Control software and user interface for the Canarias Infrared Camera Experiment (CIRCE)

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ABSTRACT

The Canarias InfraRed Camera Experiment (CIRCE) is a near-infrared visitor instrument for the 10.4-meter Gran Telescopio Canarias (GTC). This document shows CIRCE software. It will have two major functions: instrument control and observatory interface. The instrument control software is based on the UFLIB library, currently used to operate FLAMINGOS-1 and T-ReCS (as well as the CanariCam and FLAMINGOS-2 instruments under development in the University of Florida). The software interface with the telescope will be based on a CORBA server-client architecture. Finally, the user interface will consist of two java-based interfaces for the mechanism/detector control, and for quick look and analysis of data.

Keywords: Near Infrared Camera, Control Software, User Interface

1. INTRODUCTION

The Canarias InfraRed Camera Experiment (CIRCE) is a near-infrared (1-2.5 µm) instrument for the Gran Telescopio Canarias (GTC) 10.4-meter telescope. While the EMIR near-infrared facility instrument is scheduled to come on-line for GTC in 2008, CIRCE will be the only near-infrared instrument available for GTC for its first phase of operation, and will thus fill a crucial gap in first-light instrumentation between the other facility instruments: OSIRIS (covering 0.4-1.0 µm wavelengths) and CanariCam (covering 5.0-28.0 µm wavelengths). In addition, the optics and detector array of CIRCE will provide a pixel scale (0.10 arcsec/pixel) fine enough to properly sample the excellent images provided by GTC, while at the same time providing a near-IR field-of-view (∼3.4 arcminutes) comparable to any currently available on the world’s large telescopes (a real FOV ∼ 25 times larger than NIRC on Keck, and ∼ 3 times larger than NIRI on Gemini).

After the delivery of EMIR, CIRCE will continue in scientific use on the GTC Bent Cassegrain visitor ports, where its high image quality and resolution, polarimetric capability, high time-resolution readout, and lower spectral resolution (useful for very faint targets) will complement the capabilities of EMIR and continue to augment the scientific capabilities of one of the world’s largest optical/infrared telescopes.

CIRCE will be a cryogenic re-imager with a standard collimator/camera design similar in its basic layout to most modern astronomical infrared cameras, including the Wide-field InfraRed Camera (WIRC - S. Eikenberry, PI), and FLAMINGOS-2 (R. Elston, PI; S. Eikenberry, co-PI). CIRCE differs significantly from other similar instruments, however, in its all-reflective optical system using diamond-turned aspheric mirrors. This approach is a natural step in the development of similar diamond-turned complex aspheric systems for use in astronomical applications at the University of Florida, including the Gemini-South facility mid-infrared imager/spectrograph (T-ReCS - C. Telesco, PI), the GTC facility mid-infrared imager/spectrograph (CanariCam - C. Telesco, PI), and the new near-infrared image-slicing integral-field spectrograph (FISICA - S. Eikenberry and R. Elston, co-PIs). Such an optical approach provides significantly improved image quality and throughput as compared to more traditional refractive designs (which typically require ∼ 10 lenses for performance to match the CIRCE 6-mirror design). While diamond-turned aspheres have historically been difficult to test and align, there have been significant advances in their manufacture and testing over recent years, and the University of Florida has considerable experience in handling and aligning them within the necessary tolerances for the above-mentioned instruments, providing confidence that we can implement the CIRCE design successfully.

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Figure 1 illustrates the basic components of CIRCE. Incoming light from the telescope passes through the cryostat entrance window, inside of which all components are kept at temperatures of 77K to eliminate contaminating thermal near-infrared emission. At the telescope focus, CIRCE will have a slit wheel, including an imaging field stop (3.4x3.4-arcmin), a long slit for grism spectroscopy, and a partial-field imaging stop for Wollaston polarimetry (3x1.5-arcmin). After the telescope focus, a 2-mirror collimator produces an image of the telescope entrance pupil at a Lyot stop which blocks stray light from reaching the detector. CIRCE will have three filter wheels (one fore and two aft of the Lyot stop), placing bandpass filters (both broad- and narrowband) in the collimated beam, allowing the study of the infrared colors and emission features of science targets. After the filter wheel, a 4-mirror anastigmatic camera brings the light to a focus on the HAWAII-2 2048x2048-pixel infrared detector.

CIRCE spectroscopy includes two grisms, both of which are derived from designs for the FLAMINGOS-2 instrument for Gemini (and share the grating ruling masters custom-built for FLAMINGOS-2). The first grism will cover the 1.25-2.4 $\mu$m bandpass instantaneously at a resolution of R=410 at 1.25 $\mu$m and R=725 at 2.20 $\mu$m (all resolutions are FWHM for a 3-pixel slit). The second grism will have cover a single band instantaneously at a resolution of R $\sim$ 1500 (3-pixel slit) in its 3rd order (K-band), 4th order (H-band), or 5th order (J-band). The CIRCE optics will maintain seeing-limited image quality with the grism in the optical path over the entire bandpass.

CIRCE will also have a Wollaston prism polarimetric mode. In this mode, a Wollaston prism will be placed in the beam just after a rotating half-wave plate (HWP) located at the Lyot position. This prism will deviate the ordinary and extraordinary polarization beams at the pupil, resulting in a shift of the "$o$" and "$e$" images on the detector. Coupled with a half-size field mask at the telescope focus, this will provide spatially-separated images, allowing polarimetric measurements. A pair of exposures with the HWP at angles of 0-degrees and 45-degrees allows the measurement of the "$Q$" polarization component. A similar pair at 22.5-degrees and 67.5-degrees allows the measurement of the "$U$" component, and thus the complete determination of linear polarization in the source.

CIRCE will also have a sub-framing readout mode, which will enable high-speed imaging photometry in any
filter (broad- or narrowband). The MCE-3 electronics can support continuous frame rates faster than 1 Hz over fields-of-view exceeding 1x1-arcmin.

2. HARDWARE

CIRCE control hardware consists of four physical units:

1. the Cryostat housing the detector array, optics, and mechanisms.
2. the Detector Control (DC) hardware (MCE3+ Array Controller).
3. the Mechanism Control (MC) hardware.
4. the Local Control Unit (LCU) that runs the control and data transport software.

All described subsystems will be controlled through the UFLIB instrument control software.

Figure 2. CIRCE conceptual diagram

Figure 2 shows conceptual diagram of the control hardware. The DC, MC and LCU comprise the CIRCE Control System. The DC hardware, usually called the Modular Camera Electronics (MCE, version 3+), performs the clocking and readout of the detector array, and the A/D conversion of frames (a frame being the readout of
all pixels in the array). This document concentrates on the design of the DC and MC hardware, as well as the UFLIB instrument control software, running in the LCU.

The LCU is a Solaris/SPARC rack-mount computer that resides in the same rack as the MC hardware. The LCU will be connected to the GTC GBit control network. The LCU acquires detector frames from the MCE-3+ via a giga-bit rate fiber optic link using hardware and drivers developed by GATIR Electronics and EDT (Engineering Design Team). The readout of the detector array and the buffering performed by the MCE-3+ may occur at a rate of 1 Hz. The LCU is also connected via TCP/IP over Ethernet to a Perle Terminal Server, which thereby provides serial RS-232 lines for commanding devices such as MC hardware and the MCE-3+. To setup and execute the above data acquisition operations, the MCE-3+ accepts commands on an opto-isolated serial port connected to a Terminal Server. The motor indexers are daisy-chained on one serial line, and a serial line is connected to each of the monitoring devices.

3. ELECTRONICS

The warm electronics for CIRCE are based on a refurbished MCE-3 system built by the GATIR company (originally used successfully for several years on the OSCIR infrared instrument). With some slight refurbishment, this system can control the HAWAII-2 detector array in its 32-output mode as well as the CIRCE mechanisms. This refurbishment will be carried out by GATIR, Inc. The cold electronics for CIRCE include the detector fanout board and cabling from the fanout board to the MCE-3 warm electronics. The fanout board itself will be a copy of the FLAMINGOS-1 board.

The electronics interface with GTC will be closely based on the interface used for the CanariCam infrared instrument being built at the UF. The CIRCE LCU (SparcStation) will have an interface with the GCS network based on Gigabit Ethernet. The instrument LCU will be accessed remotely in order to get console messages, and start/stop the LCU.

As the instrument hardware, the Array Controller is controlled through the Perle terminal server. The science data output is transmitted via a gigabit fiber optic link to a fiber optic interface card that resides in the Solaris chassis.

All array controllers perform the same basic functions. These are 1) Clock the array in an appropriate manner, 2) process the analog output of the array, 3) Digitize and digitally process the resulting analog signal and 4) transmit that data to the host system. There many approaches that are possible, but all systems must perform these basic functions. In the MCE-3+, a single board or set of boards handles each function separately.

4. CONTROL SOFTWARE

The CIRCE control software will have two major functions: instrument control and observatory interface (header information retrieval, telescope control, data handling, etc.). The instrument control software will be based on the UFLIB library currently used to operate FLAMINGOS-1 and T-ReCS (as well as the CanariCam and FLAMINGOS-2 instruments under development). The UFLIB software is specifically designed to interface with MCE array- and mechanism-controller electronics, and will thus allow a straightforward implementation of the instrument control (based on FLAMINGOS-1). The software interface with the Telescope will be based on a CORBA server-client architecture. CIRCE will be a client of the GCS CORBA server, and will request header information and Telescope offsets.

4.1. Packages

CIRCE control software consists of three basic units:

1. Mechanism Control Agents, for temperature control and monitoring, pressure control and monitoring, and motor control.
2. Detector Control Agent
3. Frame Acquisition Server
The Mechanism & Detector Control Agents and the Frame Acquisition Server (FAS) will execute on the LCU, and would suffice to operate the instrument in standalone mode. The FAS receives data frames and the header information and stores them in the Local Data Archive in FITS format file, archiving the observation.

4.2. Architecture and Communications
This section describes the software architecture of the CIRCE Control System and the communication between components and with the hardware. Figure 3 is a diagram of software components that execute on the LCU and the hardware to be controlled. The elements containing the word "Agent" represent software components that provide interfaces to hardware devices. Note that the Device Agents communicate with the hardware through the Perle Terminal Server that is connected to the LCU via Ethernet, addressing the particular serial port that is physically connected to the respective hardware device.

The Device Agents are software components based on UFLIB classes, using UFProtocol messages over TCP/IP sockets. Each Device Agent is a single threaded process that handles client socket connections in round-robin fashion, and executes a sequence of ancillary tasks once every second when there are no pending client requests. Normally the Device Agents will execute on the LCU, however they could execute on any machine that has TCP/IP access to the Terminal Server (which is connected to the LCU).

The EDT device is a PCI card in the LCU, with Solaris device drivers and Application Interface (API) for Direct Memory Access (DMA) acquisition of data frames from a giga-bit rate fiberoptic connection. Transport

![Figure 3. CIRCE Control Software Deployment Diagram](image-url)
of detector frames occurs over the fiberoptic link between an "upper" EDT interface in the MCE-3+ and "lower" EDT interface card in the PCI bus of the LCU. The FAS is a multi-threaded process that grabs data frames from the EDT device, and therefore must execute on the LCU.

The software interface with the telescope will be based on a CORBA server-client architecture. CIRCE will be a client of the GCS CORBA server, and will request header information and Telescope offsets.

5. USER INTERFACES

The user interface will consist of two java-based interfaces: UFJCI for the mechanism and detector control, and UFJDD for quick look and analysis of data.

The UF Java Control Interface (UFJCI) is a Graphical User Interface that communicates with device agents and will allow an observer to configure, start, and monitor an observation with CIRCE. The UFJCI can be executed on any machine with TCP/IP access to the instrument's LCU, and so is usually not running on the LCU. Figure 4 shows the UFJCI Master Panel, the starting point for high-level configuration and control of the instrument.

The UF Java Data Display (UFJDD) communicates with the FAS for fetching and displaying current status and data frames for quick-look display purposes, and it will allow an observer to display, process, and analyze the data. Figure 5 shows the UFJDD panels: Zoom and analysis panel (top) and full display panel (bottom).

Note that the FAS actually processes the data frames and writes the final processed image to a FITS file on the LCU disk. This FITS file containing the final image can be copied and used without any further processing, and during good observing conditions this result would suffice.

Figure 4. UFJCI Master Panel, the starting point for high-level configuration and control of the instrument.
Figure 5. UFJDD panels: Zoom and analysis panel (top) and full display panel (bottom).