INAF Technical Report

LRS: ARC Software Specification Description

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V1.1	02-04-2020	Added § 2.3	
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Contents

1. Introduction

1.1 Scope

The purpose of this document is to provide to the SW developers all necessary information to manage the CCD readout hardware (ARC controller) together with the developed low level software and to build the acquisition system for the Low Resolution Spectrograph (LRS) at the TNG.
This document
The following documents are closely related to this SRS and should be consulted as well:

- ARC User manuals [RD07][RD08][RD09]
- Documentation of the ARC software [RD01][RD02][RD03][RD04][RD05]

1.2 Additional information

This SRS is divided into two parts; the first shall describe the hardware (ARC controller) and the minimum requirements to manage the CCD readout in the different readout mode, and a second part that describe the requirements for the scientific observation.

1.3 Reference documents

[RD01] Installation and start up

[RD02] DSP Software

[RD03] Controller Commands

[RD04] PCI Commands

[RD05] Continuous Readout

[RD06] External Interrupts

[RD07] ARC22_UsersManual

[RD08] ARC32_UsersManual

[RD09] ARC45_UsersManual

[RD10] MOTOROLA DSP ASSEMBLER REFERENCE MANUAL

[RD11] Dolores: The Graphical User Interface Manual – TNG-Dolores-001

[RD12] TNG-DD-LRS-0001, LRS Implementation of ARC controller

2. Reading a CCD with ARC controller

In this chapter will be described the hardware of the ARC controller, the DSP assembler code functions and shall be described the functioning of the engineering GUI interface that manages the CCD readout. The last paragraph gives a list of functions that has to be implemented in the software of the acquisition system for the Low Resolution Spectrograph (LRS) at the TNG.

2.1 Furnished Equipment

The furnished equipment means the equipment and the software (DSP code, libraries and test software), purchased and/or developed previously, supplied to the software developers to carry out the software of the acquisition system for the LRS instrument.

1. ARC Hardware
2. Windows libraries
3. Linux libraries
4. API examples
5. DPS code
6. Engineering GUI interface

2.1.1 The hardware

The following boards mainly make up the ARC controller:

1. The Timing board (ARC-22), that manages the communications
2. The Clock Driver Board (ARC-32), that provides the clocks signal for the CCD
3. The Video processor board (ARC-45), which provides the bias voltages for the CCD and manages the processing and digitalization of the CCD outputs.

The clock signals, bias, settings and the processing and digitalization are managed by a DSP code (*.lod) that is provided to the SW developers.

2.1.2 Windows libraries

Astronomical research camera inc provides a set of C++ application interface libraries for controller communication, image acquisition, FITS storage and post processing.
The software packages include the PCIe device drivers for Windows, the DSP assemblers for the code development of DSP56300, DPS56000 and a DPS code template.

2.1.3 Linux libraries

The same packages provided for windows (§2.1.2) are supplied for the development of the software in Linux environment but for DSP assemblers is required the installation of wine toolset to run the windows version of the assemblers in Linux.

2.1.4 API Examples

Together with the drivers and the developments tools, ARC inc give a complete set of API examples in C++ both for windows and Linux platforms in order to develops custom software for the ARC controller management.

2.1.5 The DSP code (description)

The DSP code is the core of the acquisition software for the CCD readout.
There are two assembly codes, that are linked together to generate the tim.lod DSP code.

- tim.asm
- E2VLRS.waveforms

2.1.5.1 The main assembly code: tim.asm + timCCDmisc.asm

The *tim.asm* + *timCCDmisc.asm* codes, contain the commands for the ARC management [RD03]:

- Boot commands
- Application commands
- Optional commands

Some of these commands are listed in Figure 1.

```
; Application commands
        DC      'PON',POWER_ON
        DC      'POF',POWER_OFF
        DC      'SBV',SET_BIAS_VOLTAGES
        DC      'IDL',START_IDLE_CLOCKING
        DC      'OSH',OPEN_SHUTTER
        DC      'CSH',CLOSE_SHUTTER
        DC      'RDC',RDCCD
        DC      'CLR',CLEAR

; Exposure and readout control routines
        DC      'SET',SET_EXPOSURE_TIME
        DC      'RET',READ_EXPOSURE_TIME
        DC      'SEX',START_EXPOSURE
        DC      'PEX',PAUSE_EXPOSURE
        DC      'REX',RESUME_EXPOSURE
        DC      'AEX',ABORT_EXPOSURE
        DC      'ABR',ABR_RDC
        DC      'CRD',CONTINUE_READ

; Support routines
        DC      'SBN',SET_BIAS_NUMBER
        DC      'SMX',SET_MUX
        DC      'CSW',CLR_SWS
        DC      'SOS',SELECT_OUTPUT_SOURCE
        DC      'SSS',SET_SUBARRAY_SIZES
        DC      'SSP',SET_SUBARRAY_POSITIONS
        DC      'RCC',READ_CONTROLLER_CONFIGURATION
        DC      'SPS',SELECT_PIXEL_SPEED

; Custom SALT commands
        DC      'PUP',MOVE_PARALLEL_UP
        DC      'PDN',MOVE_PARALLEL_DOWN
        DC      'RDN',READ_N_LINES
```

Figure 1 - ARC Commands

2.1.5.2 The CCD specific assembly code: E2VLRS.waveforms

The E2VLRS.waveforms contains the timing and the configuration for the e2v4240 CCD.
It implements different readout mode and speed and set the default value for a certain CCD detector.
The DSP code manages:

1. the setting of the CCD biases and clocks voltages (default values)
2. the setting of the offset (default values)
3. the generation of the clock waveforms
4. the processing and digitalization of the signals

Furthermore, the DSP code make available:

1. The clock waveform for the Vertical and horizontal wipe
2. The horizontal waveform for the readout of the CCD in three modes:
    a. Left Readout
    b. Right Readout
    c. L-R Readout (both channels)
3. The horizontal waveform for the readout of the CCD at three different speed:
    a. Fast
    b. Medium
    c. Slow
4. The horizontal waveform for the readout of the CCD in binning mode

2.1.6 Engineering GUI interface

The engineering GUI allow, in a simple way, the interface between the user and the DSP code, making available the management of the features contained in the DPS code.

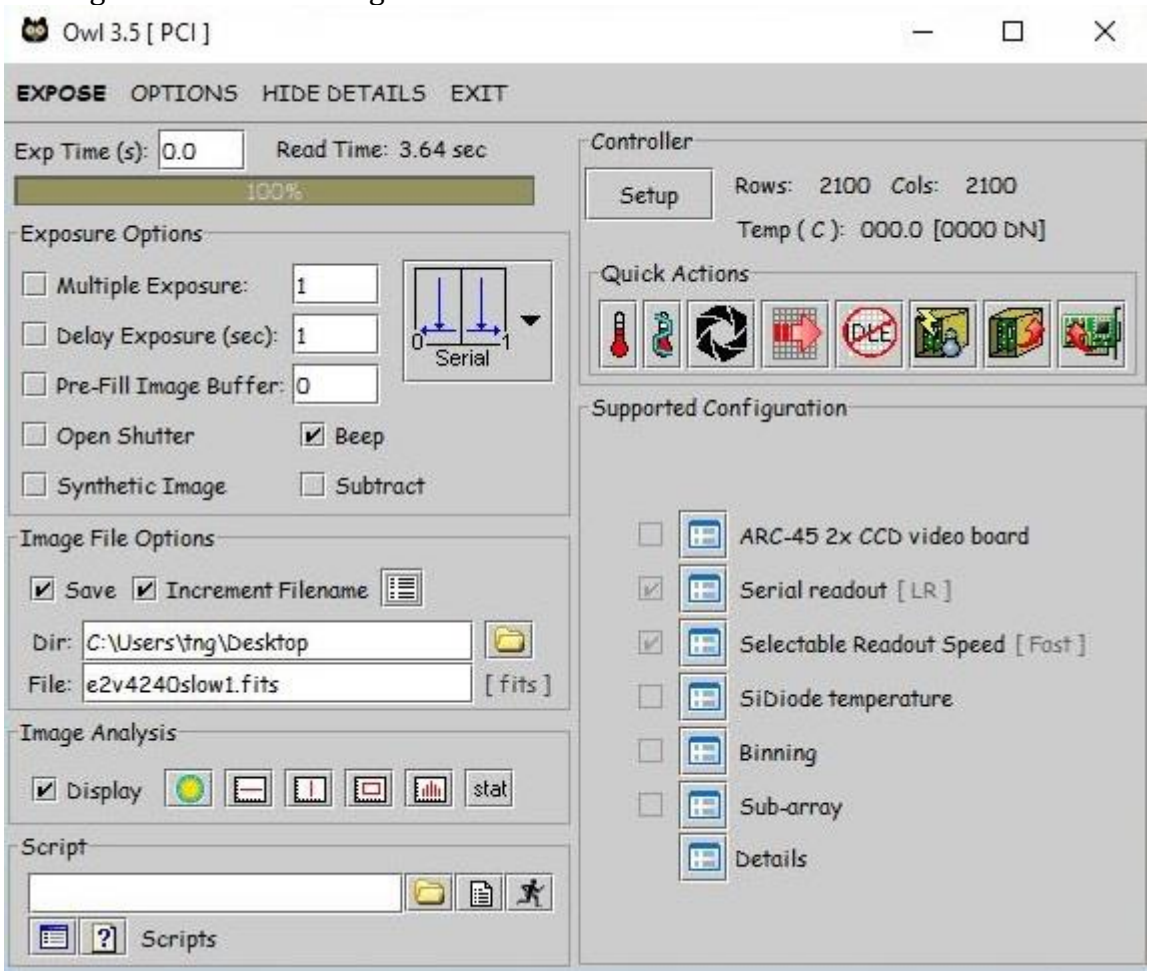

Figure 2 - The engineering GUI

2.1.6.1 Setup

The first operation to do is the setup of the CCD environment:

1. Reset controller
2. Hardware test
3. PCI communication test
4. Download of the DPS code (*.lod file)
5. Set the image size

These operations can be done by use the setup panel.

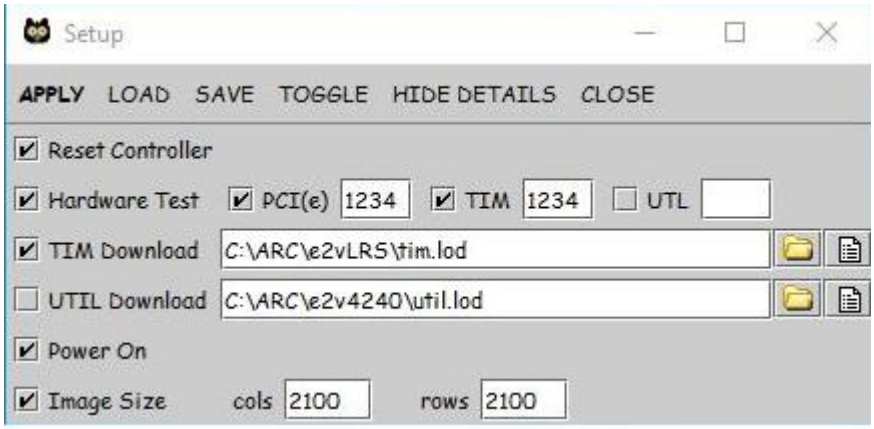

Figure 3 - Setup of the CCD environment

2.1.6.2 Acquisition

After the setting of the acquisition environment, the system is ready to acquire images from the CCD detector (default environment, provided by the DPS lod file).
From the user interface is possible to set:

1. The exposure time
2. Multiple exposure
3. Enable the opening of the shutter
4. Save the image
5. Expose and acquire an image

2.1.6.3 Change the environment

From the GUI is possible to change the environment of the acquisition, which is the readout mode, speed, binning and so on, as detailed in the following part.

Board selection and video offset:

This panel is used to set the board number (default =0) and the video offset of each channel of the ARC-45 board.

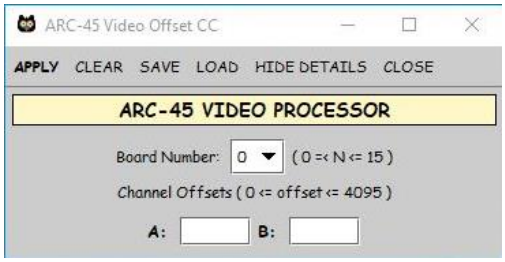

Figure 4 - board selection and video offset programming

Serial Readout:
Used to select the readout mode

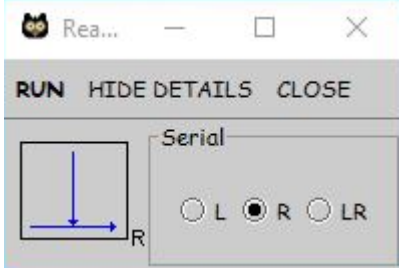

Figure 5 - readout mode selection

Selectable Readout Speed:
Change the readout speed of the CCD

Figure 6 - readout speed selection

Binning:
Change the X and Y binning if the CCD readuut

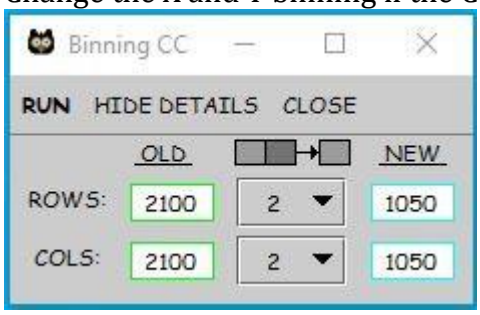

Figure 7 - CCD binning

Sub-Array:
Select the area of the CCD to be acquired, by selecting a box in a DS9 viewer.

Figure 8 - Sub-Array selection

3. Hardware and Software configuration for the LRS upgrade

The hardware and software configuration that we suggest to integrate the new ARCs CCD with DOLORES could be summed up, following the data route from the CCD to the observer computer from up to down as shown in Figure 9.
From top to bottom there are:

- The DOLORES CCD dewar
- The new connection cable.
- The new ARC controller with its low-level software and Power unit.
- The new fibers optic connection through the new ARC PCI board inside the new Linux PC.
- The internet connection that, through a new API REST service, connect the final user PC where an REST wrapper software will interface the old IDL GUI to manage the instrument configuration and image acquisition.

A new engineering GUI will be developed to grant the instrument maintenance.

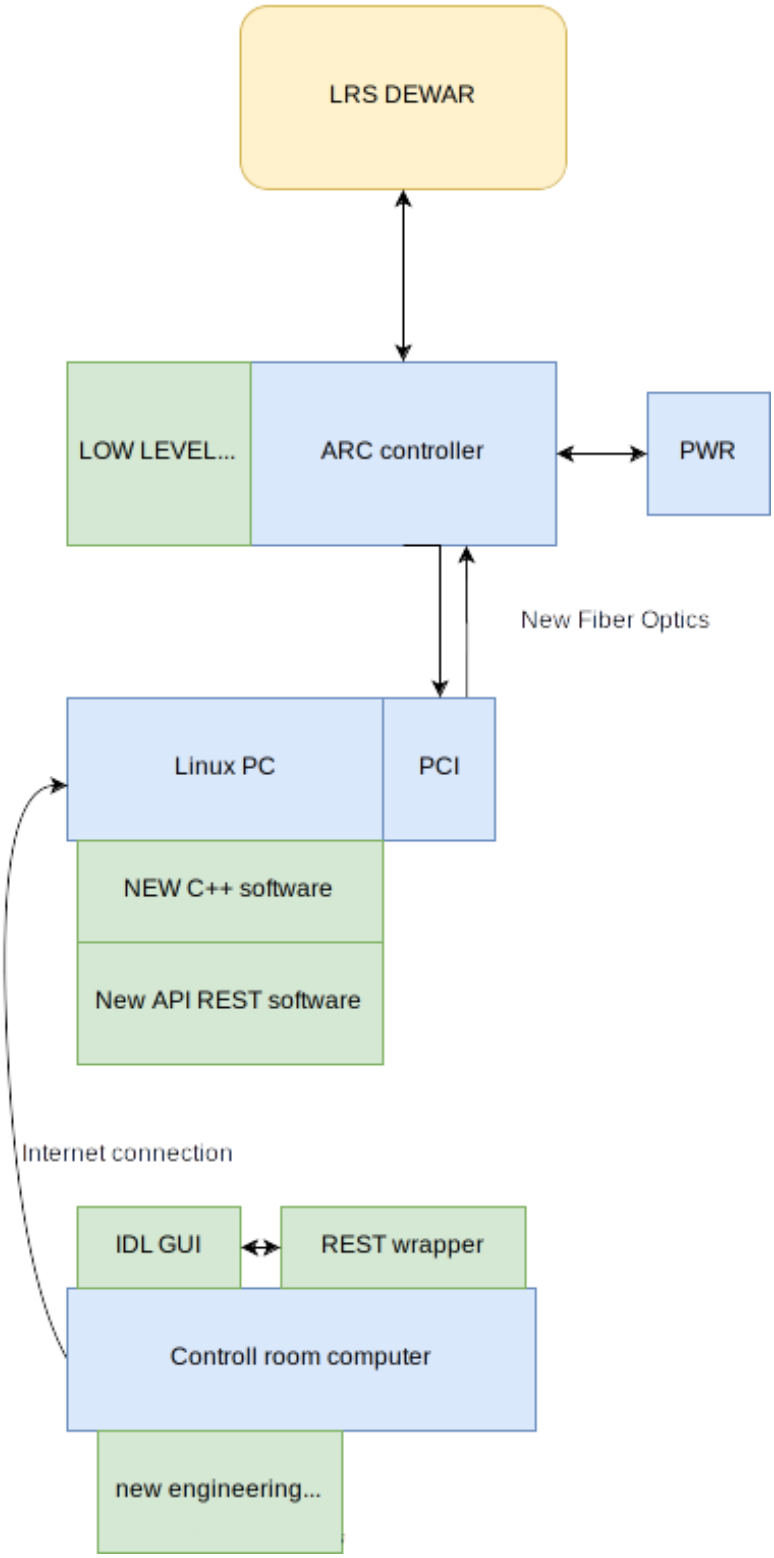

Figure 9 - hardware and Software diagram of the acquisition system

4. Software for the CCD acquisition system (NCCD software)

The software to be developed for the CCD acquisition system (NCCD) can be divided into:

- The low level software (assembly code); that is ready and tested [RD12]

- The software for the communication with the CCD controller and the assembler code (New C++ software), that includes the specific commands for the ARC camera management.
- The software for the communication with the user interfaces (New API Rest SW and the wrapper REST translator) that include the features for the broadcasting with the user interfaces (engineer, scientific and web).
- The GUI

4.1 The Low Level Software (the Assembly code)

The assembler code developed for the e2v 4240 CCD is called E2VLRS.asm and includes the configuration of the default values for the CCD setting and implementation of the different readout modes.
The code includes several horizontal sequences (sections) that implement all the reading mode and speed described previously.

Table 1 - Readout modes implemented in the assembler code

Section Name	Mode	Speed	Microsec/pixel
SERIAL_READ_LEFT_SLOW	LEFT	SLOW	10
SERIAL_READ_LEFT_MED	LEFT	MED	2.5
SERIAL_READ_LEFT_FAST	LEFT	FAST	1
SERIAL_READ_RIGHT_SLOW	RIGHT	SLOW	10
SERIAL_READ_RIGHT_MED	RIGHT	MED	2.5
SERIAL_READ_RIGHT_FAST	RIGHT	FAST	1
SERIAL_READ_SPLIT_SLOW	SPLIT	SLOW	10
SERIAL_READ_SPLIT_MED	SPLIT	MED	2.5
SERIAL_READ_SPLIT_FAST	SPLIT	FAST	1

4.2 The New C++ software

The minimum requirements of the acquisition system for the Low Resolution Spectrograph (LRS) at the TNG has to include all the feature described in §2.1.6.

The following paragraphs describe the operations to be implemented to manage the CCD acquisition, grouped in three parts:

1. The Setup (are the minimum commands that has to be executed to enable the system)
2. The Acquisition (list of command for the acquisition)
3. Commands (list of all the commands to set up the acquisition environment and to acquire the images)

4.2.1 Setup

The first operation to do is the setup of the CCD environment:

1. Reset PCI
2. Test PCI
3. Test data link
4. Load tim file

5. Power the controller
6. Set image dimensions
7. Reset controller
8. Set bias level offset *
9. Set the Board id *
10. Set the Gain *

* These parameters are set at startup inside the tim.lod file but a dedicated function is needed for tests

4.2.2 Acquisition

After the setting of the acquisition environment, the system is ready to acquire images from the CCD detector (default environment of the DPS *tim* file).
From the user interface has to be implemented the following settings:

1. Setting of the exposure time
2. Setting of multiple exposures
3. The enable/disable of the opening of the shutter
4. Expose and acquire the image
5. Pause an ongoing image. Shutter is closed and the controller don' t read the image
6. Resume. The controller open the shutter and goes on exposing the remaining fraction of the exposure time
7. Set an abort image functionality. Acquisition ends and the image is not read out
8. Set a stop image functionality. image is read out at current elapsed time
9. Set an extend image functionality. En extra time is added to the exposure time before to read the image
10. Save the image with an established name and with a minimum fits header (defined in §4.5.4).

4.2.3 Commands

The following command has to be implemented:

Table 2 - commands

Command	Parameter1/range1	Parameter2/range2	Type	Comment
Idle	Toggle On/OFF	none	user	Enable/disable the wipe of the CCD
Set board	Board # /0-15	none	startup	Default =0
Set offset	Ch # / 0-1	Value / 0-4095	User	
Set RD mode	Mode / L-R-LR*	none	User	
Set RD speed	Speed / F-M-S	none	user	
Set exp. time	Exptime / seconds	none	user	
Set delay	Delay / seconds	none	user	
Set multi exp	# exposure / int	none	user	
shutter	Flag / on-off	none	user	
Set binning	Bin X / int	Bin Y / int	user	
Set delay	Delay / seconds	none	user	
Set sub-array	To be investigated	To be investigated	user	
Expose	Time / ….	Shutter [O/C]		
Abort	No arg	No arg		

Stop	No arg	No arg		
Extend	Time			
Pause	No arg	No arg		
Resume	No arg	No arg		

IDLE → if enabled, scan the CCD continuously and force the wipe while the CCD is not exposing
Set board → set the board number
Set offset → set the offset of the video signal, to adapt the video signal range to the ADC range. Has to be verified if the range is 0-1 or 1-2
Set RD Mode → set the readout mode. In the ASM code the mode are called left, right and split. The way to select the different modes has to be investigated.
Set RD Speed → set the readout Speed. In the ASM code the speed are called fast, med and slow. The way to select the different modes has to be investigated.
Set Binning → the value of the binning has to be selected taking into account that :
Area / binning MAST be an integer
Sub-Array → has to be investigated

4.3 API REST Software

The new C++ general purpose CCD management software is an already partially developed software (Jose San Juan) to manage all the CCD cameras used at the TNG (FLI autoguide CCD cameras, scientific CDD, optical laboratory CCD ...).
The basic idea is that all the CCD cameras controllers have the same functionalities. They receive sets of configurations command, from a superior shell, to setup the exposure and they return an image.
The setup is usually the same for all the CCD. This include set the readout phases, select one of the readout electronic amplifier, receives specific command to setup a current image like set a box, set a binning, set an exposure time etc.
But every controller has its proper manufacturer command sets. This C++ program would set a scalable, full purpose superset of commands and would translate each of this command to the specific subset of the CCD controller dialect in use.
The program would be in charge to save the final fits format image including the header.
The API REST software would be in charge to receive command from an upper shell and to transfer this command to the C++ program

4.4 Wrapper REST translator

This piece of code is needed because the original IDL GUI will not have updated at this moment. Its REST functionality are not up to date and a translator to modern REST is needed.

4.5 Current IDL GUI with some actualizations

The features described in the previous chapter, that implement all the features needed in a scientific instrument, has to be implemented in the LRS acquisition system.

The first approach will be to adapt the existing LRS User interface (Figure 10 and [RD11]) to the new acquisition system, based on the ARC hardware and the basic software .

The IDL GUI interface (see Figure 10) will send command to the lower level software through the REST wrapper.

Currently, the same scheme is in use with a Java bridge in charge to send messages to the lower level. The same set of messages can be recycled and used for the functionalities that are shared by the new and old system. The new ARC controller has some feature not present in the old one. So a minor upgrade must be performed to the GUI IDL software to add these functionalities.

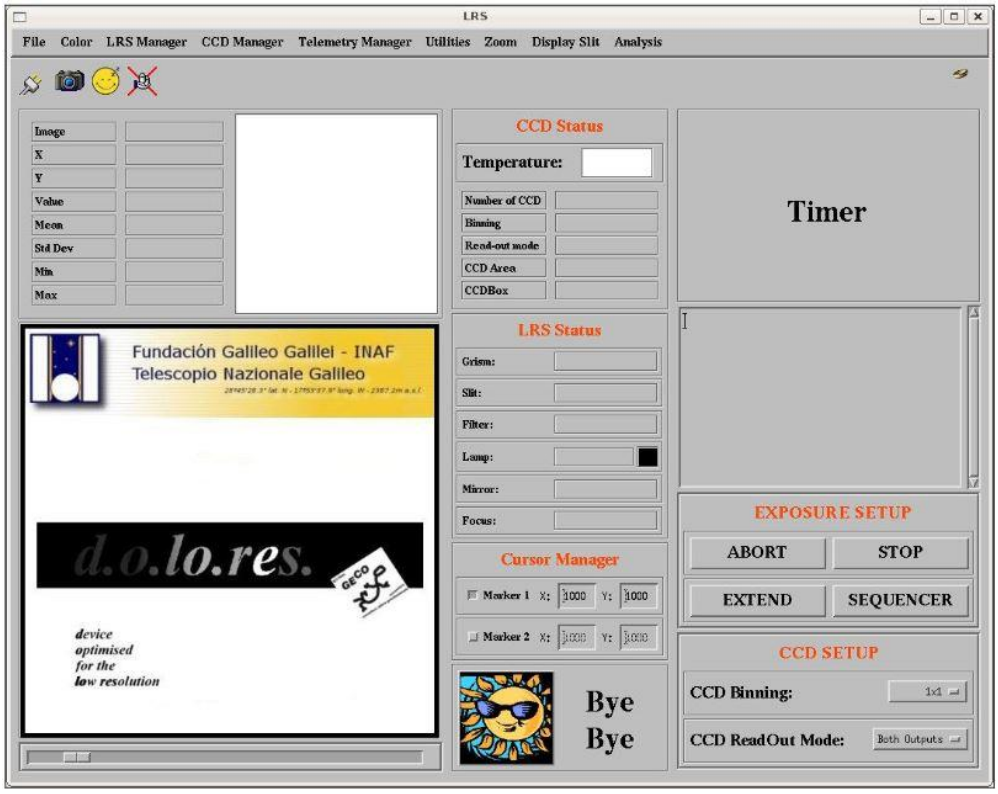

Figure 10 - LRS User Interface

The features and commands of the GUI has to be the same, but the implementation changes due to the different acquisition system.

4.5.1 Startup

The startup procedure resets and test the hardware, charges the ASM code and enables the CCD voltages. The complete sequence to startup the acquisition system is described in §2.1.6.1.

4.5.2 General Settings

The following settings of the system has to be adapted in the GUI:

- CCD SETUP
  - CCD read Out Mode → Set RD Mode
  - CCD Binning → Set Binning
  - Read Out Speed → Set RD Speed (new command)
- Exposure SETUP
  - ABORT → (stop the acquisition - no image saved)
  - STOP →see Figure 1 (stop the acquisition - save the image)
  - EXTEND → see Figure 1 (changes the exposure time while is exposing)
  - PAUSE → see Figure 1 (pause the exposure)
  - RESUME → see Figure 1 (resume the exposure)

- NEW Options (to be added to the GUI)
  - Flag to enable/disable the wipe of the CCD (Idle toggle)
  - Set the delay (to add in the interface or in the configuration file)
  - Add a sequence of wipe before each exposure (TBD)
  - More features TBD

4.5.3 The sequencer

In the sequencer are set a list of acquisitions that are executed in succession. For each acquisition the GUI send a list of commands that configure the instrument (moveable axes and CCD controller) and start the acquisition.
The Current parameters/modes are:

- **Expo Type**
  Bias → exposure with the shutter closed and Exptime =0
  Dark → Exposure with the shutter closed and exptime = Exptime
  Calibration and scientific exposure → Shutter open and exptime = Exptime
- **Cycle** → set multi exp (Table 2)
- **Exptime** → Set exp time (Table 2)
- **Xdown, XUp, Xdown, Yup** → Set Sub Array (Table 2)

More option can be added in the sequencer (TBD).

Figure 11 - LRS Sequencer

4.5.4 Keyword in the fits file (technical):

The list of technical keywords has to be discussed in detail with the software developed and with the Instrument responsible.

- Exposure time
- Readout mode
- Readout speed
- Binning X
- Binning Y
- EL Gain (Electronic Gain)
- CCD Gain
- More keywords TBD

Appendix A – List of acronyms

API	Application Programming Interface
ARC	Astronomical Research Cameras
ASM	Assembler
CCD	Charge Coupled Device
DSP	Digital Signal Processor
FITS	Flexible Image Transport System
GUI	Graphical User Interface
HW	Hardware
IDL	Interactive Data Language
LRS	Low resolution Software (Dolores)
PCI	Peripheral Component Interconnect
PCI	Personal Computer
SW	Software
TBD	To Be Decided
TCS	Telescope Control System
TNG	Telescopio Nazionale Galileo