Program status of NEWFIRM, the widefield infrared camera system for the NOAO 4-m telescopes

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Program status of NEWFIRM, the widefield infrared camera system for the NOAO 4-m telescopes

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ABSTRACT

The NEWFIRM program will provide a widefield IR imaging system optimized for survey programs on the NOAO 4-m telescopes in Arizona and Chile. The camera images a 28 x 28 arcminute field of view over 1-2.4 microns wavelength range with a 4K x 4K pixel array mosaic. We present an overview of camera design features including optics design, manufacture, and mounting; control of internal flexure between input and output focal planes; mosaic array mount design; and thermal design. We also discuss the status of other projects within the program: array control electronics, observation and pipeline reduction software, and production of the science grade array complement. The program is progressing satisfactorily and we expect to deliver the system to the northern 4-m telescope in 2005.

Keywords: Infrared camera, infrared arrays, array controller, observation control software, data reduction software

1. INTRODUCTION

The **N**OAO **E**xtremely **W**ide **F**ield **I**nfra**R**ed **M**osaic (**NEWFIRM**) program is delivering a new IR imaging capability, with hardware and software components optimized for deep survey style programs, to the Ritchie-Chrétien foci of the NOAO 4-m telescopes in Arizona and Chile. NEWFIRM has strong scientific and programmatic justifications identified in a U.S. community workshop in 2000[1]. Broad scientific themes are the cosmic history of star formation and chemical evolution, and the search for our origins in protostars and planetary systems. The programmatic purpose is to fill an identified need in the U.S. system of capabilities for deep widefield near IR survey facilities. These will give immediate science returns, provide the source catalogs needed for effective use of 6 to 10-m telescopes, and complement capabilities at other wavelengths such as SIRTF and ALMA.

The NEWFIRM program has several project components: the cryogenic camera itself, the first implementation of a new general-purpose array controller (MONSOON), the development and production of a 4K x 4K InSb mosaic using buttable 2K x 2K components (ORION), the production of observing preparation and execution software for high efficiency at the telescope, and the development of an automated data reduction pipeline that keeps pace with the raw data flow from the sky. This program was first described two years ago[2]. The purpose of this paper is to provide a technical update on progress since then. Details are given here for the camera hardware. Brief summaries and pointers to papers in other conferences of this symposium are provided for other program components.

2. THE NEWFIRM CAMERA

The NEWFIRM camera houses a refractive, collimator + camera optical design, filter wheels, and the infrared array mosaic in a cryogenic Dewar. Cooling is by means of closed cycle helium gas refrigerators. Instrument and array control electronics are mounted on the Dewar. A truss structure couples the camera to the telescope and carries a dedicated guider and support electronics. The field of view is a contiguous 28 x 28 arcminutes, and the working wavelength range is 1-2.4 microns. A graphical overview is given in Figure 1. The concept is largely unchanged since its initial description[2] but there have been some significant developments in design details.

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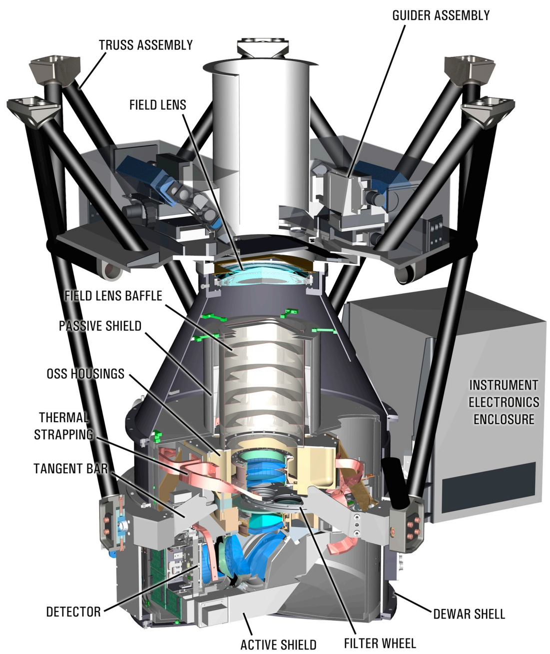


Fig. 1. Cutaway view of the NEWFIRM camera.

2.1 Filters and optics

Due to its beam size at the intermediate cold pupil image, the NEWFIRM camera requires cryogenic filters of about 120 mm diameter. The camera comes equipped with broadband filters for the standard J, H, and K_S bands (1.2, 1.6, and 2.1 microns central wavelength). These were acquired from Barr Associates as part of a consortium purchase organized by Alan Tokunaga[3]. The H and K_S filters, while acceptable, have numerous white light pinholes visible by eye when viewing a strong condensor lamp in transmission. Smaller filters acquired at the same time and implemented in ISPI[4] also have pinholes but these do not appear to affect their performance for astronomical imaging in on-telescope tests. The camera will accept narrowband filters with spectral resolution $R=\lambda/\Delta\lambda<75$ across its full field of view. This restriction is set by the maximum beam incidence angle at the pupil; the goal was R=100, but it was necessary to shorten the collimator focal length and steepen this angle in order to fit the optical design within the available space. Higher resolution filters can be used at the expense of field of view.

The optical design, described previously[2], is unchanged. It uses infrared fused silica (IRFS), CaF_2, and ZnSe lenses. BaF_2 was avoided due to its cost and lower transmission with antireflection coatings compared to the selected materials. The spherical lenses and a folding flat have been delivered from Janos Technology. Three of the IRFS lenses have one aspheric surface, in each case a conic section rather than a generalized asphere. While it was thought that these surfaces would be easier to produce on IRFS than on the other lens materials, few vendors seem to have the capability to diamond turn and polish IRFS with our required piece dimensions and steep aspheric curves (see Fig. 5 and caption). The vendor for the IRFS aspheric lenses is the University of Arizona Optical Sciences Center. We are working closely with this vendor as fabrication of these challenging optics proceeds, an interaction that is aided by our geographical proximity.

2.2 Optical system mounting

The camera mechanical design philosophy is build-to-print alignment: the system as assembled should be optically aligned within tolerance, with no need for mechanisms to provide subsequent adjustments. The optical components, with the exception of the first collimator lens, are mounted in a series of housings that form a unified Optics Support Structure (OSS) terminating with the mosaic array mount. This is distinct from the optical bench approach used in many instruments. The OSS is suspended inside the Dewar by three arms that connect it to a massive girth ring (Fig 2). While this approach was to some degree forced by the size of the instrument, it also allows the controlled flexure approach to overall alignment as discussed below. The first collimator lens is separately registered to the conical upper Dewar housing and also serves as the entrance window.

The build-to-print approach requires precise centration of each lens at both room temperature and 65 K operating temperature. We use a spring finger lens cell design[5] for all the cryogenic lenses in the OSS (Fig. 3), including a series of three camera lenses that are very closely spaced (Fig. 4). Each spring finger cell diameter is specified to lightly load its lens radially at room temperature, and have enough flexure that this load stays well under the lens material's stress limit as the cell cools and shrinks relative to the lens. Axial position of the lens is maintained by a separate multifingered spring ring that loads the lens against an internal flange formed by the fronts of the fingers. A thin G10 fiberglas liner on the inner surface of the fingers provides a thermal interface. For fabrication, a cell is finished to final

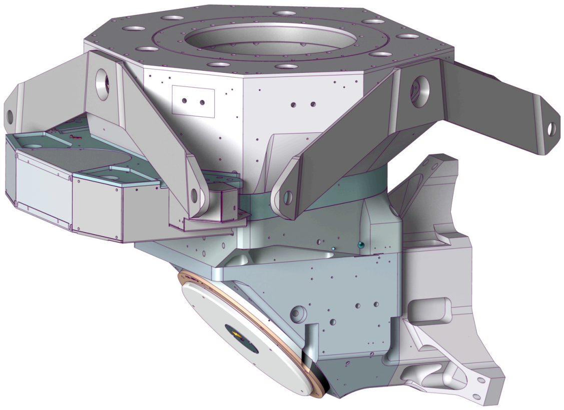


Fig. 2. Optics Support Structure and support arms.

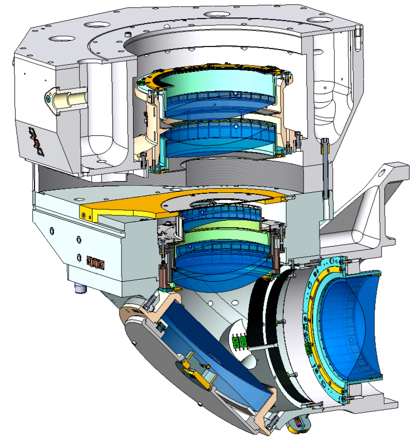


Fig. 3. Cutaway view showing optics in cells.

inside diameter and then slit to form the fingers. These tend to spring inwards slightly. Slight outwards manual pressure restores them—they seem to have a memory of their initial diameter—and cell concentricity is achieved to a few ten-thousandths of an inch. To compensate for any lateral difference between the optical and mechanical axes of a lens, the cell mounting flange can be machined to its final outer diameter eccentrically with respect to the spring finger bore. In this case the lens will have a unique orientation in its cell. This has been found to be marginally necessary for only one of the delivered spherical lenses.

The optical system has some demanding alignment tolerances that require very precise part-to-part registration. For the lens cells that fit into a given housing, this is achieved with concentric bores that accept the cell mounting flanges. A symmetric flange bolt pattern allows rotation of the lens and cell in discrete steps to optimize final optical performance. The housings are registered to each other with precisely located pins and bushings. Design solutions were developed with the precision provided by particular pieces of shop equipment in mind. Close communication between optical designer M. Liang, mechanical design engineer E. Hileman, and the instrument makers led by R. Repp has been a key factor in designing and fabricating an optics mounting scheme that satisfies tight as-built alignment requirements

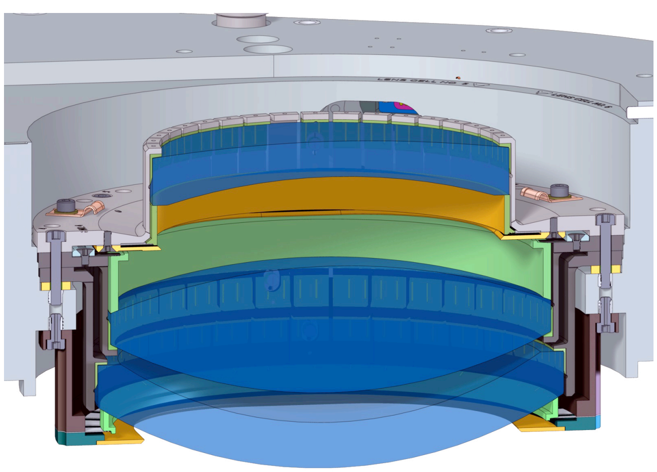


Fig. 4. Spring finger cell stackup for Lenses 4, 5, and 6. The bottom cell has internal finger flanges and loads the lens against them from the opposite face compared to the others.

2.3 Instrument alignment relative to the telescope

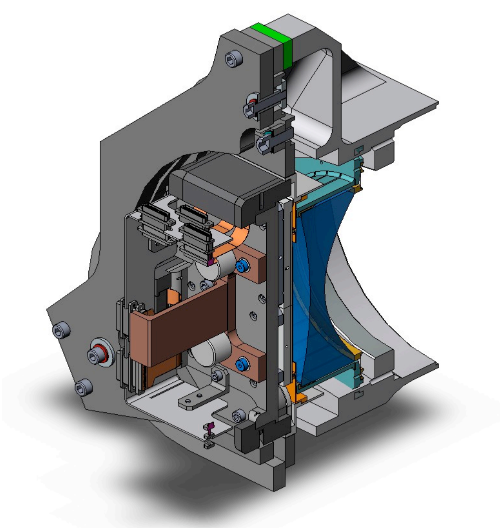
The OSS forms a very rigid assembly, and flexure between its optical elements in use is not a concern. The challenge is maintaining registration between the warm input (telescope) and cold output (IR mosaic array) focal planes against variable gravity loading as the telescope plus instrument move around the sky. This challenge is increased by the long optical path (~1.5 m) and the optomechanical fold necessary to fit the instrument within the available envelope at the telescope.

It did not prove feasible to eliminate flexure to the required degree with a very stiff overall structure. Our approach instead is to tune the OSS flexure relative to the girth ring by the dimensions and placement of the tangent bars connecting the two. The OSS rotates as a solid body around an optical node, such that a particular point on the detector focal plane remains directed at the corresponding point on the telescope focal plane to high precision as the gravity load changes. The first collimator lens does not participate in this controlled motion of the OSS, but being of low power and close to the input focal plane it has negligible impact on the result. The controlled flexure approach is fundamental to the camera's optomechanical design. This design solution to the problem of flexure in large instruments is treated in more detail in the accompanying paper by Hileman et al.[6]

2.4 Detector mount

The detector mount must simultaneously satisfy mechanical, cryogenic, optical, electronic, and interfacing needs. The NEWFIRM camera will use four, two side buttable, 2K x 2K InSb arrays. Each array is mounted on a motherboard that is glued to an Invar baseplate. Mechanically, the mount must integrate these modules into a coplanar assembly, then bring this assembly normal to and centered on the system optical axis at a specified focal point. Thermally, it must provide an adjustable but tightly controlled temperature for the arrays that is distinct from the remainder of the instrument (35 K vs. 65 K). The detector mount must also shield the arrays against unwanted longwave photons, provide connectors and cabling for hundreds of control and signal lines, and allow room for installation and electrical connection *in situ*, while remaining small enough to fit within an envelope that is restricted by the bottom of the Cass cage at the 4-m telescopes.

We were faced with the need to mechanically transition from the Invar array baseplates to the aluminum OSS while providing array cooling. The coefficients of thermal expansion (CTE) of aluminum and Invar are quite different, and Invar is a very poor thermal conductor. The latter property was particularly problematic; a design attempt at array cooling through an Invar detector mount structure was stymied by heat building up in the mount faster than it could flow out to cold straps. Our solution is shown in Fig. 5. The key aspect is separation of the thermal and mechanical tasks. Array cooling is provided via a substantial copper mass thermally strapped to the cold heads; its nominal 35 K temperature is precisely regulated. It is connected to each array module by a short length of copper braid attached at a threaded hole on the back of the Invar array baseplate. This attachment point is centered on the active area of the array. The CTE mismatch between the copper mass and the Invar structure that holds it is dealt with via oversize mounting holes and Belleville washers. The copper mass includes two large thermal buss bars protruding behind it for attachment of cold straps to the cold head second stage assemblies.



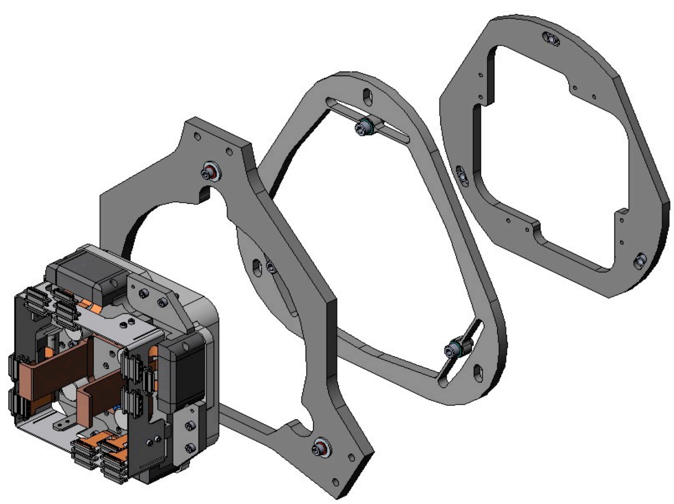


Fig. 5. Cutaway (left) and exploded (right) views of the detector mount assembly. Copper bus bars for thermal straps protrude from the back of the detector mounting block. On the left, the steep concave aspheric shape of the field flattener lens can be seen. On the right, the middle aluminum plate has mounting flexures for the following Invar plate.

Substitution of copper for Invar in the mount thermal path removed the impedance to the cold heads. However, our thermal FEA model indicates that thermal performance is fundamentally limited by the large Invar baseplate to which the array motherboard is glued. Performance requirements, set by the variation of offset bias with temperature reported[7] for ALADDIN arrays, were array temperature stability to within ±50 mK over 15 minutes, and spatial uniformity of ±20 mK across the active area. The first requirement is easily met in the case of long (100 sec) integration times in which power is input to the array intermittently; the second requirement is missed by a factor of three. Neither requirement is met in the case of continuous readout, as might be required to observe bright standard stars. The requirements did not account for offset bias drift correction using the reference pixels designed into the ORION array for this purpose[8]. Since our model shows no high spatial frequency temperature variations, reference pixel correction promises considerable amelioration of residual bias drift.

Mechanically the mount is comprised of three plates, two aluminum and one Invar, that accommodate the CTE mismatch while permitting motion in rotation, translation, and tilt for array mosaic alignment to the optical axis. The rearmost, aluminum plate is attached to the rear housing of the OSS via G10 insulating standoffs and shims for tip-tilt alignment. The frontmost, Invar plate is the attachment point for an inner Invar block. This block carries the array modules on its front face via intervening shims to bring the modules coplanar. Its rear face holds the copper thermal mass and is surrounded by a box structure carrying connector savers. These provide a transition from the short ribbon cables attached to each array module to cables that take the signals to cold stations located on the active shield. This Invar block is precision located by pinning it to the Invar plate, so the array assembly can be removed for safe storage before any other mechanical disassembly and without disturbing the alignment.

The detector mount assembly operating temperature is about 40 K. Radiation shielding is provided by labyrinthine paths for the copper braid and ribbon cable connections to the array modules; interlocking, non-contact shielding between the front of the mount and the rear OSS housing; and a closely fitting focal plane mask just above the array surface. Photons produced by electronic components on the surface of the array modules were an unanticipated source of stray light. These are blocked by incorporating an O ring into the focal plane mask to provide a contact seal around the photoactive part of the module. Finally, IRFS was chosen as the material for the last lens in the system because of its absorptive properties longward of 3 microns, to block stray out-of-band radiation in the optical path. This lens is very close to the final focal plane, which exacerbated the design difficulties for shielding. Specifying a larger minimum distance during the optical design phase would have been helpful.

Positioning of the array mosaic relies on pins, shims, and positive bolt-down locking between continuously movable components. In the latter case, the mount will be removed from the instrument and placed in a special fixture to effect precise, calculated adjustments. Each motion—translation, rotation, global piston and tilt, and individual array module piston and tilt—can be done in a controlled manner without affecting any of the other motions. The detector mount was designed by J. Andrew, with thermal finite element analysis performed by M. Abraham.

2.5 Thermal design

This is an area that has undergone some conceptual change since our initial design description[2]. A thermal gradient along the optical path, from a warm (240 K) collimator to a cold (80 K) final field flattener lens, was determined to be acceptable in terms of photon background on the array and even beneficial for instrument operation. In particular, it prevents condensation on the field lens/entrance window resulting from radiative cooling to the Dewar interior. Working within this generous thermal envelope was intended to provide design freedom. In practice, as the optomechanical design developed into the present quasi-monolithic housing structure, providing thermal breaks to maintain this gradient became a design hindrance, so it was abandoned in favor of a single nominal temperature of 65 K for the OSS.

This reintroduces the problem of condensation on the entrance window due to radiative overcooling. We tackle this problem from both sides. Inside the Dewar, the cold black baffle stack extending towards the field lens/entrance window stops substantially short of it. This gives the window, looking inwards, a large included solid angle of view to the warm Dewar walls (radiation shielding in this area closely follows the OSS and baffle stack, not the Dewar walls). This is a trade between entrance window cooling, and scattered light and out-of-beam thermal radiation entering the collimator. To control out-of-beam radiation with this shortened baffle system a warm, reflective, downlooking conical annular baffle is placed just inside the vacuum envelope, immediately below the entrance window. Looking upwards out of the science beam from the second collimator lens, one sees only the interior of the cold black baffle stack in reflection. The external, warm focal plane mask above the window is likewise polished on its downlooking face.

Analysis indicates that there will still be a tendency for the field lens/entrance window to experience condensation in moderate relative humidity (~40%). Outside the Dewar, our approach is to control the ambient environment by supplying a continuous flow of dry nitrogen gas across the window, and sealing the path from there to the telescope mirror cell to create an enclosed column of gas. This column will be dominantly dry nitrogen at the bottom and ambient air at its open top, with the flow being from bottom to top. Previous experience with damage to multilayer antireflection window coatings resulting from condensation has led us to specify a simple robust MgF_2 coating for the external face of this lens.

Other aspects of the thermal design are more conventional. The Dewar employs one active and two passive layers of radiation shielding surrounding the OSS. The OSS itself is made as light-tight as possible and forms a cold thermal mass for maintaining temperature uniformity of the optics. Cooling is provided by three two-stage cold heads. The first stages cool the OSS and the second stages cool the detector mount. The thermal path is provided by straps built up from ~50 layers of 0.01 inch thick copper ribbon. These assemblies form fairly rigid, complex shapes. The cross sections are tuned to achieve the desired delivered cooling power with a minimum of auxiliary control. This control is provided by heater resistors at the points of attachment of the straps to the cold heads.

Some of the optical materials are susceptible to thermal shock and must be protected against too rapid temperature change or large temperature drop across an interface. We use a combination of G10 standoffs between lens cells and housings, the thermal inertia of the 310 kg OSS cold mass, and careful monitoring of internal temperatures of lenses, cells, and housings to provide this protection. We anticipate that the camera will cool down in 48 hours to a steady state temperature of 65 K.

2.6 Other aspects of the camera design

The guider is mechanically separate from the instrument but is located by the same truss, close to the telescope focal plane. Registration between the input focal plane and the guider must be maintained against gravity induced flexure. The solution here is simple rigidity from the optical guide probe assembly outwards through a stackup of X, Y, and Z axis motion stages to a baseplate bolted to the truss. With most of the telescope's unvignetted focal plane taken up by the science field, guide stars must be found in the surrounding lunes. To get adequate search area the instrument focal plane is external to the Dewar and two probes, on opposite sides of the focal plane, are available.

The X and Y guider motions patrol the lune area. The positioning precision is specified to permit sub-pixel microstepping for improved recovery of spatial information by the science detector. The positioning accuracy of the 4-m telescopes themselves is likely to be the limiting factor for this. The Z motion allows focus tracking of the curved telescope focal surface, while a rotating cylinder lens in the guider optics train corrects the substantial position-dependent astigmatism found this far off axis. The guide sensors are small CCD guiders produced for the amateur astronomy market by Santa Barbara Instrument Group (SBIG). Their electronics are interfaced to the existing Linux guider software in the telescope control system.

With the various electronics boxes and other heat sources on board the camera and below the primary mirror, removal of instrument generated heat from the cage is a concern. To keep cost low and avoid complex retrofits to the telescopes, we use air as the working fluid. Heat sources are enclosed (electronics boxes form their own enclosures) and ambient air is drawn in, passed through the warm interiors, and expelled into a manifold formed by flexible ducting. The heated air is then collected by a large flexible duct running out the cage bottom and drawn to a remote location for heat exchange or simply dumping outside the observing chamber. In this way several hundred watts of onboard heat generation will be held to less than 50 watts dissipated in the instrument cage, an improvement of a factor of ten over some existing NOAO 4-m instruments.

2.6 The design and fabrication team

The core engineering design team for the NEWFIRM camera is located in Tucson. In order to speed fabrication, completion of detailed design from 3D models and subsequent fabrication of some subsystems are being carried out by experienced personnel at our other site in La Serena, Chile. This group has also lately taken on some higher level design tasks. This multi-site approach makes best use of the global resource base of the NOAO Major Instruments Program. Its success hinges on design software in common (Solidworks) and file sharing made possible by high bandwidth links; cleanly separable subsystems with careful interface definition; close communication, including a bilingual engineer on the Tucson team; and mutual enthusiasm and desire for success.

3. OTHER PROGRAM ELEMENTS

Brief updates for other project components of the NEWFIRM program are provided here. We give references to recent publications and pointers to papers in other conferences of this Symposium.

3.1 MONSOON Image Acquisition System

Array control for NEWFIRM is provided by a new system developed at NOAO for use with a wide variety of digital detectors and focal plane formats. The MONSOON system provides detector control and readout capabilities, and the first level of data reduction (e.g. image coadding and descrambling). MONSOON serves both CCDs and IR arrays with a combination of generic and application-specific components and software. It is scalable to very large pixel counts; the name comes from its ability to handle a deluge of raw data. The MONSOON concept is described extensively elsewhere[9]. It is being executed by a team led by M. Hunten[10]. The MONSOON project has entered a production phase with NEWFIRM as its first IR customer; optical CCD systems are next in line. The MONSOON IR development system has been integrated into the test station for ORION detector evaluation to serve as the laboratory array controller for this R&D effort. A series of papers at this Symposium by N. Buchholz and P. Daly[11,12,13,14] deal with software aspects of MONSOON.

3.2 ORION 2K x 2K buttable InSb array development

The camera focal plane is a 4K x 4K mosaic of four, 2K x 2K, two side buttable InSb arrays with 25 micron pixels. These ORION arrays are being developed in a collaboration between Raytheon Vision Systems, NOAO, NASA Ames Research Center, and the U.S. Naval Observatory (Flagstaff). The development program has been described by Fowler et al.[8,15]. The original ORION I multiplexer design was modified to improve yield[16]. ORION II hybrid arrays are now being manufactured and tested. Present status is reported at this Symposium by Hoffman et al.[17]. Following the successful conclusion of this development effort, the NEWFIRM program has contracted a production run of devices from which it will fill its focal plane.

Cost was the main driver for choosing ORION InSb arrays for our 1-2.5 micron instrument. While the ORION arrays have some performance advantages over other possible choices, their sensitivity out to 5.6 microns and low (35 K) required operating temperature add complications to the instrument design: control of internal thermal background, and provision of two cold temperatures for the optomechanical structure and the array.

3.3 Observation control software

The NEWFIRM Observation Control System (OCS) consists of offline preobserving software for detailed definition of the science observations to be executed, and realtime data acquisition control for the instrument and telescope. Two requirements for the OCS were that it interface smoothly with the existing telescope control environment, and that it be based as much as possible on software reuse. After evaluation of several possible choices by an internal working group, the ORAC/DRAMA system developed at UKATC[2] was chosen for data acquisition, and the UKIRT/Gemini Observing Tool for observation definition. Both require adaptation to NEWFIRM and the 4-m environment, and the success of the resulting hybrid solution relies heavily on the software engineer's expertise in integrating diverse, heterogeneous systems. The data acquisition portion has been successfully tested in simulation and, where applicable, in the real 4-m telescope environment. The observation definition portion is less well developed but substantial pieces of existing code can be re-used in its implementation. Knowledge transfer from the UKATC software team to NEWFIRM software engineer P. Daly has proceeded in a highly collegial way.

3.4 Pipeline reduction software

A highly automated data reduction pipeline is an integral component of the NEWFIRM program, with a beta version to be available at first light. This software has three levels called quick-look, quick-reduce, and pipeline. Quick-look is a combination of highly simplified pieces of the pipeline and a software toolkit, for real time evaluation of instrument, telescope, and sky performance by the astronomer. It is intended to monitor first-order system performance and flag problems such as telescope defocus, changing sky transparency, or obvious malfunctions of the control electronics or data system. For example, a running DC level meter will be displayed on the observer GUI, and a simple program will periodically identify point sources in a subtracted frame and report mean image quality. Quick-look is an automated extension of real time quality checks that astronomers presently do in a manual fashion.

The quick-reduce software provides the next level of quality control at the telescope. Its functions are to evaluate the suitability of the observing protocol, check that sufficient data have been taken to satisfy the science need, and check that the data set is complete. It will evaluate the suitability of data for flatfielding and sky subtraction processes against performance metrics; verify that target signal-to-noise ratio is being achieved for faint sources; and determine that all the science frames, calibration frames, and accompanying header information are complete for a given set of observations. Quick-reduce will work on data sets representing about an hour of observation, such as a deep dithered image set taken in a single filter, and provide feedback on the same timescale. To meet this cadence it will run the pipeline software with some steps simplified or eliminated, e.g. use of archived flatfields and skipping artifact detection. The purpose of quick-reduce is to assure the observer at the end of the night that usable and complete data are "in the can" for final processing; or if not, to specify precisely what observations need to be redone.

The purpose of the final pipeline reduction is to remove instrument signature, combine spatially dithered images to form the intended composite frames, and provide photometric and astrometric calibrations. The end result will be "science ready" and suitable for placement in a permanent public data archive. The first level of signature removal includes linearity correction, sky subtraction, and flatfielding of individual frames. These may be iterative processes. The next level is image registration and combination, including any necessary astrometric and photometric distortion removal. Finally there is artifact identification and correction or removal, where the source of artifacts may be external (satellite trails), internal (intermittent bad pixels), or both (amplifier ringing induced by a very bright source). The exact processing algorithms are still being defined, and are heavily based on previous experience with deep IR imaging and survey programs previously executed by NOAO and external teams (e.g. the NOAO Deep Wide-field Survey[18] and the Las Campanas Infrared Survey[19]). The processing algorithms may determine some observing procedures, so the NEWFIRM observing system will place requirements on what data are taken, and in what fashion, if the science user wishes to take advantage of the pipeline.

Implementation of the NEWFIRM pipeline is the responsibility of the NOAO Data Products Program headed by R. Shaw. A group at the University of Maryland is also involved as part of a buyin to NEWFIRM and other instruments at Kitt Peak. The implementation will follow, and draw heavily from, the optical CCD Mosaic camera pipeline. Mosaic is the first instance of automated science data processing at NOAO, and provides valuable experience in identifying essential environmental metadata, defining quality assurance procedures, and structuring the processing steps. The Mosaic pipeline is discussed at this Symposium by Valdes et al.[20]. The ultimate destination of pipeline reduced data is the NOAO Science Archive, discussed by Seaman et al.[21].

4. SUMMARY

The NEWFIRM program has continued down the path described previously[2] with very little conceptual change. This paper has described instrument design solutions for the optics and their mounting, flexure control, mounting and aligning the IR array mosaic, and thermal control. It has also provided overviews of the array controller, detector, and observing and pipeline software projects that complete the program.

The NEWFIRM program is delivering, not just an instrument, but a science capability. To do so requires designing and building instrument hardware, developing the next generation array controller, developing and producing large format, buttable IR arrays, creating observation definition and execution software that maximizes efficiency for large survey programs, insuring hardware and software compatibility with existing observatory systems, and building an automated reduction pipeline to keep pace with the data flow. The result is a system that turns photons into science.

In terms of overall program status, all the component projects are progressing satisfactorily. We expect to have system delivery to the northern 4-m telescope in 2005. Further information may be found at project Websites: http://www.noao.edu/ets/ with links to ORION, MONSOON, and NEWFIRM camera projects.

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