

NEWFIRM

System Overview

Ron Probst
NEWFIRM Instrument Scientist

DRAFT: Figures to be added indicated in red text

Version 1.2
November 2008

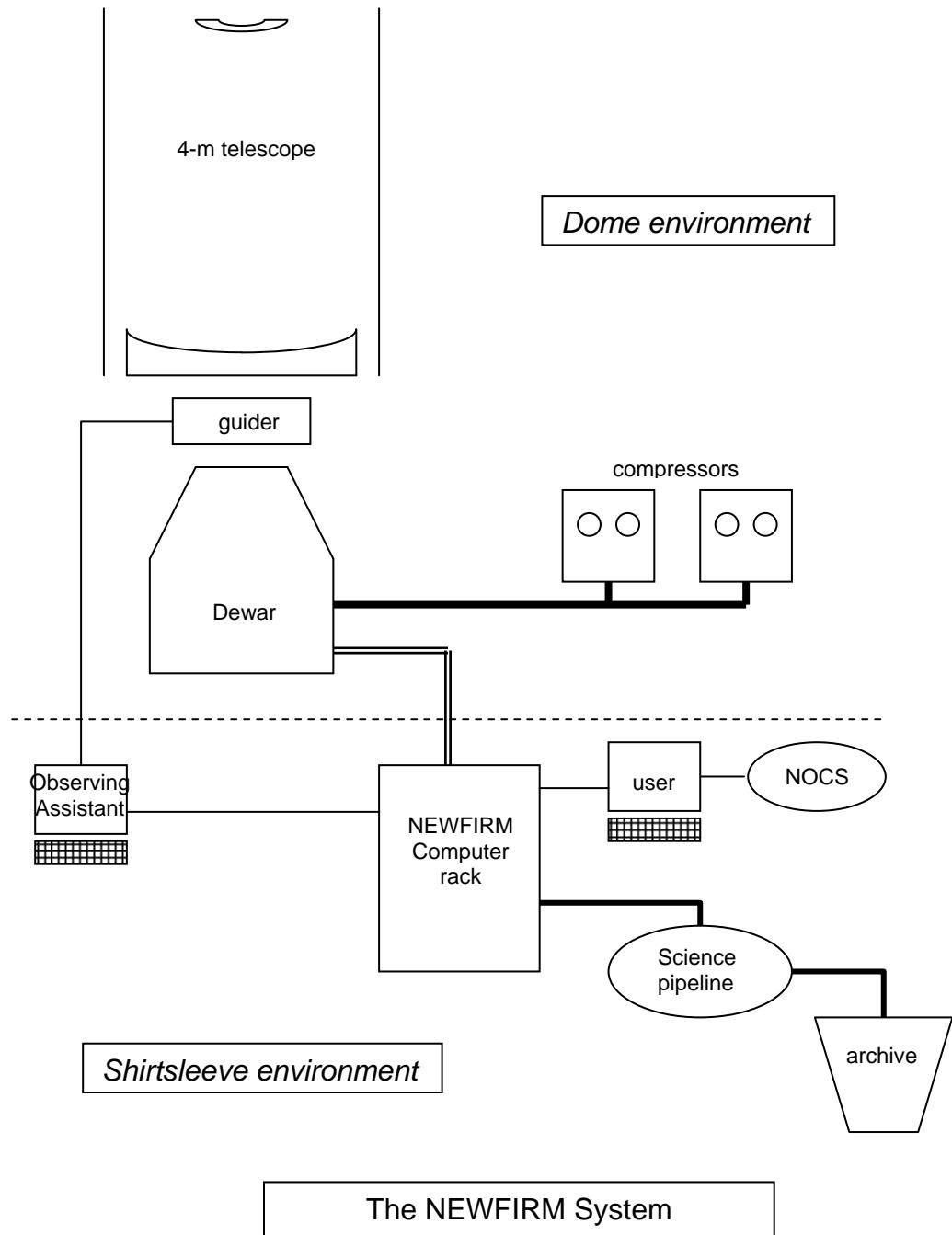
1. Purpose of this document

This document provides an overview of the NEWFIRM system—its architecture, components, and operation--for interested science users. References are provided to other documents that have more detailed information.

If you are looking for hands-on operating procedures at the telescope, please go to the document [**NEWFIRM Startup, Data Taking, and Error Recovery Procedures**](#).

Performance data and other information for preparing NEWFIRM proposals is found in the [**NEWFIRM Quick Guide for Proposal Preparation**](#).

Information about the data reduction pipelines will be found in the [**Introduction to the Quick Reduce Pipeline**](#) and the [**Introduction to the Science Reduction Pipeline**](#).



2. The NEWFIRM system

The NEWFIRM system is composed of hardware and software elements, conceived from the start to provide the user with high quality, science ready data. It is intended to support survey-style observational programs, in particular, through efficient and uniform on-telescope operations followed by rapid data processing (signature removal, and image rectification and combination).

System components, shown in the cartoon above, are discussed in the following sections.

3. The telescope

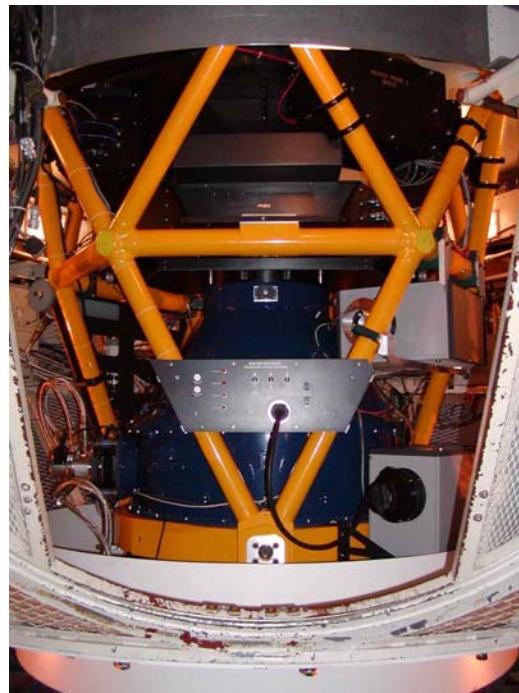
The NEWFIRM instrument is mounted at the R-C focus (or “Cass” focus) of the 4-m telescope. The clear aperture of the Mayall telescope is 3.8 m, and the input f-ratio to NEWFIRM is f/7.9.

The instrument is bolted directly to the back of the primary mirror cell. The field of view is fixed, square to the cardinal points. It cannot be rotated to change the field-of-view orientation on the sky.

Access to the instrument is via the Cass cage door and a walkaround forming the cage bottom. The cage interior is cramped but all functions, adjustments, etc. necessary for normal operations and recovery from error conditions are accessible.



**Two views of NEWFIRM installed:
from below (cage bottom removed),
and through the Cass cage door.**



4. The instrument

The on-telescope portion of the NEWFIRM system includes the Dewar, guider, various electronics boxes, cryogenic gas system, and truss. Refer to the figures to locate the various pieces. The cutaway illustration shows interior components.

The **Dewar** contains the cryogenic optics (7 lenses and a fold mirror), two filter wheels with a total of 14 filter spaces plus an open space in each wheel, and the detector mosaic of four, 2K x 2K InSb arrays. These are incorporated into a unified Optical Support Structure (OSS). The warm collimator field lens also serves as the Dewar entrance window. Operating temperatures are 65 K for the OSS and 30 K for the arrays. See the corresponding documentation for details of the [optical design](#), [filter properties](#), and [array characteristics](#), and for the current [filter set](#) installed in the Dewar.

Bolted to the top of the Dewar, just above the field lens/entrance window, is the **Environmental Cover Assembly**. This has a warm shutter to protect the window against dirt and hazards when not observing. A system of vents allows for a continuous flow of dry N₂ gas across the window to prevent fogging.

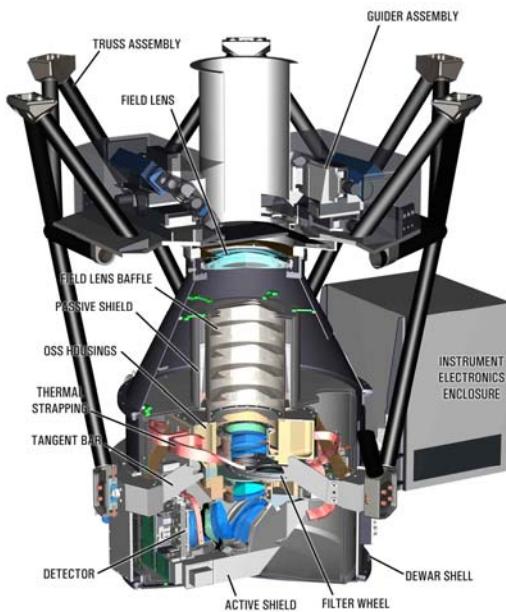
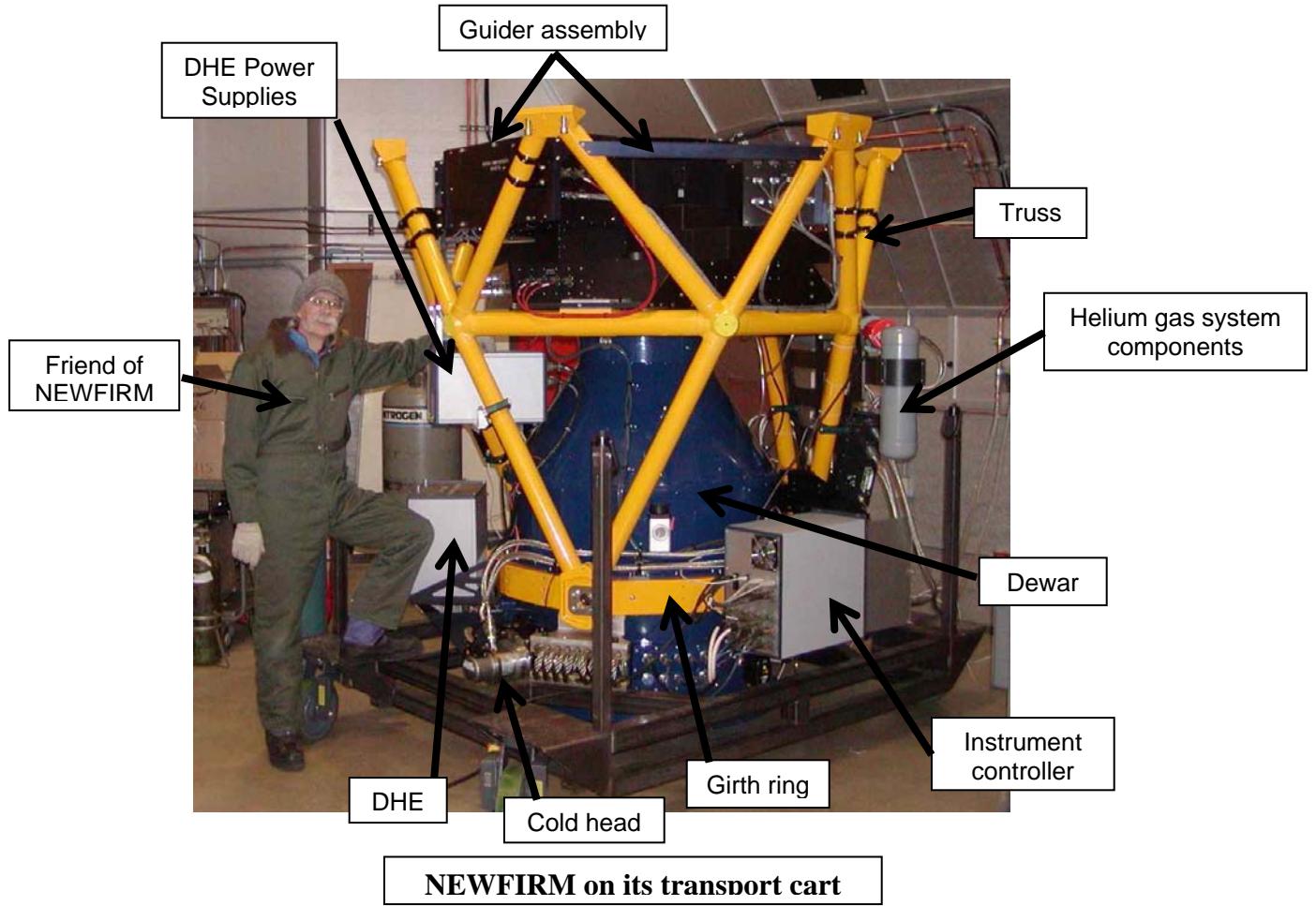
The yellow **girth ring**, part of the Dewar vacuum assembly, supports the load of the OSS and couples the Dewar to the external truss.

The yellow **truss** couples the Dewar to the telescope, and carries the guider electronics, other electronics boxes, and part of the cryogenic gas system. It is both robust and precise, carefully tuned in its deflection properties so that the warm external guider tracks the deflection of the OSS inside the Dewar.

The hardware for the dedicated **guider** is attached to the truss above the Environmental Cover Assembly. A plate holds two guide cameras, each mounted on a stackup of high precision X-Y-Z stages. These can access lune-shaped regions of the telescope focal plane adjacent to the science field on its north and south sides. These assemblies are enclosed for dust, heat, and scattered light control. Control electronics for the guiders are in a series of black boxes bolted around the upper part of the truss.

The space between the mirror cell and the Environmental Cover Assembly is enclosed by a square black **baffle box** for scattered light control. Dry N₂ gas is also injected into this area to prevent fogging of the entrance window.

The Monsoon array controller **Digital Head Electronics (DHE) box** is mounted on the Dewar to the right of the Cass cage door. It provides power, control, and readout of the arrays. A top-opening panel on the box gives access to reset buttons that are used for an error recovery procedure. The **DHE power supplies** are attached to the truss above the electronics box.



Cutaway showing internal components

The **Instrument Controller** is mounted on the Dewar on the side opposite the DHE boxes. Access is via the cage walkway. The Instrument Controller provides cryogenic temperature monitoring and control, and operates the filter wheels and the Environmental Cover warm shutter.

The helium gas cryogenic system has multiple components. Three **cold heads** are mounted on the Dewar. A black triangular plate attached to the truss holds the helium gas **manifold**, **gas heater**, **gas filter**, and **differential pressure sensor** (a safety device). These are interconnected by high pressure **gas lines**. Also mounted on this plate is a **flowmeter** for the dry N₂ gas flowing to the Environmental Cover Assembly and guider baffle box. A second flowmeter is mounted at the entry point of this gas to the cage, on a panel mounted on the east side of the cage.

Closeup of He gas system components on triangular plate, plus cold head and lines

5. Compressor room

A bank of **compressors** for the He gas is located in a utility room next to the telescope control room. These are interconnected so an individual compressor can be powered on or off while maintaining proper gas flow. Mounted on the wall are the **compressor control electronics**. These include auto-restart circuitry to recover from a power outage, and provision for autodialing cognizant personnel to alert them to error conditions.



Compressor room installation



NEWFIRM computer rack

6. Computer room

NEWFIRM has a dedicated rack of **computers** for instrument operation and data acquisition. This is located in the computer room, one story below the control room. Communications with the instrument and the observer are via two fiber optics lines. The rack is shown in the figure.

Science users should not need to have any hands-on interactions with the computer rack. Technical specifications are provided in the [NEWFIRM Computer Hardware](#) document. Installation, startup, and shutdown procedures for use by Kitt Peak staff are given in the [NEWFIRM Computer Rack Procedures](#) document.

Machine names and functions for the rack components are, top to bottom:

NFPAN-A and NFPAN-B: These Pixel Acquisition Nodes (PANs) read array data from the on-instrument Digital Head Electronics (DHE). Each PAN handles two arrays in the four-array mosaic.

NEWFIRM: the front end of the NEWFIRM Observation Control System (NOCS) which is the user interface for instrument operation and data taking. Assigns and coordinates the activities of the other computers.

NFDCA: hosts the Data Capture Agent which captures data from the DHS machines, creates the final FITS files, and produces a quick-look display of the raw mosaic frame.

Two TrendNet KVM switcher boxes connect the various machines to a local keyboard and monitor. A Procurve network switcher box connects the machines to each other.

NFDHS-01 and NFDHS-02: The Data Handling System machines that receive pixel data from the PANs and coordinate it with metadata from the Instrument Controller and the Telescope Control System.

NFPIPE-01 and NFPIPE-02: these machines run the NOAO Pipeline for NEWFIRM data. This includes both the “Quick Reduce” pipeline for near-real time data quality evaluation, and the full scientific reduction pipeline that produces science-ready data for the archive.

NFGUIDER: Operates the dedicated guider hardware and hosts the guider software; communicates with the Telescope Control System.

7. NEWFIRM Observation Control System (NOCS)

The NOCS is the **science user interface**. It is a suite of software that controls global actions for system startup, data taking and transfer, and shutdown. It converts high level instructions (command line, or scripted via user GUIs) to properly sequenced activities of the NEWFIRM Instrument Controller, the Monsoon array controller, the Data Handling System (DHS), the telescope, and the NEWFIRM guider.

The NOCS is presently operated from the 4-m workstation *nutmeg*, using *nutmeg*'s keyboard and three-headed monitor. The center monitor is used for “master control” including a command line interface, scripting GUIs, and windows that report system activities. The left monitor displays a VNC window to the Data Handling System; the user interacts with the DHS to set data paths and filenames. The right monitor has windows to the PANs and other components of the Monsoon array control and readout system.

[Photo of nutmeg console area with NOCS running](#)

[Screen capture of Monsoon windows](#)

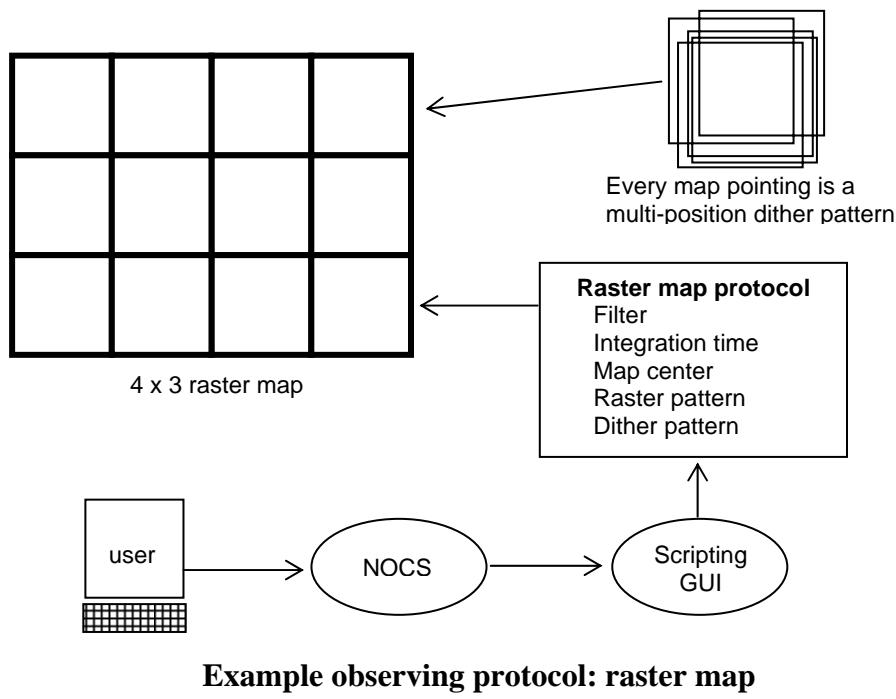
[Screen capture of NOCS GUIs](#)

[Screen capture of VNC window with all DHS displays and GUIs](#)

Detailed instructions for science user operating procedures with the NOCS are given in the [NEWFIRM Startup, Data Taking, and Error Recovery Procedures](#) document.

This guide includes science user troubleshooting and recovery procedures for the most common system error conditions.

A fundamental property of the NEWFIRM system is that data flowing to the science pipeline for reduction may only be taken with predetermined protocols which the pipeline recognizes. Protocol selection, specification of parameters (e.g. filter, integration time, telescope dither pattern), and implementation are through the NOCS GUIs and command line interface. The protocols cover all the commonly used modes of infrared imaging, including dithering, telescope rastering (mapping), and offsetting from an extended source to blank sky for sky subtraction. Calibration data such as darks and flatfields must also be obtained in a prescribed manner. A listing of protocol names, functions, and parameters can be found in the [Guide to Observing Protocols](#). The NOCS may be used to script and carry out observations in a nonstandard way, but data reduction will not be supported by the science pipeline.



The [NOCS Script Generator Tool](#) may be downloaded for observing scripts creation prior to arriving at the telescope.

8. The NEWFIRM Guider

NEWFIRM's dedicated **guider** system has hardware components mounted with the instrument in the Cass cage, a computer in the NEWFIRM rack, and user interfaces on the control room user workstation *tan* and the telescope operations workstation. Presently

these interfaces are at an engineering level, and guider operations are carried out by the Observing Assistant (OA).

Photo of operator area showing mocha and tan, video monitors

The guider hardware is attached to the instrument truss above the Dewar entrance window. There are two CCD guide cameras on high precision X-Y-Z stages. These can access lune-shaped regions of the telescope focal plane adjacent to the science field on its north and south sides. The cameras on their stages are enclosed for dust, heat, and scattered light control. Power and control electronics are in a set of black boxes bolted around the upper part of the truss, around the baffle box.

Photo of guider from above prior to mounting on telescope

The guider acquisition fields' size and placement, and guider camera sensitivity, are such that at least one guide star can be found to high probability anywhere in the sky, including the Galactic poles and dark clouds, under moderate moonlight conditions.

Ultimately the guider functions will be incorporated into the NOCS for rapid identification and acquisition of guide stars as part of scripted science observing. At present, guide stars are selected interactively in real time by the OA from a DSS display of the science and adjacent guider fields. The OA positions a guide probe to acquire the selected star, and guiding proceeds. This includes automatic probe repositioning to compensate for telescope dithers. Moving to a new telescope pointing, for example to map an extended region, requires OA intervention to find and acquire a new guide star.

Screen capture of acquisition display and GUIs

Camera controls are provided for manual X-Y positioning, focus control, astigmatism correction (considerable at this distance off-axis!), and video gain and contrast. This allows operator tweaks to camera operations driven by the interactive acquisition software. The control GUI is accessed via *tan* and is presently at an engineering level of user convenience.

Screen capture of camera control GUI on tan

Further details on guider features, performance, and operation can be found in the document [**Operation of the NEWFIRM Guider**](#).

9. The science pipeline

The NEWFIRM **data reduction pipelines** are the “second half” of the NEWFIRM system. The first half—all the components described above—captures photons and turns them into electronic bits. The **Quick Reduce pipeline** processes the bits into reduced, stacked images on a short timescale to permit careful evaluation of data quality while

observations are proceeding. The **Science Reduction Pipeline** operates offline, generates fully reduced, science-ready data products, and transfers raw and processed data to a permanent archive. For smooth operation, and to keep the effort of building these pipelines within limits, data must be taken at the telescope using predetermined generic observing protocols. Calibration data such as dark frames or flatfields must also be obtained in a prescribed manner. Observers are free to take data in nonstandard ways, but data reduction will be their responsibility in that case.

The NEWFIRM data reduction pipelines provide three levels of information return to the science observer:

- a. Real-time reporting of system health, environmental conditions, and data quality indicators (e.g. mean PSF, running sky background) together with tools for simple image manipulation and image queries.
- b. “Quick Reduce” image processing, with first-order signature removal and dithered image stacking, with about an hour’s turnaround, for evaluating sensitivity, appropriateness of data taking protocols, etc. in near-real time.
- c. Full pipeline reduction to science-ready data products, which are then passed to an archive. This will include the most accurate and complete signature removal, image stacking, mosaic assembly, astrometric and photometric calibration, and other processing, consistent with full automation.

The science pipeline will include linearity correction, distortion correction, two-pass sky subtraction, and flatfielding for individual frames; registration and stacking of dithered frames at a single major telescope pointing; and assembly of adjacent pointings into mosaicked images (??). Astrometric and photometric calibrations will be determined, to about an arcsecond and 5-10% respectively. SNR and other quality metrics will be tracked per pixel through the processing steps.

The “Quick Reduce” processing is derived from the full pipeline, and incorporates various shortcuts or approximations to reduce processing time while returning a product adequate for the intended temporary use at the telescope. “Quick Reduce” data products are automatically placed in the observer’s data directory as they are produced, but are not permanently archived.

Science observers will retrieve their fully pipeline-reduced data from the archive, post-run. Raw data may also be retrieved for processing with other toolkits, and/or transferred to observer-supplied storage media during the observing run for transport off site. If you wish to take your raw data home with you, be prepared for large data volumes, many tens of Gbytes per night. Large-capacity portable hard drives are recommended over CD or DVD media. Tape media are becoming obsolete so provision and support for them may be discontinued at any time.

Further details on pipeline operations, resulting data products, and archive storage and retrieval may be found in the [Introduction to the Quick Reduce Pipeline](#) and the [Introduction to the Science Reduction Pipeline](#).