Item	Source	Design & Sub-system Test
Mechanism Assemblies	Filters	Industry	RAL: specification UK ATC: procurement and integration
Optics Assemblies	Lenses 1-5	Industry	RAL
Wave Front Sensing	LOCS & Autoguider CCDs (6)	Industry	Durham
Focal Plane	50 Science CCDs	Industry	UK ATC

In all cases where reliance on long-lead or critical path items exist, close monitoring of the company in terms of schedule and quality will be maintained by the consortium member responsible for the design and acceptance of the item involved. By necessity of maintaining ESO compliance, it will be necessary to procure some items from a more limited set of sources typically electronic items. The one significant item here is the need to procure ESO compliant detector controllers for both the science CCDs and the WFS CCDs.

12. Operations

VISTA was designed from the first to accommodate two interchangeable cameras. Clearly with two cameras the frequency of camera mounting and dismounting will be higher than with one, leading to potential operational issues. As part of the design studies the efficiency of the mechanism of camera exchange will be investigated, and if necessary modifications to the existing exchange process proposed to enhance ease of interchange and safety of instruments and personnel.

At one extreme, it is unrealistic to propose exchanging cameras every dark time, while swapping every six months would limit the coverable range of RA. We propose swapping cameras every 6 weeks, requiring ~8 swaps per year, subject to further discussion with ESO, and will ultimately depend on the agreed science programme.

13. Management Plan

13.1 Management Structure

The construction consortium will bring together the combined expertise of instrument groups at each institute which have an established track record in building a range of instrumentation for 4-metre and 8-metre class telescopes. These include: VISTA IR (RAL/Durham/UK ATC), GMOS (UK ATC/Durham), GNIRS-IFU (Durham), WFCAM (UKATC), MICHELLE (UK ATC), CGS4 (UK ATC), UIST (UK ATC), AUTOFIB-2 (Durham), GMOS-IFU (Durham), FMOS (RAL, Durham, Oxford). This combined expertise covers important technological areas of expertise for the DarkCAM instrument including, WFS, detectors and instrument control. The project team structure is shown in the following organogram.

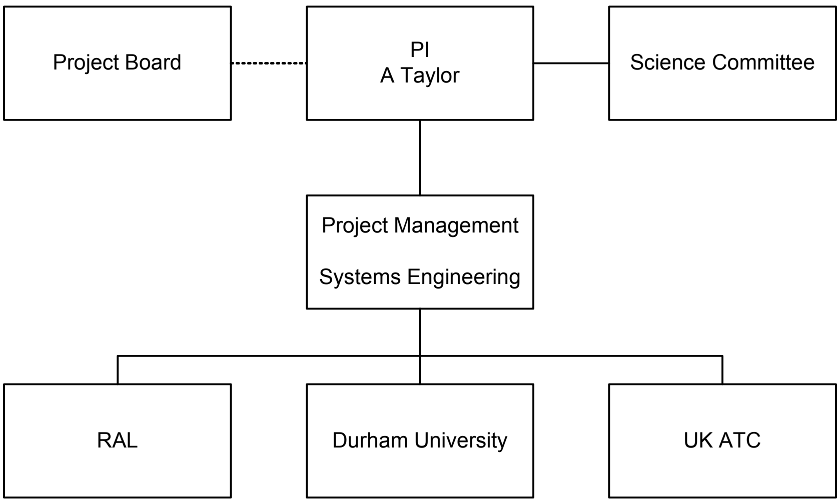

Figure 10: darkCAM management structure organogram.

The work breakdown structure is shown in Figure 11; a more detailed description is provided in Annex A. Dr Andrew Taylor will be the PI for the project providing leadership and direction to the Consortium. An experienced Project Manger will be appointed to provide the necessary control over the overall design, cost and schedule of the instrument to ensure its effective delivery and performance. The work share has been chosen to build on the technical strengths of the participating Institutes with all Institutes contributing where applicable to the AIT and Commissioning Phase.

13.2 Project Management Activities

The lead project management organisation (default organisation UK ATC) will provide a Project Manager who will lead development of the Project Management Plan (PMP) and ensure it is maintained, being responsible for delivering the instrument within budget and on schedule. The core elements of the PMP will be:

(a) Financial management, including capture of cost estimates, cost planning and reporting.
(b) Overall project strategy, particularly in relation to work flow and resource allocation.
(c) Capture of work package details.

(d) Developing the Work Breakdown Structure.
(e) Schedule coordination.
(f) Health and safety within each participating Institute and as a key requirement for an ESO instrument.
(g) Maintaining and auditing the risk register.
(h) Maintaining the actions register.
(i) Meetings coordination.

The Project Manager will also be responsible for monitoring the progress of the instrument design and development as reported by the individual Work Package leads. Monitoring will be by a combination of earned value, cash flow, milestone charts and design maturity metrics such as percentage complete of the subsystem drawing tree. The inputs from the work package leads will be summarised by the project manager into an instrument level report for the Project Board.

13.3 System Engineering Activities

The camera consortium will adopt a strong systems-level approach co-ordinated by a single systems management team. The camera consortium will consist of the systems management team and a number of "product teams" each responsible for a clearly identified subsystem or subassembly, within which the product teams have the appropriate design authority. The subsystems breakdown for darkCAM is based on that used for the VISTA IR camera and fits well into both the work breakdown structure and the project organisation structure, with each institute having a clearly defined subsystem boundary. The subsystem teams will work together via the systems engineering management to manage the project design across engineering disciplines.

The Systems Engineer will act as the focus for all project system design activity within the Consortium. In this arrangement, the Project Manager and the Systems Engineer (and nominated deputies) will operate together to drive forward the design and provision of the instrument. This arrangement of "integrated product teams" with design responsibility within their subsystem, coupled with a system level design team, has worked well on other large international projects.

13.4 Integration Methodology

A key issue from “lessons learnt” activities is that it is essential to identify the technical, integration and operations problems as soon as possible in an instrumentation projects lifecycle and mitigate against them. A strong systems engineering approach during the design phases will reduce the number of issues that reach the Integration Phase. However, there will still be a deliberate emphasis on sub-system testing aimed at reducing the amount of work, both scheduled and unscheduled, that must be carried out during the System and Paranal AIT (Assembly Integration & Test) phases. The expected procedure for AIT is that each sub-system will be subjected to testing which will determine when the sub-system is deemed “accepted” and ready for system integration. Wherever possible components, such as cables, used in the final build will be tested at this stage to identify any integration issues as early as possible in the integration phase. Once sub-systems are accepted, they are suitable for integration with other sub-systems. The nominal order of integration procedure is:

- Infrastructure integrated and tested.
- Addition of Optics assemblies.
- Addition of individual mechanism assemblies leading to verification of functionality and performance.
- Addition of Focal Plane to complete the instrument assembly.
- Following the completion of the sub-system integration, end-to-end testing aimed at verifying sub-system performance and functionality is performed.

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Doc Type: Word
State: Released
Author: ANT/AFH/IE
Date: 1st March 2005

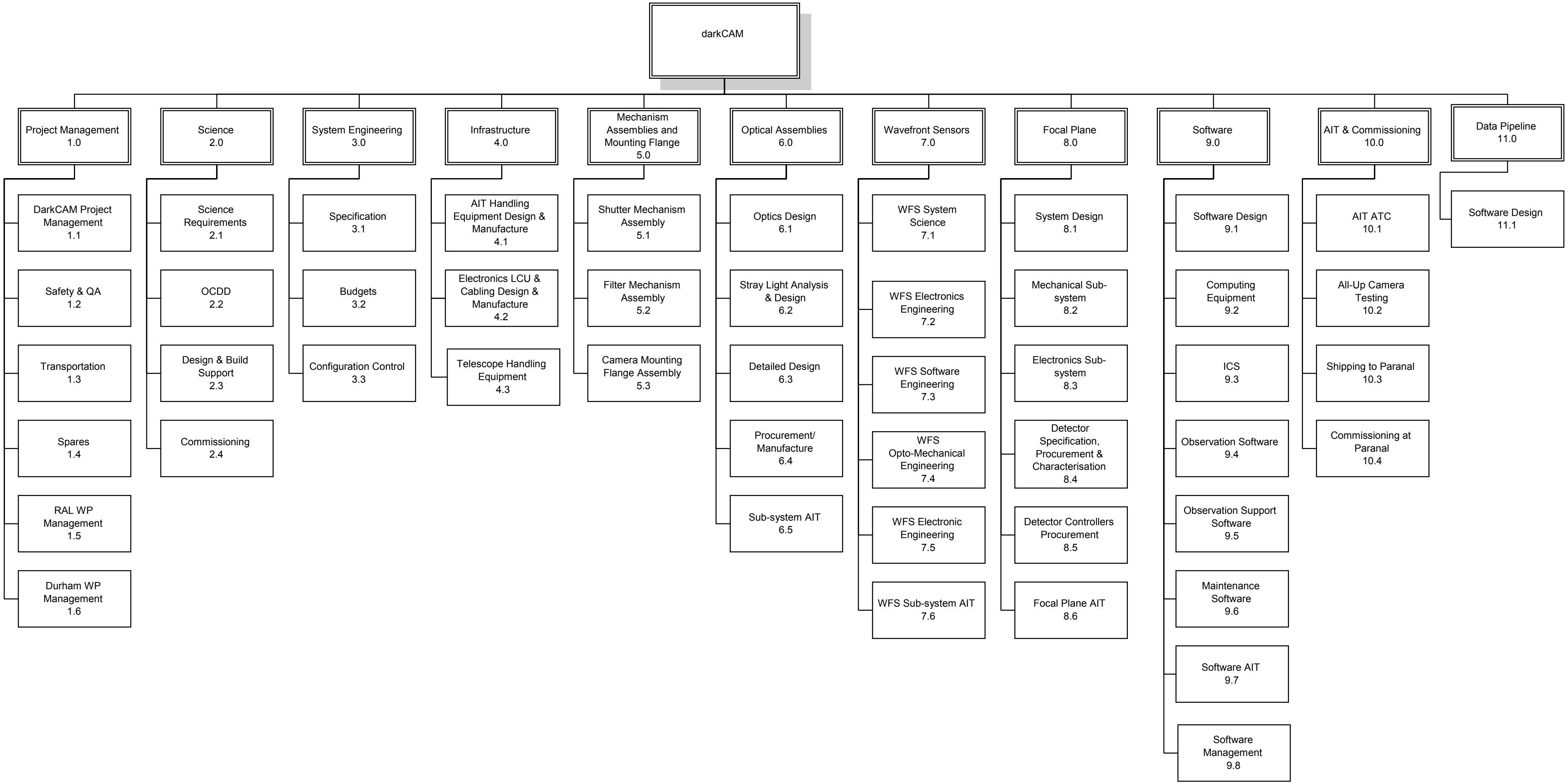

Figure 11: The darkCAM work breakdown structure

13.5 Product Assurance

Configuration and change control procedures will be put in place to ensure that modifications to the interface of a particular subsystem do not have unforeseen consequences elsewhere in the instrument. The integration and test procedures will be established early in the project and tests will be established that can verify the health of the completed instrument both at the integration site and after delivery to ESO. At all times it will be borne in mind that the use of ESO compatible hardware and software along with addressing reliability is a key feature for systems delivered to Paranal.

13.6 Project Phases

The project phases can be summarised as:-

Phase 1: Preliminary Design Phase
The aim of this phase is to consolidate the design of the instrument and subsystems as presented at the Conceptual Review and take onboard the benefits resulting from the VISTA IR Camera design and build activities. It includes identification and exploration of technical solutions which meet the specified requirements and hardware development if appropriate including tests and evaluation. The Preliminary Design Review (PDR) concludes this phase.

Phase 2: Final Design Phase
During this period darkCAM shall be designed down to the level of components. The Final Design Review (FDR) will terminate this phase.

Phase 3: Manufacture, Assembly, Integration and Test Phase
During this phase materials and commercial components will be procured along with the manufacture of parts. Each subsystem of darkCAM shall be assembled and integrated in the laboratory and subsystem tests shall be performed. Full instrument testing will be conducted. Based on the results of these tests, *Preliminary Acceptance in Europe* will be carried out by ESO. Any long-lead items (e.g. large optics, detectors) identified as needing early procurement will be covered at an earlier phase.

Phase 4: Transport to the VISTA site
The instrument and handling equipment are packed and transported to the Cerro Paranal Observatory Chile. On arrival at the VISTA site, a survival of transport inspection will be carried out along with testing in the Preparation Room.

Phase 5: Installation on the Telescope & Commissioning
DarkCAM will be assembled in the VISTA building. After successful completion of the tests which do not require light from the telescope, commissioning will start. Based on the results of all tests, ESO will declare *Provisional Acceptance in Chile.*

Phase 6: Science Verification/Exploitation
The responsibilities of the darkCAM consortium during this period will be set out in the agreement with ESO, but are expected to include Science Verification.

13.7 Schedule and goals by phase

The following two tables summarise the goals intended to be achieved by the reviews that conclude the first two project phases; PDR and FDR.

Table 5: Goals for Preliminary Design Review.

Work Package	PDR Goals
1.0 Project Management	Full project management plan in place. Financial and progress monitoring established, and ongoing. Documentation plan in place, PA/QA system in place, change control procedure in place, verification plan and procedures in place, reliability procedures established
2.0 Project Science	Scientific specification in place, and verification parameters established. Operational plan complete.
3.0 System Engineering	All technical budgets in place, Interface Control Documents (ICD) in place. End-to-end system analysis complete. Subsystem specifications at draft.
4.0 Infrastructure	Preliminary infrastructure design complete, contractors identified. Preliminary electronics design in place, ESO standards checked.
5.0 Mechanism Assemblies	Preliminary mechanical and electronics design in place, ESO standards checked. Filter specification ready for procurement
6.0 Optical Assemblies	Final Optical design in place; Preliminary mechanical and electronics design in place. Long lead optical items ready to be ordered
7.0 Wave-Front Sensors	Final Optical design in place; Preliminary mechanical and electronics design in place
8.0 Focal Plane	Detector system mount designed, component suppliers identified, detector type and manufacturer confirmed and order placed.
9.0 Software	Top level software design in place, standards established, and draft test plan complete.
10.0 AIT & Commissioning	Draft test plan ready.
11.0 Data Pipeline	Preliminary Software design.

Table 6: Goals for Final Design Review.

Work Package	FDR Goals
1.0 Project Management	Maintain project management plan. Financial and progress monitoring ongoing. Configuration control in operation,
2.0 Project Science	Preliminary operational plan complete, verify scientific specification against technical design.
3.0 System Engineering	End-to-end system design complete, detail testing plan complete. Subsystem specifications complete.
4.0 Infrastructure	Infrastructure design complete. Electronics design complete.
5.0 Mechanism Assemblies	Mechanical design complete. Electronics design complete. Filters ordered

6.0 Optical Assemblies	Mechanical design complete. Electronics design complete. Large Optics under contract
7.0 Wave-Front Sensors	Mechanical design complete. Electronics design complete. Detectors and Controllers ordered
8.0 Focal Plane	Detector system design complete, long-lead time items on order.
9.0 Software	Software design complete.
10.0 AIT & Commissioning	Preliminary test plan completed
11.0 Data Pipeline	Software design complete.

The goals for subsequent phases are clearly stated in the project phase definitions described above, each phase being marked by either an ESO acceptance statement or verification in the case of delivery of the instrument to ESO. The provisional dates for key milestones are given in the table in Annex D:

14. Risk Analysis and Management

14.1 Risk identification

An assessment has been made of the principal technical and management risks to the project, these are summarised in Annex E. At the start of the preliminary design phase these risks will be placed on the formal risk register. In addition a process of brainstorming across the disciplines involved in each sub module will be used to identify the next most significant risks for each subsystem. These will be placed on the register as well and all risks ranked according to their impact/likelihood index. Identifying Risk Reduction Actions (RRAs) for each of the principal risks will the responsibility of the Risk Owner. We will revise these risks throughout the future design phases of darkCAM.

14.2 Risk Management

Management of the identified risks will follow the guidelines currently used as standard at the UK ATC. The objective of the risk management process is to improve the probability of project success by anticipating possible problems, identifying opportunities and by taking cost effective actions to improve the current situation, margins and working efficiency.

The key activities in the risk management process are:

- Identification of all significant risks.
- Identification of cost effective Risk Reduction Actions (RRAs).
- Efficient management of all such RRAs.
- Regular risk auditing and iterative updating of the risk register to ensure that evolving circumstances are taken into consideration.

The implementation of risk management will be based on the following approach:

- Risk identification is “bottom up” by work area and should involve all team members.
- Schedule analysis at Consortium level will be used to improve the schedule model and identify the major schedule risks.
- Cost or resource risks as appropriate, informed by the relevant Project Manager

- The Consortium Project Manager (supported by Risk Owners) manages the Top 10 project risks. Local Project Managers manage their own Top 10 local risks.
- The complete risk register is analysed at project level to identify efficiency improvement actions, and provided to the national teams so that everyone is aware of the key issues involved.

14.3 Schedule Risk

Risks to the overall schedule will be assessed as follows. Each scheduled activity will be addressed, and durations assessed on the basis of nominal (or most likely), pessimistic (duration of activity if risk arises) and optimistic (minimum duration - maximum resources scenario). Minimisation of risk on the critical path will receive the highest attention, but sub-critical paths will also be regularly reviewed.

The results of the analysis provide valuable data on the impact of each activity on the compiled project end date. Management attention can be thus focused on the further mitigation of these critical areas and the process can be repeated until an acceptable level of residual risk is achieved.

15. Data Acquisition, Distribution and Analysis

DarkCAM will operate as a common-user facility class instrument on VISTA. As such it will comply with all relevant ESO requirements on software and quality control and calibration pipelines. CASU will supply the required software, based on their experience of providing software for the existing VISTA IR camera. Users of the darkCAM proprietary survey data will gain access via the WFAU Archive.

16. Scientific Exploitation

DarkCAM will undertake a large-scale weak lensing survey from guaranteed time. Scientific exploitation will be open to the darkCAM consortium. DarkCAM will also be available as a common-user instrument to all ESO astronomers via the time assignment process.

Funding for scientific data analysis will be sought competitively through the usual channel (UK grants line in the case of the proposers) at the appropriate time. Raw data archiving (Garching) and operations (Paranal) are assumed to be coverable by ESO.

17. Data Rights

We expect that the data from darkCAM taken by the darkCAM consortium during guaranteed time will be subject to the usual ESO proprietary period, which is currently 12 months for VLT instruments. Access to non-lensing data for other scientific programmes is subject to discussion.

18. Costs

The cost bases for all estimates in this submission use an engineering build-up by summing estimates from level 2 of the Work Breakdown Structure (WBS). The estimated costs for the baseline darkCAM design are shown in the following table. Full details of costs by work package and institution at level 2 of the work breakdown structure are given in Annex A, and summarised in Annex B.

Table 7: **Costs for the 4 year project timescale to the end of Acceptance of darkCAM in Chile.**

WBS Module	FTE staff year	FTE (£k)	Capital Costs (£k)	Total (£k)
1.0 Project Management	8.6	592.8	213.0	**805.8**
2.0 Science	2.0	139.8	10.3	**150.1**
3.0 Systems Engineering	2.5	171.5	0	**171.5**
4.0 Infrastructure	2.0	136.6	201.2	**337.8**
5.0 Mechanism Assemblies and Mounting Flange	3.4	232.2	370.2	**602.4**
6.0 Optical Assemblies	12.1	884.3	1,494.4	**2,378.7**
7.0 Wavefront Sensors	5.5	291.5	321.5	**613.0**
8.0 Focal Plane	7.4	511.8	2,218.2	**2,730.0**
9.0 Software	6.8	477.4	20.9	**498.4**
10.0 AIT & Commissioning	4.4	318.0	96.5	**414.5**
11.0 Data Pipeline	2.8	222.9	39.2	**262.1**
BASE COST	**57.5**	**3,978.7**	**4,985.4**	**8,964.1**
Margin (included in above)		7.5%	7.5%	
Contingency (materials at 10%, effort at 20%)		795.7	498.5	**1,294.3**
Total including contingency		**4,774.5**	**5,483.9**	**10,258.4**

19. Contingency and Working Margin

The implicit risks associated with both capital and effort costs for each Work Package have been used to generate the working margin. This will be held by the Project Manager, against which applications for release of funds will be made to the PI and agreed with the Project Board.

The cost estimate presented in this submission is a base estimate plus working margin. The working margin has been assessed for each Work Package by financial year. There are periods when experience has shown that an increased working margin is appropriate. For this reason it will be noted that the working margin is not a constant fixed value but may vary for some Work Packages. The average working margin across the whole project is 7.5 %.

In addition to the working margin described above, experience with previous instruments indicates that it would be appropriate for the Project Board to hold a project contingency of 10% on the capital costs and 20% on staff effort costs to cover any event which has not been foreseen in the original risk analysis, should the working margin have been exhausted.

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Annex A: Work Breakdown Data Sheets

WORK PACKAGE DESCRIPTION **WP No:** 1.0

Project: darkCAM **Date:** 1st March 2005
Major Subsystem: Project Management
Subsystem:
WP Title: darkCAM Project Management
WP Start Event: Authorisation to proceed
WP End Event: Completion of darkCAM integration into telescope and commissioning in Chile
WP Manager: I Egan **Organisation Responsible:** UK ATC

WP Aims

1. To ensure the efficient execution of the darkCAM project to time, budget and quality
2. To manage and control Risk

Inputs

1. Contractual documentation & Authorisation to Proceed from PPARC
2. Progress and financial information from the Project Managers of each of the principal groups
3. Telescope progress and planning information from VPO.
4. Identification of areas of risk

Outputs

1. Camera team management and control documentation as required to coordinate the activities of the principal groups in particular: the Work Package Description Document (this document); the Project Plan, including overall project MS Project GANTT chart; and overall camera costing information; Risk management; Travel budget; production of all deliverable documents
2. Contractual, financial and management documentation as required by PPARC
3. Safety Case; design reviews; internal peer reviews
4. Transportation plan and infrastructure
5. RAL WP management
6. Durham WP management

TASKS

1. Work closely with the responsible project managers in each organisation to ensure the efficient execution of the darkCAM project on time, quality and within budget
2. Produce and maintain camera team management and control documentation as required to coordinate the activities of the 3 principal groups including
   Project Plan including GANTT Chart
   Project Costing Information
3. Produce progress and financial documentation as required by sponsors
4. Create Safety Plan and maintain safety case
5. Produce spare parts list following PDR and FDR
6. Manage RAL Work Package to time, cost and quality
7. Manage Durham Work Package to time, cost and quality

Justification of Resource Levels:

Strong project management is essential to the effective and efficient completion of projects, more so when they involve a range of specialisms and are conducted over different sites. The darkCAM Project Manager (I Egan) is funded for the duration of the program. Support will be provided from RAL (K Ward) and Durham (P Berry) who have been identified as Project Managers for their Work Packages and who will be responsible for the delivery of their sub-systems to the overall project. The Project Assistant whose main duties will be documentation and administration is funded at an increased level over periods of peak activity such as the Preliminary Design Review and the Final Acceptance, and at a reduced level during the Manufacturing and Assembly, Integration and Test phase. Quality Assurance aspects are covered by a dedicated engineer.

darkCAM

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State:	Released
Author:	ANT/AFH/IE
Date:	1st March 2005

darkCAM COST PROFILE		**ATC**			Version dated:		**28 Feb 2005**	
WP 1.0 Project Management			0	1	2	3	4	
	Inflation for Staff	3.5%	1.000	1.035	1.071	1.109	1.148	
	Inflation for Bought out	2.5%	1.000	1.025	1.051	1.077	1.104	
	dsy rate (£k) 2005/06	65.1	dsy/day =	0.354				
	staff days per dsy	184						

Staff Days			**2005/06**	**2006/07**	**2007/08**	**2008/09**	**2009/10**	**TOTAL**
WP	**Name**	**Specialism**	**days**	**days**	**days**	**days**	**days**	**days**
WP 1.1	I Egan	Proj Mng	92	184	184	184	92	**736**
		Proj Asst	60	92	55	92	32	**331**
WP 1.2	J Murray	QA	10	25	20	20	15	**90**
WP 1.3	I Egan	Proj Mng			5			**5**
	D Gostick	mech eng			5			**5**
WP 1.4	I Egan	proj mng	5	5				**10**
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
		Total staff days	**167**	**306**	**269**	**296**	**139**	**1177**
Working Allowance in Above			**8**	**15**	**13**	**15**	**7**	**59**

Staff costs (£k)			2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
		Rate 05/06	£k	£k	£k	£k	£k	**£k**
WP 1.1	Proj Mng	0.354	32.6	65.1	65.1	65.1	32.6	**260**
		0.354	21.2	32.6	19.5	32.6	11.3	**117**
WP 1.2	QA	0.354	3.5	8.8	7.1	7.1	5.3	**32**
WP 1.3	Transportation	0.354	0.0	0.0	1.8	0.0	0.0	**2**
		0.354	0.0	0.0	1.8	0.0	0.0	**2**
WP 1.4	Spares	0.354	1.8	1.8	0.0	0.0	0.0	**4**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
Total Staff Costs (£k)			**59.1**	**108.3**	**95.2**	**104.7**	**49.2**	**416.4**
Working Allowance In Above		0.354	3.0	5.4	4.8	5.2	2.5	20.8

Indirect Costs (if applicable)		2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
		£k	£k	£k	£k	£k	**£k**
Rate	0%	0.0	0.0	0.0	0.0	0.0	**0.0**
Total for Staff + Indirect Costs (£k)		59.1	108.3	95.2	104.7	49.2	**416.4**
Cost of Inflation		0.0	3.8	6.8	11.4	7.3	**29.2**
Total Staff Costs Cash Planned (£k)		**59.1**	**112.1**	**102.0**	**116.1**	**56.4**	**445.6**
Working Allowance in above		3.0	5.6	5.1	5.8	2.8	**22.3**

Requisitions in (£k)		2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
Equipment		0.0	0.0	2.0	40.0	0.0	**42.0**
Consumables							**0.0**
Travel & Subsistence		17.2	18.3	19.2	15.2	4.4	**74.1**
Exceptional Items							**0.0**
VAT Recovery (Eqpt & Consumables where applicable)				0.4	7.0		**7.4**
Total (£k) with VAT recovered		17.2	18.3	20.8	48.2	4.4	**108.8**
Conversion rate if applicable	1						
Requisitions Total (£k)		**17.2**	**18.3**	**20.8**	**48.2**	**4.4**	**108.8**
Working Allowance (within Reqs Total)		0.9	0.9	1.0	2.4	0.2	**5.4**
Total Reqs Cash Planned (£k) (with inflation)		**17.2**	**18.7**	**21.9**	**51.9**	**4.8**	**114.4**
Working Allowance for Req (with inflation)		0.9	0.9	1.1	2.7	0.2	**5.8**

Grand Total Cash Planned (Effort + Requisitions)	**76.3**	**130.8**	**123.8**	**168.0**	**61.2**	**560.0**
Grand Total Working Allowance	**3.8**	**6.5**	**6.2**	**8.5**	**3.1**	**28.1**

darkCAM COST PROFILE		**RAL**			Version dated:		**28 Feb 2005**	
WP 1.0 Project Management			0	1	2	3	4	
	Inflation for Staff	3.5%	1.000	1.035	1.071	1.109	1.148	
	Inflation for Bought out	2.5%	1.000	1.025	1.051	1.077	1.104	
	dsy rate (£k) 2005/06	70.274	dsy/day =	0.335				
	staff days per dsy	210						
Staff Days			**2005/06**	**2006/07**	**2007/08**	**2008/09**	**2009/10**	**TOTAL**
WP	**Name**	**Specialism**	**days**	**days**	**days**	**days**	**days**	**days**
WP 1.5	K Ward	proj mng	90	121	58	36		**305**
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
	Total staff days		**90**	**121**	**58**	**36**	**0**	**305**
Working Allowance in Above			**5**	**6**	**3**	**2**	**0**	**15**
Staff costs (£k)			2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
		Rate 05/06	£k	£k	£k	£k	£k	**£k**
WP 1.5	Proj Mng	0.335	30.1	40.3	19.5	12.0	0.0	**102**
		0.335	0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	0.0	0.0	0.0	0.0	**0**
Total Staff Costs (£k)			**30.1**	**40.3**	**19.5**	**12.0**	**0.0**	**102.0**
Working Allowance In Above		0.335	1.5	2.0	1.0	0.6	0.0	5.1
Indirect Costs (if applicable)			2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
			£k	£k	£k	£k	£k	**£k**
	Rate	0%	0.0	0.0	0.0	0.0	0.0	**0.0**
Total for Staff + Indirect Costs (£k)			30.1	40.3	19.5	12.0	0.0	**102.0**
	Cost of Inflation		0.0	1.4	1.4	1.3	0.0	**4.1**
Total Staff Costs Cash Planned (£k)			**30.1**	**41.7**	**20.9**	**13.4**	**0.0**	**106.1**
Working Allowance in above			1.5	2.1	1.0	0.7	0.0	**5.3**
Requisitions in (£k)			2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
	Equipment							**0.0**
	Consumables		4.6	14.4	14.4	3.8		**37.2**
	Travel & Subsistence		6.0	10.0	10.0	4.0		**30.0**
	Exceptional Items							**0.0**
VAT Recovery (Eqpt & Consumables where applicable)								**0.0**
Total (£k) with VAT recovered			10.6	24.4	24.4	7.8	0.0	**67.2**
Conversion rate if applicable		1						
Requisitions Total (£k)			**10.6**	**24.4**	**24.4**	**7.8**	**0.0**	**67.2**
Working Allowance (within Reqs Total)			0.5	1.2	1.2	0.4	0.0	**3.4**
Total Reqs Cash Planned (£k) (with inflation)			**10.6**	**25.0**	**25.6**	**8.4**	**0.0**	**69.6**
Working Allowance for Req (with inflation)			0.5	1.3	1.3	0.4	0.0	**3.5**
Grand Total Cash Planned (Effort + Requisitions)			**40.7**	**66.7**	**46.5**	**21.8**	**0.0**	**175.7**
Grand Total Working Allowance			**2.0**	**3.3**	**2.4**	**1.1**	**0.0**	**8.8**

darkCAM

Doc No:	darkCAM PPRP submission
Version:	1.0
Category	Proposal
Doc Type:	Word
State:	Released
Author:	ANT/AFH/IE
Date:	1st March 2005

darkCAM COST PROFILE	Durham			Version dated:		28 Feb 2005	
WP 1.0 Project Management		0	1	2	3	4	
Inflation for Staff	3.5%	1.000	1.035	1.071	1.109	1.148	
Inflation for Bought out	2.5%	1.000	1.025	1.051	1.077	1.104	
dsy rate (£k) 2005/06	35.5	dsy/day =	0.169				
staff days per dsy	210						

Staff Days			2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
WP	**Name**	**Specialism**	**days**	**days**	**days**	**days**	**days**	**days**
WP 1.6	P Berry	Proj Mngt	26	53	53	26		**158**
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
Total staff days			**26**	**53**	**53**	**26**	**0**	**158**
Working Allowance in Above			**1**	**3**	**3**	**1**	**0**	**8**

Staff costs (£k)			2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
		Rate 05/06	£k	£k	£k	£k	£k	**£k**
WP 1.6	Proj Mng	0.169	4.4	9.0	9.0	4.4	0.0	**27**
		0.169	0.0	0.0	0.0	0.0	0.0	**0**
		0.169	0.0	0.0	0.0	0.0	0.0	**0**
		0.169	0.0	0.0	0.0	0.0	0.0	**0**
		0.169	0.0	0.0	0.0	0.0	0.0	**0**
		0.169	0.0	0.0	0.0	0.0	0.0	**0**
		0.169	0.0	0.0	0.0	0.0	0.0	**0**
		0.169	0.0	0.0	0.0	0.0	0.0	**0**
		0.169	0.0	0.0	0.0	0.0	0.0	**0**
		0.169	0.0	0.0	0.0	0.0	0.0	**0**
		0.169	0.0	0.0	0.0	0.0	0.0	**0**
		0.169	0.0	0.0	0.0	0.0	0.0	**0**
		0.169	0.0	0.0	0.0	0.0	0.0	**0**
		0.169	0.0	0.0	0.0	0.0	0.0	**0**
		0.169	0.0	0.0	0.0	0.0	0.0	**0**
		0.169	0.0	0.0	0.0	0.0	0.0	**0**
Total Staff Costs (£k)			**4.4**	**9.0**	**9.0**	**4.4**	**0.0**	**26.7**
Working Allowance In Above		0.169	0.2	0.4	0.4	0.2	0.0	1.3

Indirect Costs (if applicable)		2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
		£k	£k	£k	£k	£k	**£k**
Rate	46%	2.0	4.1	4.1	2.0	0.0	**12.3**
Total for Staff + Indirect Costs (£k)		6.4	13.1	13.1	6.4	0.0	**39.0**
Cost of Inflation		0.0	0.5	0.9	0.7	0.0	**2.1**
Total Staff Costs Cash Planned (£k)		**6.4**	**13.5**	**14.0**	**7.1**	**0.0**	**41.1**
Working Allowance in above		0.2	0.5	0.5	0.2	0.0	**1.4**

Requisitions in (£k)		2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
Equipment							**0.0**
Consumables		3.8	7.5	7.5	3.8		**22.5**
Travel & Subsistence		2.0	1.4	1.0	1.0		**5.4**
Exceptional Items							**0.0**
VAT Recovery (Eqpt & Consumables where applicable)							**0.0**
Total (£k) with VAT recovered		5.8	8.9	8.5	4.8	0.0	**27.9**
Conversion rate if applicable	1						
Requisitions Total (£k)		**5.8**	**8.9**	**8.5**	**4.8**	**0.0**	**27.9**
Working Allowance (within Reqs Total)		0.3	0.4	0.4	0.2	0.0	**1.4**
Total Reqs Cash Planned (£k) (with inflation)		**5.8**	**9.1**	**8.9**	**5.1**	**0.0**	**28.9**
Working Allowance for Req (with inflation)		0.3	0.5	0.5	0.3	0.0	**1.5**

Grand Total Cash Planned (Effort + Requisitions)	**12.2**	**22.7**	**22.9**	**12.2**	**0.0**	**70.0**
Grand Total Working Allowance	**0.5**	**0.9**	**0.9**	**0.5**	**0.0**	**2.9**

WORK PACKAGE DESCRIPTION		**WP No:**	2.0
Project:	darkCAM	**Date:**	1st March 2005
Major Subsystem:	Science		
Subsystem:			
WP Title:	darkCAM Instrument Scientist		
WP Start Event:	Authorisation to proceed		
WP End Event:	Completion of darkCAM integration into telescope and Commissioning in Chile		
WP Manager:	I Egan	**Organisation Responsible:**	UK ATC

WP Aims

1. To identify, analyse and resolve technical problems or issues in the darkCAM that may have an impact on the darkCAM project science and vice versa, working closely with the PI and VISTA Project Scientist.
2. To provide a point of contact on the darkCAM team for any darkCAM science-related issues.
3. To ensure that the completed camera will deliver the required scientific data products and capabilities.
4. To verify that the completed camera is fully integrated with the Paranal operations system

Inputs

1. Current and future darkCAM science documentation
2. darkCAM conceptual design documentation and current telescope documentation
3. darkCAM design documentation as it evolves during the project

Outputs

1. Contributions to science documentation
2. Analyses and reports responding to science-related camera issues or queries
3. Contributions to project reviews.
4. Contributions to commissioning plans and subsequent participation.
5. Science Verification of Camera operation at Paranal.

TASKS

1. Review current and future darkCAM science documentation
2. Review current and future darkCAM documentation
3. Provide a point of contact on the darkCAM team for science-related issues.
4. Identify, analyse and respond to any science-related camera issues that arise during the course of the project, working closely with the PI, darkCAM systems engineer and VISTA Project Scientist.
5. Produce documentation and support project reviews and meetings as required.
6. Contribute to commissioning plans and participate in commissioning activities.

Justification of Resource Levels:

Within the project team there will be two members who will have a major involvement with science, each with a different focus:

- The PI is the single point, formal interface for the consortium on all science and project related matters to external organisations. The PI will be supported by a Project Board that will receive advice from the consortium Project Manager, Instrument Scientist and Systems Engineer. The PI has final decision authority on any design trades, or issues that impact science or system performance, or changes in work divisions within the consortium. The PI will be responsible for co-ordinating PR activities.

- The Instrument Scientist will be responsible for ensuring that the instrument is fit for the intended science and that the science requirements are obtainable. He/she will be responsible for representing the PI and Science Team within the technical management of the project. He/she will be involved heavily in the initial design phase of the instrument and again in the AIT/Commissioning.

darkCAM

darkCAM COST PROFILE		**ATC**			Version dated:		**28 Feb 2005**	
WP 2.0 Science			0	1	2	3	4	
	Inflation for Staff	3.5%	1.000	1.035	1.071	1.109	1.148	
	Inflation for Bought out	2.5%	1.000	1.025	1.051	1.077	1.104	
	dsy rate (£k) 2005/06	65.1	dsy/day =	0.354				
	staff days per dsy	184						
	Staff Days		**2005/06**	**2006/07**	**2007/08**	**2008/09**	**2009/10**	**TOTAL**
WP	**Name**	**Specialism**	**days**	**days**	**days**	**days**	**days**	**days**
WP 2.0	TBD	Inst Science	80	70	60	78	80	**368**
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
	Total staff days		**80**	**70**	**60**	**78**	**80**	**368**
Working Allowance in Above			**4**	**4**	**3**	**4**	**4**	**18**
Staff costs (£k)			2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
		Rate 05/06	£k	£k	£k	£k	£k	**£k**
WP 2.0	Instrument Science	0.354	28.3	24.8	21.2	27.6	28.3	**130**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
Total Staff Costs (£k)			**28.3**	**24.8**	**21.2**	**27.6**	**28.3**	**130.2**
Working Allowance In Above		0.354	1.4	1.2	1.1	1.4	1.4	6.5
Indirect Costs (if applicable)			2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
			£k	£k	£k	£k	£k	**£k**
	Rate	0%	0.0	0.0	0.0	0.0	0.0	**0.0**
Total for Staff + Indirect Costs (£k)			28.3	24.8	21.2	27.6	28.3	**130.2**
	Cost of Inflation		0.0	0.9	1.5	3.0	4.2	**9.6**
Total Staff Costs Cash Planned (£k)			**28.3**	**25.6**	**22.7**	**30.6**	**32.5**	**139.8**
Working Allowance in above			1.4	1.3	1.1	1.5	1.6	**7.0**
Requisitions in (£k)			2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
	Equipment							**0.0**
	Consumables							**0.0**
	Travel & Subsistence		3.0	3.0	2.0	2.0		**10.0**
	Exceptional Items							**0.0**
VAT Recovery (Eqpt & Consumables where applicable)								**0.0**
Total (£k) with VAT recovered			3.0	3.0	2.0	2.0	0.0	**10.0**
Conversion rate if applicable		1						
Requisitions Total (£k)			**3.0**	**3.0**	**2.0**	**2.0**	**0.0**	**10.0**
Working Allowance (within Reqs Total)			0.2	0.2	0.1	0.1	0.0	**0.5**
Total Reqs Cash Planned (£k) (with inflation)			**3.0**	**3.1**	**2.1**	**2.2**	**0.0**	**10.3**
Working Allowance for Req (with inflation)			0.2	0.2	0.1	0.1	0.0	**0.5**
Grand Total Cash Planned (Effort + Requisitions)			**31.3**	**28.7**	**24.8**	**32.8**	**32.5**	**150.1**
Grand Total Working Allowance			**1.6**	**1.4**	**1.2**	**1.6**	**1.6**	**7.5**

WORK PACKAGE DESCRIPTION		**WP No:**	3.0
Project:	darkCAM	**Date:**	1st March 2005
Major Subsystem:	Systems Engineering		
Subsystem:			
WP Title:	Systems Engineering		
WP Start Event:	Authorisation to proceed		
WP End Event:	Completion of darkCAM integration into telescope and commissioning in Chile		
WP Manager:	I Egan	**Organisation Responsible:**	ATC

WP Aims

1. To provide a technical overview of all darkCAM activities in all areas from a systems engineering point of view including control of configuration and engineering budgets
2. To ensure: that all camera activities in the 3 institutes are properly coordinated; that all necessary analyses are carried out; that there is no unplanned duplication of effort
3. To identify technical problem areas and work with the responsible engineers, managers and Instrument Scientist to develop solutions to those problems.
4. To provide a point of contact for all technical issues concerning the darkCAM, working closely with the VISTA Telescope Systems Engineer

Inputs

1. darkCAM Conceptual Design documentation and darkCAM Technical Specification
2. Telescope Interface documentation
3. Telescope and darkCAM design documentation as it evolves during the project
4. ESO Standards

Outputs

1. darkCAM Req Spec and System Design document
2. Subsystem Req Specs and ICDs for all camera subsystems
3. System budgets and configuration control documents.
4. Technical support to all subsystems in all areas
5. darkCAM Acceptance Test requirements and commissioning plan
6. Camera Declared Materials List (DML)

TASKS

1. Review camera conceptual design documentation and current Telescope documentation
2. Review Camera Tech Spec and iterate with VPO to agree final Tech Spec
3. Working closely with telescope systems engineers and subsystem experts generate Camera System Budgets
4. Working closely with subsystem engineers generate and maintain Subsystem Req Specs and ICDs
5. Provide technical support to all subsystems in all areas
6. Combine subsystem DMLs into overall camera DML
7. Generate Camera Acceptance Test requirements
8. Plan and supervise all camera AIT activities
9. Chair darkCAM CCB

Justification of Resource Levels:

The distributed nature of the consortium and the benefit from a strong system engineering presence currently demonstrated in the VISTA project reinforce the need for a central point for control of specifications, budgets and leadership when interface issues are identified. 100% effort is used in the first year to ensure that internal systems are built up such as configuration control and during the last year for acceptance and commissioning activities. The phase before system AIT and Telescope Commissioning are run at a lower average level of 75%. The activities in the earlier phases of a project lead naturally into the work required to ensure that the integration and testing phases are fulfilled in as efficient and effective manner as possible. Effort for this phase is identified under WP 10.0. The darkCAM Systems Engineer will be supported by design engineers from each of the disciplines of optical, mechanical, electronic and software engineering and importantly by interactions with the Instrument Scientist.

darkCAM

Doc No:	darkCAM PPRP submission
Version:	1.0
Category	Proposal
Doc Type:	Word
State:	Released
Author:	ANT/AFH/IE
Date:	1st March 2005

darkCAM COST PROFILE	ATC			Version dated:	28 Feb 2005	
WP 3.0 Systems Engineering		0	1	2	3	4
Inflation for Staff	3.5%	1.000	1.035	1.071	1.109	1.148
Inflation for Bought out	2.5%	1.000	1.025	1.051	1.077	1.104
dsy rate (£k) 2005/06	65.1	dsy/day =	0.354			
staff days per dsy	184					

Staff Days			2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
WP	Name	Specialism	days	days	days	days	days	days
WP 3.0	TBD	Sys Eng	92	138	138	92		**460**
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
	Total staff days		**92**	**138**	**138**	**92**	**0**	**460**
Working Allowance in Above			**5**	**7**	**7**	**5**	**0**	**23**

Staff costs (£k)			2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
		Rate 05/06	£k	£k	£k	£k	£k	**£k**
WP 3.0	Systems Engineering	0.354	32.6	48.8	48.8	32.6	0.0	**163**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
Total Staff Costs (£k)			**32.6**	**48.8**	**48.8**	**32.6**	**0.0**	**162.8**
Working Allowance In Above		0.354	1.6	2.4	2.4	1.6	0.0	8.1

Indirect Costs (if applicable)		2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
		£k	£k	£k	£k	£k	**£k**
Rate	0%	0.0	0.0	0.0	0.0	0.0	**0.0**
Total for Staff + Indirect Costs (£k)		32.6	48.8	48.8	32.6	0.0	**162.8**
Cost of Inflation		0.0	1.7	3.5	3.5	0.0	**8.7**
Total Staff Costs Cash Planned (£k)		**32.6**	**50.5**	**52.3**	**36.1**	**0.0**	**171.5**
Working Allowance in above		1.6	2.5	2.6	1.8	0.0	**8.6**

Requisitions in (£k)		2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
Equipment							**0.0**
Consumables							**0.0**
Travel & Subsistence							**0.0**
Exceptional Items							**0.0**
VAT Recovery (Eqpt & Consumables where applicable)							**0.0**
Total (£k) with VAT recovered		0.0	0.0	0.0	0.0	0.0	**0.0**
Conversion rate if applicable	1						
Requisitions Total (£k)		**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Working Allowance (within Reqs Total)							**0.0**
Total Reqs Cash Planned (£k) (with inflation)		**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Working Allowance for Req (with inflation)		0.0	0.0	0.0	0.0	0.0	**0.0**

Grand Total Cash Planned (Effort + Requisitions)	**32.6**	**50.5**	**52.3**	**36.1**	**0.0**	**171.5**
Grand Total Working Allowance	**1.6**	**2.5**	**2.6**	**1.8**	**0.0**	**8.6**

WORK PACKAGE DESCRIPTION		**WP No:**	4.0
Project:	darkCAM	**Date:**	1st March 2005
Major Subsystem:	Infrastructure		
Subsystem:			
WP Title:	Infrastructure		
WP Start Event:	Authorisation to Proceed		
WP End Event:	Sub-systems ready for system integration		
WP Manager:	I Egan	**Organisation Responsible:**	ATC

WP Aims

1. To design, procure, integrate and test darkCAM infrastructure: handling equipment; electronics LCU and system cabling.
2. To design, manufacture and install any changes needed for handling at the Telescope

Inputs

1. darkCAM Conceptual Design Documentation; IR Camera handling equipment specifications.
2. Interface constraints imposed by internal ICDs and Telescope ICD
3. Subsystem designs

Outputs

1. Camera handling equipment and AIT Stand
2. LCU and all cables and connections required for system (other than FIERA cables)
3. Documentation and certification required to support the design, manufacture and delivery of work package items
4. Handling equipment for use at the Telescope

TASKS

1. Design, procure and certify camera handling equipment and AIT stand
2. Design, procure, integrate and test LCU and electronic components
3. Design, procure and integrate all cables and connections
4. Design, procure and install Handling equipment required at the Telescope

Justification of Resource Levels:

The activities covered under this Work Package take account of the various sub-systems and the need to pull them together as one system by providing electronic and handling system level components. The majority of the activities in this Work Package are mechanical in nature, with some electronic engineering support being requested for the instrument harnessing.

darkCAM COST PROFILE	ATC		Version dated:		28 Feb 2005	
WP 4.0 Infrastructure		0	1	2	3	4
Inflation for Staff	3.5%	1.000	1.035	1.071	1.109	1.148
Inflation for Bought out	2.5%	1.000	1.025	1.051	1.077	1.104
dsy rate (£k) 2005/06	65.1	dsy/day =	0.354			
staff days per dsy	184					

Staff Days			2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
WP	Name	Specialism	days	days	days	days	days	days
WP 4.1	M Cliffe	Mechanical		50				**50**
WP 4.2	D Atkinson	Electronics	20	30	10			**60**
	Electronic Technician	Electronics			40			**40**
WP 4.3	M Cliffe	Mechanical	70	70	40	40		**220**
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
Total staff days			**90**	**150**	**90**	**40**	**0**	**370**
Working Allowance in Above			**5**	**8**	**5**	**2**	**0**	**19**

Staff costs (£k)			2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
		Rate 05/06	£k	£k	£k	£k	£k	**£k**
WP 4.1	AIT Handling Eqpt	0.354	0.0	17.7	0.0	0.0	0.0	**18**
WP 4.2	LCU & Cabling	0.354	7.1	10.6	3.5	0.0	0.0	**21**
		0.354	0.0	0.0	14.2	0.0	0.0	**14**
WP 4.3	Telescope Handling Eqpt	0.354	24.8	24.8	14.2	14.2	0.0	**78**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
Total Staff Costs (£k)			**31.8**	**53.1**	**31.8**	**14.2**	**0.0**	**130.9**
Working Allowance In Above		0.354	1.6	2.7	1.6	0.7	0.0	6.5

Indirect Costs (if applicable)		2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
		£k	£k	£k	£k	£k	**£k**
Rate	0%	0.0	0.0	0.0	0.0	0.0	**0.0**
Total for Staff + Indirect Costs (£k)		31.8	53.1	31.8	14.2	0.0	**130.9**
Cost of Inflation		0.0	1.9	2.3	1.5	0.0	**5.7**
Total Staff Costs Cash Planned (£k)		**31.8**	**54.9**	**34.1**	**15.7**	**0.0**	**136.6**
Working Allowance in above		1.6	2.7	1.7	0.8	0.0	**6.8**

Requisitions in (£k)		2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
Equipment				200.9	23.5		**224.4**
Consumables							**0.0**
Travel & Subsistence							**0.0**
Exceptional Items							**0.0**
VAT Recovery (Eqpt & Consumables where applicable)				29.9	3.5		**33.4**
Total (£k) with VAT recovered		0.0	0.0	171.0	20.0	0.0	**191.0**
Conversion rate if applicable	1						
Requisitions Total (£k)		**0.0**	**0.0**	**171.0**	**20.0**	**0.0**	**191.0**
Working Allowance (within Reqs Total)		0.0	0.0	42.5	1.0	0.0	**43.5**
Total Reqs Cash Planned (£k) (with inflation)		**0.0**	**0.0**	**179.7**	**21.5**	**0.0**	**201.2**
Working Allowance for Req (with inflation)		0.0	0.0	45.5	1.1	0.0	**46.6**

	2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
Grand Total Cash Planned (Effort + Requisitions)	**31.8**	**54.9**	**213.8**	**37.2**	**0.0**	**337.8**
Grand Total Working Allowance	**1.6**	**2.7**	**47.2**	**1.9**	**0.0**	**53.5**

WORK PACKAGE DESCRIPTION		**WP No:**	5.0
Project:	DarkCAM	**Date:**	10 Jan 2005
Major Subsystem:	Mechanism Assemblies and Mounting Flange		
Subsystem:			
WP Title:	Mechanism Assemblies and Mounting Flange		
WP Start Event:	Authorisation to proceed		
WP End Event:	AIT of Sub-systems		
WP Manager:	I Egan	**Organisation Responsible:**	ATC

WP Aims

1. To design, procure and test at sub-system level: Shutter Mechanism Assembly; Filter Mechanism Assembly; Camera Mounting Flange; Balance Masses.

Inputs

1. DarkCAM Technical Specification
2. DarkCAM conceptual design
3. VISTA Telescope Interface requirements
4. Camera interface constraints with other subsystems
5. Mechanism driver and control LCU and associated software

Outputs

1. Fully assembled and tested shutter mechanism assembly ready to be integrated including any specific handling equipment
2. Fully assembled and tested filter mechanism assembly ready to be integrated including any specific handling equipment
3. Camera Mounting Flange including any specific handling equipment
4. Balance Masses including any specific handling equipment
5. Design, procurement, test and maintenance documentation to support above outputs

TASKS

1. To produce fully assembled and tested shutter mechanism assembly for integration with the rest of the system
2. To produce fully assembled and tested filter mechanism assembly for integration with the rest of the system
3. To produce the Camera mounting flange ready for assembly and integration with the rest of the system
4. To produce balance masses and fixtures to enable darkCAM centre of gravity and mass to match that of VISTA IR

Justification of Resource Levels:

This Work Package covers two of the three warm mechanisms namely the shutter and filter mechanism. It also covers the mounting flange which forms the main structural interface to the telescope and for the optics barrel and mechanisms to attach to. Most of the effort required is from the mechanical specialism, electronics support will also be required but the use of ESO compatible equipment reduces the need for design choice.

darkCAM

Doc No:	darkCAM PPRP submission
Version:	1.0
Category	Proposal
Doc Type:	Word
State:	Released
Author:	ANT/AFH/IE
Date:	1st March 2005

darkCAM COST PROFILE		ATC			Version dated:		28 Feb 2005	
WP 5.0 Mech Assemblies			0	1	2	3	4	
	Inflation for Staff	3.5%	1.000	1.035	1.071	1.109	1.148	
	Inflation for Bought out	2.5%	1.000	1.025	1.051	1.077	1.104	
	dsy rate (£k) 2005/06	65.1	dsy/day =	0.354				
	staff days per dsy	184						

Staff Days			2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
WP	Name	Specialism	days	days	days	days	days	days
WP 5.1	D Gostick	Mech Eng	15	40	38			93
	M Cliffe	Mech Eng			20			20
	Project Technician	Technician			20			20
	D Aitkinson	Electronics	5	10	15	10		40
WP 5.2	D Gostick	Mech Eng	20	30	40			90
	M Cliffe	Mech Eng			40			40
	Project Technician	Technician			43			43
	D Aitkinson	Electronics	5	10	20	10		45
WP 5.3	M Cliffe	Mech Eng	10	5	10			25
	Project Technician	Technician			10			10
WP 5.4	D Gostick	Mech Eng	5	8				13
WP 5.5	D Gostick	Mech Eng	10	10	20			40
WP 5.6	Workshop	Technician			100	40		140
								0
								0
								0
		Total staff days	70	113	376	60	0	619
Working Allowance in Above			4	6	19	3	0	31

Staff costs (£k)			2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
		Rate 05/06	£k	£k	£k	£k	£k	£k
WP 5.1	Shutter Mechanism	0.354	5.3	14.2	13.4	0.0	0.0	33
		0.354	0.0	0.0	7.1	0.0	0.0	7
		0.354	0.0	0.0	7.1	0.0	0.0	7
		0.354	1.8	3.5	5.3	3.5	0.0	14
WP 5.2	Filter Mechanism	0.354	7.1	10.6	14.2	0.0	0.0	32
		0.354	0.0	0.0	14.2	0.0	0.0	14
		0.354	0.0	0.0	15.2	0.0	0.0	15
		0.354	1.8	3.5	7.1	3.5	0.0	16
WP 5.3	Mounting Flange	0.354	3.5	1.8	3.5	0.0	0.0	9
		0.354	0.0	0.0	3.5	0.0	0.0	4
WP 5.4	Balance Mass	0.354	1.8	2.8	0.0	0.0	0.0	5
WP 5.5	Static & Dynamic Budget	0.354	3.5	3.5	7.1	0.0	0.0	14
WP 5.6	Workshop	0.354	0.0	0.0	35.4	14.2	0.0	50
		0.354	0.0	0.0	0.0	0.0	0.0	0
		0.354	0.0	0.0	0.0	0.0	0.0	0
		0.354	0.0	0.0	0.0	0.0	0.0	0
Total Staff Costs (£k)			24.8	40.0	133.0	21.2	0.0	219.0
Working Allowance In Above		0.354	1.2	2.0	6.7	1.1	0.0	11.0

Indirect Costs (if applicable)		2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
		£k	£k	£k	£k	£k	£k
Rate	0%	0.0	0.0	0.0	0.0	0.0	0.0
Total for Staff + Indirect Costs (£k)		24.8	40.0	133.0	21.2	0.0	219.0
Cost of Inflation		0.0	1.4	9.5	2.3	0.0	13.2
Total Staff Costs Cash Planned (£k)		24.8	41.4	142.5	23.5	0.0	232.2
Working Allowance in above		1.2	2.1	7.1	1.2	0.0	11.6

Requisitions in (£k)		2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
Equipment		0.0	0.0	411.5	0.0	0.0	411.5
Consumables							0.0
Travel & Subsistence				2.1			2.1
Exceptional Items							0.0
VAT Recovery (Eqpt & Consumables where applicable)				61.2			61.2
Total (£k) with VAT recovered		0.0	0.0	352.4	0.0	0.0	352.4
Conversion rate if applicable	1						
Requisitions Total (£k)		0.0	0.0	352.4	0.0	0.0	352.4
Working Allowance (within Reqs Total)		0.0	0.0	17.6	0.0	0.0	17.6
Total Reqs Cash Planned (£k) (with inflation)		0.0	0.0	370.2	0.0	0.0	370.2
Working Allowance for Req (with inflation)		0.0	0.0	18.9	0.0	0.0	18.9

Grand Total Cash Planned (Effort + Requisitions)	24.8	41.4	512.7	23.5	0.0	602.4
Grand Total Working Allowance	1.2	2.1	26.0	1.2	0.0	30.5

WORK PACKAGE DESCRIPTION		**WP No:**	6.0
Project:	DarkCAM	**Date:**	1st March 2005
Major Subsystem:	Optical Assemblies		
Subsystem:			
WP Title:	Optical Assemblies		
WP Start Event:	Authorisation to proceed		
WP End Event:	Optics assemblies ready for integration		
WP Manager:	K Ward	**Organisation Responsible:**	RAL

WP Aims

1. To design and procure camera optics
2. To design, produce/procure mechanical and electrical infrastructure to support optics.
3. To design, produce/procure Camera Baffling and M2 Baffle

Inputs

1. DarkCAM Technical Specification and VISTA Visible Camera conceptual design documentation
2. Mechanical interface constraints imposed by internal ICDs and Telescope ICD

Outputs

1. Fully assembled and tested camera optics assemblies
   Camera baffle
   M2 Baffle
2. Electronic design and components for ADC
3. Design and test documentation
4. Optics test equipment
5. Handling/lifting equipment,
6. Transport container

TASKS

1 Review VISTA conceptual design documentation and any subsequent updates
2 Perform detailed design and analysis of the camera optics, and generate the associated documentation; manufacture of optical elements and optics supporting structure
3 Assess optical test equipment requirements and prepare such equipment using existing or new equipment as necessary
4 Assemble the optical elements and optics barrel into an integrated system and test it as necessary to demonstrate it meets the defined requirements
5 Design and manufacture suitable handling equipment and transport container for the optics assembly

Justification of Resource Levels:

This Work Package involves an extensive effort to build on the conceptual optical design, the design and manufacture of the lens holders for the large lenses, the ADC mechanism and the Front end Baffle. The effort allows for stray light design including defining the requirements for manufacturing a baffle to be used with the M2 System on the VISTA Telescope when darkCAM is used.

This activity has intensive manufacturing, metrology and AIV phases and this is reflected in the effort requested for precision machining, mechanical engineering and optical metrology & testing

darkCAM

Doc No:	darkCAM PPRP submission
Version:	1.0
Category	Proposal
Doc Type:	Word
State:	Released
Author:	ANT/AFH/IE
Date:	1st March 2005

darkCAM COST PROFILE		RAL			Version dated:		28 Feb 2005	
WP 6.0 Optical Assemblies			0	1	2	3	4	
	Inflation for Staff	3.5%	1.000	1.035	1.071	1.109	1.148	
	Inflation for Bought out	2.5%	1.000	1.025	1.051	1.077	1.104	
	dsy rate (£k) 2005/06	70.274	dsy/day =	0.335				
	staff days per dsy	210						

Staff Days			2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
WP	**Name**	**Specialism**	**days**	**days**	**days**	**days**	**days**	**days**
WP 6.1	**Optics System Design**							
	Martin Caldwell	optical	90	50				**140**
	Ian Tosh	optical	105	130	35			**270**
WP 6.2	**Stray-light & Baffle Design**							
	Tony Richards	optical	83	172				**255**
WP 6.3	**Mechanical & Electrical Design**							
WP 6.3.1	**Mechanical Design**							
	Martin Whalley	mechanical	85	115				**200**
	Ruben Edeson	mechanical	100	180	45			**325**
	Kevin Burke	mechanical	100	210	55			**365**
WP 6.3.2	**Electrical Design**							
	Dave Parker	electrical	35	25				**60**
WP 6.4	**Procurement**							
WP 6.4.1	**Lens components**							
	Ian Tosh	optical	30	45	40			**115**
WP 6.4.2	**Baffle components**							
	Tony Richards	optical		35				**35**
WP 6.4.3	**Mechanical & Electrical**							
	Martin Whalley	mechanical			35			**35**
	Kevin Burke	mechanical			55			**55**
	Dave Parker	electrical		25	35			**60**
WP 6.4.4	**Test equipment**							
	Martin Caldwell	optical AIT		20	25			**45**
	Martin Whalley	mechanical		20	25			**45**
WP 6.5	**Optics sub-systems AIT**							
WP 6.5.1	**Lens cells**							
	Ian Tosh	optical		35	145			**180**
WP 6.5.2	**Baffle assemblies**							
	Tony Richards	optical		15	30			**45**
	Martin Whalley	mechanical		10	20			**30**
WP 6.5.3	**ADC mechanism assys**							
	Dave Parker	electrical		10	25			**35**
	Martin Whalley	mechanical		15	55			**70**
WP 6.5.4	**Lens barrel**							
	Martin Caldwell	optical AIT				45		**45**
	Ian Tosh	optical				65		**65**
	Martin Whalley	mechanical				65		**65**
	Total staff days		**628**	**1112**	**625**	**175**	**0**	**2540**
Working Allowance in Above			**95**	**90**	**50**			**235**

Staff costs (£k)			2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
		Rate 05/06	£k	£k	£k	£k	£k	**£k**
WP 6.1	Optics System Design		0.0	0.0	0.0	0.0	0.0	**0**
		0.335	30.1	16.7	0.0	0.0	0.0	**47**
		0.335	35.1	43.5	11.7	0.0	0.0	**90**
WP 6.2	Stray-light & Baffle Design		0.0	0.0	0.0	0.0	0.0	**0**
		0.335	27.8	57.6	0.0	0.0	0.0	**85**
WP 6.3	Mechanical & Electrical Design		0.0	0.0	0.0	0.0	0.0	**0**
WP 6.3.1	Mechanical Design		0.0	0.0	0.0	0.0	0.0	**0**
		0.335	28.4	38.5	0.0	0.0	0.0	**67**
		0.335	33.5	60.2	15.1	0.0	0.0	**109**
		0.335	33.5	70.3	18.4	0.0	0.0	**122**
WP 6.3.2	Electrical Design		0.0	0.0	0.0	0.0	0.0	**0**
		0.335	11.7	8.4	0.0	0.0	0.0	**20**
WP 6.4	Procurement		0.0	0.0	0.0	0.0	0.0	**0**
WP 6.4.1	Lens components		0.0	0.0	0.0	0.0	0.0	**0**
		0.335	10.0	15.1	13.4	0.0	0.0	**38**
WP 6.4.2	Baffle components		0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	11.7	0.0	0.0	0.0	**12**
WP 6.4.3	Mechanical & Electrical		0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	0.0	11.7	0.0	0.0	**12**
		0.335	0.0	0.0	18.4	0.0	0.0	**18**
		0.335	0.0	8.4	11.7	0.0	0.0	**20**
WP 6.4.4	Test equipment		0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	6.7	8.4	0.0	0.0	**15**
		0.335	0.0	6.7	8.4	0.0	0.0	**15**
WP 6.5	Optics sub-systems AIT		0.0	0.0	0.0	0.0	0.0	**0**
WP 6.5.1	Lens cells		0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	11.7	48.5	0.0	0.0	**60**
WP 6.5.2	Baffle assemblies		0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	5.0	10.0	0.0	0.0	**15**
		0.335	0.0	3.3	6.7	0.0	0.0	**10**
WP 6.5.3	ADC mechanism assys		0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	3.3	8.4	0.0	0.0	**12**
		0.335	0.0	5.0	18.4	0.0	0.0	**23**
WP 6.5.4	Lens barrel		0.0	0.0	0.0	0.0	0.0	**0**
		0.335	0.0	0.0	0.0	15.1	0.0	**15**
		0.335	0.0	0.0	0.0	21.8	0.0	**22**
		0.335	0.0	0.0	0.0	21.8	0.0	**22**
			0.0	0.0	0.0	0.0	0.0	**0**
			0.0	0.0	0.0	0.0	0.0	**0**
Total Staff Costs (£k)			**210.2**	**372.1**	**209.1**	**58.6**	**0.0**	**850.0**
Working Allowance In Above		0.335	31.8	30.1	16.7	0.0	0.0	78.6
Indirect Costs (if applicable)			2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
			£k	£k	£k	£k	£k	**£k**
Rate		0%	0.0	0.0	0.0	0.0	0.0	**0.0**
Total for Staff + Indirect Costs (£k)			210.2	372.1	209.1	58.6	0.0	**850.0**
Cost of Inflation			0.0	13.0	14.9	6.4	0.0	**34.3**
Total Staff Costs Cash Planned (£k)			**210.2**	**385.1**	**224.0**	**64.9**	**0.0**	**884.3**
Working Allowance in above			31.8	31.2	17.9	0.0	0.0	**80.9**

Requisitions in (£k)		2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
Equipment		0.0	1359.5	318.4			**1677.9**
Consumables				10.0			**10.0**
Travel & Subsistence		4.5	6.5	2.0			**13.0**
Exceptional Items							**0.0**
VAT Recovery (Eqpt & Consumables where applicable)			202.5	47.4			**249.9**
Total (£k) with VAT recovered		4.5	1163.5	283.0	0.0	0.0	**1451.0**
Conversion rate if applicable	1						
Requisitions Total (£k)		**4.5**	**1163.5**	**283.0**	**0.0**	**0.0**	**1451.0**
Working Allowance (within Reqs Total)		7.8	123.5	30.5			**161.8**
Total Reqs Cash Planned (£k) (with inflation)		**4.5**	**1192.6**	**297.3**	**0.0**	**0.0**	**1494.4**
Working Allowance for Req (with inflation)		7.8	127.8	32.7	0.0	0.0	**168.3**

Grand Total Cash Planned (Effort + Requisitions	**214.7**	**1577.7**	**521.4**	**64.9**	**0.0**	**2378.7**
Grand Total Working Allowance	**39.6**	**159.0**	**50.6**	**0.0**	**0.0**	**249.2**

WORK PACKAGE DESCRIPTION		**WP No:**	7.0
Project:	DarkCAM	**Date:**	1st March 2005
Major Subsystem:	Wavefront Sensors		
Subsystem:			
WP Title:	Wavefront Sensors		
WP Start Event:	Specification of Durham Work Packages		
WP End Event:	Completion of the wavefront sensor system, ready for instrument integration and test		
WP Manager:	P Berry	**Organisation Responsible:**	Durham

WP Aims

1. To produce the wavefront sensor system ready for integration into the focal plane cryostat together with associated controllers and software compatible with ESO standards.

Inputs

1. darkCAM Technical Specification, darkCAM conceptual design documentation and VISTA IR design
2. Mechanical and electronic interface constraints imposed by the cryostat and focal plane array

Outputs

1. Wavefront Sensor System, comprising: Curvature sensors and associated controller and software; and Autoguider sensor and associated controller and software
2. Wavefront sensor design and test documentation

TASKS

1. Review darkCAM conceptual design documentation and VISTA IR design.
2. Perform detailed design and analysis of the wavefront sensors; generate the necessary documentation; produce the sensors; procure the associated controllers; develop the software associated with the operation and test of the wavefront sensors.
3. Prepare a suitable test environment for the sensors and verify their performance as far as practicable outside the cryostat.
4. Integrate the wave-front sensors into the complete Wavefront Sensor System.

Justification of Resource Levels:

Durham's position in providing the Wave-Front Sensors for the VISTA IR Camera makes them a natural choice to perform the tasks of designing and manufacturing the WFS sub-system for darkCAM. The concept calls for the low-order curvature sensors and autoguiders to be placed in the focal plane on opposite sides of the science detectors (similar to the OmegaCAM solution). Where possible the results of the work carried out for the IR camera will be reused. This approach is supported by ensuring that effort is identified in the working allowance should more mechanical design effort be required than anticipated in the design and subsequent manufacturing phase.

Doc No:	darkCAM PPRP submission
Version:	1.0
Category	Proposal
Doc Type:	Word
State:	Released
Author:	ANT/AFH/IE
Date:	1st March 2005

darkCAM COST PROFILE		Durham				Version dated:		28 Feb 05
WP 7.0 WFS			0	1	2	3	4	
	Inflation for Staff	3.5%	1.000	1.035	1.071	1.109	1.148	
	Inflation for Bought out	2.5%	1.000	1.025	1.051	1.077	1.104	
	dsy rate (£k) 2005/06	Variable	dsy/day =	0.165				
	staff days per dsy	210						

Staff Days			2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
WP	Name	Specialism	days	days	days	days	days	days
WP 7.1	Richard Myers	Science	26	26				**52**
WP 7.2	Paul Berry	Electronics	78	158	106	53		**395**
	Chris Moore	Electronics			105			**105**
WP 7.3	Eddy Younger	Software	52	106	26	26		**210**
WP 7.4	Peter Luke	Opto-Mech	52	132	26			**210**
	George Teasdale	Mechanical			105			**105**
WP 7.5	Paul Berry	Electronics			52	26		**78**
								0
								0
								0
								0
								0
								0
								0
								0
Total staff days			**208**	**422**	**420**	**105**	**0**	**1155**
Working Allowance in Above			**26**	**54**	**54**	**12**		**146**

Staff costs (£k)			2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
		Rate 05/06	£k	£k	£k	£k	£k	**£k**
WP 7.1	WFS Systems Scier	0.219	5.7	5.7	0.0	0.0	0.0	**11**
WP 7.2	Electronics Eng	0.169	13.2	26.7	17.9	9.0	0.0	**67**
	Electronics Tech	0.135	0.0	0.0	14.2	0.0	0.0	**14**
WP 7.3	Software	0.169	8.8	17.9	4.4	4.4	0.0	**35**
WP 7.4	Opto-Mech Eng	0.169	8.8	22.3	4.4	0.0	0.0	**35**
	Mech Tech	0.135	0.0	0.0	14.2	0.0	0.0	**14**
WP 7.5	Sub-System AIT	0.169	0.0	0.0	8.8	4.4	0.0	**13**
		0.000	0.0	0.0	0.0	0.0	0.0	**0**
		0.000	0.0	0.0	0.0	0.0	0.0	**0**
		0.000	0.0	0.0	0.0	0.0	0.0	**0**
		0.000	0.0	0.0	0.0	0.0	0.0	**0**
		0.000	0.0	0.0	0.0	0.0	0.0	**0**
		0.000	0.0	0.0	0.0	0.0	0.0	**0**
		0.000	0.0	0.0	0.0	0.0	0.0	**0**
		0.000	0.0	0.0	0.0	0.0	0.0	**0**
Total Staff Costs (£k)			**36.5**	**72.6**	**63.8**	**17.7**	**0.0**	**190.7**
Working Allowance In Above		0.165	4.3	8.9	8.9	2.0	0.0	24.1

Indirect Costs (if applicable)		2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
		£k	£k	£k	£k	£k	**£k**
Rate	46%	16.8	33.4	29.4	8.2	0.0	**87.7**
Total for Staff + Indirect Costs (£k)		53.2	106.0	93.2	25.9	0.0	**278.4**
Cost of Inflation		0.0	3.7	6.6	2.8	0.0	**13.2**
Total Staff Costs Cash Planned (£k)		**53.2**	**109.7**	**99.8**	**28.7**	**0.0**	**291.5**
Working Allowance in above		4.3	9.2	9.5	2.2	0.0	**25.3**

Requisitions in (£k)		2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
Equipment		5.0	87.5	226.0	12.0		**330.5**
Consumables							**0.0**
Travel & Subsistence		1.0	1.6	3.0	1.0		**6.6**
Exceptional Items							**0.0**
VAT Recovery (Eqpt & Consumables where applicable)				29.0			**29.0**
Total (£k) with VAT recovered		6.0	89.1	200.0	13.0	0.0	**308.1**
Conversion rate if applicable	1						
Requisitions Total (£k)		**6.0**	**89.1**	**200.0**	**13.0**	**0.0**	**308.1**
Working Allowance (within Reqs Total)		0.1	4.2	8.7	0.5		**13.5**
Total Reqs Cash Planned (£k) (with inflat		**6.0**	**91.3**	**210.1**	**14.0**	**0.0**	**321.5**
Working Allowance for Req (with inflation)		0.1	4.3	9.3	0.6	0.0	**14.3**

	2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
Grand Total Cash Planned (Effort + Requisitions)	**59.2**	**201.1**	**310.0**	**42.7**	**0.0**	**613.0**
Grand Total Working Allowance	**4.4**	**13.6**	**18.9**	**2.8**	**0.0**	**39.6**

WORK PACKAGE DESCRIPTION		**WP No:**	8.0
Project:	darkCAM	**Date:**	1st March 2005
Major Subsystem:	Focal Plane		
Subsystem:			
WP Title:	Focal Plane		
WP Start Event:	Authorisation to proceed		
WP End Event:	To produce and test the darkCAM focal plane assembly and associated controllers		
WP Manager:	I Egan	**Organisation Responsible:**	UK ATC

WP Aims

1. To design, produce, test and integrate the darkCAM focal plane assembly and associated controllers

Inputs

1. darkCAM system and subsystem design documentation
2. Cryostat hardware equipment
3. Camera control hardware definition and subset of control software
4. Requirements and interface specifications

Outputs

1. darkCAM focal plane assembly
2. Suite of FIERA controllers suitable for operating the CCD focal plane assembly
3. Design and test documentation

TASKS

1. Design and manufacture darkCAM focal plane array
2. Procure and characterise CCDs
3. Install & check out focal plane array in cryostat
4. Procure FIERA detector controllers for use in 2 and 3 above
5. Develop any additional software needed for integrating and testing the focal plane array
6. Produce all necessary documentation

Justification of Resource Levels:

This Work Package covers all the activities required to produce the focal plane assembly. The main task is the procurement, characterisation and integration of the 50 CCDs. Detector controllers will be procured from ESO. In addition, mechanical design, testing and integration of the cryostat and focal plane plate for mounting the detectors will be required. This Work Package has the longest lead time for any of the procured items (detectors 2 years from start of contract to final delivery with the first delivery 8 months after contract start).

darkCAM

Doc No:	darkCAM PPRP submission
Version:	1.0
Category	Proposal
Doc Type:	Word
State:	Released
Author:	ANT/AFH/IE
Date:	1st March 2005

darkCAM COST PROFILE		ATC			Version dated:		28 Feb 2005	
WP 8.0 Focal Plane			0	1	2	3	4	
	Inflation for Staff	3.5%	1.000	1.035	1.071	1.109	1.148	
	Inflation for Bought out	2.5%	1.000	1.025	1.051	1.077	1.104	
	dsy rate (£k) 2005/06	65.1	dsy/day =	0.354				
	staff days per dsy	184						

Staff Days			2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
WP	Name	Specialism	days	days	days	days	days	days
WP 8.1	M Ellis	Electronics	60	15				75
	D Gostick	Mechanical	15	15				30
WP 8.2	M Ellis	Electronics		15				15
	D Gostick	Mechanical	30	70	50			150
	M Cliffe	Mechanical			40			40
WP 8.3	D Atkinson	Electronics		120	50			170
	Electronic Technician	Electronics			154	96		250
	M Cliffe	Mechanical		30	90			120
WP 8.4	M Ellis	Electronics	20	40	130	90		280
WP 8.5	M Ellis	Electronics		60	40			100
WP 8.6	M Ellis	Electronics				60		60
	D Gostick	Mechanical				70		70
								0
								0
								0
								0
	Total staff days		125	365	554	316	0	1360
Working Allowance in Above			6	18	28	16	0	68

Staff costs (£k)			2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
		Rate 05/06	£k	£k	£k	£k	£k	£k
WP 8.1	System Design	0.354	21.2	5.3	0.0	0.0	0.0	27
		0.354	5.3	5.3	0.0	0.0	0.0	11
WP 8.2	Mechanical Assembly	0.354	0.0	5.3	0.0	0.0	0.0	5
		0.354	10.6	24.8	17.7	0.0	0.0	53
		0.354	0.0	0.0	14.2	0.0	0.0	14
WP 8.3	FPA Cabling & Electronics	0.354	0.0	42.5	17.7	0.0	0.0	60
		0.354	0.0	0.0	54.5	34.0	0.0	88
		0.354	0.0	10.6	31.8	0.0	0.0	42
WP 8.4	CCD Characterisation	0.354	7.1	14.2	46.0	31.8	0.0	99
WP 8.5	CCD Controllers	0.354	0.0	21.2	14.2	0.0	0.0	35
WP 8.6	Focal Plane AIT	0.354	0.0	0.0	0.0	21.2	0.0	21
		0.354	0.0	0.0	0.0	24.8	0.0	25
		0.354	0.0	0.0	0.0	0.0	0.0	0
		0.354	0.0	0.0	0.0	0.0	0.0	0
		0.354	0.0	0.0	0.0	0.0	0.0	0
		0.354	0.0	0.0	0.0	0.0	0.0	0
Total Staff Costs (£k)			44.2	129.1	196.0	111.8	0.0	481.2
Working Allowance In Above		0.354	2.2	6.5	9.8	5.6	0.0	24.1

Indirect Costs (if applicable)		2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
		£k	£k	£k	£k	£k	£k
Rate	0%	0.0	0.0	0.0	0.0	0.0	0.0
Total for Staff + Indirect Costs (£k)		44.2	129.1	196.0	111.8	0.0	481.2
Cost of Inflation		0.0	4.5	14.0	12.2	0.0	30.6
Total Staff Costs Cash Planned (£k)		44.2	133.7	210.0	124.0	0.0	511.8
Working Allowance in above		2.2	6.7	10.5	6.2	0.0	25.6

Requisitions in (£k)		2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
Equipment		0.0	455.9	1599.5	413.6	0.0	2469.0
Consumables							0.0
Travel & Subsistence		5.0	4.0	2.0			11.0
Exceptional Items							0.0
VAT Recovery (Eqpt & Consumables where applicable)			67.9	238.2	61.6	0.0	367.7
Total (£k) with VAT recovered		5.0	392.0	1363.3	352.0	0.0	2112.3
Conversion rate if applicable	1						
Requisitions Total (£k)		5.0	392.0	1363.3	352.0	0.0	2112.3
Working Allowance (within Reqs Total)		0.3	19.6	68.2	17.6	0.0	105.6
Total Reqs Cash Planned (£k) (with inflation)		5.0	401.8	1432.3	379.1	0.0	2218.2
Working Allowance for Req (with inflation)		0.3	20.3	73.0	19.5	0.0	113.1

Grand Total Cash Planned (Effort + Requisitions)	49.2	535.5	1642.3	503.0	0.0	2730.0
Grand Total Working Allowance	2.5	27.0	83.5	25.7	0.0	138.7

WORK PACKAGE DESCRIPTION		WP No:	9.0
Project:	darkCAM	**Date:**	1st March 2005
Major Subsystem:	Software		
Subsystem:			
WP Title:	Software		
WP Start Event:	Authorisation to proceed		
WP End Event:	Completion of darkCAM integration into telescope and commissioning in Chile		
WP Manager:	I Egan	**Organisation Responsible:**	ATC

WP Aims

1. To produce all camera software & computing hardware required to operate the camera

Inputs

1. VISTA Telescope Interface and darkCAM Conceptual Design documentation
2. VISTA Instrument Software Requirements
3. VISTA Software Architectural Design
4. ESO software standards documents, especially the "ESO VLT Instrument Software Specification" document

Outputs

1. Fully integrated and tested software ready for commissioning at Paranal
2. darkCAM software test report
3. Support for AIT and commissioning

TASKS

1. To refine the overall requirements for the darkCAM software
2. To procure all the computing hardware needed by the darkCAM software
3. To produce software for controlling all the darkCAM mechanisms
4. To design and implement the top level darkCAM Observation Software
5. The generation of instrument configuration files and observing sequences.
6. To co-ordinate the development of low level utilities for testing individual instrument components.
7. To provide high level utilities for verifying the correct operation of the entire instrument.
8. To bring together the various software packages making up the darkCAM software into one integrated whole.
9. To test that all software interfaces adhere to the ICDs.
10. To verify that the darkCAM software meets its requirements.

Justification of Resource Levels:

This Work Package covers all the activities required to produce all darkCAM software & computing hardware required to operate darkCAM and deliver data (in the form of FITS files) to disk in Paranal. Software to take this data from disk and assess its quality in Paranal, and later in Garching along with calibration is contained in WP11, which covers ESO's requirements. As with the Wave-Front Sensing activities advantage will be taken of the knowledge gained form carrying out the VISTA IR camera design and integration phases

darkCAM

Doc No:	darkCAM PPRP submission
Version:	1.0
Category	Proposal
Doc Type:	Word
State:	Released
Author:	ANT/AFH/IE
Date:	1st March 2005

darkCAM COST PROFILE		ATC			Version dated:		28 Feb 2005	
WP 9.0 Software			0	1	2	3	4	
		Inflation for Staff	3.5%	1.000	1.035	1.071	1.109	1.148
		Inflation for Bought out	2.5%	1.000	1.025	1.051	1.077	1.104
		dsy rate (£k) 2005/06	65.1	dsy/day =	0.354			
		staff days per dsy	184					

Staff Days			2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
WP	Name	Specialism	days	days	days	days	days	days
WP 9.1	I Smith	Software	90	120	90			300
WP 9.2	X Gao	Software	10	20	20			50
WP 9.3	X Gao	Software		110	110			220
WP 9.4	I Smith	Software		50	80	140		270
WP 9.5	X Gao	Software				60		60
WP 9.6	X Gao	Software			60	70		130
WP 9.7	I Smith	Software				40	100	140
WP 9.8	I Smith	Software	20	25	25	20		90
								0
								0
								0
								0
								0
								0
								0
								0
Total staff days			120	325	385	330	100	1260
Working Allowance in Above			35	55	30	20		140

Staff costs (£k)			2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
		Rate 05/06	£k	£k	£k	£k	£k	£k
WP 9.1	Software Design	0.354	31.8	42.5	31.8	0.0	0.0	106
WP 9.2	Computing Equipment	0.354	3.5	7.1	7.1	0.0	0.0	18
WP 9.3	Instrument Control SW	0.354	0.0	38.9	38.9	0.0	0.0	78
WP 9.4	Observation Software	0.354	0.0	17.7	28.3	49.5	0.0	96
WP 9.5	Observer Support SW	0.354	0.0	0.0	0.0	21.2	0.0	21
WP 9.6	Maint & Verification SW	0.354	0.0	0.0	21.2	24.8	0.0	46
WP 9.7	Software AIT	0.354	0.0	0.0	0.0	14.2	35.4	50
WP 9.8	Software management	0.354	7.1	8.8	8.8	7.1	0.0	32
								0
								0
								0
								0
								0
								0
								0
								0
Total Staff Costs (£k)			42.5	115.0	136.2	116.8	35.4	445.8
Working Allowance In Above		0.354	12.4	19.5	10.6	7.1	0.0	49.5

Indirect Costs (if applicable)		2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
		£k	£k	£k	£k	£k	£k
Rate	0%	0.0	0.0	0.0	0.0	0.0	0.0
Total for Staff + Indirect Costs (£k)		42.5	115.0	136.2	116.8	35.4	445.8
Cost of Inflation		0.0	4.0	9.7	12.7	5.2	31.6
Total Staff Costs Cash Planned (£k)		42.5	119.0	145.9	129.4	40.6	477.4
Working Allowance in above		12.4	20.1	11.4	7.8	0.0	51.7

Requisitions in (£k)		2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
Equipment		5.9			9.4		15.3
Consumables							0.0
Travel & Subsistence		2.0	1.0	1.0	3.0		7.0
Exceptional Items							0.0
VAT Recovery (Eqpt & Consumables where applicable)		0.9			1.4		2.3
Total (£k) with VAT recovered		7.0	1.0	1.0	11.0	0.0	20.0
Conversion rate if applicable	1						
Requisitions Total (£k)		7.0	1.0	1.0	11.0	0.0	20.0
Working Allowance (within Reqs Total)		0.4	0.1	0.1	0.6	0.0	1.0
Total Reqs Cash Planned (£k) (with inflation)		7.0	1.0	1.1	11.8	0.0	20.9
Working Allowance for Req (with inflation)		0.4	0.1	0.1	0.6	0.0	1.1

Grand Total Cash Planned (Effort + Requisitions)	49.5	120.0	147.0	141.3	40.6	498.4
Grand Total Working Allowance	12.7	20.2	11.4	8.5	0.0	52.8

WORK PACKAGE DESCRIPTION		WP No:	10.0
Project:	DarkCAM	**Date:**	1st March 2005
Major Subsystem:	Assembly, Integration & Test		
Subsystem:			
WP Title:	Assembly, Integration & Test		
WP Start Event:	Camera system design underway		
WP End Event:	Fully integrated and tested darkCAM		
WP Manager:	I Egan	**Organisation Responsible:**	ATC

WP Aims

1. To assemble and integrate the various subsystems of the darkCAM and to perform functional and performance testing to verify the performance of the camera as far as practicable without the full telescope optics completing with European acceptance

Inputs

1. DarkCAM subsystems from ATC, RAL and Durham, together with associated documentation
2. Regularly updated planning & schedule data from all parties involved with the AIT.
3. AIT Facility Requirements Document
4. darkCAM Acceptance Test Procedures

Outputs

1. AIT Plans and procedures
2. Fully commissioned and documented AIT Facilities suitable for darkCAM
3. Fully functional and complete darkCAM ready for shipment to Chile for telescope integration
4. Results and Reports from AIT leading to European acceptance
5. Fully commissioned camera on the VISTA Telescope.

TASKS

1. Prepare detailed plans and procedures for the AIT activities
2. Prepare an AIT Facility suitable for the VISTA darkCAM within predefined budget constraints and within a timescale compatible with darkCAM schedule
3. Integrate and test the darkCAM
4. Perform and document darkCAM Acceptance Testing
5. Prepare Progress Reports and updated schedule data concerning the development of the AIT Facilities and the AIT activities.

Justification of Resource Levels:

The integration and assembly of darkCAM will be a major activity leading towards European acceptance and shipment to Cerro Paranal. The integration team will be led by the systems engineer with full support from the Instrument Scientist. The team will be technical in nature, consisting of technicians from the disciplines of mechanical and electrical engineering. It will also include an optical engineer for specific tasks such as alignment and a software engineer to drive the instrument level checkout system and to develop the required test scripts.

darkCAM COST PROFILE		**ATC**			Version dated:		**28 Feb 2005**	
WP 10.0 System AIT			0	1	2	3	4	
	Inflation for Staff	3.5%	1.000	1.035	1.071	1.109	1.148	
	Inflation for Bought ou	2.5%	1.000	1.025	1.051	1.077	1.104	
	dsy rate (£k) 2005/06	65.1	dsy/day =	0.354				
	staff days per dsy	184						
Staff Days			**2005/06**	**2006/07**	**2007/08**	**2008/09**	**2009/10**	**TOTAL**
WP	**Name**	**Specialism**	**days**	**days**	**days**	**days**	**days**	**days**
WP 10.1	TBD	Sys Eng	10	10	20	40		**80**
WP 10.2	TBD	Sys Eng				60	30	**90**
	S Todd	Optical				30	30	**60**
	D Gostick	Mechanical				45	30	**75**
	M Ellis	Electronic				45	30	**75**
	workshop	Technician Mec				40	30	**70**
	workshop	Technician Elec				40	30	**70**
								0
WP 10.3	D Gostick	Mechanical					5	**5**
	M Ellis	Electronic					5	**5**
	workshop	Technician Mec					5	**5**
	workshop	Technician Elec					5	**5**
								0
WP 10.4	TBD	Sys Eng					30	**30**
	S Todd	Optical					20	**20**
	D Gostick	Mechanical					30	**30**
	M Ellis	Electronic					30	**30**
	workshop	Technician Mec					20	**20**
	workshop	Technician Elec					20	**20**
	X Gao	Software					80	**80**
								0
								0
								0
								0
Total staff days			**10**	**10**	**20**	**300**	**430**	**770**
Working Allowance in Above			**1**	**1**	**1**	**15**	**22**	**39**

Staff costs (£k)			2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
		Rate 05/06	£k	£k	£k	£k	£k	**£k**
WP 10.1	Planning	0.354	3.5	3.5	7.1	14.2	0.0	**28**
WP 10.2	System AIT Europe	0.354	0.0	0.0	0.0	21.2	10.6	**32**
		0.354	0.0	0.0	0.0	10.6	10.6	**21**
		0.354	0.0	0.0	0.0	15.9	10.6	**27**
		0.354	0.0	0.0	0.0	15.9	10.6	**27**
		0.354	0.0	0.0	0.0	14.2	10.6	**25**
		0.354	0.0	0.0	0.0	14.2	10.6	**25**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
WP 10.3	Shipping	0.354	0.0	0.0	0.0	0.0	1.8	**2**
		0.354	0.0	0.0	0.0	0.0	1.8	**2**
		0.354	0.0	0.0	0.0	0.0	1.8	**2**
		0.354	0.0	0.0	0.0	0.0	1.8	**2**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
WP 10.4	Commissioning	0.354	0.0	0.0	0.0	0.0	10.6	**11**
		0.354	0.0	0.0	0.0	0.0	7.1	**7**
		0.354	0.0	0.0	0.0	0.0	10.6	**11**
		0.354	0.0	0.0	0.0	0.0	10.6	**11**
		0.354	0.0	0.0	0.0	0.0	7.1	**7**
		0.354	0.0	0.0	0.0	0.0	7.1	**7**
		0.354	0.0	0.0	0.0	0.0	28.3	**28**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
		0.354	0.0	0.0	0.0	0.0	0.0	**0**
Total Staff Costs (£k)			**3.5**	**3.5**	**7.1**	**106.1**	**152.1**	**272.4**
Working Allowance In Above		0.354	0.2	0.2	0.4	5.3	7.6	13.6

Indirect Costs (if applicable)		2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
		£k	£k	£k	£k	£k	**£k**
Rate	0%	0.0	0.0	0.0	0.0	0.0	**0.0**
Total for Staff + Indirect Costs (£k)		3.5	3.5	7.1	106.1	152.1	**272.4**
Cost of Inflation		0.0	0.1	0.5	11.5	22.4	**34.6**
Total Staff Costs Cash Planned (£k)		**3.5**	**3.7**	**7.6**	**117.7**	**174.6**	**307.0**
Working Allowance in above		0.2	0.2	0.4	5.9	8.7	**15.4**

Requisitions in (£k)		2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
Equipment					41.1		**41.1**
Consumables							**0.0**
Travel & Subsistence						48.4	**48.4**
Exceptional Items							**0.0**
VAT Recovery (Eqpt & Consumables where applicable)					6.1		**6.1**
Total (£k) with VAT recovered		0.0	0.0	0.0	35.0	48.4	**83.4**
Conversion rate if applicable	1						
Requisitions Total (£k)		**0.0**	**0.0**	**0.0**	**35.0**	**48.4**	**83.4**
Working Allowance (within Reqs Total)					1.8		**1.8**
Total Reqs Cash Planned (£k) (with inflation)		**0.0**	**0.0**	**0.0**	**37.7**	**53.4**	**91.1**
Working Allowance for Req (with inflation)		0.0	0.0	0.0	1.9	0.0	**1.9**

Grand Total Cash Planned (Effort + Requisitions)	**3.5**	**3.7**	**7.6**	**155.4**	**228.0**	**398.2**
Grand Total Working Allowance	**0.2**	**0.2**	**0.4**	**7.8**	**8.7**	**17.3**

darkCAM

Doc No:	darkCAM PPRP submission
Version:	1.0
Category	Proposal
Doc Type:	Word
State:	Released
Author:	ANT/AFH/IE
Date:	1st March 2005

darkCAM COST PROFILE	Durham		Version dated:	28 Feb 05		
WP 10.0 System AIT		0	1	2	3	4
Inflation for Staff	3.5%	1.000	1.035	1.071	1.109	1.148
Inflation for Bought out	2.5%	1.000	1.025	1.051	1.077	1.104
dsy rate (£k) 2005/06	65.1	dsy/day =	0.310			
staff days per dsy	210					

Staff Days			2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
WP	Name	Specialism	days	days	days	days	days	days
WP 10.2	P Berry	Electronics				40		**40**
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
								0
Total staff days			**0**	**0**	**0**	**40**	**0**	**40**
Working Allowance in Above			**0**	**0**	**0**	**2**	**0**	**2**

Staff costs (£k)			2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
		Rate 05/06	£k	£k	£k	£k	£k	£k
WP 10.2	System AIT	0.169	0.0	0.0	0.0	6.8	0.0	**7**
			0.0	0.0	0.0	0.0	0.0	**0**
			0.0	0.0	0.0	0.0	0.0	**0**
			0.0	0.0	0.0	0.0	0.0	**0**
			0.0	0.0	0.0	0.0	0.0	**0**
			0.0	0.0	0.0	0.0	0.0	**0**
			0.0	0.0	0.0	0.0	0.0	**0**
			0.0	0.0	0.0	0.0	0.0	**0**
			0.0	0.0	0.0	0.0	0.0	**0**
			0.0	0.0	0.0	0.0	0.0	**0**
			0.0	0.0	0.0	0.0	0.0	**0**
			0.0	0.0	0.0	0.0	0.0	**0**
			0.0	0.0	0.0	0.0	0.0	**0**
			0.0	0.0	0.0	0.0	0.0	**0**
			0.0	0.0	0.0	0.0	0.0	**0**
			0.0	0.0	0.0	0.0	0.0	**0**
Total Staff Costs (£k)			**0.0**	**0.0**	**0.0**	**6.8**	**0.0**	**6.8**
Working Allowance In Above		0.310	0.0	0.0	0.0	0.6	0.0	0.6

Indirect Costs (if applicable)		2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
		£k	£k	£k	£k	£k	£k
Rate	46%	0.0	0.0	0.0	3.1	0.0	**3.1**
Total for Staff + Indirect Costs (£k)		0.0	0.0	0.0	9.9	0.0	**9.9**
Cost of Inflation		0.0	0.0	0.0	1.1	0.0	**1.1**
Total Staff Costs Cash Planned (£k)		**0.0**	**0.0**	**0.0**	**10.9**	**0.0**	**10.9**
Working Allowance in above		0.0	0.0	0.0	0.7	0.0	**0.7**

Requisitions in (£k)		2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
Equipment							**0.0**
Consumables							**0.0**
Travel & Subsistence					5.0		**5.0**
Exceptional Items							**0.0**
VAT Recovery (Eqpt & Consumables where applicable)							**0.0**
Total (£k) with VAT recovered		0.0	0.0	0.0	5.0	0.0	**5.0**
Conversion rate if applicable	1						
Requisitions Total (£k)		**0.0**	**0.0**	**0.0**	**5.0**	**0.0**	5.0
Working Allowance (within Reqs Total)		0.0	0.0	0.0	0.3	0.0	**0.3**
Total Reqs Cash Planned (£k) (with inflation)		**0.0**	**0.0**	**0.0**	**5.4**	**0.0**	**5.4**
Working Allowance for Req (with inflation)		0.0	0.0	0.0	0.3	0.0	**0.3**

	2005/06	2006/07	2007/08	2008/09	2009/10	TOTAL
Grand Total Cash Planned (Effort + Requisitions)	**0.0**	**0.0**	**0.0**	**16.3**	**0.0**	**16.3**
Grand Total Working Allowance	**0.0**	**0.0**	**0.0**	**1.0**	**0.0**	**1.0**

WORK PACKAGE DESCRIPTION		**WP No:**	11.0
Project:	darkCAM	**Date:**	01 Mar 2005
Major Subsystem:	Data Pipeline		
Subsystem:			
WP Title:	Data Flow Pipeline		
WP Start Event:	Authorisation to proceed		
WP End Event:	Delivery of ESO deliverables and commissioning in Chile & Garching		
WP Manager:	I Egan	**Organisation Responsible:**	Cambridge (CASU)

WP Aims

1. To produce all software required to meet ESO's data flow requirements

Inputs

1. ESO requirements specified in "*Data Flow for the VLT instruments requirements specification",* VLT-SPE-ESO-19000-1618, issue 2.0, 2004-05-22 known as "1618"
2. VISTA darkCAM Observation Software Design Description
3. VISTA IR Camera Pipeline documentation
4. darkCAM Observing modes

Outputs

1. Deliver documentation files and modules to ESO as specified in 1618
2. Support commissioning of pipeline in Paranal and Garching.

TASKS

1. To refine the overall requirements for the darkCAM pipeline software
2. Produce to following 5 documents *Data Flow Impact Document, Calibration Plan, Data Reduction Library Specifications, Data Reduction Library Design, Exposure Time Calculator Specifications* which includes generation of the ancillary software packages to support the preparation of darkCAM observation proposals and Observing Blocks.
3. To present these documents for PDR and FDR by ESO.
4. To implement the associated software
5. To produce the associated software including the following modules *Data Reduction Library, Specific DFS Tools (i.e. Survey Definition Tool),*
6. To produce (with other WPs) the following data packages for ESO *ETC Description Database, Instrument Package, Instrument test and Calibration Data*
7. To assist ESO in integrating these into their system
8. To assist ESO in commissioning the data flow pipeline

Justification of Resource Levels:
This workpackage covers all the activities required to meet the ESO requirements specified in *Data Flow for the VLT instruments requirements specification,* VLT-SPE-ESO-19000-1618, issue 2.0, 2004-05-22. These include an Exposure Time Calculator, generation of Quality Control (QC) measures in Paranal and Garching, and removal of instrumental effects to produce photometrically and astrometrically calibrated data. As with the other activities advantage will be taken of the knowledge gained form carrying out the equivalent task for the VISTA IR camera. This completes responsibility for deliverables to ESO.

Note that the UK Data Analysis and Archiving are both expected to be coverable within separate arrangements already made for VISTA data (from its IR camera) at the Cambridge Astronomical Surveys Unit – CASU, and at the Wide Field Astronomy Unit – WFAU - Edinburgh. Subsequent science exploitation (e.g. weak lensing analysis) of the calibrated frames will be covered by a standard grant application to PPARC.

darkCAM

Doc No:	darkCAM PPRP submission
Version:	1.0
Category	Proposal
Doc Type:	Word
State:	Released
Author:	ANT/AFH/IE
Date:	1st March 2005

darkCAM COST PROFILE	**Cambridge**				Version dated:		**1 Mar 05**
WP 11.0 Pipe Line		0	1	2	3	4	
Inflation for Staff	3.5%	1.000	1.035	1.071	1.109	1.148	
Inflation for Bought out	2.5%	1.000	1.025	1.051	1.077	1.104	
dsy rate (£k) 2005/06	Variable	dsy/day =	0.235				
staff days per dsy	210						

Staff Days			**2005/06**	**2006/07**	**2007/08**	**2008/09**	**2009/10**	**TOTAL**
WP	**Name**	**Specialism**	**days**	**days**	**days**	**days**	**days**	**days**
WP 11.1	Bunclark	Documentation	15	15	105	105	50	**290**
	Lewis	Software	0	10	20	40	30	**100**
	Irwin	Mgt/software	5	5	10	20	15	**55**
	Hodgkin	Calibration	5	5	10	20	15	**55**
	Pool @10% (formu	Computer Mngr	3	4	15	19	11	**52**
	Pool @8% (formula	Secretary	2	3	12	15	9	**41**
								0
								0
								0
								0
								0
								0
								0
								0
								0
		Total staff days	**30**	**42**	**172**	**219**	**130**	**593**
Working Allowance in Above			**2**	**2**	**9**	**11**	**7**	**30**

Staff costs (£k)			2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
		Rate 05/06	£k	£k	£k	£k	£k	**£k**
WP 11.1	Bunclark	0.250	3.8	3.8	26.3	26.3	12.5	**73**
	Lewis	0.250	0.0	2.5	5.0	10.0	7.5	**25**
	Irwin	0.270	1.4	1.4	2.7	5.4	4.1	**15**
	Hodgkin	0.250	1.3	1.3	2.5	5.0	3.8	**14**
	Pool @10% (formu	0.169	0.5	0.7	2.5	3.2	1.9	**9**
	Pool @8% (formula	0.109	0.2	0.3	1.3	1.6	1.0	**4**
		0.000	0.0	0.0	0.0	0.0	0.0	**0**
		0.000	0.0	0.0	0.0	0.0	0.0	**0**
		0.000	0.0	0.0	0.0	0.0	0.0	**0**
		0.000	0.0	0.0	0.0	0.0	0.0	**0**
Total Staff Costs (£k)			**7.1**	**9.9**	**40.3**	**51.5**	**30.6**	**139.4**
Working Allowance In Above		0.235	0.4	0.5	2.0	2.6	1.5	7.0

Indirect Costs (if applicable)		2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
		£k	£k	£k	£k	£k	**£k**
Rate	46%	3.3	4.5	18.5	23.7	14.1	**64.1**
Total for Staff + Indirect Costs (£k)		10.3	14.4	58.8	75.2	44.7	**203.5**
Cost of Inflation		0.0	0.5	4.2	8.2	6.6	**19.5**
Total Staff Costs Cash Planned (£k)		**10.3**	**14.9**	**63.0**	**83.4**	**51.3**	**222.9**
Working Allowance in above		0.4	0.5	2.2	2.9	1.8	**7.6**

Requisitions in (£k)		2005/06	2006/07	2007/08	2008/09	2009/10	**TOTAL**
Equipment		2.5					**2.5**
Consumables		0.1	0.1	0.2	0.2	0.5	**1.1**
Travel & Subsistence		2.0	2.0	7.0	7.0	15.0	**33.0**
Exceptional Items							**0.0**
VAT Recovery (Eqpt & Consumables where applicable)							**0.0**
Total (£k) with VAT recovered		4.6	2.1	7.2	7.2	15.5	**36.6**
Conversion rate if applicable	1						
Requisitions Total (£k)		**4.6**	**2.1**	**7.2**	**7.2**	**15.5**	**36.6**
Working Allowance (within Reqs Total)		0.2	0.1	0.4	0.4	0.8	**1.8**
Total Reqs Cash Planned (£k) (with inflatior		**4.6**	**2.2**	**7.6**	**7.8**	**17.1**	**39.2**
Working Allowance for Req (with inflation)		0.2	0.1	0.4	0.4	0.9	**2.0**

Grand Total Cash Planned (Effort + Requisitions)	**14.9**	**17.0**	**70.6**	**91.1**	**68.4**	**262.1**
Grand Total Working Allowance	**0.6**	**0.6**	**2.6**	**3.3**	**2.6**	**9.6**

Annex B1: Staff Effort Overview by Institute

Institute:	ATC	2005/06	2006/07	2007/08	2008/09	2009/10	Total
Name	**Title**	**Staff Mths**	**Staff Mths**	**Staff Mths**	**Staff Mths**	**Staff Mths**	
I Egan	Project Manager	6.3	12.3	12.3	12.0	6.0	**49.0**
V Ramsey	Project Assistant	3.9	6.0	3.6	6.0	2.1	**21.6**
J Murray	QA Engineer	0.7	1.6	1.3	1.3	1.0	**5.9**
TBD	Instrument Scientist	5.2	4.6	3.9	5.1	5.2	**24.0**
TBD	Systems Engineer	6.7	9.7	10.3	12.5	3.9	**43.0**
D Gostick	Mechanical Engineer	6.2	11.3	10.0	7.5	4.2	**39.2**
M Cliffe	Mechanical Engineer	5.2	10.1	15.7	2.6	0.0	**33.6**
M Ellis	Electronics Engineer	5.2	8.5	11.1	12.7	4.2	**41.7**
D Atkinson	Electronics Engineer	2.0	11.1	6.2	1.3	0.0	**20.5**
I Smith	Software Engineer	7.2	12.7	12.7	13.0	6.5	**52.2**
X Gao	Software Engineer	0.7	8.5	12.4	8.5	5.2	**35.2**
S Todd	Optical Engineer	0.0	0.0	0.0	2.0	3.3	**5.2**
workshop	Electronic Tech	0.0	0.0	12.7	8.9	3.6	**25.1**
workshop	Project Tech	0.0	0.0	4.8	2.6	3.6	**11.0**
workshop	Technician	0.0	0.0	6.5	2.6	0.0	**9.1**
							0.0
							0.0
							0.0
							0.0
							0.0
Total Staff Months		**49.2**	**96.3**	**123.4**	**98.6**	**48.8**	**416.3**
Total Staff Costs		266.8	522.6	669.4	535.0	265.0	**2258.7**
Total Staff Costs with inflation		**266.8**	**540.9**	**717.1**	**593.1**	**304.1**	**2421.9**

Institute:	RAL	2005/06	2006/07	2007/08	2008/09	2009/10	Total
Name	**Title**	**Staff Mths**	**Staff Mths**	**Staff Mths**	**Staff Mths**	**Staff Mths**	
K Ward	Project Manager	5.1	6.9	3.3	2.1	0.0	**17.4**
M Caldwell	Systems/Optics	5.1	4.0	1.4	2.6	0.0	**13.1**
I Tosh	Optics Engineer	7.7	12.0	12.6	3.7	0.0	**36.0**
T Richards	Optics Engineer	4.7	12.7	1.7	0.0	0.0	**19.1**
M Whalley	Mechanical Engineer	4.9	9.1	7.7	3.7	0.0	**25.4**
R Edeson	Mechanical Engineer	5.7	10.3	2.6	0.0	0.0	**18.6**
K Burke	Mechanical Engineer	5.7	12.0	6.3	0.0	0.0	**24.0**
D Parker	Electrical Engineer	2.0	3.4	3.4	0.0	0.0	**8.9**
							0.0
							0.0
Total Staff Months		**41.0**	**70.4**	**39.0**	**12.1**	**0.0**	**162.6**
Total Staff Costs		222.6	382.1	211.8	65.4	0.0	**881.9**
Total Staff Costs with inflation		**240.3**	**426.9**	**244.9**	**78.3**	**0.0**	**990.4**

Institute:	Durham	2005/06	2006/07	2007/08	2008/09	2009/10	Total
Name	**Title**	**Staff Mths**	**Staff Mths**	**Staff Mths**	**Staff Mths**	**Staff Mths**	
Richard Myers	Science	1.5	1.5	0.0	0.0	0.0	**3.0**
Paul Berry	Electronics	5.9	12.1	12.1	8.3	0.0	**38.3**
Chris Moore	Electronics	0.0	0.0	6.0	0.0	0.0	**6.0**
Eddy Younger	Software	3.0	6.1	1.5	1.5	0.0	**12.0**
Peter Luke	Opto-Mech	3.0	7.5	1.5	0.0	0.0	**12.0**
George Teasdale	Mechanical	0.0	0.0	6.0	0.0	0.0	**6.0**
							0.0
Total Staff Months		**13.4**	**27.1**	**27.0**	**9.8**	**0.0**	**77.3**
Total Staff Costs		59.6	119.1	106.3	42.2	0.0	**327.2**
Total Staff Costs with inflation		**59.6**	**123.3**	**113.9**	**46.8**	**0.0**	**343.5**

Institute:	Cambridge	2005/06	2006/07	2007/08	2008/09	2009/10	Total
Name	**Title**	**Staff Mths**	**Staff Mths**	**Staff Mths**	**Staff Mths**	**Staff Mths**	
Bunclark	Documentation	0.9	0.9	6.0	6.0	2.9	**16.6**
Lewis	Software	0.0	0.6	1.1	2.3	1.7	**5.7**
Irwin	Mgt/software	0.3	0.3	0.6	1.1	0.9	**3.1**
Hodgkin	Calibration	0.3	0.3	0.6	1.1	0.9	**3.1**
Pool @10% (formula	Computer Mngr	0.2	0.2	0.9	1.1	0.6	**3.0**
Pool @8% (formula)	Secretary	0.1	0.2	0.7	0.9	0.5	**2.3**
							0.0
Total Staff Months		**1.7**	**2.4**	**9.8**	**12.5**	**7.4**	**33.9**
Total Staff Costs		10.3	14.4	58.8	75.2	44.7	**203.5**
Total Staff Costs with inflation		**10.3**	**14.9**	**63.0**	**83.4**	**51.3**	**222.9**

Annex B2: Total Funding by Financial Year

Staff Effort Costs	2005/06	2006/07	2007/08	2008/09	2009/10	Total
UK ATC	266.8	540.9	717.1	593.1	304.1	**2422**
University of Durham	40.8	84.4	78.0	32.0	0.0	**235**
RAL	240.3	426.9	244.9	78.3	0.0	**990**
Cambridge	7.1	10.2	43.5	57.8	35.8	**154**
	555.0	**1062.4**	**1083.5**	**761.3**	**339.9**	3802

Equipment						
WP1	0.0	0.0	2.1	43.1	0.0	**45**
WP2	0.0	0.0	0.0	0.0	0.0	**0**
WP3	0.0	0.0	0.0	0.0	0.0	**0**
WP4	0.0	0.0	211.1	25.3	0.0	**236**
WP5	0.0	0.0	432.4	0.0	0.0	**432**
WP6	0.0	1393.5	334.5	0.0	0.0	**1728**
WP7	5.0	89.7	237.4	12.9	0.0	**345**
WP8	0.0	467.3	1680.5	445.4	0.0	**2593**
WP9	5.9	0.0	0.0	10.1	0.0	**16**
WP10	0.0	0.0	0.0	44.3	0.0	**44**
WP11	2.5	0.0	0.0	0.0	0.0	**3**
	13.4	**1950.4**	**2898.1**	**581.1**	**0.0**	**5443**

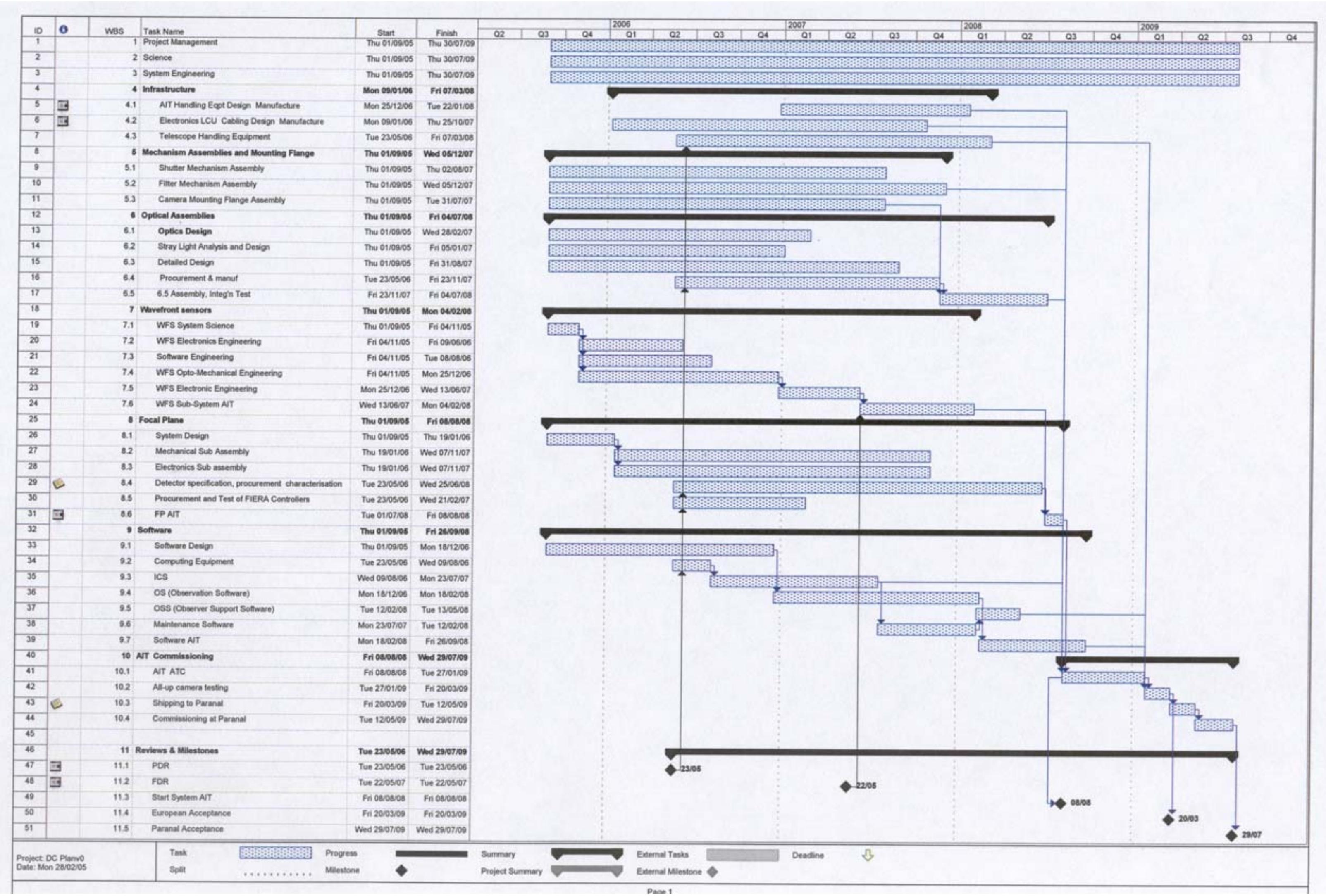
Travel						
WP1	25.2	30.4	31.7	21.7	4.8	**114**
WP2	3.0	3.1	2.1	2.2	0.0	**10**
WP3	0.0	0.0	0.0	0.0	0.0	**0**
WP4	0.0	0.0	0.0	0.0	0.0	**0**
WP5	0.0	0.0	2.2	0.0	0.0	**2**
WP6	4.5	6.5	2.0	0.0	0.0	**13**
WP7	1.0	1.6	3.2	1.1	0.0	**7**
WP8	5.0	4.1	2.1	0.0	0.0	**11**
WP9	2.0	1.0	1.1	3.2	0.0	**7**
WP10	0.0	0.0	0.0	5.4	53.4	**59**
WP11	2.0	2.1	7.4	7.5	16.6	**35**
	42.7	**48.8**	**51.6**	**41.1**	**74.8**	**259.0**

Totals	2005/06	2006/07	2007/08	2008/09	2009/10	Total
Staff Effort	555.0	1062.4	1083.5	761.3	339.9	**3802**
Equipment	13.4	1950.4	2898.1	581.1	0.0	**5443**
Travel	42.7	48.8	51.6	41.1	74.8	**259**
Indirect Costs	22.0	43.5	55.3	40.2	15.6	**177**
Consumables	8.5	22.6	33.7	8.3	0.6	**74**
Exceptional Items	0.0	0.0	0.0	0.0	0.0	**0**
VAT Recovery (where applicable)	-0.9	-277.1	-426.7	-85.7	0.0	**-790**
Overall Totals by Year	**641**	**2851**	**3696**	**1346**	**431**	**8964**

Annex B3: Total Funding by Institute and Work Package

WBS	UK ATC	Durham	RAL	Cambridge	Capital Costs less any VAT Recovery	Total
WP 1 Project Management	445.6	41.1	106.1		213.0	**806**
WP 2 Science	139.8				10.3	**150**
WP 3 Systems Engineering	171.5				0.0	**171**
WP 4 Infrastructure	136.6				201.2	**338**
WP 5 Mechanical Assemblies	232.2				370.2	**602**
WP 6 Optical Assemblies			884.3		1494.4	**2379**
WP 7 WFS		291.5			321.5	**613**
WP 8 Focal Plane	511.8				2218.2	**2730**
WP 9 Software	477.4				20.9	**498**
WP 10 AIT	307.0	10.9			96.5	**414**
WP 11 Data Pipeline				222.9	39.2	**262**
TOTAL	**2421.9**	**343.5**	**990.4**	**222.9**	**4985.4**	**8964**

Annex C: Gantt Chart



ID WBS Task Name Start Finish
2006 2007 2008 2009
Q1 Q2 Q3 Q4
1 1 Project Management Thu 01/09/05 Thu 30/07/09
2 2 Science Thu 01/09/05 Thu 30/07/09
3 3 System Engineering Thu 01/09/05 Thu 30/07/09
4 4 Infrastructure Mon 09/01/06 Fri 07/03/08
5 4.1 AIT Handling Eqpt Design Manufacture Mon 25/12/06 Tue 22/01/08
6 4.2 Electronics LCU Cabling Design Manufacture Mon 09/01/06 Thu 25/10/07
7 4.3 Telescope Handling Equipment Tue 23/05/06 Fri 07/03/08
8 5 Mechanism Assemblies and Mounting Flange Thu 01/09/05 Wed 05/12/07
9 5.1 Shutter Mechanism Assembly Thu 01/09/05 Thu 02/08/07
10 5.2 Filter Mechanism Assembly Thu 01/09/05 Wed 05/12/07
11 5.3 Camera Mounting Flange Assembly Thu 01/09/05 Tue 31/07/07
12 6 Optical Assemblies Thu 01/09/05 Fri 04/07/08
13 6.1 Optics Design Thu 01/09/05 Wed 28/02/07
14 6.2 Stray Light Analysis and Design Thu 01/09/05 Fri 05/01/07
15 6.3 Detailed Design Thu 01/09/05 Fri 31/08/07
16 6.4 Procurement & manuf Tue 23/05/06 Fri 23/11/07
17 6.5 6.5 Assembly, Integ'n Test Fri 23/11/07 Fri 04/07/08
18 7 Wavefront sensors Thu 01/09/05 Mon 04/02/08
19 7.1 WFS System Science Thu 01/09/05 Fri 04/11/05
20 7.2 WFS Electronics Engineering Fri 04/11/05 Fri 09/06/06
21 7.3 Software Engineering Fri 04/11/05 Tue 08/08/06
22 7.4 WFS Opto-Mechanical Engineering Fri 04/11/05 Mon 25/12/06
23 7.5 WFS Electronic Engineering Mon 25/12/06 Wed 13/06/07
24 7.6 WFS Sub-System AIT Wed 13/06/07 Mon 04/02/08
25 8 Focal Plane Thu 01/09/05 Fri 08/08/08
26 8.1 System Design Thu 01/09/05 Thu 19/01/06
27 8.2 Mechanical Sub Assembly Thu 19/01/06 Wed 07/11/07
28 8.3 Electronics Sub assembly Thu 19/01/06 Wed 07/11/07
29 8.4 Detector specification, procurement characterisation Tue 23/05/06 Wed 25/06/08
30 8.5 Procurement and Test of FIERA Controllers Tue 23/05/06 Wed 21/02/07
31 8.6 FP AIT Tue 01/07/08 Fri 08/08/08
32 9 Software Thu 01/09/05 Fri 26/09/08
33 9.1 Software Design Thu 01/09/05 Mon 18/12/06
34 9.2 Computing Equipment Tue 23/05/06 Wed 09/08/06
35 9.3 ICS Wed 09/08/06 Mon 23/07/07
36 9.4 OS (Observation Software) Mon 18/12/06 Mon 18/02/08
37 9.5 OSS (Observer Support Software) Tue 12/02/08 Tue 13/05/08
38 9.6 Maintenance Software Mon 23/07/07 Tue 12/02/08
39 9.7 Software AIT Mon 18/02/08 Fri 26/09/08
40 10 AIT Commissioning Fri 08/08/08 Wed 29/07/09
41 10.1 AIT ATC Fri 08/08/08 Tue 27/01/09
42 10.2 All-up camera testing Tue 27/01/09 Fri 20/03/09
43 10.3 Shipping to Paranal Fri 20/03/09 Tue 12/05/09
44 10.4 Commissioning at Paranal Tue 12/05/09 Wed 29/07/09
45
46 11 Reviews & Milestones Tue 23/05/06 Wed 29/07/09
47 11.1 PDR Tue 23/05/06 Tue 23/05/06
48 11.2 FDR Tue 22/05/07 Tue 22/05/07
49 11.3 Start System AIT Fri 08/08/08 Fri 08/08/08
50 11.4 European Acceptance Fri 20/03/09 Fri 20/03/09
51 11.5 Paranal Acceptance Wed 29/07/09 Wed 29/07/09
23/05
22/05
08/08
20/03
29/07
Project: DC Planv0
Date: Mon 28/02/05
Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External Milestone
Deadline

Annex D: Milestones

Project Milestone/Activity	Provisional Dates		Comments
	Start	Finish	
Preliminary Design Phase	1 Sep 05	30 May 06	Assumes PPARC approval to start gained by 1 Aug 05 (ESO endorsement also required)
Formal acceptance by ESO	1 Sept 05		Negotiations on Telescope time with ESO will be necessary.
PDR	22 May 06	23 May 06	Assumes Kick-off (TO) is 1 Sep 05
Final Design Phase	1 June 06	31 May 07	
FDR	23 May 07	24 May 07	Hardware Commitment prior to this date limited to risk mitigation and long lead items.
Manufacture and AIV	1 June 07	28 Feb 09	All sub modules will be individually performance tested. Complete Instrument Integration and Verification.
European Acceptance	8 March 09	20 March 09	ESO accepts performance against technical specification.
Commissioning Paranal	7 May 09	24 Jul 09	The commissioning schedule to be confirmed by ESO subsequent to European Acceptance.

Annex E: Risks

Work Package	Work Package Cost £k	Largest Critical Risk Factor	Effect of Risk	Proposed Actions to Mitigate Risk
1.0 Project Management	806	Distributed project team	Consortium fails to function effectively	Effective Management Organisation with clearly defined responsibilities and communication methods.
2.0 Project Science	150	Lack of Instrument Scientist identified for project	Failure to provide scientific input during early design stages	Engage Instrument Scientist. In immediate short term use scientific knowledge from PI and VISTA scientists.
3.0 System Engineering	171	Lack of systems engineer identified for project	Technical budgets and configuration control at greater risk.	Engage dedicated systems engineer.
4.0 Infrastructure	338	Handling issues	Delay whilst issues resolved	Build on Handling expertise built up with VISTA IR - Ensure Telescope and Bode Interfaces are considered from start of project
5.0 Mechanism Assemblies	602	Flexure	Instrument does not meet specification	Consider flexure and budget from beginning of PDR phase
6.0 Optical Assemblies	2379	Large camera optics manufacturing overruns	Potential delay to programme	Order optics as early as possible, commensurate with design status, so that they do not impact critical path
7.0 Wave-Front Sensors	613	EMC Issues wrt science detectors	Degraded performance; time delay whilst issues addressed	Apply best design practice, note solution in WFCAM
8.0 Focal Plane	2730	Detectors delivered late	Delay to completion of integration and delivery to schedule	Detectors are items with longest lead time on project. Initiate procurement process at earliest possible stage (pre-PDR if appropriate approvals and agreements are in place)
9.0 Software	498	Unforeseen software complexity	Increase in effort to solve, delay to critical path if found during late stages of AIT	Learn from current implementation for VISTA IR Camera software, implement any relevant lessons learnt. Make use of standard ESO solutions wherever viable.
10.0 AIT & Commissioning	414	ESO interaction	Delay	Take note of VISTA IR experience and build into plan.
11.0 Data Pipeline	262	Unforeseen software complexity	Increase in effort to solve	Take note of VISTA IR experience and build into plan.

Annex F: CVs of Key Personnel

PI, PM

Name:		Dr Andrew Taylor
Organisation:		University of Edinburgh
Position:		Lecturer
Project Role:		darkCAM Principle Investigator
Time allocated to project:		100%
Year	**Qualification**	**Subject**
1988	**BSc**	**Physics with Astrophysics**
1992	**PhD**	**Cosmology**

Employment:
1992-2000 PPARC PDRA, University of Edinburgh
2000-2005 PPARC Advanced Research Fellow, University of Edinburgh
2002- Lecturer in Astrophysics, University of Edinburgh

Major research interests in Cosmology and AstroParticle Physics

- Gravitational Lensing in 2-D and 3-D and the study of the Dark Matter distribution and Dark Energy
- Analysis of Cosmic Microwave Background temperature and polarization anisotropies and Gravitational Waves
- Early Universe (Inflation and gravitinos) and String/M-Theory (Inflation)
- Analysis of Galaxy Redshift Surveys (QDOT, PSCz, 2dF) and velocity surveys (6dF) and the local Universe.

Related Experience:

- Head of Gravitational Lensing Group, Edinburgh.
- P.I. and Science coordinator of ESO-WFI COMBO-17 gravitational lensing survey.
- Science coordinator and co-I of QUaD CMB polarization experiment.
- Head of data analysis pipeline, QUaD CMB polarization experiment.
- Science associate of 6dF Galaxy Redshift and Velocity Survey.
- Science associate of 2dF Galaxy Redshift Survey.
- Science associate of PSCz Galaxy Redshift Survey.
- Science associate of QDOT Galaxy Redshift Survey.

Other Non-related Experience:

- Author of over 50 refereed papers, with a total of over 1300 citations in Cosmology

Name:		Ian Egan
Organisation:		UK ATC
Position:		Project Manager
Project Role:		darkCAM Project Manager
Time allocated to project:		100%
Year	**Qualification**	**Subject**
1980	**BSc**	**Applied Physics with Solid State Electronics**
2003	**dMBA**	**Business Administration**

Employment:

1980-1996 Royal Air Force (11 years flying duties and 7 years working on avionic system flight trials programmes)

1996-1999 GEC Marconi Project Manager for Electro-optic Technology Demonstrator programmes

1999-2000 Engineering management research at Heriot-Watt University, Edinburgh

2000- Project Manager UK ATC

Related Experience:

- Seven years of working, leading and managing complex avionic flight trials for new products including NVGs, FLIR and electro-optic targeting pods at UK Official Flight Test Centre.
- Three years of industrial project management working for a large aerospace company covering electro-optic programmes involving systems, electrical, detector, mechanical, software, commercial, accounting, QA, manufacturing, marketing specialists. All projects were multi-discipline and involved joint working with other UK or European companies.
- Carrying out action based research (now in the final stages of a part-time PhD) into the management of the engineering design process.
- Four years of experience in the astronomy community working at UK ATC on various projects including work package manager activities for the M2 Unit, and M1 and M2 mirrors for VISTA.

Other non-related Experience:

- Eleven years working as a team member or leader in the low level fast-jet environment.

Annex G: darkCAM Consortium

The darkCAM Consortium is a collaboration between a large number of UK institutes. The consortium leader is

Dr Andrew Taylor (PI) University of Edinburgh

The roles and responsiblities of the PI are set out in Section 4 of the main submission. The darkCAM Co-I's and principal contacts are

Prof Alan Heavens University of Edinburgh
on behalf of the UK Weak Lensing Consortium at the Universities of Edinburgh, Cambridge, Nottingham, Durham, Oxford, Imperial College and Cardiff.

Prof George Efstathiou Cambridge
on behalf of the Planck Consortium

Prof Jim Emerson Queen Mary, University of London

Dr Will Sutherland Cambridge
both on behalf of the VISTA Consortium of 18 UK Universities.

Partners:

Prof Ian Robson UK Astronomy Technology Centre (UKATC)

Prof Ray Sharples University of Durham

Prof Richard Holdaway RAL

The roles and work package details for UK institutes are set out in Section 4 of the main submission. RAL will be responsible for WP6 (Optical Assemblies, baffles and ADC mechanism). Durham will be responsible for WP7 (WFS). UKATC will be responsible for the remaining Work Packages.

Prof Thierry Courvoisier Geneva Observatory

Prof Georges Meylan Ecole Polytechnique Federale de Lausanne; EPFL

Dr Mike Irwin Cambridge Astronomical Survey Unit, Cambridge

Dr Nigel Hambly Wide Field Astronomy Unit, Edinburgh

Annex H: Public Outreach

Doc No:	darkCAM PPRP submission
Version:	1.0
Category	Proposal
Doc Type:	Word
State:	Released
Author:	ANT/AFH/IE
Date:	1st March 2005

A UK Consortium led by Dr Andrew Taylor of the University of Edinburgh is building darkCAM: a Dark Energy Camera for European Southern Observatory's (ESO) Visible and Infrared Survey Telescope for Astronomy (VISTA) at the Paranal Observatory in Chile. The site is part of the European Southern Observatory which is an intergovernmental European organisation for astronomical research with currently ten member countries including the UK. The UK institutes involved in building the instrument are the Astronomical Technology Centre (Edinburgh), the University of Durham and the Rutherford Appleton Laboratories (RAL). The UK staff effort is funded by PPARC.

The Dark Energy Camera, known as darkCAM, is scheduled for completion in 2009 and, integrated with VISTA, will have the best wide-field image quality in the world. darkCAM's mission will be to image billions of galaxies to detect the gravitational lensing effect due to the intervening Dark Matter in the Universe. Combined with the distance to these galaxies, darkCAM will build up a 3-Dimensional map of the Dark Matter distribution in the Universe, which will tie down the properties of the Dark Matter to a few percent. But the major aim of the survey will be to use this 3-D map to pin down the properties of the mysterious Dark Energy to high precision, and determine if it is Einstein's Cosmological Constant, or if it is due to the energy of the vacuum itself. Both of these problems constitute the biggest outstanding issues in Cosmology and Physics.

The darkCAM concept includes a number of specialised technologies, some of which have been developed in collaboration with UK industry.

Contact People

Dr Andrew Taylor	University of Edinburgh	+44(0)131-668-8298
Prof Jim Emerson	Queen Mary University of London	+44(0)207-882-5040

Annex I: Statement of Interest from Swiss Partners

Statement of interest
in a potential participation
in the DarCAM project

In view of the potentially very high scientific output of DarkCAM which is in the line with our scientific research, we are very interested in the current discussion about a possible Swiss participation in DarkCAM.

After discussions in Switzerland between Francesco Pepe (Geneva Observatory) and Thierry Courvoisier (Integral Science Data Center - Geneva Observatory) and after two teleconferences with Jim Emerson, Alan Heavens, Will Sutherland, and Andrew Taylor of the DarkCAM project, we indentify possible areas of contribution, such as: (i) Mechanism Assemblies and Mounting Flange, and/or (ii) Wavefront sensors, and/or (iii) contribution to the scientific analysis pipeline.

In case of a positive outcome of this collaboration, we would look forward to participating in the scientific exploitation of the DarCAM results.

Prof. Georges Meylan
Directeur Laboratoire d'astrophysique
Ecole Polytechnique Federale de Lausanne (EPFL)
Observatoire
CH-1290 Chavannes-des-Bois
Switzerland