Community Needs for the Dark Energy Camera & Data Management System

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Changes for Version 2.5

Other that minor grammatical and clarifications, the more major changes are:

Revised text in requirements: C5, C7, C9, C24, C33.   Note in particular that C24, the requirement now states only 1x1 binning mode should be supported, not 1x1 and 2x2.

Revised explanatory text: C1, C4, C12, C15, C27, C29, C30

1   Introduction

The Dark Energy Survey (DES) is an ambitious project planning to map 5000 sq. degrees in multiple filters and use this observational dataset to constrain the characteristics of dark energy with four different and independent methods. The DES Collaboration is building the Dark Energy Camera (DECam) to be installed on the NOAO/CTIO Blanco 4m telescope in order to collect the needed data. The DES Collaboration is also developing a Data Management System (DMS) to process the DES data in support of the necessary scientific analysis to achieve the survey goals. In exchange for the delivery of this facility instrument (including the DMS), NOAO is providing the DES Collaboration 30% of the time on the Blanco telescope for five years. As a facility instrument, NOAO anticipates that the astronomical community will use the DECam extensively during time allocated through the standard NOAO peer-reviewed time allocation process. Addressing the needs of this community is an important component of the delivery of an acceptable facility instrument.

The requirements on the DECam and DMS flow from many sources, but can very generally be broken down into *scientific requirements* and *functional requirements*. The most stringent scientific requirements almost certainly flow from the DES project itself, as the DES must strive to control and understand the detailed systematics of the data obtained in order to achieve its scientific objectives. There are also scientific requirements that are derived from the community use of the DECam. Most of these requirements originate as properties of current instruments such as MOSAIC Some of these requirements will be similar, and probably less stringent, than those from the DES, but others will not overlap with the DES use of the instrument, and thus will represent truly distinct requirements. Finally, the functional requirements will cover how the delivered DECam and DMS integrate into the NOAO data management environment, including software and hardware interfaces as well as operational aspects and documentation of the system.

In this document, we attempt to provide an overview of the important components of the DECam and DMS, how they will be used, and the interfaces and expected interactions with the NOAO environment. We focus on the community use of the DECam, as opposed to the use by the DES Collaboration, since the *Dark Energy Camera Specifications and Technical Requirements (Ver 2.0 10 December 2007, DES document*

806) covers the DES-specific requirements. We first provide a general overview of the DECam and DMS, and then describe specific uses and features of the system that will be needed to provide full functionality to the NOAO user community.

2 An Overview of DECam Community Use

Once it is commissioned, the DECam will be the only available optical imager for use by the astronomical community on the Blanco 4m telescope, a premier U.S. national telescope facility in the Southern hemisphere. As such, it will serve a diverse community, from planetary scientists studying potentially hazardous asteroids (PHAs) to extragalactic astronomers performing deep imaging reaching the edge of the observable universe. Most of these users will observe in what is generally known as "classical" mode, coming to the telescope to use the instrument with only minimal training during the first few hours of their observing run. Here we describe the general flow of such an observing run, from the proposal through time allocation, the observer's activities on the mountain, and the expectations from the data management system.

Time on the Blanco 4m is obtained through peer-review of observing proposals submitted by deadlines twice a year, in the end of March and September. Prospective observers are expected not only to describe their scientific objectives, but also to technically justify their use of the telescope and instrument to achieve those objectives. They must base their experimental and technical justification on documentation that describes both the characteristics and the operational protocols of the facilities. Observing proposals are ranked based on their scientific merit, and from the ranked list a telescope schedule is drawn up based on how the time requests, rankings, different instruments, and moon phases interact. Successful proposers are then notified that they have observing time and should start planning their observing run. Observing runs usually run from 3 to 10 nights, although shorter and longer runs are occasionally granted. Proposals for greater than 10 nights are often "survey proposals", which are usually multi-year allocations of time, with individual observing runs typically 5 to 20 nights.

Before arriving at the telescope, the observers usually review the documentation again to prepare and/or refine their observing plans. They often arrive a night before their observing run begins to watch the previous observers using the instrument. This is often the extent of their "training", so the transition from reading the manual to using the instrument must be relatively straightforward.

The typical observer will be operating the instrument with a rough plan in mind, but with the ability to change their plan continuously based on the information being collected, both from the instrument and from other sources, such as weather conditions, seeing, etc. Given the large quantity of data collected in a single DECam exposure, statistical information about the data quality (e.g., avg. sky level, avg. noise level, avg. PSF size) is an important component of the observing process. In addition, the observer needs the capability to review and interactively manipulate the data as it comes in to inform his or

her decisions. Finally, the observer needs a flexible observing environment to change plans and strategies easily.[1]

As the data are taken, the images and associated metadata are captured into the NOAO data management environment and automatically backed up to multiple off-site locations, providing safe storage in case of disk failure or other problems on the mountain. All data and most of the metadata are ingested into the NOAO Science Archive (NSA) to make them available for later download. Once the observing run has been completed (or possibly even during the observing run), the observers may download their raw data from the NSA for processing at their home institution(s). Pipeline reduced data should also be available, providing at least thorough data quality assessment if not science-ready data products which can be used to move forward in their scientific analysis. Both the raw and reduced data are held for access limited to the Principal Investigator (PI) and related investigators for the length of the proprietary period, typically 18 months, after which access is allowed to everyone. Access to the metadata is generally allowed to all users immediately, unless the PI has requested that it be made proprietary for some period less than or equal to that of the proprietary period for the data.

3   The DECam Camera Project

> **C-1**   Where not stated, the performance metrics as specified in the DECam Specifications and Technical Requirements Document are assumed to have been met.

DECam will be delivered with a set of *special spares* that are the not-off-the-shelf-items. Examples are CCDs and data acquisition circuit cards. In general, purchasable items shall be provided by CTIO. A full list of spares will be developed, showing quantities, vendor, cost, and purchaser. Special spares, and any spares thought likely to become obsolete and possibly difficult to obtain during the 10-year operating period, shall be flagged.

> **C-2**   DECam will be provided with a complete set of spares, consistent with an expected instrument lifetime of 10 years.

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[1] Implementation: The Observer Console will provide both manual target selection and scripting, and will support the observer with a display showing the full focal plane for every image (we call that the comfort display), An Image Health module will provide near real-time status. An Observer Workstation will receive a copy of every image and the observer can use it to run any algorithm, analysis package etc. SISPI will provide the results of a more detailed image analysis via the Quick Reduce system. QR will only sample images.

3.1 Hardware Components

3.1.1 F/8 and Top End

The Blanco 4m telescope supports multiple instruments for the astronomical community. DECam will be the only prime focus instrument. Other instruments will be installed at the Cassegrain focus. The f/8 mirror is a critical component to using the Cassegrain focus, and as such is a necessary component to the top end of the telescope.

> **C-3**   DECam will incorporate a mechanism by which the f/8 focus may be used with at least the same level of functionality and precision that is available with the current top-end.

> **C-4**   It must be possible to adjust alignment (tip/tilt) and focus of the f/8 secondary mirror via a remotely controlled system.

The f/8 mirror will *not* be carried on the same hexapod used to support, focus & align the DECam.) Control of the f/8 mirror is not part of DECam, but provision must be made for accommodating control lines, power lines, and the control computer. The latter will be upgraded prior to DECam's arrival, and will be smaller than the present computer.

The top end is an operationally complex structure, and will require occasional maintenance and repair, sometimes requiring servicing on a rapid turnaround basis (<8 hours for a daytime repair).

> **C-5**   DECam will be designed so that as many individual components as possible may be removed from the top end for servicing. In particular, it should be possible to remove the filter mechanism, shutter mechanism and camera, individually or together, without further dismantling the top end. These procedures should be able to be carried out within a single working day, and thus not cost observing time.

The current top end allows for removal of the entire Mosaic II camera with its filter track. The current corrector can also be removed in one working day. This will not be possible with DECam, but the design should address the issue insofar as it may be necessary to clean optical components and recoat them if necessary.

> **C-6**   DECam will be designed to allow for dismantling and removing the corrector for cleaning or recoating if necessary. The timescale for the removal or re-installation of the corrector may cover more than one working day.

3.1.2 Optics & Transmission

In order to support the wide range of science that the NOAO community pursues, the transmission of the optical imager should ideally be maximized across a broad range of wavelengths. For the DECam, this translates into a specific desire not to diminish the

sensitivity across wavelengths below that currently available on Mosaic. In the current DECam design, the corrector elements will be made of fused silica. In that case the band pass is limited by the CCDs and u-band observations are possible on DECam at about the same efficiency per unit area as Mosaic.

C-7 The detected efficiency per unit area of DECam focal plane should not be less than that of Mosaic II & the current corrector across any filter or defined band pass.

Atmospheric Dispersion Corrector (ADC): The DES, concentrating for the most part on redder pass bands at low air mass, does not require an ADC. Although some community science, such as projects that *only* require blue or ultraviolet observations, will be compromised by not having an ADC, for most projects satisfactory results should be able to be obtained by applying the operational constraint that observations in the bluer pass bands be carried out at low air masses. For community use there is not sufficient justification for having an ADC.

3.1.3 Shutter

Community shutter performance requirements are based on the precision required to make calibrations via standard star observations, and are met by the DES shutter requirements (see *DECam Specifications & Technical Requirements* document, requirements TOM.28 through TOM.36).

3.1.4 Filters

The variety of filters available in the prime focus camera for community use has a direct impact on the range and types of science that can be undertaken with the instrument. While clearly more filters support more community science, the cost and complexity of the large filters for DECam will intrinsically limit the variety of filters that CTIO will support for community use. CTIO is charged with developing a prioritized list of possible filter purchases besides those used by the DES. This list will be developed by consulting both the NOAO User's committee and the user community.

C-8 NOAO, in collaboration with the community, will establish a prioritized list of possible filter purchases besides those used by the DES. Purchased filters shall be supported by CTIO.

3.1.4.1 Filter Changes

Assuming the impossibility of DECam having a filter jukebox holding a large number (e.g. 12), and assuming that NOAO and/or its users will purchase at least a few additional filters to the DES survey filters, then filters should be able to be swapped safely and efficiently.

C-9   DECam shall be designed to allow the safe removal of a filter from the instrument and its replacement with another within a time period of 2 hours, with 1 hour as the goal. This is a daytime operation that should require no more than 2 people.

Given the science requirements of the DES and the need to closely control systematics, we assume here that the DES filters should not be swapped out during each year's DES observing season.   This implies a (possible) restriction on community use of other filters during this time.   This assumption is in place to adequately protect vital, possibly irreplaceable filters through the lifetime of the survey.   In principle such filter changes are possible without affecting the survey provided the filters are not damaged, but the observatory is strongly averse to their occurrence.

C-10   DES filters should not be removed from the instrument during each year's DES observing season for purposes other than necessary repair or maintenance.

3.1.4.2 Filter Mechanism Capacity

Given the high initial cost of DECam filters, and their high value, filter-swapping needs to be minimized.   With a 6-filter (3-cartridge) system there is likely to be demand for filter swaps of non-DES filters at around one occasion per month.   Of the filters anticipated, installation of a set of narrow-band filters would require disturbing the DES filters, and so this would be limited to the non-DES observing season, and could be limited to one or at the most two in-out swaps per year. To avoid disturbing the survey filters, considerable changing of equally valuable non-survey filters would be necessary, and program scheduling constrained, e.g. a program requiring Washington C, M, DDO51 would need to use only two of the filters on a given night.   An 8-filter (4 cartridge) system would make filter swapping in general very infrequent, and may even allow the DES filters to remain untouched for the whole survey.

C-11   The DECam filter mechanism should include a minimum of six slots with eight as a strongly desired goal.

3.1.4.3 Filter Alignment

Filter cells and their mechanical interface to the cartridges (assuming a PANSTARRS-like system) should allow for accurate repeatable alignment of filter cells within the cartridges (and hence filters with respect to the focal plane). The DECam specification (TOM.25) is for alignment to < 0.5 mm, which is also adequate for community use.

3.1.5 Front-end Electronics & Focal Plane

C-12   The collaboration shall supply maintenance and repair protocols, diagnostic tools, and full documentation for the front-end electronics and focal plane.

Diagnostic tools can consist of a set of low-level test routines that run from an engineering interface.

If the project experiences significant delays resulting from an unexpectedly low manufacturing yield of CCDs, the camera may be installed on the telescope without its full compliment of detectors. Moreover, it is anticipated that the camera may suffer the loss of CCDs in the course of operation. Both of these conditions require that it be possible to remove the camera from the instrument for installation or replacement of CCDs. (See requirement C-5)

C-13   DECam will be provided with Front End Electronics spares sufficient to replace 3 separate CCD signal chains (that is although a CCD may share its signal chain components with other CCDs, this chain nevertheless counts as one chain).

3.2 Data & Metadata

3.2.1 Data Format

C-14   DECam data will be provided in standard FITS format. Multi-Extension FITS (MEF) is preferred.

3.2.2 Image Headers

C-15   Data provided from the Dark Energy Camera will include header keywords in accordance with NOAO standards.

These keywords, to be developed in collaboration between DES and NOAO, include information needed to correctly reduce the data, information to support identification of the data with observational program, information to track the provenance of the data, and information to support data mining applications of the NOAO NVO portal. The necessary keywords will be documented. Iterations are possible, by agreement between all parties.

3.2.3 Additional Instrument Metadata

C-16   The image headers will incorporate instrument metadata indicating the status of the camera subsystems during the exposure.

This includes, but is not limited to:

- FPA bias and clock voltage telemetry,
- FPA and environmental temperatures,
- software versions,

- camera and instrument controller card ID numbers,
- focus & hexapod positions,
- cryogenic system activity,
- dewar pressure,
- shutter performance

3.2.4 Auxiliary Information

In addition to the instrument metadata, there are an extensive set of additional metadata that are needed or desired to fully characterize the observations and the resulting raw data. These include information about and or status of the telescope, information about the environment (weather & seeing), logs of problems and observing logs. Capturing this auxiliary metadata is important not only to the PI, but also for the archival use of the data by the astronomical community.

Logging of observations is normally a procedure left to the preferences of the classical observer. However, as NOAO has begun to capture all raw data for archival use, the need to capture observing logs uniformly across NOAO telescopes has been recognized and is currently being worked on. This work can proceed in collaboration with DES or can produce separate logging service from that DES uses, as DES survey-specific requirements may exceed or differ from the community requirements sufficiently that different systems may be called for.

C-17	An NOAO observation logging service should be supported.

This may take the form of a comment database with time-tagged entries, or the attachment of comment cards to the FITS headers of the images. In any case, it should be possible to "attach" (for example, in a comment database; not necessarily in the FITS header) a comment to any image taken during the night at any time, which implies an ability to comment an image already partway, or completely, processed by the pipeline.

Both NOAO and DES have identified the need to capture and manage the extensive auxiliary metadata that are associated with all observations. These data include the observing logs discussed above, as well as the following other sources (not necessarily ALL sources are listed here):

- Telescope environment telemetry
- Weather station data
- All-sky (optical) camera data
- IR sky camera data
- End of night/run reports
- Problem reports (and solutions)

In addition, there are other metadata that are required by community use of the camera, such as proposal ID, proposal PI, unique file identifier, and other information that is produced in the general use of the instrument. Some of these metadata are expected to be included into the header (e.g., telescope position), while others can be stored separately.

The Telescope Control System will record various telescope performance data into the Facility Database,

C-18   Metadata stored separately from the science data archive should be accessible to the community user of DECam through the standard community access.

C-19   To the extent that the DES *metadata management system* differs from the solution NOAO/SDM provides for all other NOAO instruments, the portion of the DES system designed to provide for community use should be compatible with the NOAO system.

Note that the NOAO policy is that metadata associated with the observation is immediately available and searchable to the community through the archive.

3.3 Observing Environment

3.3.1 Protocols/Planning Observations

C-20   Working with NOAO, the Dark Energy Survey Collaboration will establish and document a set of supported observing protocols.

C-21   Observations made according to the supported observing protocols, which include calibration procedures, will be able to be reduced and calibrated to the same photometric and astrometric precisions as achieved by equivalent observations for the Dark Energy Survey, and not less than specified in the *Dark Energy Camera Specifications and Technical Requirements* Document.

The supported protocols will include the ability to make observations with the following recommended parameters:
NB C24 TBC by Chris Smith

C-22   Supported observing protocols will allow for filters with central wavelength from 330 to 1050 nm and bandwidth from 5 to 300 nm

C-23   Supported observing protocols will allow for observations at air masses less than 2.5.

C-24   Supported observing protocols will allow for binning factors of 1 X 1 only.

N.B. Prior to v2.4 of this document, C-24 stated that both 1x1 and 2x2 binning modes shall be supported.

C-25 Supported observing protocols will allow for sky backgrounds below a level corresponding to 30 degrees from the full moon (maximum) and expected sky backgrounds at new moon (minimum) in all available filters (including non-DES filters).

C-26 Supported observing protocols will allow exposure times from 1 second to 1800 seconds per exposure

3.3.2 Support for all Major Observing "modes"

C-27 The observer should be able to acquire direct control over all major configuration aspects, including filter choice, exposure time, guide stars selection, focus etc.

The need for scripting observations implies the need for efficient and automated control (limited or no configuration) of focus, guide star selection, etc. There needs to be a quick and efficient way to select suitable guide stars. DES observations will have pre-selected guide stars. Community Use should be able to handle pre-selected guide stars, guide stars automatically provided at time of observation, and manually selected guide stars.

C-28 It should be possible to abort any given instrument function/process and return it to a default state within a reasonable time period (significantly less than an average exposure time) and without the need to manually restart any instrument component.

3.3.2.1 Single Object / Pointing

Single object pointing is currently the default observing mode for most observers on the Blanco telescope. Target fields are selected and observed on an individual basis. It should be possible to manually select guide stars and modify the focus. See DECam specifications TOM.13 through TOM.15.

3.3.2.2 Dithered

In this observing mode, multiple exposures are taken of the same field but each offset from the others by a small amount suitable to "fill in the gaps" between CCDs in a final, co-added image.

This is not a DES requirement, but DES requirements incorporate all the components necessary to implement any reasonable dither sequence – a scripting capability including the commands: take an exposure, offset by an arbitrary amount in an arbitrary direction, acquire guide stars, take an exposure, etc.

3.3.2.3 Survey

In survey mode, observations are made of a sequence of fields and with a sequence of instrument configurations (changing filters, focus, etc). Observations are made according to scripts that are written before the run. These scripts should be interruptible in the event that appropriate observing conditions are not met.

This is a DES requirement.

3.3.2.4 Planetary (Non-Sidereal Tracking)

> **C-29** The telescope shall be capable of tracking at non-sidereal rates in declination and right ascension. Guiding shall not be required during exposures taken while the telescope is tracking at non-sidereal rates. Full reduction (including photometric and astrometric calibration) of data taken with non-sidereal tracking does not necessarily have to be done automatically in the provided data management system, although basic calibration (removal of instrument signatures) should be a goal.

Non-sidereal guiding may be implemented (non DES) later. In designing the guiding module, nothing should be done that excludes this development.

3.3.2.5 Engineering

The engineering mode assumes low-level access to the component subsystems of DECam. Such interfaces should be available at the normal observing console and also via temporary connections with a laptop at the point of connection of the given subsystem to the controlling network. These interfaces should provide immediate feedback that is at least partially understandable to the operator and appropriate to the identification and diagnosis of problems.

> **C-30** An appropriately qualified worker should be able to deliver atomic commands to any subsystem for test purposes.

3.3.3 Feedback to observer

To support the collection of high quality astronomical data, one not only must have a highly functional instrument, but must also be able to understand the data as it is collected in order to make educated observing decisions and correct for unexpected events or problems in the data acquisition process (ranging from atmospheric effects to instrumental issues).

> **C-31** The DECam system must provide both visual and statistical feedback to the observer to enable him/her to make educated decisions, and also must allow the observer to probe further into the data being collected by interacting with the data directly.

3.3.3.1 Quality Assessment (QA)

Given the volume of data the DECam will produce, and the fact that the DECam will be used most often in some sort of large scale survey mode (both for the DES and for other NOAO surveys), it is important to provide observers with automated feedback regarding the quality of the data being collected in order to ensure that the resulting data and data products are scientifically useful.

C-32   DECam system should provide some sort of automated feedback, most likely in (graphical) statistical form, on at least a subset of the data being collected.

Statistical measures such as bias levels and trends, sky brightness, PSF size (i.e., seeing) and shape (e.g., ellipticity), photometric depth and estimates of photometric conditions, are all examples of the type of feedback which would enable effective observing and enhance the resulting collected data.

3.3.3.2 Image interaction

Both for confirmation of the information provided by QA feedback and for investigation of issues identified by QA feedback (e.g., PSF shape anomalies), the observer must be able to see and interact with the images coming out of the DECam in real time. The most rapid form of such feedback is a "Real Time Display" (RTD) service.

C-33   Real Time Display: The observer should be able to view the entire field of view (albeit in a heavily binned version) to visualize the large-scale properties of the data (e.g., is an extended object centered, are there any gross anomalies in the image).   The observers should also be able to view a sub-set of the focal plane at full resolution to investigate detailed problems such as instrumental or optical (PSF) issues. This latter service, which could be separate from the RTD, may involve a single or small number of CCDs, preferably selectable.

C-34   The observer should be able to interact with the data in "standard" ways, for example being able to measure image characteristics such as PSFs for selected stars, measure noise, and/or compare one image (or sub-image) to another.

The types of interactions which are currently performed in the IRAF environment on Mosaic images provide a good baseline for the needs of the community using DECam. IRAF has the ability to select any CCD, then display and interact with it at full resolution (e.g., use of a tool such as IRAF's imexamine, providing access to both statistical evaluations and PSF shape evaluation).

4   The Data Management System (DMS)

> **C-35** The DMS for the DECam must support use both by the DES and the wider astronomical community that will use DECam for a wide range of scientific investigation.

NOAO's SDM program was established to manage data and data products from all NOAO facilities, and is developing a general DMS infrastructure. This DMS provides "end-to-end" (E2E) management of the data, from the instrument to the end user (astronomer – either observer or archival researcher). As a facility instrument, DECam and its DMS should fit into this general E2E system infrastructure in order for NOAO to effectively and efficiently support community use of the instrument and derived data and data products.

NOAO will be responsible for the overall data management system for community use of DECam, which will involve supporting for DECam in the E2E system currently under development for all NOAO facility instruments. The DES Collaboration is responsible for developing and delivering a pipeline processing component which will be integrated into the E2E system to complete the DECam community use DMS.

4.1 Data Capture & Transport

The first key component of any DMS must be to capture and safely store data, metadata, and data products. Data objects must be protected from the time they leave the instrument data acquisition system against loss or damage, including but not limited to, accidental deletion, failures of storage media, and illegal access.

> **C-36** Data capture should include registration of all raw data and associated metadata (3.2 above) into the NOAO E2E system so that they may be tracked.

> **C-37** Data must be transported to multiple NOAO sites & NCSA for safe (redundant) storage.

> **C-38** If transported using shared NOAO network facilities, the transport must be done in such a way that allows for NOAO management as well as recognition that this is a shared resource used by other users at the observatory.

The NOAO/SDM "data transport system" (DTS) supports these needs for all NOAO facility instruments, and is a satisfactory and preferred solution to meeting the DECam needs for data capture and data transport.

4.2 Archive & Access Services

The DECam DMS must provide not only back-end services for data access at the archive level, but must provide for effective data access for both PI use to access proprietary data and general community use to access non-proprietary data and data products. Given the

need to maintain restricted access to proprietary data, the security model must extend from the archive to the access mechanism. Efficient delivery of data to the end user must also be included in the access mechanism.

The NOAO NVO Portal will provide access to all NSA holdings, as well as access to holdings of other NVO-compatible archives distributed throughout the world. Inasmuch as the DECam data flows automatically into the NSA for raw and reduced data storage, the NOAO NVO Portal will fulfill the access needs of both the PI users and archival users of DECam data and data products.

> **C-39** Observers should be able to retrieve their raw data from an archive within 48 hours of the end of their observing run.

> **C-40** The archive must provide a security model that correctly limits access according to NOAO proprietary period policies.

> **C-41** The archive must provide all science and calibration data in a standard file format (some flavor of FITS)

> **C-42** The archive must include appropriate metadata and header keywords in accordance with NOAO standards

> **C-43** The DMS must support automatic transfer of the raw and reduced data to the NOAO Science Archive (NSA) for archival research

> **C-44** The archive must provide adequate access for at least three users simultaneously (where adequate is TBD, but defined in the context of multiple users downloading images in a timeframe of less than the length of time it took to obtain the data).

> **C-45** The archive must provide access to instrument scientists to both proprietary and non-proprietary data for evaluation of instrument health as well as investigation of problems or issues.

> **C-46** This archive must be operated and supported for the lifetime of the instrument.

> **C-47** Support includes both ensuring that the archive is operating correctly and efficiently and interacting with community users.

Given that the NSA will be fulfilling these needs for other NOAO facility instruments, it can also do so for the DECam given appropriate interfaces are recognized and supported by the DECam DMS.

4.3 Pipeline Processing

C-48   For observations obtained following approved, documented observing protocols (Section 3.3.1), a pipeline will be provided as part of the DMS to correct raw DECam data for instrumental signature, including (but not limited to) bias, dark, illumination, fringing, geometric distortion, astrometric calibration, and any other effects such as pupil images that require expertise associated with the instrument in order to remove. An approximate photometric calibration should be provided where available (e.g. SDSS, USNO-B), and the source identified in the image header.

C-49   The parameters used for any particular application of the pipeline will be recorded in a way that will allow observers to understand quantitatively what has been done to the data.

C-50   The NOAO community must have access to and support of pipeline processing, including archival access to pipeline processed data products, for the lifetime of the instrument.

C-51   Pipeline reduced DECam data (non-DES data) should be available to the PIs within a week of their observing run through the NSA.

C-52   Reduced DES data and data products should be made available automatically through the NVO-compliant NSA at the latest by the termination date of the proprietary period (preferably as soon as the data is processed).

In order to meet the needs of the NSA and NVO, the pipeline must produce metadata that allows for effective data discovery and scientific analysis. These metadata needs will be specified in a separate document that details the interface between pipeline and the E2E system.

In so far as the need for a pipeline extends beyond the period of the DES activities, delivery of a pipeline for operations by NOAO/SDM, and associated integration into the NOAO/SDM E2E system is arguably the most effective way to fulfill these community needs. For this reason the pipeline, known as the "Community Pipeline" has been defined as a deliverable to NOAO along with the camera itself.

The specific requirements and technical specifications of the Community Pipeline are detailed in the *DECam Community Pipeline Requirements and Technical Specifications* document, which should be considered an auxiliary part of this document.

4.4 Data Management Infrastructure

4.4.1 Data Transport

DECam data may be transported either by network or by producing portable copies of the data on hard disks, DVDs, or other media. Transmission of the data over the network is the baseline operational concept for both DES and community use of DECam.

> **C-53** The data transport of DECam data must be designed to respect the shared use of bandwidth resources and allow for NOAO management of the use of bandwidth.

Current CTIO network resources include a 155Mbps link from the mountain to La Serena, and half of a shared 45Mbps link from La Serena to the U.S. mainland. In order to support DECam operations, CTIO plans to upgrade these resources as necessary to meet the needs of DECam use. General community use of DECam is projected to require a sustained bandwidth of 36 Mbps over 18 hours to transfer a single, typical night of compressed data. While this minimum required bandwidth is within the currently contracted international bandwidth of 45Mbps, this bandwidth may not be sufficient to simultaneously transport the data from all NOAO-South facility instruments through the NOAO Data Transport System (DTS). However, NOAO considers meeting the additional bandwidth needs a general site operation issue and plans to meet those needs within the standard Observatory operations budget by the time DECam operation begins.

4.4.2 Additional NOAO Infrastructure

While much, if not all, of the data processing will occur using NCSA or national Grid resources, NOAO will endeavor to operate a pipeline processing cluster itself to provide rapid feedback from full frame reductions to the observers. Installation and operation of pipeline processing on such a platform should be supported by the delivered pipeline software and accompanying documentation.

> **C-54** The delivered pipeline software should be installable at non-NCSA sites, such as at the NOAO facilities both in La Serena and in Tucson.

4.4.3 NCSA Infrastructure

Through the NCSA-NOAO MOU, both institutions have agreed to support community use of data and data products generated at NOAO and affiliated telescopes. As an NOAO facility instrument, the data from DECam (both DES and non-DES use) will be included under this agreement.

> **C-55** NCSA may provide the resources needed for long-term storage of both raw and reduced DECam data, both for DES and community use. Insomuch as NCSA does not provide these resources, NOAO is responsible for identifying the necessary resources to provide for long-term storage of at least the raw DECam data.

The DES may have separate agreements with NCSA for holdings outside of the NSA.

NOAO will manage pipeline processing of community data through agreements with NCSA covering processing in support of all NOAO instruments (which may include joint proposals to the Teragrid for computing resources). Processing of community data may also be done using NOAO resources.

5 Operations

The operations and maintenance plan is described in detail in a separate document. This plan covers normal support for the instrument, including daily tasks of checking and maintaining the instrument's health, regular calibrations, and procedures for changing filters and other "user support" setup issues. It also includes nighttime observation plans, describing the use of the instrument by visiting astronomers. Finally, it includes the operation of the DMS from end-to-end, including support for the NOAO user community.

In "point and shoot" mode, DECam should not be significantly more difficult to use than MOSAIC, which can easily be operated by one person, especially if the observer is taking long (more than 2-3 minutes) exposures.   Most visiting observers work in a 2-person mode – one managing the queue and taking/overseeing exposures, the other monitoring the data as it comes off the telescope.

5.1 DES Staffing & Support

During DES operations, DES and CTIO staff will:

- conduct survey observations and related tasks
- respond to emergencies
- respond to detailed technical queries about camera
- respond to queries about pipeline or other DMS components
- respond to "issues" generated by pipeline data reduction/analysis

During community use, CTIO staff will:

- support observations by visiting astronomers
- respond to emergencies

- provide first level response to detailed technical queries about camera
- provide first level response to queries about pipeline or other DMS components
- provide first level response to "issues" generated by pipeline data reduction/analysis

In cases where first level response is insufficient to resolve the issue, the CTIO staff will involve the previously identified camera or DMS contacts for more information.

5.2 CTIO Staffing & Support

Operations of the DECam for both DES and community use will rely upon the standard staffing levels for NOAO facility instruments at CTIO. Standard CTIO staffing includes limited daytime support from one or two electronic technicians, one or two mechanical technicians, and one higher-level support staff ("observer support"). It also includes nighttime support from a telescope operator, who is responsible for the health and safety of both the telescope and the instrument during the night. When there are problems during the night, the telescope operator may call upon help from local resources (the above mentioned electronic technicians on the mountain, the local instrument scientist, and/or other NOAO resources) as well as a pre-defined set of remote support resources from Fermilab (usually in the case of emergencies which risk the health of the camera).

5.3 SDM Staffing & Support

Assuming the DECam DMS is sufficiently integrated into the NOAO E2E system, SDM staff will monitor data flow from the mountain to the archive sites, raw data ingest into the NSA, and ingestion of reduced data into the NSA. Given a well documented pipeline which is integrated into the E2E system, SDM staff will monitor data flow into and out of the pipeline, and provide a "first look" monitoring of data quality for reductions of data originating from community use of the DECam. In this data quality monitoring, SDM staff may contact local instrument scientists, a pre-defined set of camera support staff, and/or a pre-defined set of data management support staff for help in understanding and characterizing apparent problems with the data, data products, or data flow. SDM will also support a helpdesk for community use of the data and data products, directing questions to the appropriate individuals either within NOAO (instrument scientists or SDM support scientists) or within the DES Collaboration (camera team or data management team).

5.4 Division of Responsibilities

The division of responsibilities for support and operation of the DECam and data management system will be detailed in the operations and maintenance plan. Here we document only the highest-level responsibilities.

C-58   Division of responsibility between CTIO operations staff and DES staff will be specified in the Operations and Maintenance plan, and will be consistent with ensuring safe operation of the instrument, and achieving less than 5% unscheduled down-time.

C-59   Responsibility for maintenance and repair of DECam will be shared by CTIO and the collaboration.

C-60   During the DES observing time, the DES collaboration will be responsible for providing the appropriate observing staff, not including the telescope operator, who is made available by CTIO.

C-61   During the DES observing time, the DES collaboration will be responsible for overseeing operations of the pipeline (specifically) and operations data management system in collaboration with the SDM operational staff. SDM staff will continue to be responsible for relevant portions of the E2E system in support of DECam operations.

C-62   During non-DES observing time, the DES collaboration will be responsible for providing the appropriate support for efficient camera operations (generally responding to queries and emergencies in which CTIO staff require additional help)

C-63   During non-DES observing time, the DES collaboration will be responsible for providing the appropriate support for efficient operations of the Community Pipeline (generally responding to queries and emergencies in which SDM staff require additional help)

6 Documentation

6.1 General Documentation, Version and Change Control

The DES collaboration and CTIO will work together to produce appropriate design, testing, maintenance, support, and user documentation.

After delivery, documentation must be updated to respond to changes in either the hardware or software components of the system.   In order to keep distributed documentation updated, some type of version control must be implemented to document and track changes.   Significant changes to any component of the system be they motivated by operational issues or scientific optimization, must be subject to a procedure of change control.

C-64   The DES collaboration will define a procedure to allow consideration and approval of significant changes in the DECam and data management systems and to record such changes in all related documentation.

C-65 The DES collaboration will provide a version control system (or systems) for all software AND documentation and define policies and procedures for use of the system to update software and documentation and to distribute changes. All participating sites will work from documents and software contained within this system so that updates are universally available.

In general, DECam camera and data management documentation should include:
1. design documentation (both descriptive and technical)
2. software documentation (documentation of code)
3. acceptance testing criteria and test plans
4. installation documentation
5. operations documentation (for staff use)
6. user documentation, where needed for external users such as visiting astronomers

6.2 Design & Coding Documentation

The camera system will be delivered as a combination of multiple hardware and software components. Full documentation of the hardware is necessary for the acceptance and ongoing support of the instrument at CTIO. This documentation includes as-built drawings, schematics, and descriptions of the functionality of the components. System control software must be delivered with design documentation and source code.

C-66 The DES collaboration will provide a complete set of as-built drawings and schematics, source code, and manuals for all DECam components and software.

In order to allow for long-term support of software, use of proprietary code which cannot be altered or binary distributions of software without source code are discouraged.

To provide for the operation and support of the data management system, as well as for the scientific curation of the raw data and data products (answering questions about what was done to the data in detail), the system must be delivered with full design documentation as well as component software documentation (code level documentation) for the complete system.

C-67 The DES collaboration will provide a complete set of design documentation, source code, and manuals for all developed components of the Community Pipeline in support of not only operations, but also scientific curation. NOAO SDM will provide documentation for the components and/or interfaces of E2E, which are used in the data management system.

6.3 Documentation for Delivery & Deployment

Delivery and deployment of the camera and DMS at CTIO requires that the system pass through stages of integration, installation, acceptance testing, commissioning, and science verification before full operations begin and community use is supported.

C-68   The DES collaboration and CTIO will document an integration plan for DECam and installation instructions and/or procedures for the DECam on the Blanco 4m telescope.

C-69   The DES collaboration and SDM will document an integration plan for the DMS including integration into the existing E2E system. They will also document instructions for installation of the system at NCSA and also NOAO sites.

C-70   The DES collaboration and NOAO will document a set of acceptance tests for the DECam, which confirm that the community needs of the system are met. These tests will be carried out as part of the acceptance procedure for the camera.

C-71   The DES collaboration and NOAO will agree upon and document a set of acceptance tests for the DMS, which confirm that the community needs of the system are met. These tests will be carried out on all installed systems at NCSA and NOAO sites as part of the acceptance procedure for the DMS.

The DES may have extensive additional acceptance tests that confirm that the DECam and DMS meet the science requirements of the survey.

C-72   The DES collaboration and NOAO will document a plan for commissioning and science verification of the complete DECam and DMS.

6.4 Operations Documentation

Ongoing operations of the DECam and DMS requires documentation for operations and staff support of the system as well as documentation for community use of the system.

C-73   The DES collaboration and CTIO will develop and document a Technical Operations and Maintenance Plan for the camera.

C-74   The DES collaboration and SDM will develop and document an Operations Plan for the DMS.

A set of standard tests is important to verify that the camera is in good working order after any changes, upgrades, and/or repairs are made to the camera, or whenever the camera is maintained or removed from the telescope.

C-75 The DES collaboration and CTIO will develop and document a standard test suite to be run on the camera to confirm that it is in good working order before continued operations

Similarly, the DMS will likely undergo significant upgrades and changes during the lifetime of the instrument. A regression test suite, including a documented set of test data, is needed to ensure that as the DMS evolves, the system continues to meet both community needs and DES science requirements.

C-76 The DES collaboration and SDM will develop and document a standard regression test suite, with associated test data, to be run on the DMS to confirm that the system continues to meet acceptance test standards.

C-77 The DES collaboration and NOAO (CTIO+SDM) will work together to produce an observer's manual for DECam and a user's manual for DECam data and data products.

7 Appendix A: List of Major Components

7.1 Fundamental Components of DECam

DECam consists of the following fundamental components:

- **Hexapod** – The mechanical system, which maintains precise positioning control of the instrument.
- **Corrector** – The optical system designed to bring telescopic light to a flat, undistorted focus at the focal plane of the camera
- **Camera** – The CCDs, their mount, and their enclosing dewar
- **Cryogenics and cooling** – The system that maintains the FPA at its operating temperature and limits the dissipation of heat into the prime focus environment.
- **Monsoon A (FPA, focus & alignment CCDs)** – The electronic system that converts the electronic signals on the FPA and the focus & alignment CCDs, into digital images.
- **Monsoon B (guiders)** – The electronic system which converts the electronic signals on the guider CCDs, into digital images
- **Prime focus cage instrument control** – The instrument subsystem managing control of the shutter, filter control, hexapod, cryogenics, instrument cooling and f/8
- **SISPI** – The software suite which provides control interfaces for the observer and through which the observer controls DECam
- **On-site data analysis system** – The software suite that analyzes image data in near real time for quality control purposes.
- **TCS** – The telescope control system

7.2 Major Component Interfaces of DECam

Interfaces required between observatory systems (TCS, DIMM, etc) and DECam are in the purview of the SISPI group of the DECam collaboration and CTIO staff responsible for upgrading and maintaining the relevant systems. SISPI is generating Interface Control Documents where appropriate and CTIO is developing a TCS upgrade proposal.

7.3 Fundamental Components of the DMS

Community use of the DMS for DECam relies upon the following high-level components:

- **Data capture & transport system** – a system which captures the data as the come out of the camera, ensures against loss (by writing duplicate copies), and transports the data to NCSA and other sites for storage, processing, and archival access.
- **Image Archive** – an archive which provides for storage of raw and reduced images and supports efficient access to them through VO standard

protocols. The image archive must also ensure the security of proprietary data and data products.

- **Pipeline Processing System** – a system, which removes the instrumental signature from the images and also provides astrometric and photometric calibrations. This has been identified as the "Community Pipeline" above and in other DES documents.
- **Access mechanisms for both PIs and public** – the component, which provides the user interface for access to the raw and reduced images. This "portal" supports the user authentication necessary to allow access to proprietary data.

The DES will require substantial additional functionality, including pipelines to produce higher-level data products as well as systems to support the scientific efforts of the DES collaboration. These are considered beyond the scope of community needs, and are therefore not listed here as "fundamental components", despite their importance in the accomplishment of the DES scientific requirements.

8 Appendix B: Acronyms

CCD	Charge Coupled Device
CPU	Central Processing Unit
CR	Cosmic Ray
CTIO	Cerro Tololo Inter-American Observatory
DB	Database
Dec	Declination
DECam	Dark Energy Camera
DES	Dark Energy Survey (Consortium)
DES DM	DES Data Management (Group)
DMS	Data Management System
E2E	End-to-End
FITS	Flexible Image Transportation System
FWHM	Full Width Half Maximum
NOAO	National Optical Astronomy Observatory
NSA	NOAO Science Archive
PSF	Point Spread Function
RA	Right Ascension
RMS	Root Mean Square
SDM	(NOAO) Science Data Management (Group)
SDSS	Sloan Digital Sky Survey
SIF	Single Image Fits
SQL	Structured Query Language
UCAC	USNO CCD Astrographic Catalog
USNO	United States Naval Observatory

9 Appendix C: Summary of Community Needs

C-1 Where not stated, the performance metrics as specified in the DECam Specifications and Technical Requirements Document are assumed to have been met.

C-2 DECam will be provided with a complete set of spares, consistent with an expected instrument lifetime of 10 years.

C-3 DECam will incorporate a mechanism by which the f/8 focus may be used with at least the same level of functionality and precision that is available with the current top-end.

C-4 It must be possible to adjust alignment (tip/tilt) and focus of the f/8 secondary mirror via a remotely controlled system.

C-5 DECam will be designed so that as many individual components as possible may be removed from the top end for servicing. In particular, it should be possible to remove the filter mechanism, shutter mechanism and camera, individually or together, without further dismantling the top end. These procedures should be able to be carried out within a single working day, and thus not cost observing time.

C-6 DECam will be designed to allow for dismantling and removing the corrector for cleaning or recoating if necessary. The timescale for the removal or re-installation of the corrector may cover more than one working day.

C-7 The detected efficiency per unit area of DECam focal plane should not be less than that of Mosaic II & the current corrector across any filter or defined band pass.

C-8 NOAO, in collaboration with the community, will establish a prioritized list of possible filter purchases besides those used by the DES. Purchased filters shall be supported by CTIO.

C-9 DECam shall be designed to allow the safe removal of a filter from the instrument and its replacement with another within a time period of 2 hours, with 1 hour as the goal. This is a daytime operation that should require no more than 2 people.

C-10 DES filters should not be removed from the instrument during each year's DES observing season for purposes other than necessary repair or maintenance.

C-11 The DECam filter mechanism should include a minimum of six slots with eight as a strongly desired goal.

C-12 The collaboration shall supply maintenance and repair protocols, diagnostic tools, and full documentation for the front-end electronics and focal plane.

C-13 DECam will be provided with Front End Electronics spares sufficient to replace 3 separate CCD signal chains (that is although a CCD may share its signal chain components with other CCDs, this chain nevertheless counts as one chain).

C-14 DECam data will be provided in standard FITS format. Multi-Extension FITS (MEF) is preferred.

C-15 Data provided from the Dark Energy Camera will include header keywords in accordance with NOAO standards.

C-16 The image headers will incorporate instrument metadata indicating the status of the camera subsystems during the exposure.

C-17 An NOAO observation logging service should be supported.

C-18 Metadata stored separately from the science data archive should be accessible to the community user of DECam through the standard community access.

C-19   To the extent that the DES *metadata management system* differs from the solution NOAO/SDM provides for all other NOAO instruments, the portion of the DES system designed to provide for community use should be compatible with the NOAO system.

C-20   Working with NOAO, the Dark Energy Survey Collaboration will establish and document a set of supported observing protocols.

C-21   Observations made according to the supported observing protocols, which include calibration procedures, will be able to be reduced and calibrated to the same photometric and astrometric precisions as achieved by equivalent observations for the Dark Energy Survey, and not less than specified in the *Dark Energy Camera Specifications and Technical Requirements* Document.

C-22   Supported observing protocols will allow for filters with central wavelength from 330 to 1050 nm and bandwidth from 5 to 300 nm

C-23   Supported observing protocols will allow for observations at air masses less than 2.5.

C-24   Supported observing protocols will allow for binning factors of 1 X 1 only.

C-25   Supported observing protocols will allow for sky backgrounds below a level corresponding to 30 degrees from the full moon (maximum) and expected sky backgrounds at new moon (minimum) in all available filters (including non-DES filters).

C-26   Supported observing protocols will allow exposure times from 1 second to 1800 seconds per exposure

C-27   The observer should be able to acquire direct control over all major configuration aspects, including filter choice, exposure time, guide stars selection, focus etc.

C-28   It should be possible to abort any given instrument function/process and return it to a default state within a reasonable time period (significantly less than an average exposure time) and without the need to manually restart any instrument component.

C-29   The telescope shall be capable of tracking at non-sidereal rates in declination and right ascension. Guiding shall not be required during exposures taken while the telescope is tracking at non-sidereal rates. Full reduction (including photometric and astrometric calibration) of data taken with non-sidereal tracking does not necessarily have to be done automatically in the provided data management system, although basic calibration (removal of instrument signatures) should be a goal.

C-30   An appropriately qualified worker should be able to deliver atomic commands to any subsystem for test purposes.

C-31   The DECam system must provide both visual and statistical feedback to the observer to enable him/her to make educated decisions, and also must allow the observer to probe further into the data being collected by interacting with the data directly.

C-32   DECam system should provide some sort of automated feedback, most likely in (graphical) statistical form, on at least a subset of the data being collected.

C-33   Real Time Display: The observer should be able to view the entire field of view (albeit in a heavily binned version) to visualize the large-scale properties of the data (e.g., is an extended object centered, are there any gross anomalies in the image). The observers should also be able to view a sub-set of the focal plane at full resolution to investigate detailed problems such as instrumental or optical (PSF) issues. This latter service, which could be separate from the RTD, may involve a single or small number of CCDs, preferably selectable.

C-34 The observer should be able to interact with the data in "standard" ways, for example being able to measure image characteristics such as PSFs for selected stars, measure noise, and/or compare one image (or sub-image) to another.

C-35 The DMS for the DECam must support use both by the DES and the wider astronomical community that will use DECam for a wide range of scientific investigation.

C-36 Data capture should include registration of all raw data and associated metadata (3.2 above) into the NOAO E2E system so that they may be tracked.

C-37 Data must be transported to multiple NOAO sites & NCSA for safe (redundant) storage.

C-38 If transported using shared NOAO network facilities, the transport must be done in such a way that allows for NOAO management as well as recognition that this is a shared resource used by other users at the observatory.

C-39 Observers should be able to retrieve their raw data from an archive within 48 hours of the end of their observing run.

C-40 The archive must provide a security model that correctly limits access according to NOAO proprietary period policies.

C-41 The archive must provide all science and calibration data in a standard file format (some flavor of FITS)

C-42 The archive must include appropriate metadata and header keywords in accordance with NOAO standards

C-43 The DMS must support automatic transfer of the raw and reduced data to the NOAO Science Archive (NSA) for archival research

C-44 The archive must provide adequate access for at least three users simultaneously (where adequate is TBD, but defined in the context of multiple users downloading images in a timeframe of less than the length of time it took to obtain the data).

C-45 The archive must provide access to instrument scientists to both proprietary and non-proprietary data for evaluation of instrument health as well as investigation of problems or issues.

C-46 This archive must be operated and supported for the lifetime of the instrument.

C-47 Support includes both ensuring that the archive is operating correctly and efficiently and interacting with community users.

C-48 For observations obtained following approved, documented observing protocols (Section 3.3.1), a pipeline will be provided as part of the DMS to correct raw DECam data for instrumental signature, including (but not limited to) bias, dark, illumination, fringing, geometric distortion, astrometric calibration, and any other effects such as pupil images that require expertise associated with the instrument in order to remove. An approximate photometric calibration should be provided where available (e.g. SDSS, USNO-B), and the source identified in the image header.

C-49 The parameters used for any particular application of the pipeline will be recorded in a way that will allow observers to understand quantitatively what has been done to the data.

C-50 The NOAO community must have access to and support of pipeline processing, including archival access to pipeline processed data products, for the lifetime of the instrument.

C-51 Pipeline reduced DECam data (non-DES data) should be available to the PIs within a week of their observing run through the NSA.

C-52 Reduced DES data and data products should be made available automatically through the NVO-compliant NSA at the latest by the termination date of the proprietary period (preferably as soon as the data is processed).

C-53 The data transport of DECam data must be designed to respect the shared use of bandwidth resources and allow for NOAO management of the use of bandwidth.

C-54 The delivered pipeline software should be installable at non-NCSA sites, such as at the NOAO facilities both in La Serena and in Tucson.

C-55 NCSA may provide the resources needed for long-term storage of both raw and reduced DECam data, both for DES and community use. Insomuch as NCSA does not provide these resources, NOAO is responsible for identifying the necessary resources to provide for long-term storage of at least the raw DECam data.

C-56 In collaboration with NCSA staff, NOAO/SDM will be responsible for monitoring and maintaining the holdings of DECam data in the operational portion of the NSA at NCSA.

C-57 NCSA and Teragrid resources may be used to pipeline process the DES and community data.

C-58 Division of responsibility between CTIO operations staff and DES staff will be specified in the Operations and Maintenance plan, and will be consistent with ensuring safe operation of the instrument, and achieving less than 5% unscheduled down-time.

C-59 Responsibility for maintenance and repair of DECam will be shared by CTIO and the collaboration.

C-60 During the DES observing time, the DES collaboration will be responsible for providing the appropriate observing staff, not including the telescope operator, who is made available by CTIO.

C-61 During the DES observing time, the DES collaboration will be responsible for overseeing operations of the pipeline (specifically) and operations data management system in collaboration with the SDM operational staff. SDM staff will continue to be responsible for relevant portions of the E2E system in support of DECam operations.

C-62 During non-DES observing time, the DES collaboration will be responsible for providing the appropriate support for efficient camera operations (generally responding to queries and emergencies in which CTIO staff require additional help)

C-63 During non-DES observing time, the DES collaboration will be responsible for providing the appropriate support for efficient operations of the Community Pipeline (generally responding to queries and emergencies in which SDM staff require additional help)

C-64 The DES collaboration will define a procedure to allow consideration and approval of significant changes in the DECam and data management systems and to record such changes in all related documentation.

C-65 The DES collaboration will provide a version control system (or systems) for all software AND documentation and define policies and procedures for use of the system to update software and documentation and to distribute changes. All participating sites will work from documents and software contained within this system so that updates are universally available.

C-66 The DES collaboration will provide a complete set of as-built drawings and schematics, source code, and manuals for all DECam components and software.

C-67 The DES collaboration will provide a complete set of design documentation, source code, and manuals for all developed components of the Community Pipeline in support of not only operations, but also scientific curation. NOAO SDM will provide documentation for the components and/or interfaces of E2E, which are used in the data management system.

C-68 The DES collaboration and CTIO will document an integration plan for DECam and installation instructions and/or procedures for the DECam on the Blanco 4m telescope.

C-69 The DES collaboration and SDM will document an integration plan for the DMS including integration into the existing E2E system. They will also document instructions for installation of the system at NCSA and also NOAO sites.

C-70 The DES collaboration and NOAO will document a set of acceptance tests for the DECam, which confirm that the community needs of the system are met. These tests will be carried out as part of the acceptance procedure for the camera.

C-71 The DES collaboration and NOAO will agree upon and document a set of acceptance tests for the DMS, which confirm that the community needs of the system are met. These tests will be carried out on all installed systems at NCSA and NOAO sites as part of the acceptance procedure for the DMS.

C-72 The DES collaboration and NOAO will document a plan for commissioning and science verification of the complete DECam and DMS.

C-73 The DES collaboration and CTIO will develop and document a Technical Operations and Maintenance Plan for the camera.

C-74 The DES collaboration and SDM will develop and document an Operations Plan for the DMS.

C-75 The DES collaboration and CTIO will develop and document a standard test suite to be run on the camera to confirm that it is in good working order before continued operations

C-76 The DES collaboration and SDM will develop and document a standard regression test suite, with associated test data, to be run on the DMS to confirm that the system continues to meet acceptance test standards.

C-77 The DES collaboration and NOAO (CTIO+SDM) will work together to produce an observer's manual for DECam and a user's manual for DECam data and data products.