DECam Community Pipeline Software Requirements and Technical Specifications

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1. Introduction

This document defines the requirements and technical specifications for the Dark Energy Camera (DECam) Community Pipeline, which will be used to process data taken by visiting astronomers using DECam on the Blanco 4m telescope at Cerro Tololo Inter-American Observatory (CTIO), a division of the National Optical Astronomy Observatory (NOAO). The Community Pipeline will provide a set of processed data products to support scientific analysis of DECam data by the community user.

DECam will replace the MOSAIC II imager in 2011 and will be the principal wide-field optical imager for the U.S. astronomical community in the southern hemisphere. As a facility instrument, NOAO anticipates that the astronomical community will use DECam extensively during the time allocated through the standard NOAO peer-reviewed time allocation process. Community use of DECam is expected to represent a broad range of scientific pursuits, from observations of solar system objects to distant clusters of galaxies.

In order to support the scientific analysis of DECam data generated during community use, NOAO has specified that a pipeline is needed to provide reduced data products to the community users. This requirement has been incorporated in the *Memorandum of Understanding for the Dark Energy Survey* (DES doc #1772-v1) as a deliverable from the DES Collaboration:

> *A data processing pipeline, the Community Pipeline, which will remove the instrumental signatures and provide astrometric and rough photometric calibration for images taken under a broad, but well defined, set of observing modes. This pipeline will be integrated into E2E, the NOAO data management system, and it will comply with appropriate interfaces in that system, and be operational as part of that system.*

The general requirements for both DECam and the Community Pipeline are set out at a high level in the document entitled *Community Needs for the Dark Energy Camera and Data Management System* (DES doc #1354 v2.3), henceforth the *Community Needs*. The requirements listed in that document, together with other explanatory text such as the description of observing modes, are considered as inherited into the present document. The key high-level requirement specified in the Community Needs document states:

> *For observations obtained following approved, documented observing protocols, 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 shall be provided where available (e.g. SDSS, USNO-B), and the source identified in the image header.

The requirements and specifications in the present document flow from an analysis of the community requirements for use of DECam and DECam data, so that community users of DECam will be able to quickly and effectively proceed from observations to scientific analysis.

The operations and maintenance support phases (i.e. post-delivery) are covered in the document *DECam Community Pipeline Operations and Maintenance Support* (DES Doc # TBD).

NOTE REGARDING NOMENCLATURE: The word "image" is used ambiguously in the astronomical literature. In this document, "image" refers to the FITS format representation of the data read out from the DECam 62-CCD focal plane. The oft-used equivalent "frame" is not used here, so some commonly used terms will appear a little unfamiliar, e.g. "fringe frame" .will appear as "fringe image". The word "image" as used here does not represent a particular detection found in DECam data, for that the words "star", "stellar profile", "object", "source", or "artifact" are used, depending on context.

2. Baseline Observations and Calibrations

The Community Pipeline will be used to process data taken by visiting astronomers for a wide variety of scientific investigations and under a wide range of environmental conditions. Except where specified, the processing requirements discussed in this document shall be held applicable for observations of astronomical fields with mean stellar separations of >5 arcsec, exposure times >30s, stellar profile full-width-half-maximum (FWHM) <2 arcsec, and with <1 magnitude of extinction due to clouds. The categories of observations for which modification of these specifications is appropriate are defined and described in Appendix B of the present document.

Community users will be asked to make a standard pre-defined set of calibration observations appropriate to their observations. The final list of such standard calibrations will be developed during the commissioning phase in collaboration with both the DECam Project Team and with the DES DM Group. Additional standard calibrations, such as baseline WCS solutions and cross-talk coefficients, as well as special calibrations such as dark images, will be maintained and updated by the CTIO staff, as a responsibility of the DECam Instrument Scientist. In Appendix A we list the baseline set of calibrations expected to be available for the Community Pipeline.

CP 1. The Community Pipeline shall be able to process data using a set of defined standard calibrations.

Some calibrations should normally be derived from daily and/or nightly observations by visiting observers or CTIO staff. Due to weather or other reasons, use of library (archival) calibrations may be required to process the data, and the pipeline shall default to such calibrations in the case that the nightly calibrations are not available or cannot be produced from the observations themselves (e.g., night-sky flats). The library calibrations may come from regular institutional engineering observations and/or from prior community user observations that have been extracted from the NOAO Science Archive (NSA) for this purpose.

Standard, high quality DES calibration data (such as stacked master bias images, master flat fields in DES filters, etc.) shall be provided from DES observations (as processed by the DES DM system), so that the calibrations may be used by the Community Pipeline for general observations.

CP 2. The Community Pipeline shall use library calibrations to process data in cases in which some standard calibrations are missing or unrecognized. DES DM will make DES library calibration files available for use in the Community Pipeline.

In some cases, suitable calibration material may not be available to process the community user images. The Community Pipeline shall behave rationally and gracefully in circumstances where, due to the nature of the data or the lack of or limited availability of suitable calibrations, normal processing of the data is not possible. This is further discussed in Appendix B.

CP 3. The Community Pipeline shall ignore any image for which neither appropriate standard calibrations nor appropriate library calibrations are available. It shall log the reason(s) why the image was ignored.

3. Processing

3.a. Removal of the Instrumental Signature

The Community Pipeline shall enable the removal of the instrument signature from all science exposures. This signature degrades the scientific value of the data and stems from a variety of effects, each requiring a well-defined and well-documented procedure for its removal. The level of the removal shall be such that the astrometric and photometric solutions can be met as described in 3.b and 3.c below.

The Pipeline shall include all procedures necessary for removing the instrument signature from the data. Examples of procedures that may be necessary are cross-talk correction, bias subtraction and trimming, dark current removal, flat fielding, saturation correction or flagging, correcting for stable scattered light patterns, removal of fringe patterns, and removal of persistence patterns. In some cases, it is expected that the Community Pipeline will enable the creation of intermediary master calibration files during the instrument signature removal process. In other cases, it is expected that the Community Pipeline will create and/or utilize library calibration files (as supplied by DES, DECam instrument scientists, or other sources). The following procedures assume the availability of sufficient and appropriate calibration data.

The instrumental signature effects and the required pipeline functionality for their removal are described here:

- Cross-talk is defined as any correlations between the signals in pixels that correspond to different CCD amplifiers. Cross-talk is usually strongest when the signal path from one CCD amplifier propagates information to a signal path from another amplifier on the same CCD. However, the video-cards themselves (each with 12 amplifiers) may also propagate information between their signal paths, or to signal paths governed by other video cards. It is expected to be stable with time unless CCDs or DECam analog front-end electronics cards are changed.

CP 4. The Community Pipeline shall have the capability to process cross-talk signals from all source CCD amplifiers or any set of amplifiers to any particular target amplifier and correct the image accordingly.

CP 5. Library crosstalk calibrations shall be provided by NOAO. However the Community Pipeline should have the ability to calculate the crosstalk coefficients from suitable calibration images obtained for that purpose.

- Bias is defined as the base-level pixel value offset of the amplified region of the CCD, as seen in a shuttered, zero exposure time image. The pipeline shall allow for multiple techniques to remove a stable (over the period of one night) bias level. At a minimum, the bias subtraction procedures shall include overscan subtraction and zero correction. The overscan region is produced by clocking the CCD beyond the physical pixel limit, producing a reference signal 20-50 columns wide. The pipeline shall specifically include the capability for overscan subtraction to be removed from the image on a line-by-line basis, in addition to function fitting. The pipeline shall enable the trimming off of this overscan bias section to produce CCD or amplifier sections that contain the full signal. A zero-correction procedure involves combining a set of zero exposure time images in order to subtract off the measured two dimensional bias structure corresponding to the light-sensitive region of the CCD. Signal may appear in the non-overscan regions, e.g. spurious charge from the parallel clocking process during readout, and thus would not be removed by simple overscan subtraction. The pipeline shall allow for zeros to be combined after an overscan correction has been applied and after bad pixels have been accounted for, either by ignoring them via a bad pixel mask or by interpolating over them. During this procedure, the pipeline shall enable the creation of bad pixel masks (i.e., those pixels which are non-functional based on zero-exposures).

CP 6. The Community Pipeline shall allow for multiple techniques to remove a stable (over the period of one night) bias level, and allow for overscan trimming. Overscan fitting techniques available shall consist of polynomial fitting of up to third order, spline fitting, and line-by-line averaging. In all cases outlier rejection shall be possible.

CP 7. The Community Pipeline shall allow for zeros to be combined after an overscan correction has been applied and after taking account of bad pixels.

- Dark count is the charge that accumulates in CCD pixels due to thermal noise. It is expected for any DECam exposure, even with narrow band filters, that the dark count will be much smaller than the sky background, and that the dark count subtraction step of the pipeline will by default be turned off. Dark count can be quantified by means of dark images, which are means of non-zero exposure time images taken with the shutter closed, with rejection of ephemeral events such as cosmic rays. Such images can be scaled to the exposure time of science exposures, and then subtracted. It is possible for dark count to be non linear with exposure time, in which case multiple library dark count images will be available, covering the full range of exposure times. Interpolation within the library images

CP 8. The Community Pipeline shall be able to subtract dark count on a pixel-by-pixel basis if dark images were taken by the observer. Otherwise, the pipeline shall enable the use of library calibration dark images appropriate for the exposure time of the image to remove the dark count.

to the observed science image exposure time is then required. Otherwise, if the dark count is linear with time, it is permissible to scale from a single long-exposure library dark image, or from a dark image constructed from suitable images taken by the observer.

- Flat field corrections account for the fact that the sensitivity of a CCD is not uniform across the whole of its surface. Flat field corrections also take into account stable vignetting of the telescope beam. The pipeline shall enable a combined master flat to be created from calibration images taken during an observer's run, which may include dome flats, twilight sky flats and sky flats produced from object images. The pipeline shall be able to produce filter-dependent master flats from these sources or allow for the use of library calibration files, in order to flatten the images. Dome flats shall be preferentially used when available, followed by twilight flats, sky flats, library flats.

CP 9. The Community Pipeline shall enable a combined master flat to be created from calibration images taken during an observer's run.

- Saturation occurs when a CCD pixel reaches its full charge capacity. Prior to saturation, the response of the CCD or its output amplifier can become non-linear. During readout, a saturated pixel can "bleed" along the readout columns and sometimes even across them. The pipeline shall allow for a non-linearity limit to be defined for each CCD amplifier. Pixel values that exceed this non-linearity limit are either removed from the final datasets and replaced with interpolated values, or to the saturation is noted as part of the Data Quality Mask (see below). Any bleeds shall also be either removed and replaced with interpolation values or noted in the mask.

CP 10. The Community pipeline shall allow for a non-linearity limit to be defined for each CCD amplifier, and pixels exceeding this limit shall be flagged.

- Scattered light can occur due to the geometry of the instrument optics and the detector surface. Static scattered light residuals in the images (e.g., pupil ghosts) can be removed from science images using appropriate calibration images such as

CP 11. The Community Pipeline shall enable dark sky flats to be created from images taken during an observers run if dithered exposures of the correct filter were taken in areas of low object density and without known diffuse emission. The pipeline shall use this dark sky flat or allow for the use of suitable library calibration files, to remove scattered light effects.

dark-sky flats.

- Fringing is caused by the multiple reflection and interference of the night-sky emission lines in the CCD substrate. Any deviations from a planar geometry of the CCD causes interference (Newton Ring) effects which are additive in pixel value.

CP 12. The Community Pipeline shall enable scaled subtraction of a library fringe image, provided by NOAO.

- Persistence is the carry-over of charge or residual signal on a pixel-by-pixel basis between adjacent exposures. From laboratory tests it appears that persistent charge is not found with the DECam CCDs. Assuming this remains the case from tests of the DECam Imager with science CCDS installed, and thus a persistence charge subtraction module is not developed for the DESDM pipeline, then such a module need not be developed for the Community Pipeline.

CP 13. The pipeline shall be able to measure and subsequently removal persistent charge from the images, should this be found to be a feature of the DECam CCDs.

CP 14. The Community Pipeline shall create Data Quality Masks for each detrended image that indicate compromised pixels and why they are compromised, and these masks shall be delivered as a component of the images.

The instrumental signature as defined above shall be removed from the raw data according to the rules in Appendix B. The data product produced after removal of the instrument signal from each CCD is called a *detrended CCD image.* The algorithms shall in themselves not degrade the pixel-to-pixel noise levels of the raw images or compromise the data quality, for instance by making excessive approximations in the pursuit of computational speed.

3.b. Astrometric Solution

CP 15. The processing shall include assignment of an astrometric solution per CCD included in the image header, enabling pixel-to-equatorial conversions. Resampled images will contain tangent projections for the CCDs. Stacked images shall include a solution for the entire field of view,

CP 16. Should the accuracy of the astrometric reference catalog be sufficient, the solution across the whole image shall provide positions to as good or better than 0.1 arcsec RMS relative to the reference catalog for exposures where the astrometric catalogs match the unsaturated magnitude range of the stars in common.

Furthermore, the astrometric positions given by the solution shall be of comparable accuracy as that of the best catalog available for the location and magnitude of the image being processed.

CP 17. The Community Pipeline shall choose the best underlying available large-scale catalog (e.g., USNO-B, UCAC, SDSS, DES) that matches the magnitude range of the given image.

3.c. Photometric Solution

The Community Pipeline shall produce stable and reliable photometric solutions for observations of astronomical fields taken under good conditions (as described in section 2). The solution shall allow catalogs of stars to be created that have RMS accuracies as described below. Relative photometric solutions are measured in the photometric system of the instrument, and are relative to the same stars or other stars observed with the same instrument. Global photometric solutions are calculated for each image by comparison to published photometric catalogs. All of the requirements below refer to observations and measurements of isolated stars sufficiently bright such that Poisson noise is <1%, but not so bright as to exceed the linearity or saturation limits of the detector or amplifier.

CP 18. The relative photometric solution shall provide better than 1% RMS instrumental accuracy for stars in the field of view between consecutive un-dithered exposures on a photometric night with stellar profile FWHM better than 2 arcsec.

CP 19. This relative photometric solution shall also provide better than 2% RMS instrumental accuracy over the field of view for stars as they are shifted around the field (CCD-to-CCD, center to edge) for similar observations.

As one moves stars around the field of view, one samples not only different areas of the flat field, but also different plate scales. The preceding requirement ensures that the calibrations and photometric solutions properly account for the variations in plate scale of the focal plane.

CP 20. The processing shall include assignment of a global photometric zero point based on the best available catalog of local standards (catalogs may include USNO-B, SDSS, or other similar resources, and shall include DES catalogs once they are publically available).

Determination of color terms for non-DES filters will be the responsibility of NOAO. In other areas of the sky, the available photometric catalogs (e.g., USNO-B) will have different photometric accuracies, which will determine the accuracy to which the images

CP 21. The global photometric zero point shall achieve the accuracy of the input standard catalog for observations made in the same bandpasses, under good conditions. Specifically, given observations made in areas covered by SDSS or DES (when available) observations, the photometric zero point in the DES survey filters (g,r,I,z, but not Y) shall be accurate to better than 5% RMS. Observations in other filters (e.g., DES Y, B,V,R,I) shall be accurate to better than 10% RMS.

can be calibrated.

3.d. Reprojected Images

CP 22. The Community Pipeline shall produce reprojected images, projected to a specified tangent point.

The tangent point for the reproduction shall be determined from a standard tiling on a fixed grid provided by NOAO.

3.e. Dither Combination/Stacking

CP 23. The Community Pipeline shall create stacked images using the mean pixel values (or statistical equivalent) of unmasked pixels after accounting for variable sky backgrounds, seeing, and exposure times in the individual images within a stack. The stellar profiles of the stacked images should not be degraded by more than 5% , for the case of an input set of images with equal FWHM. Stacks shall only be produced for images taken during the same night. It should be possible to produce a stacked image from up to 50 suitable individual images.

The images within a stack will be a subset of the detrended CCD images from an instrument dither sequence specified in the image headers (originating from the raw source image). If no sequence is available, the pipeline will apply a simple logic to determine which instrument pointings should be included in a stack over the period of the observing run. Only images taken with the same filter shall go into a stack. The field-of-view of a stacked image can be as little as 20% of the focal plane. The image stack should be reprojected to the tangent point determined from a standard tiling on a fixed grid provided by NOAO.

The pipeline can reject images from inclusion in the stack based on data quality issues (e.g. too many masked pixels, poor seeing). The header of the image stack must indicate

the individual images used to create the stack in the image header as well as data quality measures such as PSF, magnitude depth, and zero point.

It is expected that the algorithms used to combine the images and to reject transient features will be based upon those used in the processing of DES data.

CP 24. Stacking shall reject/remove transient features such as cosmic rays, asteroids, and airplane or satellite trails to at least 1/Nth of the original level, where N is the number of images in the stack.

As a goal (under the provisions of section 9) NOAO desires an implementation of the optimal, PSF homogenized, stacking algorithm which DES will use to produce its final data products.

3.f. Catalogs

CP 25. The Community Pipeline shall produce catalogs of all objects in the images that are 5-sigma above the noise and outside of masked regions. The catalogs shall include for each object at least the x,y pixel positions, the equatorial positions (RA, Dec), the magnitude, and a star/galaxy classification parameter. Catalogs are not needed for reprojected images.

It is expected that the catalogs will be produced by the standard algorithms and software used in the creation of DES catalogs, with similar star/galaxy classification. The calibration of the catalogs will be based on the photometric calibrations previously mentioned.

3.g. Provenance and Data Quality Information

CP 26. Each processed image shall have a machine parsable summary of provenance and data quality in the header. Catalogs shall include provenance.

The provenance shall include software and calibrations used, associations (e.g. raw to reduced, calibration files to reduced, individual reduced to stacked), data quality for operator review. The data quality information provided shall include zero point, effective magnitude depth, and a full width half maximum measurement.

3.h. Image Components

CP 27. Each processed CCD image shall include four components, including one sky image, one weight map, one data quality flag mask, and one exposure map. There should also be an associated thumbnail of the sky image.

In more detail, the included components to each processed image are:

- One sky image
- One weight map (1/variance or similar).
- One data quality flag mask that stores some pixel states like saturation, interpolation, intrinsic bad pixel, etc.
- One exposure map, documenting the number of times a pixel has been visited on the sky.
- An associated thumbnail of the sky image, in jpg or png format

These components provide a full pixel description of the data, allowing scientific analysis to proceed with an accurate understanding of the processed data at the pixel level. The exposure map is only relevant for stacked images, not for reduced or resampled images.
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3.i. Data Products Formats

In more detail, the pipeline data products are:

- Reduced images, which have had the instrument signature removed and have astrometric solutions and rough photometric calibration
- Reprojected images, projected to a specified tangent point
- Catalogs of objects from the individual reduced images (source catalogs)
- Combined (stacked) images of well-identified dither groups
- Catalogs of objects from combined images (object catalogs)

CP 28. The formats of all files shall be in the FITS standard. Reduced detrended CCD images, reprojected CCD images, and the image stacks, together with their associated weight maps, data quality masks, and exposure maps should consist of a single Multi Extension FITS (MEF) file per image, with one extension per CCD. Mask and Weights are separate, but associated, files,

The DESDM pipeline will write FITS files in format suitable for ingestion into the NSA. If necessary, file conversion to the correct format can be a post-processing step. To lessen mass-storage requirements, it is anticipated that a Rice tile compression algorithm with a compression factor of ~5 will be applied to pipeline-reduced floating-point images.

Depending on dynamic range, scaling to 16-bit images, achieving a compression of ~4, may be an alternative.

For individual exposures, the calibrated catalogs will be considered *source* catalogs. These catalogs may contain cosmic rays (CRs) and other non-astronomical artifacts. The catalog software shall provide a classification attempting to distinguish between stars, galaxies, and artifacts (including CRs). Transient-finding algorithms should be configured to be conservative, in order to make sure that no stars are affected.

Catalogs from combined (stacked) images will be considered *object* catalogs, given that transient and image artifacts will be suppressed in these images (as described in section 3.e).

As a goal (under the provisions of section 9) NOAO desires the advanced catalog products (including higher moments of PSFs, etc.) that are to be produced by DES for its final data products.

The provenance and associations of all data products shall be well documented in headers. This information may in addition also be represented in a separate file, e.g. an XML file.

3.j. Processing Time

CP 29. The Community Pipeline shall be able to process a full night of data in <12 hours for >90% of the observing nights.

This processing is distinct from that described in Section 3.3.3.1 (Quick Reduce feedback) of the Community Needs document.

4. Interface with E2E Systems

The Community Pipeline will be operated by the NOAO Science Data Management (SDM) Operations team, most likely at an NOAO site (either in Tucson, La Serena, or both). The pipeline will be run on NOAO computing systems in a well-defined standard environment. This pipeline environment, consisting both of the physical environment as well as the standard software environment (defined below), will interface to the NOAO End-to-End (E2E) system, which provides the infrastructure for moving and archiving all of the raw and reduced data and delivering those data to community users.

Pipelines in the E2E system act as largely stand-alone modules, with well-defined interfaces to the rest of the system. The Community Pipeline shall conform to those interfaces. The two main interfaces are data retrieval from the NOAO Science Archive (NSA) and data delivery to the NSA.

CP 30. The Community Pipeline shall function as an integrated component of the E2E system. As such, it shall interface to the NOAO Science Archive (NSA) through well-defined interfaces, such as the data retrieval and data delivery interfaces.

4.a. Data Retrieval

The E2E system will define and run operational queries that select appropriate datasets out of the NSA for delivery to the pipeline system staging area. These datasets may be limited to timescales from partial nights to runs, where runs may involve several nights of data with common science goals and observational characteristics. The queries will also attempt to identify necessary calibration data (e.g., library calibrations) should those data NOT be included in the initial query, i.e., if the necessary calibrations cannot be generated from the dataset itself.

CP 31. The Community Pipeline shall operate on the data placed in the staging area retrieved via queries from the NOAO archive. NOAO shall maintain the calibration repository.

The pipeline shall apply standard algorithms to automatically determine the best application of the calibration files available, e.g., determining which files are zeros and flats based on image metadata, and whether those calibration files are raw (and thus must be processed and combined) or are library calibrations which can be applied directly.

CP 32. The Community Pipeline shall be able to access local copies of necessary astrometric and photometric catalogs.

If the pipeline needs said catalogs in formats that are not their native or default formats (as published), the DES shall provide the appropriately formatted catalogs for storage on the local pipeline system.

4.b. Data Delivery

CP 33. The Community Pipeline shall use an interface that provides the ability to deliver reduced data, data products, and associated metadata to the NSA for ingestion, as specified in the document *SDM E2E Integration Interface Control Document*.

This pipeline/NSA interface is to be developed jointly by NOAO and DES DM as the Community Pipeline and NSA are further developed. The current MOSAIC/NSA interface description provides the basis for understanding the type of interface that will be in place for DECam operations.

4.c. Metadata and Supporting Calibrations

Metadata standards will be provided, including lists of expected header keywords used in the NSA and E2E system.

Included in those metadata shall be provenance and association information, which shall allow users to determine all calibrations and data that have been used to produce the data product in question. This provenance shall be included in both image and catalog data products.

The pipeline shall rely not only on the calibrations produced by non-DES data, but also shall be able to take advantage of the standard master calibration products used for DES processing (e.g., highly processed bias, dark, cross-talk, fringe, or other calibration images). Such calibration images shall be routinely delivered for use in the community pipeline (on whatever frequency they are updated by and for the DES).

CP 34. The Community Pipeline will use metadata standards as defined in the documents *SDM E2E Integration Interface Control Document*, *NOAO Essential Imaging Metadata* and *FITS Keyword Definitions for NOAO Imaging*.

5. Operations and Monitoring

Such information shall include reports on, and the ability to change, current state (e.g., up, down, problem), current dataset, pipeline parameters, and error conditions both for pipeline components and data being processed.

5.a. Monitoring

CP 35. The Community Pipeline shall provide an interface or interfaces to monitor pipeline status and quality.

The required interfaces are:

- Pipeline state and queue – An interface to view what datasets are currently in the Pipeline, their status (pending/completed), and most recent datasets processed and yet to be processed.
- Pipeline Control - GUI or command line procedure to: 1) cold start, 2) restart, and 3) stop the pipeline process.
- Pipeline State - GUI interface to monitor current pipeline processes.
- Pipeline Data Quality – An interface to obtain Pipeline meta-data that reflect the data quality, e.g., a data quality summary for datasets being processed. This interface shall provide an overview/status view and the ability to drill down to look at possibly problematic images (initially in thumbnail format).
- Pipeline Message Monitor – An interface to view the Pipeline message log.

5.b. Logging

CP 36. The Pipeline shall send notification of failed processing with sufficient information to track the file and help understand the cause of the failure

CP 37. The Community Pipeline shall log separately successful and failed processing events. The logging shall be configurable.

5.c. Pipeline Housekeeping Tasks

CP 38. The Community Pipeline shall be delivered with written housekeeping and trouble-shooting procedures.

These procedures include:

- How to detect problems using the monitors provided above.
- How to investigate problems.
- How to perform pipeline recovery (track down pipeline errors).
- How to perform Data recovery (re-queue problematic data for reprocessing, change parameters to increase probability of processing, etc.)

5.d. Data Quality Evaluation

CP 39. The Community Pipeline shall be delivered with written guidelines relating to the review of the quality of pipeline reductions:

These guidelines include:

- How to identify problematic images.
- Contact information for instrument scientist or pipeline scientist (a variable field with contact information to be filled in by NOAO SDM Operations team).

5.e Pipeline Report Generation

CP 40. The Community Pipeline shall provide pipeline summary reports to include processing statistics, including the number of data sets processed each day, month, and year, number of errors, number and types of data quality problems, and the time delay between the ingest of raw data and the generation of a complete data product set.

6. Hardware/Software Requirements

6.a. Cluster of Linux OS Computers

CP 41. The Community Pipeline shall run on a standard Linux cluster of the type used at NOAO.

DES DM shall provide NOAO SDM with optimum hardware and middleware requirements for the pipeline, e.g., what is the 'optimum' foot print for the Pipeline (number of CPUs, CPU speeds, required RAM); are the processes memory bound, disk I/O bound; what is more important disk performance or data protection (RAID0 vs. RAID10). The cluster may be assumed to be of 64-bit multi-core architecture, dedicated to the Community Pipeline processing framework and operations. The cluster will be running a standard Linux OS, with the baseline as of this writing being CentOS. The cluster will rely upon standard gigabit Ethernet intra-connectivity. Each core shall have a minimum of 1GB RAM. By scaling from the hardware requirements needed to run the Essence Project pipeline, SDM have estimated that the baseline system should be a cluster of 4 nodes each with dual 2.5GHz quad-core processors and 8GB of RAM, two gigabit network interfaces, and 2TB of local disk storage per node. DES DM will recommend a configuration capable of running the Community Pipeline, with details (in particular) of the assumptions made for the size and number of stacks computed per night, and the type of algorithms employed. NOAO will investigate the cost and benefits of optimizing the cluster based on the recommendations provided by DES DM, which may include increasing the number of nodes.

CP 42. An orchestration component shall be delivered to provide for effective operation of the pipeline on the cluster, allowing all components of the pipeline to be operated from a single master software component that coordinates the operations of all other components.

6.b. Underlying (Proprietary) Software Requirements

CP 43. Any proprietary software used by the system shall be clearly called out and agreed upon early during the development process, as such design dependencies may create/imply significant costs in licensing and support over the life of the instrument system (e.g., DB system shall be discussed). Approval shall be sought from NOAO before proprietary software is included in the community pipeline.

6.c. Installation Requirements

CP 44. The Community Pipeline shall be delivered with detailed instructions for installation on the NOAO cluster.

The system delivery shall include an installation bundle or tar-balls that contain detail instructions and make files. Pre-requisite third party software, if not included in the installation bundle, must be identified by program name and version number and include configuration instructions specific to pipeline component needs.

For Pipeline specific software, NOAO SDM Operations will not be responsible for making any modifications to delivered code during the period for which it is supported by DES DM. The Pipeline configuration shall be made using configuration files external to the code. This configuration file shall contain all necessary parameters or properties to include but not limited to:

- database names/users/passwords/ports/hosts
- required communication ports (if necessary)

Requests for additional daemon accounts shall be clearly documented, i.e., the account that the software will be run under, the account that the Operations GUI will be run under, and other accounts that may be necessary to operate the pipeline system.

6.d. Testing Requirements

The NOAO SDM Operations team shall provide test systems to install and test the Pipeline software, and shall perform software installation on these test systems.

CP 45. The Community Pipeline system shall be delivered with fundamental tests that verify functionality upon installation.

CP 46. The Community Pipeline shall be delivered with regression tests (like Perl Test::Harness, gmake check, unit tests) based on standard data inputs.

The NOAO SDM Operations team shall perform integration tests for the Pipeline and will include but not limited to:

- Software Acceptance Test Plan - including test cases, and Acceptance Test Procedures.
- Behavioral Testing - testing the software from the viewpoint of the operator.
- Test-checklist - a mutually agreed upon list of tasks that NOAO must perform and sign-off on. This shall include both Pipeline checklist and full-integration checklist.

6.e. Software Version Control

CP 47. The source code developed for the Community Pipeline system shall be delivered and be maintained under a standard version control system, preferably SVN.

The maintenance of this system will initially be under the control of the DES DM development team, but will be transferred to the NOAO SDM Operations team after post-delivery, once the code has stabilized. In that the Community Pipeline may contain modules that are shared with the DES DM system, the DES and NOAO groups shall establish procedures to keep the version control systems of the DES DM system and the Community Pipeline system in sync where necessary.

6.f. Production Systems

NOAO SDM shall deploy the Pipeline on NOAO production systems. NOAO shall restrict access to production systems to NOAO SDM staff.

7. Documentation

7.a. Technical Documentation

CP 48. The Community Pipeline technical documentation shall include general design documentation, documentation on individual modules, and well-documented code.

Code shall have comment lines explaining all major functionality. NOAO SDM will review the architecture and code for maintainability.

Unit tests shall be included as part of the code and/or documentation of individual modules.

7.b. Operator Documentation

CP 49. The Community Pipeline operator documentation shall include installation documentation and operations documentation, including maintenance procedures, trouble-shooting guidelines, and error recovery procedures for both pipeline problems and data-produced problems.

7.c. User Documentation

CP 50. The Community Pipeline user documentation shall include documentation for the astronomical users of the data and data products produced by the pipeline. The methodology shall follow that in the relevant sections of the NOAO Data Handbook.

8. Operations by NOAO SDM

CP 51. The Community Pipeline system shall be operable in the E2E system environment

8.a. Stand-Alone System

CP 52. It shall be possible to run the Community Pipeline at NOAO in a mode without interfaces to the E2E system, e.g. for testing purposes.

A subset of the debugging mechanisms shall be documented and/or implemented so that problems can be efficiently investigated in this stand-alone mode.

CP 53. The Community Pipeline system shall be capable of running in stand-alone mode on a cluster.

In this mode the data and data products shall be written to a local disk for review by the operator. Implementation and maintenance of this mode on systems other than at NOAO is the responsibility of NOAO.

9. Additional Features Beyond Those Required

DES DM may choose to develop and offer NOAO features beyond those required for the delivery of the DECam instrument system. NOAO will review the offered features and accept those that it feels would truly benefit the community users. Once accepted, these features shall NOT be classified as additional requirements, but will continue to be considered as benefits that DES DM may provide beyond the scope of the initial agreement. As such, these features can be considered as *Broader Impacts* of the work DES DM is performing.

As an example, DES DM may build into the Community Pipeline methods to detect when community observations have been obtained with an observing mode similar to, or the same as that used during DES observations. In such a case, DES DM may provide a higher level of reduction and/or calibration for those observations, using the same methodology and algorithms as are used to produce the science-quality DES data.

Compliance with these requirements and specifications will be certified by a rigorous set of acceptance tests to be run initially by the developers (DES DM) and finally by NOAO SDM Operations team once the pipeline has been installed in a test NOAO E2E data management environment.

Appendix A: Baseline Calibrations for Community Pipeline Processing

The following list is a preliminary list of calibration products that the Community Pipeline should expect to have access to in order to proceed in processing DECam data taken by community users.

- Calibration information to be obtained by observer (e.g., nightly or at least once during an observer's run)
  - Bias Images (at least 9 per night).
  - Dome Flat Images (at least 5 per filter used).
  - These should be included in the dataset provided by the E2E system to the Community Pipeline. However, in the event that these are not provided in a clearly identifiable manner in the dataset (e.g., by obstype), the Community Pipeline shall use library calibrations referred to below.

- Calibration information to be maintained by CTIO staff, updated on a regular (TBD) basis, and made available on the community pipeline cluster:
  - Cross-talk coefficients (derived regularly from specific images).
  - Baseline WCS coefficients (derived regularly from specific images).
  - dark count images.
  - Library calibration images, including bias images and flat fields for all filters, and fringe images for relevant filters.

- Calibration information to be maintained by the NOAO SDM Operations team and made available on the community pipeline cluster:
  - Astrometric calibration catalogs (including SDSS, USNO-B, UCAC, and the latest available DES catalogs).
  - Photometric calibration catalogs (including SDSS, USNO-B, UCAC, and the latest available DES catalogs.

Appendix B: Categories of Applicability for DECam Community Pipeline Specifications

1. Introduction

The Community Pipeline will be used to process data taken by visiting astronomers for a wide variety of scientific investigations and under a wide range of environmental conditions. The processing requirements discussed in the present document shall be held applicable for observations of astronomical fields with:

- mean stellar separations of >5 arcsec
- exposure times >30s
- stellar profile full-width-half-maximum (FWHM) <2 arcsec
- <1 magnitude of extinction due to clouds.

There will be specific observational circumstances under which meeting the specifications set forth above may be extremely difficult or impossible due to the nature of the data, or to the nature of how the data were taken. We define these cases so that they may be held exempt from specific specifications and not be used as part of acceptance criteria or testing. However, the pipeline shall fail these specifications *gracefully*, which is taken to mean that other non-exempted specifications shall be met and that in not meeting any given specification, the pipeline shall continue to function and deliver the appropriate data products to the extent possible (i.e., the pipeline shall not crash on data that fall in the cases in which specifications are relaxed).

2. Category Definitions

Here we define different ***categories*** related to aspects of observations with DECam.

The Filter category

- DES: All data taken using standard DES-supplied broad-band filters
- NOAO: All data taken using standard NOAO-supplied broad-band filters
- NARROW: All data taken using standard NOAO-supplied narrow-band filters. The narrow-band filters are not expected to cover the full DES science field
- OTHER: All data taken using non-NOAO, non-DES filters
- ALL: All of the above

The Conditions category:

- BAND1: Photometric conditions with seeing <2"
- BAND2: Photometric conditions, seeing >2"
- BAND3: Non-photometric, seeing <2"
- BAND4: Everything else
- ALL: All of the above

The Mode category:

- SINGLE: Single pointing, single exposure
- MULTIPLE: Single pointing, multiple exposures
- DITHERED: Dithered with supplied dither pattern
- OTHER: Some other mode
- ALL: All of the above

3. Pipeline Processing

We now discuss the application of specifications with respect to these categories. . Where a list of cases in a category is given, the specifications apply only to observations consistent with these cases.

We first identify three exception cases:

- *Observations lacking suitable calibrations.* If data were taken in one of the above observing modes but WITHOUT the proper calibration, images could be reassigned "MODE = OTHER" and then only the minimal processing will be done by the pipeline.

- *Observations of regions of extremely high stellar density (>1 star per resolution element above 3-sigma detection limit) occupying more than 50% of the focal plane.* This case may prevent the creation of effective pupil masks, scattered light, and/or fringe images. Therefore the specifications regarding these calibrations are understood to be relaxed and will be held to a best effort basis, which may involve the use of library calibrations to undertake these reduction steps.

- *Observations of regions of extensive (covering >50% of any given CCD) diffuse illumination (for example, emission-line regions, especially in the case of narrow-band observations).* This case may prevent the creation of effective pupil masks, scattered light, and/or fringe images. Therefore the specifications regarding these calibrations are understood to be relaxed and will be held to a best effort basis, which may involve the use of library calibrations to undertake these reduction steps.

The extent of the pipeline processing provided is now matched to the categories:

A. **Basic Processing:** cross-talk, bias, (dark count), and provide a flattened image:

Filter:	ALL
Conditions:	ALL
Mode:	ALL

B. **Advanced Processing**, should additionally correct for pupil, scattered-light, fringes:

Filter: DES, NOAO
Conditions: BAND1, BAND2, BAND3
Mode: SINGLE, MULTIPLE, DITHERED

C. **Astrometric solution:**

Filter: DES, NOAO
Conditions: BAND1, BAND2, BAND3
Mode: SINGLE, MULTIPLE, DITHERED

C. **Photometric Solution:**

Filter: DES, NOAO
Conditions: BAND1, BAND2
Mode: SINGLE, MULTIPLE, DITHERED

D. **Dither stacking:**

Filter: DES, NOAO,
Conditions: BAND1, BAND3
Mode: MULTIPLE, DITHERED

E. **Catalogs:**

Filter: DES, NOAO
Conditions: BAND1, BAND2
Mode: SINGLE, MULTIPLE, DITHERED

Appendix C: External Documents Referenced

- Memorandum of Understanding for the Dark Energy Survey (DES Doc #1772), Referenced in Section 1. http://des-docdb.fnal.gov:8080/cgi-bin/RetrieveFile?docid=1772&version=1&filename=DES_MOU_as_executed.pdf
- DECam Community Pipeline Operations and Maintenance Support (DES DOC #TBD). Referenced in Section 1.
- Community Needs for the Dark Energy Camera and the Data Management System (DES Doc #1354). Referenced in Section 1. http://des-docdb.fnal.gov:8080/cgi-bin/RetrieveFile?docid=1354&version=3&filename=DECam%20Community%20Use%20v2-3.pdf
- Categories of Applicability for DECam Community Pipeline Specifications (DES Doc #TBD). Referenced in Sections 2 and 3a.
- NOAO Essential Imaging Metadata. Referenced in CP 35. http://chive.tuc.noao.edu:8080/DPPDOCS/software-technical-reports
- FITS Keyword Definitions for NOAO Imaging. Referenced in CP35. http://chive.tuc.noao.edu:8080/DPPDOCS/software-technical-reports
- SDM E2E Integration Interface Control Requirements. Referenced in CP 34,35. http://chive.tuc.noao.edu:8080/DPPDOCS/software-technical-reports
- NOAO Data Handbook. Referenced in CP 51. http://archive.noao.edu/doc/NOAO_DHB/

Appendix D: Definition of 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

Appendix E: Associated letters of transfer

Version 3.1: From Alistair Walker, NOAO DECam instrument scientist, to John Peoples, DES Director, 16 December 2009.

Dear John,

The document "DECam Community Pipeline Software requirements and Technical Specifications" has been iterated as a result of several conversations and comment exchange between DESDM and NOAO over the last ~ two months. The intent was to iterate to produce a set of understandable and unambiguous requirements that could in principle be implemented. With these requirements and specifications in hand DESDM can produce a CP implementation plan with cost and schedule, a process underway now. I expect that as a result of that exercise we may wish to modify the specifications document, and to reflect this Jim Myers has suggested we call this version the "Final Draft". Please advise whether we should call it something else.

The document is generally very similar to earlier versions. There are two substantial changes. The first is that the section on Operations & Maintenance has been removed, and will be the subject of a separate document. The second is the addition of Appendix B, which was previously a separate draft document. It specifies how the pipeline should behave under various observational circumstances. There have also been a few apparently small changes that are worth highlighting. For instance, the production of stacked images has a limit provided for the number of component images, and the time period for which a stack is produced is limited to a single night. There are changes to bring requirements in sync with what is being produced for DES. These sort of changes have implications (good) on both software effort and hardware cost. The latter is for NOAO of course.

I would like to post this document to Doc-DB, please let me know if you identify anything that I should modify before I do that.

Best regards

Alistair

Version 2.8: From David Silva, NOAO Director, to John Peoples, DES Director, 9 September 2009.

Dear John,

Attached please find the final version of the DECam Community Pipeline Software Requirements and Technical Specifications document.

Our apologies that producing a final version has taken so much longer than originally promised.

Best,

dave

Requirements Summary

CP 1. The Community Pipeline shall be able to process data using a set of defined standard calibrations.
CP 2. The Community Pipeline shall use library calibrations to process data in cases in which some standard calibrations are missing or unrecognized. DES DM will make DES library calibration files available for use in the Community Pipeline.
CP 3. The Community Pipeline shall ignore any image for which neither appropriate standard calibrations nor appropriate library calibrations are available. It shall log the reason(s) why the image was ignored.
CP 4. The Community Pipeline shall have the capability to process cross-talk signals from all source CCD amplifiers or any set of amplifiers to any particular target amplifier and correct the image accordingly.
CP 5. Library crosstalk calibrations shall be provided by NOAO. However the Community Pipeline should have the ability to calculate the crosstalk coefficients from suitable calibration images obtained for that purpose.
CP 6. The Community Pipeline shall allow for multiple techniques to remove a stable (over the period of one night) bias level, and allow for overscan trimming. Overscan fitting techniques available shall consist of polynomial fitting of up to third order, spline fitting, and line-by-line averaging. In all cases outlier rejection shall be possible.
CP 7. The Community Pipeline shall allow for zeros to be combined after an overscan correction has been applied and after taking account of bad pixels.
CP 8. The Community Pipeline shall be able to subtract dark count on a pixel-by-pixel basis if dark images were taken by the observer. Otherwise, the pipeline shall enable the use of library calibration dark images appropriate for the exposure time of the image to remove the dark count.
CP 9. The Community Pipeline shall enable a combined master flat to be created from calibration images taken during an observer's run.
CP 10. The Community pipeline shall allow for a non-linearity limit to be defined for each CCD amplifier, and pixels exceeding this limit shall be flagged.
CP 11. The Community Pipeline shall enable dark sky flats to be created from images taken during an observers run if dithered exposures of the correct filter were taken in areas of low object density and without known diffuse emission. The pipeline shall use this dark sky flat or allow for the use of suitable library calibration files, to remove scattered light effects.
CP 12. The Community Pipeline shall enable scaled subtraction of a library fringe image, provided by NOAO.
CP 13. The pipeline shall be able to measure and subsequent removal persistent charge from the images, should this be found to be a feature of the DECam CCDs.
CP 14. The Community Pipeline shall create Data Quality Masks for each detrended image that indicate compromised pixels and why they are compromised, and these masks shall be delivered as a component of the images.

CP 15. The processing shall include assignment of an astrometric solution per CCD included in the image header, enabling pixel-to-equatorial conversions. Resampled images will contain tangent projections for the CCDs. Stacked images shall include a solution for the entire field of view,
CP 16. Should the accuracy of the astrometric reference catalog be sufficient, the solution across the whole image shall provide positions to as good or better than 0.1 arcsec RMS relative to the reference catalog for exposures where the astrometric catalogs match the unsaturated magnitude range of the stars in common.
CP 17. The Community Pipeline shall choose the best underlying available large-scale catalog (e.g., USNO-B, UCAC, SDSS, DES) that matches the magnitude range of the given image.
CP 18. The relative photometric solution shall provide better than 1% RMS instrumental accuracy for stars in the field of view between consecutive un-dithered exposures on a photometric night with stellar profile FWHM better than 2 arcsec.
CP 19. This relative photometric solution shall also provide better than 2% RMS instrumental accuracy over the field of view for stars as they are shifted around the field (CCD-to-CCD, center to edge) for similar observations.
CP 20. The processing shall include assignment of a global photometric zero point based on the best available catalog of local standards (catalogs may include USNO-B, SDSS, or other similar resources, and shall include DES catalogs once they are publically available).
CP 21. The global photometric zero point shall achieve the accuracy of the input standard catalog for observations made in the same bandpasses, under good conditions. Specifically, given observations made in areas covered by SDSS or DES (when available) observations, the photometric zero point in the DES survey filters (g,r,I,z, but not Y) shall be accurate to better than 5% RMS. Observations in other filters (e.g., DES Y, B,V,R,I) shall be accurate to better than 10% RMS.
CP 22. The Community Pipeline shall produce reprojected images, projected to a specified tangent point.
CP 23. The Community Pipeline shall create stacked images using the mean pixel values (or statistical equivalent) of unmasked pixels after accounting for variable sky backgrounds, seeing, and exposure times in the individual images within a stack. The stellar profiles of the stacked images should not be degraded by more than 5% , for the case of an input set of images with equal FWHM. Stacks shall only be produced for images taken during the same night. It should be possible to produce a stacked image from up to 50 suitable individual images.
CP 24. Stacking shall reject/remove transient features such as cosmic rays, asteroids, and airplane or satellite trails to at least 1/Nth of the original level, where N is the number of images in the stack.
CP 25. The Community Pipeline shall produce catalogs of all objects in the images that are 5-sigma above the noise and outside of masked regions. The catalogs shall include for each object at least the x,y pixel positions, the equatorial positions (RA, Dec), the magnitude, and a star/galaxy classification parameter. Catalogs are not needed for reprojected images.
CP 26. Each processed image shall have a machine parsable summary of provenance and data quality in the header. Catalogs shall include provenance.

CP 27. Each processed CCD image shall include four components, including one sky image, one weight map, one data quality flag mask, and one exposure map.
CP 28. The formats of all files shall be in the FITS standard. Reduced detrended CCD images, reprojected CCD images, and the image stacks, together with their associated weight maps, data quality masks, and exposure maps should consist of a single Multi Extension FITS (MEF) file per image, with one extension per CCD. Mask and Weights are separate, but associated, files,
CP 29. The Community Pipeline shall be able to process a full night of data in <12 hours for >90% of the observing nights.
CP 30. The Community Pipeline shall function as an integrated component of the E2E system. As such, it shall interface to the NOAO Science Archive (NSA) through well-defined interfaces, such as the data retrieval and data delivery interfaces.
CP 31. The Community Pipeline shall operate on the data placed in the staging area retrieved via queries from the NOAO archive. NOAO shall maintain the calibration repository.
CP 32. The Community Pipeline shall be able to access local copies of necessary astrometric and photometric catalogs.
CP 33. The Community Pipeline shall use an interface that provides the ability to deliver reduced data, data products, and associated metadata to the NSA for ingestion, as specified in the document *SDM E2E Integration Interface Control Document*.
CP 34. The Community Pipeline will use metadata standards as defined in the documents *SDM E2E Integration Interface Control Document*, *NOAO Essential Imaging Metadata* and *FITS Keyword Definitions for NOAO Imaging.*
CP 35. The Community Pipeline shall provide an interface or interfaces to monitor pipeline status and quality.
CP 36. The Pipeline shall send notification of failed processing with sufficient information to track the file and help understand the cause of the failure
CP 37. The Community Pipeline shall log separately successful and failed processing events. The logging shall be configurable.
CP 38. The Community Pipeline shall be delivered with written housekeeping and trouble-shooting procedures.
CP 39. The Community Pipeline shall be delivered with written guidelines relating to the review of the quality of pipeline reductions:
CP 40. The Community Pipeline shall provide pipeline summary reports to include processing statistics, including the number of data sets processed each day, month, and year, number of errors, number and types of data quality problems, and the time delay between the ingest of raw data and the generation of a complete data product set.
CP 41. The Community Pipeline shall run on a standard Linux cluster of the type used at NOAO.
CP 42. An orchestration component shall be delivered to provide for effective operation of the pipeline on the cluster, allowing all components of the pipeline to be operated from a single master software component that coordinates the operations of all other components.
CP 43. Any proprietary software used by the system shall be clearly called out and agreed upon early during the development process, as such design dependencies may create/imply significant costs in licensing and support over the life of the instrument

system (e.g., DB system shall be discussed). Approval shall be sought from NOAO before proprietary software is included in the community pipeline.

CP 44. The Community Pipeline shall be delivered with detailed instructions for installation on the NOAO cluster.

CP 45. The Community Pipeline system shall be delivered with fundamental tests that verify functionality upon installation.

CP 46. The Community Pipeline shall be delivered with regression tests (like Perl Test::Harness, gmake check, unit tests) based on standard data inputs.

CP 47. The source code developed for the Community Pipeline system shall be delivered and be maintained under a standard version control system, preferably SVN.

CP 48. The Community Pipeline technical documentation shall include general design documentation, documentation on individual modules, and well-documented code.

CP 49. The Community Pipeline operator documentation shall include installation documentation and operations documentation, including maintenance procedures, trouble-shooting guidelines, and error recovery procedures for both pipeline problems and data-produced problems.

CP 50. The Community Pipeline user documentation shall include documentation for the astronomical users of the data and data products produced by the pipeline. The methodology shall follow that in the relevant sections of the NOAO Data Handbook.

CP 51. The Community Pipeline system shall be operable in the E2E system environment

CP 52. It shall be possible to run the Community Pipeline at NOAO in a mode without interfaces to the E2E system, e.g. for testing purposes.

CP 53. The Community Pipeline system shall be capable of running in stand-alone mode on a cluster.