1 The VISTA Hemisphere Survey SMP

PI: Richard McMahon, University of Cambridge, UK (rgm@ast.cam.ac.uk)
Deputy/Co-PI: Andrew Lawrence, Institute for Astronomy, University of Edinburgh, UK

Co-I's: F. Abdalla(UCL), D. Alexander(Durham), J. Alfonso(IAC), C. Bailer-Jones(MPIA), M. Balcells(IAC), X. Barcons(Santander), D. Barrado y Navascues(Madrid), V. Belokurov(Cam), E. Bell(MPIA), N. Benítez(Granada), J. Bouvier(Grenoble), M. Bremer(Bristol), S. Bridle(UCL), L. Cairos(IAC), F. Carrera(Santander), F. Castander(Barcelona), E. Caux(Toulouse), M. Cioni(Edinburgh), A. Collister(Cambridge), R. Crittenden(Portsmouth), G. Dalton(Oxford), J. Davies(Cardiff), P. Doel(UCL), M. Doherty(ESO), S. Driver(St Andrews), A. Edge(Dur), E. Edmundson(Portsmouth), J. Emerson(QMUL), J. Espinosa(IAC), A. Ferguson(Edin), E. Fernández(Barcelona), P. Fosalba(Barcelona), P. Garcia(Porto), J. García-Bellido(Madrid), F. Garzon(IAC), E. Gaztañaga (Barcelona), B. Goldman(MPIA), G. Gilmore(Cam), E. Gonzalez(Cam), N. Hambly(Edin), A. Hererro(IAC), P. Hewett(Cam), S. Hodgkin(Cam), R. Ibata(Stras), L. Infante(PUC), M. Irwin(Cam), P. James(LJMU), R. Jameson(Lei), M. Jarvis(Oxf), B. Jones(QMUL), H. Jones(Herts), T. Kendall(Herts), P. Kroupa (Bonn), N. Kumar(Porto), G. Lagache(IAS), O. Lahav(UCL), J. Lalli(UCL), A. Liddle(Sussex), N. Lodieu(IAC), J. Loveday(Sussex), P. Lucas(Herts), R. Maartens(Ports), A. Manchado(IAC), R. Mann(Edin), E. Martin(IAC), N. Martin(Stras), M. Martínez(Barcelona), J. Maza(U.Chile), R. Miquel(Barcelona), J. Miralda-Escudé(Barcelona), M. Moles(Granada), M. Molla(Madrid), J-L Monin(Grenoble), E. Moraux(Grenoble), C. Munoz-Tunon(IAC), T. Naylor(Exeter), R. Nichol(Ports), P. O'Brien(Leic) S. Oliver(Sussex), A. Omont(IAP), M. Page(UCL), F. Palla(Arcetri), J. Peacock(Edin), W. Percival(Ports), I. Perez-Fournon(IAC), C. Peroux(ESO), P. Petitjean(IAP), S. Phillips(Bristol) D. Pinfield(Herts), J-L. Puget(IAS), S. Randich(Arcetri), S. Rawlings(Oxf), R. Rebolo(IAC), M. Riello(Cam), H-W. Rix(MPIA), K. Romer(Sussex), H. Rottgering(Leiden), M. Rowan-Robinson(IC), E. Sánchez (Madrid), R. Savage(Sussex), R-D. Scholz(AIP), S. Serjeant(Open), T. Shanks(Dur), R. Somerville(MPIA) G. Smith(Birm), W. Sutherland(Cam), A. Swope(AIP), N. Tanvir(Herts), L. Testi(Arcetri), B. Venemans(Cam), P. Viana(CAUP), F. Walter(MPIA), N. Walton(Cam), S. Warren(IC), M. Watson(Leic), N. Webb(Toulouse), J. Weller(UCL), C. Wolf(Oxf), H. Zinnecker(AIP) D. Zucker(Cam)

1.1 Abstract

The VISTA Hemisphere Survey(VHS) is a panoramic Infra-Red survey, which when combined with other large area VISTA Public Surveys (i.e. VIKING, VVV, VMC) will result in coverage of the whole southern celestial hemisphere ($\sim$20,000deg^2) to a depth $\sim$4 magnitudes fainter than 2MASS/DENIS in at least two wavebands J and K_s. In the South Galactic Cap, $\sim$5000deg^2 will be imaged deeper, including H band, and will have supplemental deep multi-band grizY imaging data provided by the Dark Energy Survey (DES). The remainder of the high galactic latitude sky will be imaged in $YJHK_s$ combined with ugriz wavebands from the VST ATLAS survey. The medium term scientific goals include: a huge expansion in our knowledge of; the lowest-mass and nearest stars; deciphering the merger history our own Galaxy; measurement of large-scale structure out to $z \simeq 1$ and measuring the properties of Dark Energy; discovery of the first quasar with z>7. In addition the survey will provide essential support for the ESA Cornerstone missions; XMM-Newton, Planck, Herschel and GAIA. This SMP has a number of issues that we would like to investigate as part of a Public Survey Science Verification phase before Public Survey observations start.

---

2 Survey Observing Strategy

This section should be read in conjunction with the enclosed Excel spreadsheet and the three figures that show the main tabular data contained with this Excel spreadsheet. There is one tabular figure for each of the three VHS survey components described below.

2.1 Scheduling requirements

The VHS survey is divided into 3 components for survey planning and management and purposes, based on their common OB structures. These components in alphabetic order are:

- VHS-ATLAS ($\sim$5000 deg^2); consists of two regions of sky, one in the north galactic cap(NGC; $\sim$2500 deg^2) and the second in the south galactic cap (SGC;$\sim$2500deg^2) to be observed in YJHK$_s$ for 60secs per waveband.
- VHS-DES ($\sim$4500 deg^2); a contiguous region of sky in the SGC to be observed in JHK$_s$ for 120secs per waveband.
- VHS-GPS ($\sim$8200 deg^2); A region of lower galactic latitude which we define as the VHS Galactic Plane Survey(GPS) with $5° < |b| < 30°$ ($\sim$8200 deg^2); excluding the VVV and VMC regions; to be observed in J and K for 60secs per waveband.

The coverage on the celestial sphere is show in equatorial coordinates in figure 1 where the VHS can be divided into three contiguous regions of the celestial sphere.

1. VHS-NGC(North Galactic Cap): $b > 30°$; $\delta < 0°$ ($\sim$2500deg^2); excluding the VIKING NGP region. This is the NGC part of VHS-ATLAS. Propose to start with the VST-ATLAS region, Baseline exposures of 60secs per band in YJHK$_s$.
2. VHS-SGC(South Galactic Cap): $b < -30°$; $\delta < 1.0°$ ($\sim$7000 deg^2); excluding the VIKING SGP region and VMC region. JHK$_s$ for 120secs over VHS-DES region on the assumption that the US led Dark Energy Survey(DES) project will project provide matching Y and Z. This is defined as the VHS-DES region and is 4500^2. The full DES footprint is defined below. YJHK$_s$ for 60secs over the remainder of the SGC starting with the region to be covered with the VST ATLAS survey (note that some the VST-ATLAS survey lies within the VHS-DES footprint). This region is the SGC part of the VHS-ATLAS.
3. VHS-GPS (Galactic Plane Survey): as described above.

The footprint of the Dark Energy Survey(DES) consists of three connected regions in the SGC.

- 20hrs $< \alpha <$ 7hrs; $-65° < -30°$ and 19hrs $< \alpha <$ 20hrs; $-65° < \delta < -45°$; 4000deg^2; South Pole Telescope(SPT) survey region
- 1.3hrs $< \alpha <$ 3.4hrs; $-65° < \delta < -30°$; 800deg^2
- 20.6hrs $< \alpha <$ 3.4hrs; $-1° < \delta < 1°$; 200deg^2; SDSS Stripe82

The area of VHS-DES footprint is assumed to be 4500 deg^2 out of the full DES footprint of 5000 deg^2 since part of VIKING overlaps with the DES footprint as shown in figure 1.

We intend to locate VHS tile field centres in a series of strips of constant declination(ICRS). Tiles that completely overlap with VIKING, VVV or VMC will be removed. In addition, it is possible that some VISTA open time observations especially if taken on the VHS tile pattern may satisfy some the VHS coverage requirements. A method of preventing such duplication of may be worth considering. We present here two options for the tile spacing in the declination or Y direction;

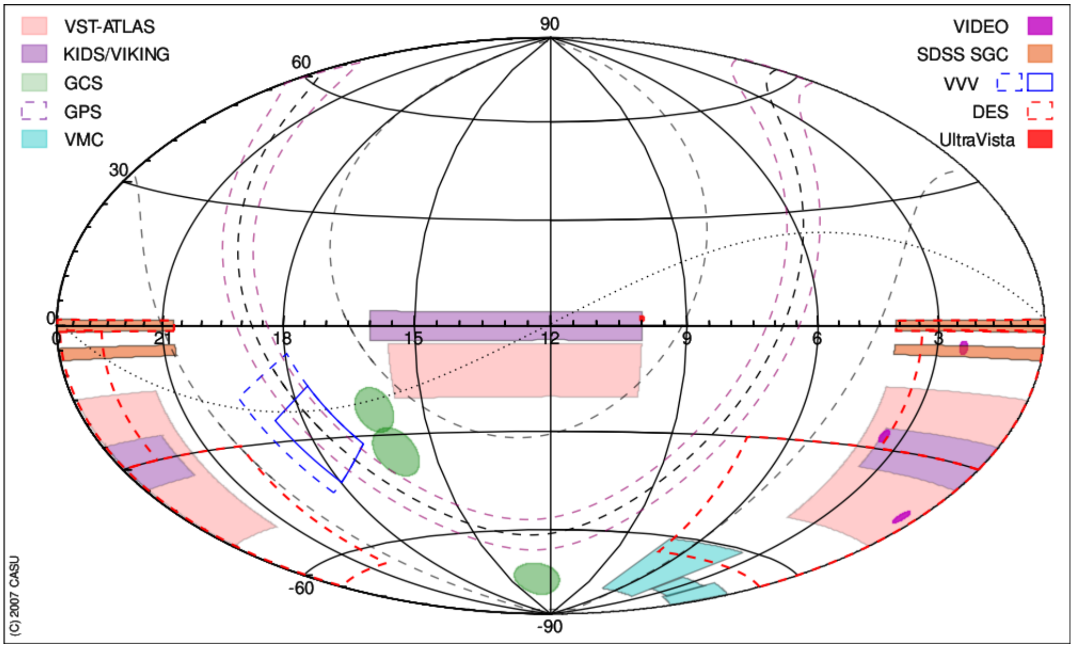

Figure 1: Overview of VHS and other VISTA survey coverage(Best viewed in colour)

(i) In the first which is a *conservative* strategy we propose to use 59.0 arcmin (0.983°) in declination or Y direction as proposed by VIKING which is driven by the footprint of the VST. Since it is intended to combine VISTA and VST data having a grid pattern that matches in at least one axis aids scientific exploitation. This tiling strategy also results in the minimisation of overlap of partial tiles in observing footprint for VHS and VIKING. The above strategy will result in an overlap of 2 arcmin between stripes at the full VISTA depth after adjacent VHS stripes have been observed. This overlap will be used for global astrometric and photometric re-calibration. It will also minimise the number of astronomical objects that are chopped in half by the edges of the VISTA field of view and window pane effects that is often observed in mosaiced data. The RA or X spacing will be 1.46° which will give 1arcmin overlap between neighbouring VISTA tiles in the same declination stripe. The unique area for this tiling strategy is $1.46° \times 0.983° = 1.435\text{deg}^2$. This total time required using this strategy is shown in table 1. A more detailed breakdown in terms of the OB design is given in the enclosed spreadsheet. The main tables from the spreadsheet are shown in Appendix 1.

(ii) In the second case we assume a zero tile overlap strategy and assume an effective tile footprint of 1.636deg^2. This total time required using this strategy is shown in table 2

(iii) Since submitting the first version of the VHS SMP(v0.5) we have investigated the overlap strategy used by other surveys. For SDSS and 2MASS the overlap is 1' along edges. The UKIDSS LAS uses an minimum overlap of 3% which is 25arcsec. In practice we need to determine the number of stars objects that would be detected at S/N of 10 within the overlap regions for each chip between adjacent tiles. Also there tend to be larger systematic uncertainties near the boundaries of detectors. A pragmatic approach based on other similar surveys is to use an overlap of 30". For this strategy the effective tile size is 1.614deg^2 and the total time required with this tiling strategy is 3025hours. We will also need evaluate whether to observe with the default PA=0 or PA=90 since observations at PA=90 when combined with linked OB in declination strips will minimise the difference in observing conditions in the half-chip overlap regions.

The total time required for VHS assuming the 'conservative' tiling strategy of 1.435deg^2 and overheads from the ETC is 3402 hours. Thus the total time has increased from 3107 hours to 3402 hours as defined in Table 7

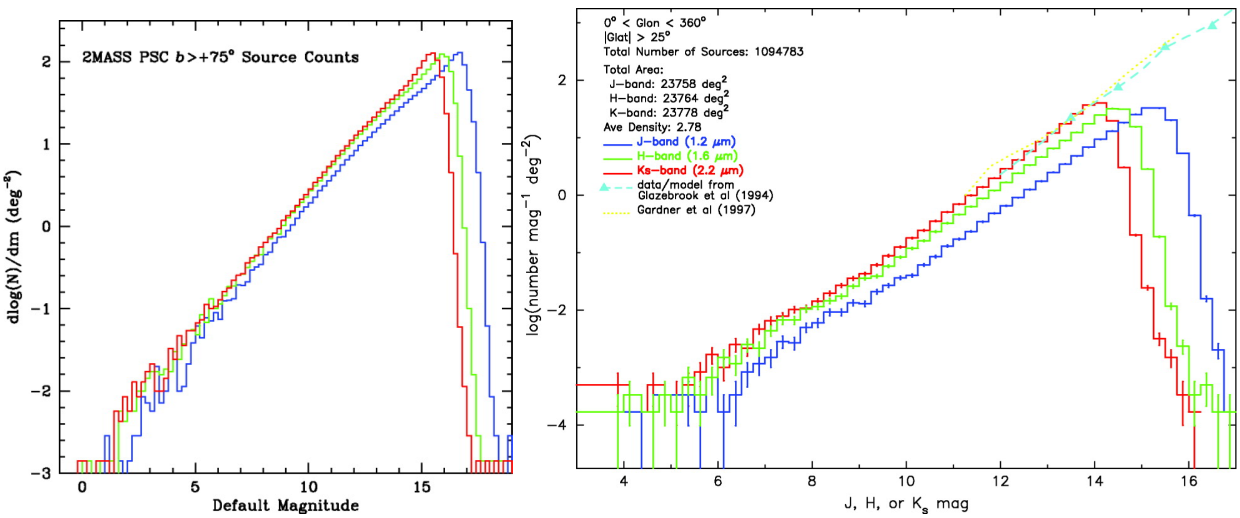

Figure 2: Star and galaxy counts from 2MASS(Skrutskie et al, 2006)

in the Sep, 2006 PSP-OPC submission due to the following factors:

1. increase in overheads due to the inclusion of a jitter in the VHS-ATLAS and VHS-GPS so that all sky regions are sampled by more than one independent pixel even in the presence of bad pixels.
2. overhead increase due to an increase in the number of DITS in H and K to avoid detector saturation.
3. we have changed the effective tile size from 1.50 deg^2 to 1.435deg^2 as defined above.

The increases caused by these have been offset by reducing the area of the VHS-ATLAS survey from 6000 deg^2 to 5000 deg^2. This is possible because, the PSP-OPC Sep, 2006 submission had some double counting between the footprints of VIKING, VHS-ATLAS and VHS-DES.

In the case of a 'zero overlap' strategy the total time required is 2986 hours at a cost in uniformity of the survey data. In particular in the inter-tile overlap region the resultant data that would be co-added would have different seeing, sky transparency, sky brightness and epoch of observations. This inter-tile overlap region has a width of 5.5arcmin at the top and bottom i.e. north and south edges in the default PA=0 orientation. This would effect ∼10% of the sky coverage. Note that a PA=90 may be used in VHS.

The control of systematic uncertainties is an important science requirement for the large scale structure and Dark Energy science case which is the primary science driver for the VHS-DES region. We would therefore favour the conservative tiling strategy for this region. We request that the optimal tiling strategy in investigated during a VHS Science Verification phase. One intermediate tiling strategy would be to have a 0.5-1.0arcmin region around all 4 sides that has 100% exposure overlap. A related factor is that bad pixels and other processing steps tend to more unreliable near the edges. These need on-sky determinations.

VHS has fields over the full RA range when all three components are considered so that the survey can be carried out in all months of the year. VHS also has a fields over the full range of declinations so that fields should be available in the presence of all wind direction constraints. Due to the wide declination range at all RA, there should also always be fields that are sufficiently far from the ecliptic that moon avoidance does not restrict scheduling.

In Table **??** we show the RA distribution of the priority of each survey component. In addition we shall supply finer grained priorities for specific regions of sky within each survey e.g. by declination stripe for the VHS-DES and VHS-ATLAS components or galactic l, b in the case of VHS-GPS with seeing limits that take into account stellar confusion.

Table 1: VHS total time per waveband assuming an effective tile size of 1.435 deg^2

Sub-Survey	deg^2	Y	J	H	K	Total
VHS-ATLAS	5000	284	284	296	296	1160
VHS-DES	4500	-	423	434	434	1290
VHS-GPS	8200	-	466	-	485	951
Total Elapsed	17,700	284	1074	729	1215	3402
Total Science		174	774	488	774	2209
Efficiency(%)		61	66	67	64	65

Notes: (i) We have assumed that ATLAS is extended beyond 4500deg^2 current 3 year goals and a total area for VHS-ATLAS of 5000deg^2. (iI) DES will cover 5000deg^2 but we assume that 500deg^2 overlaps with VIKING. (iii) We have recomputed the combined area covered by VHS-DES and VHS-ATLAS and it is 9,500 deg^2 compared with 10,500 deg^2 in the original proposal. We have therefore reduced the VHS-ATLAS footprint from 6000 deg^2 to 5,000 deg^2. Some of the VST-ATLAS region lies within the VHS-DES region.

Table 2: VHS total time per waveband assuming an effective tile size of 1.636 deg^2

Sub-Survey	deg^2	Y	J	H	K	Total
VHS-ATLAS	5000	249	249	260	260	1018
VHS-DES	4500		371	381	381	1132
VHS-GPS	8200		409		426	835
Total Elapsed	17,700	249	1030	640	1066	2986
Total Science		153	679	428	679	1939
Efficiency(%)		61	66	67	64	65

Notes: see notes to table 1.

Following the PSP recommendation we propose to complete the survey in 10 periods over 5 years. In Table 4 we summarize the time required per period. Initially we ask for an evenly divided spread in time in each period. It is possible that this may need amending after a few periods have passed. The distribution of observing time request with period over the first 10 Periods is given in Table 4 assuming a total of 10 periods for the whole survey. The original submission assumed a survey start in P79. Here we assume a start in P80(Oct'07-Mar'08).

Each tile will be observed only once in each waveband. For all the surveys we require that a minimum of two wavebands are observed with a time interval between bands of no more that 30 minutes so that the effects of short term variability are minimised and that moving objects can be identified. Therefore the separate wave bands will be observed via concatenated OBs as follows:

- VHS-ATLAS; Y and J concatenated; H and K concatenated [same strategy as UKIDSS LAS]
- VHS-DES; H and K concatenated and J unconcatenated or all three concatenated or with a goal to observe within 1hr of the concatenated HK OBs.
- VHS-GPS; J and K concatenated OBs

Another requirement on OB links is that in the IR, the sky has to subracted and we will require a minimum of 2 tiles in order to determine the sky that has to be subtracted from each observation. Thus in Y, J H and K we will need to concatenate two tiles in each waveband. The elapsed time per tile per waveband is shown in Table 5. The total time, for a group of concatenated OBs ranges from 972 secs for the DES J band observations, 1200secs for ATLAS and GPS to 1792 secs for the DES HK concatenated observations of two adjacent tiles.

In the case of the VHS-ATLAS survey concatenated YJ Obs will be observed during grey/dark time and concatenated HK OBs will be observed during any observing conditions. The concatenated OBs should be

Table 3: VHS Survey Top Level survey region Priorities by RA

	Priority		
RA	1	2	3
00-01	DES	ATLAS	
01-02	DES	ATLAS	
02-03	DES	ATLAS	
03-04	DES	ATLAS	
04-05	DES	ATLAS	
05-06	DES	ATLAS	GPS
06-07	DES	ATLAS	GPS
07-08	GPS		
08-09	GPS		
09-10	ATLAS	GPS	
10-11	ATLAS	GPS	
11-12	ATLAS	GPS	
12-13	ATLAS	GPS	
13-14	ATLAS	GPS	
14-15	ATLAS	GPS	
15-16	ATLAS	GPS	
16-17	GPS		
17-18	GPS		
18-19	GPS		
19-20	GPS		
20-21	DES	ATLAS	GPS
21-22	DES	ATLAS	GPS
22-23	DES	ATLAS	
23-24	DES	ATLAS	

Notes: These are the top level priorities between the VHS survey components. Additional finer grained priorities as a function of declination and/or galactic latitude are also planned.

observed ideally within 1 month. A goal would to be observe all wavebands in a tile within 6 months otherwise long term variability will reduce the scientific value of the multi-colour data.

Other observing priority drivers that may require intervention during an observing period are caused by the link with the VST ATLAS survey. We would like to increase the OB priority for VHS tiles that are for regions of sky that have already been observed by VST-ATLAS. These priorities will be updated at the start of each observing period but it may be desirable to alter OB priorities during an obserging period on a monthly basis.

2.2 Observing requirements

The science goals require that we cover the whole southern sky in a minimum of two wavebands and $ZYJHK_s$ and over the high galactic latitude sky. In the first instance Z will come from the VST ATLAS survey and/or the CTIO DES project. The DES project will also provide Y band data over the DES footprint. We assume 1.2" seeing as measured on VIRCAM images at the VISTA focal plane in each filter and 5sigma detection limits in a 2arcsec diameter aperture. Baseline exposure times of 60 seconds in all bands are assumed except over the DES region where 120secs in JHK_s are used.

Because of potential variables we ideally wish to get at least two filters observed within 30 minutes of each other by having them in concatenated OBs. For example studies of the variability in a 4Myr-old OB association by

Table 4: VHS Observing Time Request by Observing Period

Period	Time (h)	Mean RA	Moon	Seeing	Transparency	Comment
P80(Oct'07 - Mar'08)	256 (JHK_s)	06h	any	<1.2,1.4	THIN, CLEAR	
P80(Oct'07 - Mar'08)	55 (YJ)	06h	grey	<1.2,1.4	THIN,CLEAR	
P81(Apr'08 - Sep'08)	256 (JHK_s)	18h	any	<1.2,1.4	THIN, CLEAR	Planck, Herschel launch
P81(Apr'08 - Sep'08)	55 (YJ)	18h	grey	<1.2,1.4	THIN, CLEAR	
P82(Oct'08 - Mar'09)	256 (JHK_s)	06h	any	<1.2,1.4	THIN, CLEAR	Planck, Herschel reach L2
P82(Oct'08 - Mar'09)	55 (YJ)	06h	grey	<1.2,1.4	THIN, CLEAR	
P83(Apr'09 - Sep'09)	256 (JHK_s)	18h	any	<1.2,1.4	THIN, CLEAR	
P83(Apr'09 - Sep'09)	55 (YJ)	18h	grey	<1.2,1.4	THIN, CLEAR	
P84(Oct'09 - Mar'10)	256 (JHK_s)	06h	any	<1.2,1.4	THIN, CLEAR	WISE launch
P84(Oct'09 - Mar'10)	55 (YJ)	06h	grey	<1.2,1.4	THIN,CLEAR	
P85(Apr'10 - Sep'10)	256 (JHK_s)	06h	any	<1.2,1.4	THIN, CLEAR	
P85(Apr'10 - Sep'10)	55 (YJ)	06h	grey	<1.2,1.4	THIN,CLEAR	
P86(Oct'10 - Mar'11)	256 (JHK_s)	06h	any	<1.2,1.4	THIN, CLEAR	DES starts on CTIO 4m
P86(Oct'10 - Mar'11)	55 (YJ)	06h	grey	<1.2,1.4	THIN,CLEAR	
P87(Apr'11 - Sep'11)	256 (JHK_s)	06h	any	<1.2,1.4	THIN, CLEAR	
P87(Apr'11 - Sep'11)	55 (YJ)	06h	grey	<1.2,1.4	THIN,CLEAR	
P88(Oct'11 - Mar'12)	256 (JHK_s)	06h	any	<1.2,1.4	THIN, CLEAR	
P88(Oct'11 - Mar'12)	55 (YJ)	06h	grey	<1.2,1.4	THIN,CLEAR	
P89(Apr'12 - Sep'12)	256 (JHK_s)	06h	any	<1.2,1.4	THIN, CLEAR	
P89(Apr'12 - Sep'12)	55 (YJ)	06h	grey	<1.2,1.4	THIN,CLEAR	

Naylor (priv comm) finds that more than 1 percent of the stars have varied by more than 0.05 mags within 2 hours. So if you are looking for rare objects, say if you expect 1 in a hundred stars to deviate from some colour relationship by 0.05 mags, a time separation of 2 hours destroys such a study because 1% will have varied by that amount in 2 hours.

Experience with WFCAM on UKIRT indicates that the increased sky background at bright time in Y is significant. OBs containing Y will be carried out away from bright time. Grey time should be sufficient. In dark time, Y band observations may be dark current limited so there may be little to gain scientifically from the use of dark time.

There is little speed to be gained in shortening exposure times much below 60secs since overheads such as detector read out, disk i/o and telescope motion and noise sources such as read-out noise start to dominate. We will carry out a 2-point jitter for each observations. Thus in principle in the absence of detector defects, all pixels in a single tile from 6 exposures each sky pixel have up to 4 independent detection pixels and in the presence of bad pixels the majority have 3 or more independent detections. However a 1-point jitter would result in many regions of sky only having a single pixel detection.

2.2.1 Overview of the OBs characteristics

Our baseline plan is that observations use standard 6 pointing tiles which gives two observations per sky pixel with two jitters at each pointing. This produces 4 observations per sky pixel neglecting the effect of bad pixels. The duration of a single waveband per tile OB is given in Table 5. The elapsed time per tile is in the range ∼300–500 seconds (∼5–7 minutes).

All OBs or groups of concatenated OBs will have a total time less than 1 hour in duration. We require two adjacent tiles in the same waveband to be observed consecutively in order to determine a robust sky. Current ESO rules allow 1 tile or pointing per OB. Therefore currently each OB is a single tile in a single waveband and we will concatenate two OBs with the same filter together. Alternatively, a double-tile could be defined within an OB using a pointing centre and 11 offset positions. Naively this may save overheads with little impact in

Table 5: VHS Elapsed time(secs) per single tile

	Time(secs) per singe tile Elapsed(Exposure)			
Sub-Survey	Y	J	H	K_s
VHS-ATLAS	294(180)	294(180)	306(180)	306(180)
VHS-DES		486(360)	498(360)	498(360)
VHS-GPS		294(180)		305(180)

Notes: (1) The time per tile is 3 times the exposure time on sky due to the sparse filled VIRCAM mosaic. (2) The elapsed times only include the overheads included in the VISTA ETC for a tile and do not include the time required to point the telescope as referred to in RIX#2.8

OB schedulability but there may be subtle issues such as the offset vectors may not be parallel near the poles for both tiles.

Concatenated groups of OB with two tiles in multiple wavebands have an estimated elapsed duration in the range 1000 to 2000 seconds although this uncertain due the uncertainties in the observing overheads. Shorter groups of concatenated OBs are possible by reducing the number of adjcent tiles per concatenated OB.

Based on VDFS WFCAM experience in order to make a robust estimate of the sky a minimum of two tiles are required per filter. If the two-tile per concatenated OB requirement is relaxed shorter blocks of concatenated OBS will result. The trade-off in schedulability versus quality of the science products will need to be determined.

VHS-ATLAS; 2 adjacent tiles in 2 wavebands The total integration time per waveband is 60 seconds in each of four wavebands; Y, J, H,K. Normally 2 adjacent tiles in RA on the same Dec stripe will be observed consecutively in the same filter. The filter will then be changed and two of the filters observed via concatenated OBs. Concatenated groups of OBs will either contain observations in YJ or HK. The order of the fYJ filters will always be YJ. The order of the filters in the HK concatenated OBs will either be HK_s or K_sH to take advantage of the fact that K_s can be observed during astronomical twilight. i.e K_s will be observed before H in evening twilight and H will be observed before K_s in morning twilight.

VHS-DES; 2 tiles and 1 or 2 concatenated wavebands The total integration time per waveband is 120 secs in three wavebands; J, H,K. Normally two adjacent tiles in RA on the same Dec stripe will be observed consecutively in the same filter in concatenated OBs. The H and K observations shall be concatenated to minimise the effects of variability and to identify moving objects. The order of the filters in the HK concatened OBs will either be HK_s or K_sK to take advantage of the fact that K_s can be observed during astronomical twilight. The HK and J observations should be observed within 1 month.

VHS-GPS; 2 tiles in 2 wavebands The total integration time per waveband is 60 secs in two wavebands; J, K. Two adjacent tiles will be observed consecutively in the same filter in each group of concatenated OBs. The order of the filters will either be JK or KJ in order to take advantage of the fact that K can be observed during astronomical twilight. In regions of high stellar density and or regions with large spatial variations linked offset-OBs may be required to determine the sky background. In the early stages of VHS we will attempt to avoid such regions.

2.2.2 Order of wavebands for OBs and concatenated OBs

In order to maximise the usable time during a nominal Paranal night we note the following sky brightness observations and trends. In YJH the sky maybe too bright during twilight for useful science observations. In K science useful observations can be obtained during twilight. In YJH the sky gets darker during the night as the OH 'relaxes'. Analysis of the sky brightness trends by Riello(2007, ESO Calibration workshop) shows that the measured K band sky brightness as observed with UKIRT WFCAM on Mauna Kea, during both evening and morning period between nautical(12degee) and astronomical(18degree) twilight is not significantly brighter that the night time value. Therefore in blocks of multi-filter concatenated OBs K_s should be observed first during evening twilight and last in the morning twilight. In principle this gains up to 30 minutes of twilight time for science observing each night. This means that the OB order in concatenated OBs will have to be updated periodically for fields that are observable during twilight.

Below we consider some other filter order suggestions for each VHS component.

VHS-ATLAS YJ generally in second half of night and avoiding twilight. KH order in evening with K observations starting within astronomical twilight. HK order in morning twilight with K observations possible during astronomical twilight.

VHS-DES If all three bands as linked, the order could be KHJ in first half of night with K observations possible during evening astronomical twilight. JHK_s in last quarter of the night with K within dawn twilight.

VHS-GPS Normally we will observe tiles first in K and then the same group of tiles in J except that in final hour of night the order should be reversed to that science observations can be carried out in K during twilight.

2.2.3 THIN and SEEING constraint

Since a prime science goal is to make the depth as uniform as possible we shall want to avoid observing in BOTH the worst permissible seeing AND in thin conditions so THIN will have a seeing limit of 1.2 whereas in general CLEAR will have seeing limit of 1.4.

We would like to explore in the future the option of increasing the integration time by 50-100% in THIN conditions. This would impact on the total time required. The actual impact would depend on the fraction of observations observed in THIN conditions and the observing overheads. This increase in time would be partially compensated for by a reduction in the fraction of OBs that would have to be reobserved.

2.2.4 Link between SKYBRIGHTNESS, THIN and SEEING constraints

The UKIDSS survey strategy includes the ability to increase the integration time of observations when the combined observed conditions would result in observations that would fail the magnitude limit science requirements. An option to increase the exposure time by 50% or 100% may be useful if we find that a significant number of OBs tail to reach the magnitude limits required in mediocre conditions.

This is predominantly a problem in the shorter wavebands compared with K band which shows the smallest range in sky brightness. However on particularly warm nights during the Paranal summer it may be worth considering increasing the K band exposures. We note that the increase in total observing time will not be linear when overheads are taken into account.

We accept that that at present ESO policies for Service Mode Observations (which will apply to VISTA observing) the exposure cannot be adjusted at the telescope (Rix#2.3).

2.2.5 Very bright stars and galaxies; see also response to Rix#2.6

We are concerned about the effects of very bright stars in terms of affecting sky frames and persistence. In Figure 2 we reproduce star and galaxy counts from 2MASS (Skrutskie et al, 2006AJ....131.1163S). We may want to avoid the brightest stars that have a surface density of 1 per $100deg^2$ e.g. $K_s<4$ in the VHS footprint during the first period of survey operations so that we can quantify the effects caused by such stars for the pipeline and detectors. A possible strategy would be to observe these tiles at the end of the night so that their impact on subsequent observations is minimised. Similarly we would like to quantify the quality of the pipeline reduction for galaxies larger than a quarter of a chip which corresponds to K_s<8 and which have a surface density of $\sim$0.01deg^{-2} i.e. 1 per 60 tiles.

We request that some very bright stars and large galaxies are observed during a Science Verification phase to that their effects are quantified. Apart from persistence effects, such observations will quantify scattering and ghost effects if significant. It may be worth observing a bright star on all chips so that any chip to chip variation can also be quantified.

2.2.6 Global strategy

In any period we will supply OBs with the same seeing requirements in adjacent stripes i.e. <1.2" or <1.4" in groups of 5 stripes on the basis that on average 10 equatorial stripes will be observed per year or 3500deg^2. We will provide OBs for 7000 deg^2 as a pool with half at a higher priority than the other. Half the OBs will be in the North i.e $\delta > -25°$ and half in the South i.e $\delta < -25°$so that any wind direction constraint can be accommodated.

2.3 PA orientation of VISTA camera

We have not decided whether observations will be at PA=0 or PA=90. A choice of PA=90 is being considered in order to minimise the time time difference and hence observing condition variation between adjacent tiles that require inter-tile overlap stacking due to the half-chip step size in the intra-tile mosiacing.

3 Survey data calibration needs

We anticipate that the standard VISTA calibration plan will be adequate for VHS observations. We refer to the Calibration Plan, Ref. [01], the proposed draft for the VISTA Calibration plan available at www.vista.ac.uk/vdfs/esoqc1/ for further details, but summarise the main that are most relevant to VHS here:

3.1 Instrumental signature removal

Ref. [01] specifies the basic instrument calibration frames (dark frames, reset frames, dome flats and linearity calibration, twilight flats) which will be available as part of the VISTA standard operating procedure, mainly from daytime and twilight procedures.

- Dark frames: one set for each typical DIT value expected to be taken approximately weekly during daytime and daily during the initial operations phase of VISTA.
- Dome flats: one set expected to be taken weekly during daytime, (primarily for detector health checks and logging of bad pixels).
- Linearity frames: these comprise sets of dome flats with stable illumination spanning a wide range of different exposure times. We anticipate a set of linearity frames will be taken every few months, and after any major maintenance on the IRACE detector controllers.
- Twilight flats will be taken in several filters nightly. (There is likely to be insufficient twilight time to obtain twilight flats in all science filters every night, but a cyclic ordering should get twilight flats in all filters every 2 nights, with priority given to those pass-bands most used recently) .

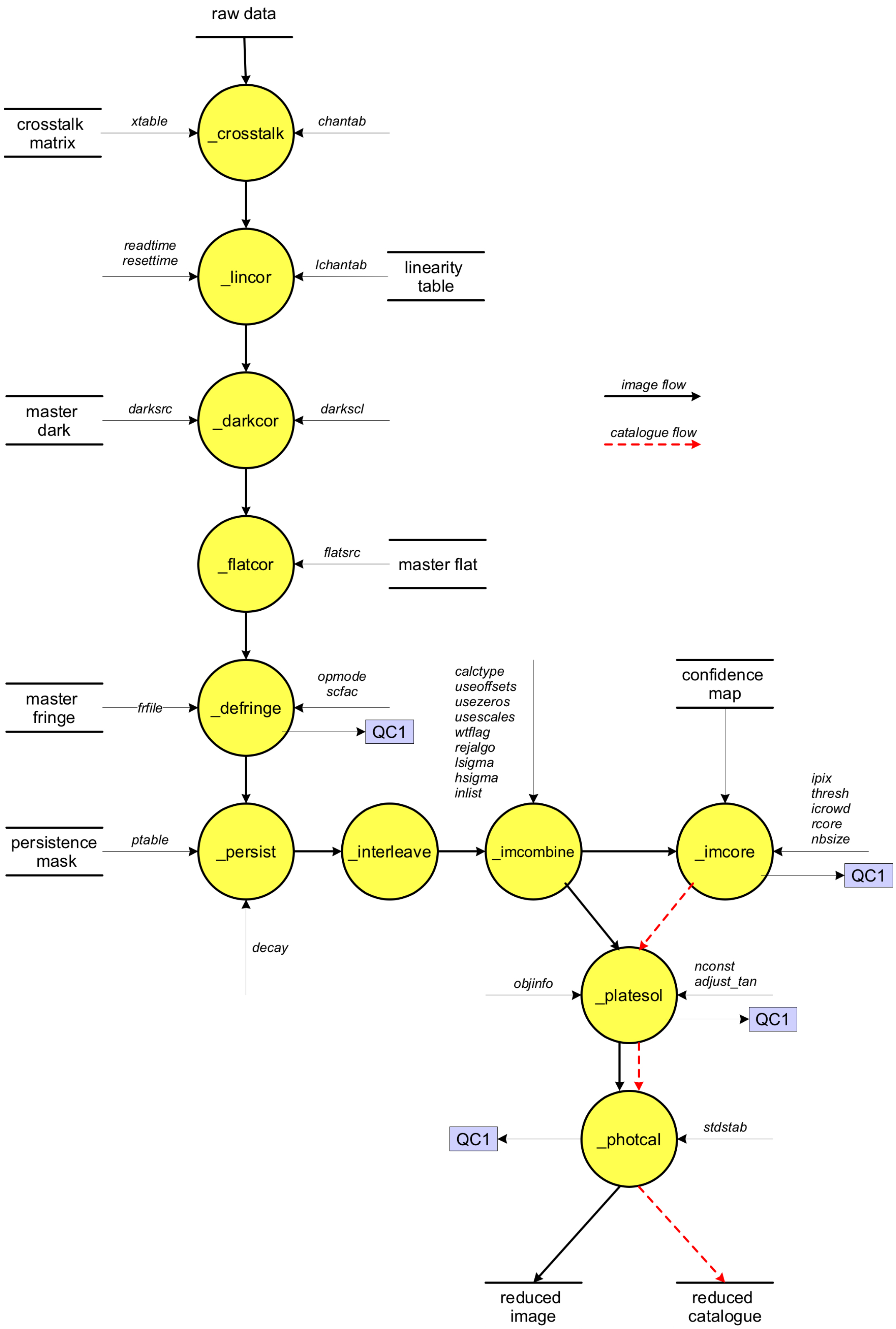

Figure 3: A block diagram showing the pipeline processing from raw data to the calibrated product.

We note here that both the VISTA dome and VIRCAM dark filter have excellent light-tightness by design (in fact, VIRCAM can take dark frames in a normally-lighted lab), so daytime darks and dome flats should not have significant leaks. This will be checked during VISTA commissioning.

3.2 Astrometric calibration

The basic astrometric procedure is a 2-stage calibration: firstly, a radial distortion correction of the form

$$r_{\rm lin} = r + k_3 r^3 + k_5 r^5$$

is fitted, where r is image radius (in mm), k_3 and k_5 are distortion coefficients, $r_{\rm lin}$ is a linearised radius proportional to $\tan\theta$, where θ is angle from the pointing axis ; this form is an excellent fit to real distortion in axisymmetric systems. The distortion parameters k_3, k_5 will be calculated within the VDFS pipeline on regular time basis based on fitting to a stack of a large number of independent frames of moderately high stellar density.

For individual VIRCAM frames a catalogue of bright unsaturated stars is matched to 2MASS using the approximate pointing information in the FITS headers as a start-point. The radial distortion correction is applied to give linearised coordinates x_l, y_l for each measured object, then a standard 6-parameter "plate constant" solution is performed, of the form

$$\xi = a x_l + b y_l + c \qquad \eta = d x_l + e y_l + f$$

where ξ, η are standard warped tangent-plane coordinates with respect to the telescope pointing axis. This allows for pointing error, rotation, scale change and shear. The coefficients $a \ldots f$ are fitted with a robust fit to minimise observed-predicted residuals on a per-detector basis. The above astrometric solution will then be stored in the Multi-extension FITS headers in the ICRS system, using the `ZPN` notation to handle the distortion.

This procedure is very similar to that used currently for WFCAM data, which is demonstrated to give residuals over the whole field to less than 0.1 arcsec systematic and 0.1 arcsec random rms (with the latter limited by 2MASS random errors at its moderate SNR ~ 10).

While VISTA has a larger absolute distortion term, we anticipate that astrometric stability across the VISTA focal plane is likely to be at least as good or probably better than equivalent WFCAM results, for several reasons:

1. VIRCAM covers 3× the area of WFCAM per single pawprint, giving correspondingly more useful 2MASS stars per frame.
2. VISTA's detectors are firmly attached to a common CTE-matched mounting plate, rather than held in ZIF sockets,
3. VIRCAM's corrective lenses are closer to the focal plane than WFCAM's, reducing relative flexure.
4. The chromatic aberration in VIRCAM is smaller.

Additional efforts such as monitoring trends in VIRCAM-2MASS residuals over many frames and long timescales may be capable of reducing systematics further below the 0.1 arcsec level , but this is outside the scope of the current VHS plans.

3.3 Photometric calibration

The VHS survey does not require the hourly observations of standard stars as described on page 31 in Section 5.4 of the v1.4pre1 of the VDFS VIRCAM calibration plan. The VHS requirement is to photometrically calibrate VIRCAM data to 2%.

VHS photometric calibration will use 2MASS to carry out the photometric calibration of each VHS tile in YJHK using the 2MASS JHK stellar photometry following the VDFS procedures developed for the WFCAM instrument and the UKIDSS LAS survey by Hodgkin et al(in preparation). The requirement on VDFS is to photometrically calibrate WFCAM and VIRCAM data to 2%. Nikolaev et al. (2000) claim that the 2MASS all-sky point-source catalogue has photometry that is globally consistent to 1

For photometry, the standard instrumental signature removal of Section 3.1 corrects for dark current, non-linearity, bad pixel masking, flat-field variations does an internal gain correction to put all detectors onto a uniform internal system.

After this, there are in principle three independent routes to photometric calibration:

1. Matching to 2MASS stars, with suitable colour equations.
2. Using the nightly standards (for photometric nights)
3. Global solution using matching of overlapping tiles.

The main photometric calibration will be (a) 2MASS, with method (b) used as a check and (c) applied in the longer term when sufficient overlaps are available.

Each VIRCAM pawprint will contain over 100 useful 2MASS stars (SNR > 10 in 2MASS, and also unsaturated in the VHS frames), corresponding to e.g. $13 \lesssim J \lesssim 15$.

As part of the general VDFS VIRCAM calibration procedure, colour equations transforming the 2MASS system to the VIRCAM system will be derived of the form

$$J_t = J_2 + C_J(J_2 - H_2), \quad H_t = H_2 + C_H(H_2 - K_2), \ldots$$

where J_2 etc is 2MASS magnitude, J_t is transformed to the VISTA filter system, and the colour terms C_J, C_H, C_K will be derived from fitting to a large number of frames and subsequently held fixed.

For routine reductions, the above colour equations with fixed coefficients give a transformed magnitude J_t, H_t, K_t in the VISTA system for each 2MASS star.

Then due to the internal gain calibrations only a single zero-point for each pawprint is needed, e.g.

$$J_{cal} = J_{ins} + ZP_J - e_J(X - 1),$$

where $J_{ins} = -2.5\log_{10}(ADU/\text{sec})$ is the raw VIRCAM instrumental magnitude, ZP_J is the zeropoint, e_J (normally fixed) is the extinction coefficient, X is airmass and J_{cal} is the calibrated VIRCAM magnitude on a standard system e.g. Vega. Thus, fitting $J_{ins} - e(X - 1)$ vs J_t should give a line of slope 1, intercept ZP_J and small scatter due to 2MASS random errors and colour residuals; both of which average down in the final ZP_J.

This assumes that the 2nd order colour term from 2MASS to VIRCAM magnitude, and the colour-dependence of extinction, are both negligible: these are generally a good approximation in the near-IR where most stars have relatively smooth spectra. Errors in the assumed extinction coefficients cancel to first order since they give an opposite error in ZP (if a per-frame zeropoint is adopted). Also, this method is robust against isolated 2MASS errors, since any single VISTA tile overlaps with a large number of distinct 2MASS stripes.

If a night is photometric, the instrument response is stable and the extinction term is correct, then all frames in the ith passband should give the same value of ZP_i . Analysing trends with time or airmass can reveal non-photometric nights, long-term drift in throughput or gain (e.g. dust accumulation on the optics or IRACE gain drift) or errors in the assumed extinction coefficient. The VDFS CASU pipeline also computes and monitors detector level variations in the zeropoints as a measure of the photometricity of the observations.

3.3.1 Y band calibration

For the Y band, the situation is slightly more complex since there are no direct 2MASS measurements. (z-band combined with 2MASS J will be investigated as a proxy; z-band from SDSS available in some of the DES region, and z-band data will exist soon in the SGP from the Australian Skymapper project). As a first pass, we intend to use the well-defined stellar locus to bootstrap from 2MASS J,K_s to Y band calibration as used for WFCAM calibration within the VDFS pipeline.

The Y filter will be calibrated using 2MASS JHK stellar photometry following the procedures developed for the WFCAM instrument and the UKIDSS LAS survey by Hodgkin et al(in preparation). See also http://casu.ast.cam.ac.uk/surveys-projects/wfcam/technical/photometry. Independent checks on 2MASS based Y calibration will be carried out using the Skymapper z band photometric survey and 2MASS J band via interpolation.

3.3.2 Illumination and geometric correction

As a final step in photometric calibration, an "illumination correction" will be applied to correct for the fact that a standard flat-fielding procedure does not lead to precise photometry, due to two effects: firstly distortion leads to varying pixel areas, and secondly stray-light forms an *additive* and roughly axisymmetric background offset. The illumination correction will be a position-dependent offset calculated from either stacked residuals vs 2MASS, and/or mesostepped frames across the touchstone fields.

3.4 Bad pixels

The effects of the bad pixel regions will be recorded in the VDFS confidence maps and detected sources that are in the vicinity of spatially fixed artifacts can be flagged in the source catalogues.

3.5 Star galaxy discrimination calibration

We request that VHS depth exposures are obtained in the COSMOS field and CDFS-GEMS fields as part of the science verification phase of VISTA. These fields have HST images that can be use to calibrate the reliability of star galaxy classification in VISTA.

Our backup plan is to use SDSS and other spectroscopic classifications. For instance SDSS used the COMBO survey classifications see: http://www.sdss.org/dr5/products/general/stargalsep.html

4 Data reduction process

We will use the VISTA Data Flow System (VDFS, Emerson et al, 2004, 2006, Irwin et al, 2004; Hambly et al, 2004) for all aspects of data processing and archiving. The Cambridge Astronomical Survey Unit (CASU) at Cambridge will be responsible for pipeline processing, and first-level calibration, and the Wide Field Astronomy Unit (WFAU) at Edinburgh will be responsible for the Science Archive with both a human and and a VO interface with query facilities, data export capabilities and creation of higher-level products e.g. list-driven photometry. For a more detailed description of this system see `http://www.maths.qmul.ac.uk/~jpe/vdfs/`, and `http://casu.ast.cam.ac.uk/` (CASU), and `http://www.roe.ac.uk/~nch/wfcam/` (WFAU).

Both the VDFS pipeline and archive facilities have been designed specifically for VISTA, and have already been scientifically verified by processing wide-field near-IR imaging from UKIRT's WFCAM imager, at routine rates up to 250GB/night. Versions of the pipeline have also been used to process ESO ISAAC data, and data from a wide range of optical CCD mosaic cameras. Sample from the UKIDSS project are published in Warren et al (2007MNRAS.375..213W), Dye et al (2006MNRAS.372.1227D), Lawrence et al (2006, MNRAS submitted, astro-ph/0604426) Venemans, McMahon et al (2006, MNRAS, 2007MNRAS.376L..76V, astro-ph/0612162)

We note here that VHS is a close analogue of the UKIDSS Large Area survey and the VDFS has been used successfully for this for almost two years already. There are already various papers on astro-ph that have used UKIDSS LAS data successfuly.

The uniformity of photometric zero points across the whole survey area and the global astrometry will be checked and verified independently by both the VDFS and VHS teams. They will be checked by the VHS team via comparison with 2MASS and also via a comparison of photometry and astrometry for sources that are detected in more than one tile. e.g. using the tile overlap regions

The data reduction will be using the VDFS, operated by the VDFS team, and augmented by effort from the VHS co-Is, their postdocs and graduate students, especially for Quality Control and Assurance of the VDFS products. We also note the considerable synergy between the science goals and the data products from VHS and VIKING survey. McMahon and Sutherland aim to collaborate on the development of automated QA procedures for the two surveys. In addition the VHS QA teams will work closely with the VDFS pipeline and science archive groups.

Table 6: Responsibilities and Group Leaders

Name	Function	Affiliation	Country
R. McMahon	PI and OB Preparation	Cambridge	UK
A. Lawrence	Deputy/Co-PI	Edinburgh	UK
J. Emerson	VDFS PI and OB Preparation	Queen Mary, London	UK
CASU (VDFS) team†	Pipeline processing and QC	Cambridge	UK
WFAU (VDFS) team‡	Science Archive and QC	Edinburgh	UK
N. Walton	VO Standards	Cambridge	UK
VHS Survey Progress, Data Quality Control and Assurance			
R. McMahon	OB Preparations and Survey Progess WG leader	Cambridge	UK
R. McMahon	Data Quality WG leader	Cambridge	UK
H-W Rix	Data Quality WG leader	MPIA, Heidelberg	D
R. Rebolo	Data Quality WG leader	IAC, Tenerife	S
F. Castander	Data Quality WG leader	Barcelona	S
VHS Survey specific tasks			
T. Naylor	VISTA Surveys photometry cross-calibration WG	Exeter	UK
F. Castander	DES Cordination Working Group	Barcelona	S
F. Carrera	XMM-Newton Working Group	Santander	S
C. Bailer-Jones	GAIA Working Group	MPIA	D
J. Emerson	Photometric Calibration WG	Queen Mary, London	UK
S. Oliver	Herschel Working Group	Sussex	UK
G. Lagache	Planck Working Group	IAS, Paris	F
H. Rottgering	LOFAR and radio surveys WG	Leiden	NL
N. Lodieu	Galactic Cluster Working Group	Leicester	UK
K. Romer	Galaxy Cluster Working Group	Sussex	UK

Notes: † The CASU (VDFS) team is currently led by Irwin who is a VHS co-I. ‡ The WFAU (VDFS) team is currently led by Hambly who is a VHS co-I.

4.1 Pipeline processing

The VDFS pipeline is a modular design allowing alternative configurations of the processing components depending on the on-sky system performance of VIRCAM. Standard processing in Cambridge is on a nightly basis with data products defined by the overall OB structure.

The VDFS pipeline at CASU will perform all the processing steps for instrumental signature removal and catalogue generation for the VHS Tiles. The pipeline includes the following steps and is schematically shown in Figure 3.

- instrumental signature removal – bias, non-linearity,dark, flat, fringe, cross-talk, systemic noise;
- sky background tracking and removal using all relevant OBs during a night; this may include extra homogenisation during image stacking and mosaicing to incorporate removal of unexpected 2D systematic effects from imperfect multi-sector operation of detectors;
- assessing and dealing with image persistence from preceding exposures if necessary (and if possible);
- combining frames if part of an observed dither sequence or tile pattern;
- producing a consistent internal photometric calibration to put observations on an approximately uniform system;
- image catalogue generation including astrometric, photometric, shape and Data Quality Control (DQC) information;
- final astrometric calibration based on the catalogue with an appropriate World Coordinate System (WCS) placed in all FITS headers - the default is to base this on 2MASS;
- photometric calibration for each generated catalogue using 2MASS or augmented by monitoring of suitable pre-selected standard areas covering the entire field-of-view to measure and control systematics;
- all frames and catalogues supplied with astrometric and photometric calibration information and detected object morphological classification embedded in FITS files;
- bad pixel handling, propagation of error arrays and effective exposure times by use of confidence maps;
- realistic errors on selected derived parameters for images and catalogues;
- nightly extinction measurements in relevant passbands;
- pipeline software version control – version used recorded in FITS header;
- processing history including calibration files recorded in FITS headers.

The pipeline processing centre hosts a data quality database that is updated daily with the data quality control information for pipeline processed products. The UKIDSS WFCAM version is available at http://casu.ast.cam.ac.uk/.

Calibration library frames i.e. darks, flats are built with a significant amount of human checking. Basic quality control (e.g. rejection of frames with serious cloud, tracking/guiding failures, EMC interference, other hardware problems, Moon problems) will also be carried out at this stage using mainly automated procedures based on standardised QC parameters compared with 'typical' values. Warnings will be generated if they lie outside an approved range (see section 6 for more details).

4.2 Science Archive

The VISTA Science Archive (VSA) at WFAU is modeled on the WFCAM Science Archive. The VSA will ingest the metadata and catalogue outputs from pipeline processing into a relational database management system, and will then curate the FITs images and catalogues and derived products to produce enhanced database-driven products.

The functions carried out by VSA will include:

- Band merging of the single waveband catalogues to provide multi-colour source lists i.e. JHK_s in the VHS-DES region; JK in the VHS-GPS region and $YJHK_s$ in the VHS-ATLAS region.

- List-driven photometry to provide upper limits of objects detected in one waveband but undetected in other wavebands.
- Quality control features and metadata, as defined and agreed by the VHS team in collaboration with the VDFS team.

The VSA will have a user-friendly interface based on SQL queries; both simple and advanced interfaces are available, with the simple interface for ease of use while the advanced interface exposes the full relational database structure to the user enabling more complex queries and manipulation.

5 Human resources and hardware capabilities devoted to data reduction and quality assessment

5.1 Team Members

The full list of VHS team members is given on page 1 of this document. Table 6 lists the members of the VHS collaboration who currently have specific responsibilities within the VHS collaboration. These members will work with other members of the collaboration supplemented with effort from post-docs and graduate students to deliver the agreed VHS science products to ESO.

The VHS team is large but has a few nodes that have a critical mass in terms of experience and number of co-Is. Some specific groups and group leaders are listed below:

- Barcelona(ICE, IFAE, CIEMAT); Castander
- Cambridge(IOA); McMahon
- Edinburgh (IFA); Lawrence
- Heidelberg(MPIA); Rix
- London (QMUL); Emerson
- Tenerife(IAC); Rebolo

The six named individuals are members of the VHS Management Board.

McMahon, Lawrence and Emerson are co-I's of the VDFS project. A number of the VHS co-I's were members of the team who worked on the early phases of the SDSS. e.g. Castander, Loveday, Nichol. They have considerable experience in wide field survey image and catalogue quality assurance. The VHS team also consists of members of the ESO community who are members of the UKIDSS consortium who have have involved in the UKIDSS LAS survey. The VHS team also include the PIs of four other VISTA public surveys (Jarvis, Cioni, Lucas, Sutherland) and this will facilitate the exchange of quality control and assurance best practice between the projects.

A number of major institutes have multiple co-I and thus will have the local critical mass. These co-I's will lead independent but coordinated Quality Control and Assurance working groups i.e. MPIA, Heidelberg, Rix et al; Barcelona, Castander et al; Rebolo et al, IAC; McMahon et al, Cambridge. Data quality control and assurance will be a distributed task across the consortium within four working groups working semi-independently with some tasks replicated. It will be coordinated by the four group leaders who will meet via Telecon with others leading QA taks on a monthly basis when the data starts to flow. Other members of the collaboration will work with these teams.

Experience shows that the a full data scientific validation is only possible when people start trying to do science with the data. Thus in addition to the quality assurance working groups we will also have a number of Scientific

Table 7: VHS Committed Effort

IOA, Cambridge	Node leader and PI: Richard McMahon
Yearly FTE commitment:	1.5 [excludes CASU commitment]
Tasks	Quality assurance, OB preparation, Survey progress
Scientific focus	Quasars and AGN, Galactic structure, Planck, GAIA
Barcelona	Node leader; member of VHS management Board: Francisco Castander
Yearly FTE commitment:	2.0
Survey Tasks	Quality assurance, OB preparation, Catalogue validation, Galaxy photometry and incompleteness, DES coordination
Scientific focus	Large scale structure of the Universe, Quasars and active galaxies, Planck, Photometric redshifts, Galaxy clusters
IAC, Tenerife	Node leader; member of VHS management Board: Rafael Rebolo
Yearly FTE commitment:	3.0
Survey Tasks	Quality assurance, OB preparation, Astrometry, Catalogue validation, Galaxy photometry and incompleteness, Multi-waveband merging
Scientific focus	Quasars and active galaxies, low mass stars, starbursts, GTC follow-up, multi-wavelength surveys, galaxy clusters, photometric redshifts.
MPIA, Heidelberg	Node leader; member of VHS management Board: Hans-Walter Rix
Yearly FTE commitment:	2.0
Survey Tasks	Quality assurance, OB preparation, Galaxy photometry, Stellar photometry
Scientific focus	Galaxy evolution, Galactic structure, GAIA
Queen Mary, London	Node leader; member of VHS management board: Jim Emerson
Yearly FTE commitment:	1.0
Survey Tasks	Quality assurance, OB preparation, Artifact quantification, Stellar photometry
Scientific focus	Galactic structure, Low mass stars, Large scale structure of the Universe
CAUP, Porto	Node leader: M. S. Nanda Kumar
Yearly FTE commitment:	1.0
Survey Tasks	Quality assurance, Photometric calibration, Stellar photometry, Stellar confusion
Scientific focus	Star forming regions, Embedded and Open Clusters, Low mass stars, Galaxy clusters
Portsmouth	Node leader: Bob Nichol
Yearly FTE commitment:	1.5
Survey Tasks	Quality assurance, DES coordination, photometric calibration, galaxy photometry
Scientific focus	Large scale structure of the Universe, ISW, Photometric redshifts
Sussex	Node leader: Kathy Romer
Yearly FTE commitment:	1.0
Survey Tasks	Multi-band catalogue validation, Galaxy photometry and incompleteness
Scientific focus	Cluster of galaxies, Large scale structure of the Universe, Galaxy stellar mass functions
UCL, London	Node leader: Ofer Lahav
Yearly FTE commitment:	1.5
Survey Tasks	Galaxy photometry, DES coordination
Scientific focus	Large scale structure of the Universe, Photometic redshifts

Working groups (following the themes of the goals listed in the science objectives). Table 6 lists the current set of exemplary groups. Any data quality problems found by these teams will be passed to one or more of the quality control working groups as required.

5.1.1 VHS committed effort

In Table 7 we list the effort that has been committed by the members of he VHS to the project. Only nodes that have committed 1.0 or more FTEs are listed. OB preparation will be cordinated by McMahon and Emerson with effort also from Heidelberg, Barcelona and Tenerife. The total effort commited to the task is 1.0 FTE per year.

5.2 VDFS human resources and hardware capabilities

The VDFS UK pipeline will be used to process all data taken on VISTA. Based on 2 years of experience at running the WFCAM processing pipeline, CASU have estimated their human resource requirements to carry out the tasks outlined above in section 4.1 as 3 FTE. This includes normal processing, quality control, reprocessing after major bug fixes and/or enhancements, system maintenance and upgrades, and liaison with major users.

Hardware CPU requirements for the Cambridge processing pipeline are specified to have an overcapacity of a factor of at least 3 (to allow for the inevitable variations of data flow rates and reprocessing requirements). Data storage will be purchased as required and all raw and processed files will be stored using lossless Rice tile compression to save a factor of 4 in hardware requirements.

Manpower provision at the VDFS Edinburgh science archive centre currently stands at 2.0 FTE dedicated operations staff and around 1.0FTE of astronomer-scientist management, oversight and systems support. Hardware provision for storage of pipeline-processed science product files, database server catalogue storage and associated web servers and other infrastructure is currently funded, via a rolling grant, to 2010 and is renewed every two to three years.

6 Data quality assessment process

The assessment of data quality is is a 3-stage process: a quick assessment is performed at Paranal, then following VDFS pipeline processing a second stage (QC-I) performed by VDFS, and the final stage(QC-II) before general data release is the responsibility of the VHS team. These stages are outlined in more detail below.

6.1 VHS Data quality assessment and control process

The VHS PI will be the primary point of contact between the VHS collaboration and the overall VDFS project. In addition VHS will identify individuals who will be the primary day to day point of contact at each of the two main components of the VDFS; (i) the VDFS-Pipeline at CASU, Cambridge and (ii) the VDFS Science Archive at WFAU, Edinburgh. The VHS team will define and agree in consultation with the VDFS team(s), QC criteria that can be applied to the VDFS VISTA dataproducts in advance of preparing data releases to the ESO SAF.

The QC criteria and thresholds will be communicated to the VDFS via the VHS consortium primary point of contact. In practice the QC work may involve one of more individuals from the VHS consortium working closely in-situ for a period with one or both of the two VDFS groups.

Within the VDFS project considerable effort has gone into automated QC parameter generation in the pipeline design, (see the Data Reduction Library Design v1.6 available at http://www.vista.ac.uk/vdfs/esoqc1/) for further information). The most basic version of the QC process occurs in near-time on Paranal, while more sophisticated versions will be run in Garching and later in Cambridge. All of the Cambridge pipeline QC information will be available to VHS Quality Assurance teams via a QC database in Cambridge (for an example see http://casu.ast.cam.ac.uk/surveys-projects/wfcam/data-processing/) and is also recorded in the data product FITS headers.

The VHS quality control process will include the requirement to identify obvious datasets where the pipeline has under performed in some clear manner and feeding information back to the CASU group so that an investigation of what went wrong can be put in place. If the pipeline is clearly at fault then early reprocessing with modified pipeline components will take place.

The quality control process will also consist of identifying datasets where the observations were carried out incorrectly, ie. appropriate calibration files were not available, or in bad conditions. Such datasets that cannot be fixed by altering the pipeline and may need to be reobserved with appropriate changes to the observing strategy. Note that the catalogue generated QC information will help to pick out these cases but some level of visual inspection will also be planned for. The VDFS WFCAM pipeline DQC and survey progress graphical interface is available here: http://casu.ast.cam.ac.uk/survey-progress/wfcam/.

The Archive quality control process itself consists of a data modification script coded up manually by the VDFS science archive staff based on the QC criteria specified by the EPS consortium. Quality Control issues currently implemented in the WFCAM Science Archive can be viewed at this URL: http://surveys.roe.ac.uk/wsa/www/gloss_d.html#lasde Example QC plots and further information can be found in Dye et al., MNRAS, 372, 1227 (2006) and Warren et al., 2007MNRAS.375..213W)

6.2 VDFS quality control

In the VDFS pipeline, considerable effort has gone into the design of automated QC parameters which are generated automatically during the reductions and compared with typical ranges. All of the CASU pipeline QC information will be made available to the VHS team via a web-based QC interface (for an example, see Ref. [05]) and these QC parameters are also recorded in the FITS headers.

A complete list of QC parameters are available in Ref. [02] Appendix A , while some examples include:

- Pointing differences between blind telescope pointing and final calibrated WCS.
- Mean sky level and rms noise.
- Number of objects classified as “noise”.
- Saturation level (from bright stars)
- Mean FWHM and ellipticity for objects classified as “stellar”.
- Aperture correction (fraction of stellar flux outside 2 arcsec).
- Photometric zeropoint from 2MASS
- Photometric zeropoint from nightly standards
- Stellar magnitude limit (computed from the above).

In order to maxmise the legacy value of the VHS survey the VHS team plans to produce an online Explanatory Supplement modeled on the 2MASS Explanatory Supplement (http://www.ipac.caltech.edu/2mass/releases/allsky/doc/explsup.

6.3 VHS team quality control

Additional tests that may be done at both the post-pipeline and post-archive stage by the VHS QC team, include the following:

- Low resolution tile background images binned at 32x32 pixels to produce 406x512 pixels images which can be eyeballed initially and used to develop and train objective machine based techniques with possible human intervention as required.
- Tile level dot plots that show the spatial distributions of stars and galaxies and noise objects.
- Tile level spatial distributions of matched and unmatched objects from the multi-colour band merging.
- Colour counts and median colours as a function of magnitude for each tile and compared with template results.
- Additional checks of QC parameters generated by the pipeline, to look for low-level effects or trends which may not trigger the automated warnings.
- Inspection of colour-colour and colour-magnitude diagrams at a single Tile level In general stars and galaxies lie on distinct sequences in near-IR colour-colour space, with most stars forming a relatively tight locus, so inspection of these plots plus morphological classification forms a powerful check for many systematic errors (see Ref [06] for examples).
- Masking of defects: Localised image problems are usually apparent by inspection of dot-plots, especially for objects of unusual colours. Localised problems creating significant numbers of spurious images (such as diffraction spikes, aircraft or satellite trails, bright-star ghosts etc) are readily apparent.

  Based on early experience, we will create an automated masking and flagging around bright stars, i.e. flag a magnitude-dependent radius around each bright star.
- Overlap matching. The VHS conservative tiling strategy will provide significant edge overlaps ~ 2 arcmin wide at the North and South edges of each tile, containing > 100 objects per overlap. Thus, comparison of image parameters for objects duplicated in the overlap regions will provide a strong check of most systematic errors (with the exception of centre-to-edge systematics which will be investigated via the stacking of residuals from mean properties). Larger samples are available from the 'wings' 5.5 arcmin wide with full exposure in one tile and half in the other.

During the early stages of the public survey all images and catalogue products will be visually verified by the VHS team. The goal is develop and train machine learning based techniques that require only human intervention in the case of 1-2% of tiles.

The VHS quality assurance will be divided up into a range of tasks that will then be managed by the QA team. Some specific tasks that are planned in addition to the list above are:

1. Independent source catalogue generation
2. Source catalogue validation
3. Astrometry
4. Star-galaxy separation
5. Photometric calibration
6. Stellar photometry
7. Stellar confusion
8. Stellar incompleteness
9. Galaxy photometry
10. Galaxy incompletness
11. Multi-waveband merging
12. Artifact characterisation and quantification

7 Data product and VO compliance:

The VHS products that will be delivered to the ESO SAF are listed below. All products will be FITS images or tables with metadata contained within the FITs headers to fufil the ESO VO requirements as defined in http://www.eso.org/observing/ps/VOS-RRD.pdf. The VDFS will be used able to deliver flat FITS images and catalogues on a tile basis to the ESO Science Archive Facility as follows:

(a) Tile based survey quality-controlled pipeline processed products: instrumentally corrected stacked science frames along with their associated single-passband catalogue detection lists, all photometrically and astrometrically calibrated from 2MASS.

(b) The catalogue products are defined in the VDFS document VDF-SPE-IOA-00009-0001v4(Irwin, 2007) and is available at this URL: http://www.ast.cam.ac.uk/ rgm/vhs/smp/WFCAM-catalogues-v4p0.pdf. The extraction parameters were initially developed as part of the science requirements analysis by the UK community for the VISTA pipeline and the UKIDSS surveys. The PI and many other members of the VHS team were involved in both these processes. In the case of the UKIDSS surveys the ESO community has also been involved.

    The current set of parameters will be reviewed during the period when VHS is being carried out, to ensure that the VHS parameter set are consistent with the parameter sets for VST ATLAS and DES.

(c) Confidence maps, dark frames and flat fields used in the production of (a).

(d) Tile based associated source catalogues linking the parameters of individual objects across all of the observed filter bands.

(e) Aperture matched photometry and aperture based upper limits for sources detected in (a).

All available metadata will be included in the FITS headers. The VHS data will be delivered from the VSA to the ESO Science Archive via the Internet.

8 Timeline delivery of data products to the ESO archive:

Raw VISTA data is normally expected to arrive in the UK roughly 2-3 weeks days after the observations are taken. The turnaround time for ingesting and verifying the raw data is expected to be normally another working week assuming no significant problems. CASU estimate that when a steady state is reached for the data processing normally data will have been pipeline processed and QC checked by CASU within 3-4 working weeks of successful data ingest. Data will then be available for VHS quality assurance and transfer to the Vista Science Archive in Edinburgh with secure data access provided to the VHS quality assurance teams.

Normally during the steady state, VHS expects that it will deliver the agreed survey data products using the VDFS to the ESO Science Archive before the end of the semester following the one in which the raw data were delivered to CASU.

Based on recent experience from the SDSS and UKIDSS projects we anticipate that a longer delivery period will be required for at least the first full semesters and possibly also for the second full semester. We therefore wish to make provision for a more extended quality control and analysis period by the VDFS and VHS teams during the first year of public survey operations and to allow for a VDFS reprocessing phase with improved software parameters to correct problems discovered in the first-look analyses of the data from the first period of observations. We also request the provision of survey science verifiation phase where a series observations can be carried out so that observing strategy can be optimised.

We estimate that the data products from the first period of VHS observation data could be delivered to ESO not more than one year later than the end of the first full period i.e. by the end of the third observing period.

There would then be a 'catch up' phase with a goal of delivering the 2nd period of observations during the 4th period and the 3rd period of observations by the end of the 4th period and thereafter we would follow the one period for data delivery model.

Thus for example, assuming VHS observations start in period 80, the delivery of period 80 data would be by the end of period 82. Period 81 data would be delivered sometime during period 83 and period 82 by the end of period of period 83. This will clearly be somewhat in advance of a presumed 2-year review which would nominally be carried out during period 84. If required we could release a subset of the first period of data earlier in the form of an 'Early Data Release' which is a model which has been used by successfully by 2MASS, SDSS and UKIDSS. This would consist of a small representative set of data. For example 2MASS released a single night of data from the night of 1997 November 16 a year later on 1998 Dec 8. They then had their first major release of data covering data data between 1997 June and 1998 January in 1999 May. The content and delivery plan for the VHS Early Data Release could be timed so that feedback from this data could be used for one of the the 6 monthly progress reviews.

9 References

[01] P. Bunclark and S. Hodgkin. "VISTA Infrared Camera Calibration Plan", VIS-SPE-IOA-20000-0002, v1.4, 2006/11/13.

[02] J. Lewis, P. Bunclark, S. Hodgkin., "VISTA Data Reduction Library Design", VIS-SPE-IOA-20000-0010, v1.6, 2006/12/20.

[03] "VISTA Data Flow System: Status" Jim Emerson, Mike Irwin, Nigel Hambly in Observatory Operations: Strategies, Processes, and Systems, edited by David R. Silva, Rodger E. Doxsey, Proc. of SPIE Vol. 6270, 30, 2006

"VISTA Data Flow System: Overview" Jim Emerson, Mike Irwin, Jim Lewis, Simon Hodgkin, Dafydd Evans, Peter Bunclark, Richard McMahon, Nigel Hambly, Robert Mann, Ian Bond, Eckhard Sutorius, Michael Read, Peredur Williams, Andrew Lawrence, Malcolm Stewart in Observatory Operations: Strategies, Processes, and Systems, eds David R. Silva, Rodger E. Doxsey,Proc. of SPIE Vol. 5493, 401, 2004

VISTA data flow system: pipeline processing for WFCAM and VISTA, Irwin, Bunclark, Evans, Hodgkin, Lewis, McMahon, Emerson, Beard, Stewart, in Optimizing Scientific Return for Astronomy through Information Technologies, eds Quinn & Bridger, Proc of SPIE, 5493, 411, 2004
VISTA data flow system: survey access and curation: the WFCAM science archive, Hambly, Mann, Bond, Sutorius, Read, Williams, Lawrence, Emerson, in Optimizing Scientific Return for Astronomy through Information Technologies, eds Quinn & Bridger, Proc of SPIE, 5493, 423, 2004

[04] `http://www.vista.ac.uk/vdfs/esoqc1/`

[05] `http://casu.ast.cam.ac.uk/surveys-projects/wfcam/data-processing/` ,

[06] Dye, S. et al, 2006, MNRAS, 372, 1227.

Appendix 1: Spreadsheet tables

VHS_ATLAS SMP_VHS_obs_spreadsheet_v3p0.xls

	Z	Y	J	H	Ks
Time & depth on sky in coadded Tiles					
Depth (Vega) required		20.3	19.9	19.0	17.9
Depth(AB) required		20.9	20.9	20.3	19.8
Sigma required		5.0	5.0	5.0	5.0
Assumptions					
SED assumed in ETC		BB10000	BB10000	BB10000	BB10000
Aperture assumed in ETC - arcsec		2.0	2.0	2.0	2.0
In band sky brightness assumed - Vega mag/arcsec		17.2	16.0	14.1	13.0
Airmass assumed in ETC		1.2	1.2	1.2	1.2
In band on-chip image size assumed - arcsec		1.2	1.2	1.2	1.2
Extra extinction assumed		0.00	0.00	0.00	0.00
Detector Integration Time (DIT) sec		15	15	7.5	7.5
N.B. the DIT assumed will affect the number of seconds to reach a specified depth, because it affects the amount of read noise.					
Time required per object sec		60	60	60	60
Area required sq. deg		5000	5000	5000	5000
Tiles required to cover area(s)		3484	3484	3484	3484
Effective useful sq deg/tile		1.435	1.435	1.435	1.435
Priorities of different areas?		yes	yes	yes	yes
Single Tile Strategy					
Parameters set					
DIT already assumed above		15	15	7.5	7.5
Exposure coadds (Ndit) #		1	1	2	2
Exposure loops (Nexp) #		1	1	1	1
Microsteps (Nmicro) # steps <3 arcsec		1	1	1	1
Jitters (Njitter) # steps odd # of 0.5 pixels < 30 arcsec		2	2	2	2
Pawprints in tile (Npaw)		6	6	6	6
Repeat tile in same OB how many times?		1	1	1	1
Multiple filters in same OB? If so which?					
Mutiple tile positions in same OB? If so number?					
Resulting values					
Total Exposure sec/tile		180	180	180	180
Total Elapsed sec/tile		293.7	293.7	305.7	305.7
Total Elapsed hr/tile		0.08	0.08	0.08	0.08
Observing efficiency %/tile		61.3	61.3	58.9	58.9
Time per object for s-to-n -single OB		60	60	60	60
Signal to noise (at depth required in row 3) - single OB		5	5	5	5
Depth[Vega] (to 5 sigma) - single OB		20.3	19.9	19.0	17.9
Multiple Tile Strategy					
# of Tiles per filter for S/N		1	1	1	1
Time links between OBs in same filter on a Tile?		no	no	no	no
Priorities between OBs in same filter on a Tile?		no	no	no	no
Time links between OBs on a Tile in different filters?		yes	yes	yes	yes
Priorities between OBs on a Tile in different filters?		yes	yes	yes	yes
Time links between Tiles by position?		yes	yes	yes	yes
Priorities between Tiles by position?		yes	yes	yes	yes
Total Elapsed Hours per filter including ETC overheads		284.3	284.3	295.9	295.9
Total Elapses Hours per filter with no overheads		174.2	174.2	174.2	174.2
Effiicency for each waveband		61.3	61.3	58.9	58.9
Total Elapsed time	876.0				
Total time with no overheads	522.6				
Average Observing Efficiency	59.7				

Figure 4: VHS-ATLAS observation requirements

VHS_DES SMP_VHS_obs_spreadsheet_v3p0.xls

Time & depth on sky in coadded Tiles					
Depth (Vega) required			20.3	19.4	18.3
Depth(AB) required			21.2	20.8	20.2
microJy [SI]			11.6	17.7	30.2
Sigma required			5.0	5.0	5.0
Assumptions					
SED assumed			BB10000	BB10000	BB10000
Aperture assumed - arcsec			2.0	2.0	2.0
In band sky brightness assumed - Vega mag/arcsec			16.0	14.1	13.0
Airmass assumed			1.2	1.2	1.2
In band on-chip image size assumed - arcsec			1.2	1.2	1.2
Extra extinction assumed			0.00	0.00	0.00
Detector Integration Time (DIT) sec			15	10	10
N.B. the DIT assumed will affect the number of seconds to reach a specified depth, because it affects the amount of read noise.					
Time required per object sec			120	120	120
Area required sq. deg			4500	4500	4500
Tiles required to cover area(s)			3135.9	3135.9	3135.9
Effective useful sq deg/tile			1.44	1.44	1.44
Priorities of different areas?			yes	yes	yes
Single Tile Strategy					
Parameters set					
DIT already assumed above			15	10	10
Exposure coadds (Ndit) #			2	3	3
Exposure loops (Nexp) #			1	1	1
Microsteps (Nmicro) # steps <3 arcsec			1	1	1
Jitters (Njitter) # steps odd # of 0.5 pixels < 30 arcsec			2	2	2
Pawprints in tile (Npaw)			6	6	6
Repeat tile in same OB how many times?			1	1	1
Multiple filters in same OB? If so which?					
Mutiple tile positions in same OB? If so number?					
Resulting values					
Total Exposure sec/tile			360	360	360
Total Elapsed sec/tile			485.7	497.7	497.7
Total Elapsed hr/tile			0.13	0.14	0.14
Observing efficiency %/tile			74.1	72.3	72.3
Time per object for s-to-n -single OB			120	120	120
Signal to noise (at depth required in row 3) - single OB			5	5	5
Depth (5sigma) Vega - single OB			21.2	20.8	20.2
Multiple Tile Strategy					
# of Tiles per filter for S/N			1	1	1
Time links between OBs in same filter on a Tile?			no	no	no
Priorities between OBs in same filter on a Tile?			no	no	no
Time links between OBs on a Tile in different filters?			yes	yes	yes
Priorities between OBs on a Tile in different filters?			yes	yes	yes
Time links between Tiles by position?			yes	yes	yes
Priorities between Tiles by position?			yes	yes	yes
Total Elapsed Hours per filter			423.1	433.5	433.5
Total Elapses Hours per filter with no overheads			313.6	313.6	313.6
Effiicency for each waveband			74.1	72.3	72.3
Total Elapsed time	1290.2				
Total time with no overheads	940.8				
Observing Efficiency	72.9				

Figure 5: VHS-DES observation requirements

VHS_GPS SMP_VHS_obs_spreadsheet_v3p0.xls

	Z	Y	J	H	Ks
Time & depth on sky in coadded Tiles					
Depth (Vega) required			20.5		17.9
Depth(AB) required			21.1		19.8
uJy [SI units]			13.3		43.3
Sigma required			5.0		5.0
Assumptions					
SED assumed			BB10000K		BB10000K
Aperture assumed - arcsec			2.0		2.0
In band sky brightness assumed - Vega mag/arcsec			16.0		13.0
Airmass assumed			1.2		1.2
In band on-chip image size assumed - arcsec			1.2		1.2
Extra extinction assumed			0.00		0.00
Detector Integration Time (DIT) sec			15		7.5
N.B. the DIT assumed will affect the number of seconds to reach a specified depth, because it affects the amount of read noise.					
Time required per object sec			60		60
Area required sq. deg			8200		8200
Tiles required to cover area(s)			5714		5714
Effective useful sq deg/tile			1.44		1.44
Priorities of different areas?			yes		yes
Single Tile Strategy					
Parameters set					
DIT already assumed above			15		7.5
Exposure coadds (Ndit) #			1		2
Exposure loops (Nexp) #			1		1
Microsteps (Nmicro) # steps <3 arcsec			1		1
Jitters (Njitter) # steps odd # of 0.5 pixels < 30 arcsec			2		2
Pawprints in tile (Npaw)			6		6
Repeat tile in same OB how many times?			1		1
Multiple filters in same OB? If so which?					
Mutiple tile positions in same OB? If so number?					
Resulting values					
Total Exposure sec/tile			180		180
Total Elapsed sec/tile			293.7		305.7
Total Elapsed hr/tile			0.082		0.085
Observing efficiency %/tile			61.3		58.9
Time per object for s-to-n -single OB			60		60
Signal to noise (at depth required in row 3) - single OB			5		5
Depth (5sigma) Vega - single OB			20.5		17.9
Multiple Tile Strategy					
# of Tiles per filter for S/N			1		1
Time links between OBs in same filter on a Tile?			no		no
Priorities between OBs in same filter on a Tile?			no		no
Time links between OBs on a Tile in different filters?			yes		yes
Priorities between OBs on a Tile in different filters?			yes		yes
Time links between Tiles by position?			yes		yes
Priorities between Tiles by position?			yes		yes
Total Elapsed Hours per filter			466.2		485.2
Total Elapses Hours per filter with no overheads			285.7		285.7
Effiicency for each waveband			61.3		58.9
Total Elapsed time	951.4				
Total time with no overheads	571.4				
Observing Efficiency	60.1				

Figure 6: VHS-GPS observation requirements