

BTFI Software System Requirements

Version 1.0

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1 – Introduction

1.1 – Purpose of this document

This document defines the operational requirements for the BTFI Instrument Control System. The purpose is to inform and help developers and engineers to trace all the requirements, and to accompany and refine software development to agree with the science requirements. It shows specific functional requirements for the software system of the instrument.

1.2 – Scope

The document will be oriented mainly to developers and engineers of the control system. The impact of the science requirements, as well the requirements of the detector operation and control will be covered in this document as well.

1.3 – Applicable Documents

Report “The Brazilian Tunable Filter Imager for SOAR” to FAPESP

BTFI_11.01_Requirements_v01 - BTFI Instrument Requirements and Specifications

BTFI_80_Functional_REQ_v01 – BTFI Control System Software Functional Requirements

BTFI_80_Description_ICS_v01 – BTFI Control System Conceptual Description

1.4 – Abbreviations and Acronyms

This document employs several abbreviations and acronyms to refer concisely to an item, after it has been introduced. The following list is aimed to help the reader in recalling the meaning of each short expression:

API	Application Programming Interface
ICS	Instrument Control System
BTFI	Brazilian Tunable Filter Imager
F-P	Fabry-Perot
FITS	Flexible Image Transport Format
GUI	Graphical User Interface
iBTF	imaging Bragg Tunable Filter
OCS	Observatory Control System
PSF	Point Spread Function
SCL	SOAR Communications Library

SDSU	San Diego State University
SOAR	Southern Astrophysical Research Telescope
TCS	Telescope Control System
VPHG	Volume Phase Holographic Grating

1.5 – Brief overview

The software system is responsible for the control of the overall components of the instrument, such as movable parts, optics and detectors. It can communicate with the TCS as well, consequently, the instrument can be operated remotely via Internet connection.

In the development of the software, we will use three types of software:

- Developed software – main parts of the control system will fall in this type of software, and it is software specifically developed for the instrument. It also includes the software embedded into hardware, such as in the controllers.
- Open-source software – some parts of the control system will use a set of open-source tools, such as VNC (for remote connection).
- External software – any type available that is not exclusively for this system and can be found elsewhere, such as data reduction tools, operating systems, etc.

2 – General Description

2.1 – System Users

The users of the BTFI ICS can be classified in the following categories:

- Observer – This person, an astronomer, will be responsible for the observation, to observe an object and make data cubes of it.
- Telescope Operator – Is the on-site controller of the instrument. Will be responsible to ensure that all systems of the instrument are running properly and accurately. The operator works with the observer to make that the observations are good as possible.
- Technician – A person that is responsible for the maintenance of the system and subsystems, and also to verify all the connections of the system to the TCS.
- Engineer – This person will be responsible for the hardware of the system and also can make the same things that the technician, such as maintenance.
- Developer – Responsible for the design, test, configuration and upgrade of the software system.

2.2 – Levels of operation

The BTFI instrument can run in the following operational levels:

- Observation level – This operation is that when the instrument is running a observation. In other words, is the standard level.
- Maintenance and Engineering level – This mode permits low-level access to the system, to make diagnostics and maintenance, such as low-level commands to the detector controller (for adjust of bias voltage, DSP codes, etc).
- Testing level – This level are the lowest level of operation, to install and deinstall of subsystems, change of the gratings, and includes deep diagnostics and calibration of the optics.

2.3 – Operations mode

The ICS should imposes to the system, according with the user, a set of privileges that user can have access. The purpose of the user privileges is to avoid accidental changes by the observer that may compromise the operation of the instrument and to keep only the necessary in the graphical interface for each type of user. So, the ICS software imposes specific operation mode. The available modes are:

- Observation mode: This mode provides all the necessary parameters for the instrument and have a quick look on the data. In this mode, the observer is not allowed to set any type of low-level commands (this task is for technicians and engineers), ensuring a safe operation and access to the system.
- Monitoring mode: This mode is a special case of the observation, to verify a current observation.
- Operation mode: This mode is for direct control of the instrument, generally during the observation mode. This mode is only for the telescope operator.
- Test mode: This mode provides full and direct control of all the parts of the instrument system. Normally is restricted for technicians and engineers.

2.4 – User-level requirements

Table 1: User-level requirements

Type of user	Level of operation	Operation mode	Graphical Interface
Astronomer (Observer)	Observation	Observation / Monitoring	The most simplest possible and easy to handle, but with all the necessary for the observation
Telescope operator	Observation, Maintenance	Observation, Monitoring,	Controls easy to handle and

	and Testing	Operation and Test	quick access to important commands if the system enters in unusual conditions and monitoring of the subsystems.
Technician	Maintenance and Test	Monitoring, Operation and Test	Easy access to overall system
Engineer	Maintenance and Test	Monitoring, Operation and Test	Easy access to overall system
Developer	Maintenance and Test	Monitoring and Test	In tests, easy access to sub-system under test.

2.5 – Observing modes requirements

The ICS shall provide to the users as many observations mode as possible. Generally, for the SOAR's instruments, the user can have access to the instrument on in-situ mode, queue-based or remote operation.

- In-situ mode: Direct operation of the instrument on the site of the telescope.
- Queue-based: The observer submits a observation to be sent to a queue of observation. This type of observation must be the most automated possible. The SOAR team is responsible for provide the necessary tools for it (Observation Queue in the OCS).
- Remote operation: The observer can handle the instrument via a Internet connection, through sockets and TCP/IP protocol.

3 – General requirements

3.1 – Control System specifications

We need to project a good and robust control system to ensure the maximum performance and operation of the instrument. The ArcVIEW system, designed by CTIO, SOAR and Imaginetics, can fill some requirements of the instrument. Initially designed to handle with detector's controllers, later was extended to control any type of hardware, adding the necessary module without affecting the other parts of the system.

3.1.1 – A brief explanation about ArcVIEW

The package ArcVIEW is written in LabView. All user controls are implemented by a graphical user interface (GUI).

It works in a client-server scheme. A server should be available to receive requests from the connected client (the main GUI) to execute actions. After the end of an action, the server sends a response to the client or reports any error, if one occurred.

The server is responsible to load and call the selected modules for performing any requested command. The current action is performed for some specific module, and this module is the only one which knows the details of the process or the systems that it is handling. For example, if a command arrives, such as EXPOSURE, which is a controller command, the server will call the specific module referring to the controller (for example, the SDSU module). The module knows how to send the command to the controller because it knows the driver and the C libraries which communicate with this controller hardware.

When the action is finished, the server receives a response from the module and forwards it to the client GUI who requested the action.

This architecture allows the easy creation of modules to control specific hardware. If more controllers are needed, it is just a matter of adding a new specific module for that hardware, and other parts of the system are not affected.

The client will be the main GUI of the BTFI ICS and there will also be other auxiliary GUIs (like plug-ins). The buttons and options in the GUI will be transformed into ASCII commands and sent through a socket to the server.

3.1.2 – Modules specifications

In the ArcVIEW, the modules will be responsible for every action to be made on the instrument. The ArcVIEW modules are:

- Communications Module;
- Camera Controller Module;
- Fabry-Perot Controller Module;
- iBTF Module;
- General Purpose Modules;
- Utility Modules.

Table 2: Summary of control system requirements

Requirement ID	Requirement	Description
REQ-80.01	A package to the control system software	ArcVIEW will be used. We will optimize the code and code the necessary modules.
REQ-82.01	A manager and router of commands (server)	The ArcVIEW server will provide the required functionality. It will handle all the incoming commands and forwards them to the correct module. Also sends the received responses to the client.
REQ-83.01	General Purpose and Utility modules	The General Purpose Modules have general functionality and the Utility are modules that make specialized functions (such as data processing)

REQ-84.01	Hardware Modules	ArcVIEW Modules that controls specific hardware (camera controller, FP, etc)
REQ-85.01	A client interface	ArcVIEW will provide the necessary to design a client connection within a graphical interface.

3.2 – Data specifications

The result of a observation on BTFI instrument is a data cube, in high resolution quality. The data must be acquired and stored in the best way. The link which will transfers data from detector link to the data computer must be fast as possible to avoid bottlenecks.

The result of a exposure will be a raw data and stored for quick look and after, the data must be preprocessed in a transport format.

The transport format for the data cube will be in a FITS format. On the FITS header of the data cube, will be written many important parameters such as time and data of the frame, a time tag for each event, name of the object, the current detector's temperature, the scanning wavelength, object's coordinates, etc.

Table 3: Summary of data requirements

Requirement ID	Requirement	Description
REQ-87.01	Data cube in FITS format	The FITS is a robust format that can fill the requirements of the data cube
REQ-87.02	FITS Headers	The header must be the most complete possible, with the principal parameters of the observation, such as coordinates x, y and time tag of the event in each frame, scanning wavelength, name of the object, etc.
REQ-86.01	Real Time Quick look	During the observation, the ICS must show the option to show or not show in real-time the acquisition of data cube

3.3 – Communications specifications

The BTFI ICS needs to communicate with TCS for a proper control and also needs a good stable connection with the subsystems and with the data reduction module.

The SOAR telescope already has a infrastructure for communications, with Fast Ethernet, connecting all the systems and subsystems of the telescope (telescope control, guiding, focus, environmental control, dome control and mount control). These systems are based in Labview and the instruments systems make large use of Arcview for the control of their detectors and other parts. A

fundamental software requirement for BTFI ICS is to be able to interface to these existing systems, mainly to the TCS.

Table 4: Summary of communications requirements

Requirement ID	Requirement	Description
REQ-83.02	Communication Protocol	A ArcVIEW module will provide the protocol (TCP/IP) and tools for the client, server and modules communicate with other parts of the system

4 – Commands

4.1 – Routing and structure

The ArcVIEW Server will process the commands through tcp/ip sockets and forward it to the correct module which will handles it. In the client graphical interface, don't exist any command that can be send directly to a module. Every command should pass by the server.

The commands have the following structure:

Command [parameters]

Where command is a unique command of a specific module and the parameters are handled by this module. Command may represent too a internal command to the server, which will handle it, in some cases.

The server accepts commands via a queue because it process only a command by time. It don't process two or more commands at the same time.

4.2 – General Purpose Commands

When the ICS is loaded, it must perform the following actions before the observation starts:

- Initialize the instrument, so needs performs a init command
- Position of the telescope, to guide to the target
- Basic configuration of the instrument (detectors, FP, iBTF, controllers voltage, etc)
- Wait for these operations above to complete
- Start acquiring the observational data

Table 5: Summary of basic commands requirements

Requirement ID	Requirement	Description
REQ-82.02	Basic and general commands for the instrument	The ArcVIEW server has these general commands (init, get status, set [configuration], etc)

5 – Specific requirements

5.1 – L3CCD modes of operation

In the graphical interface, it is needed to show to the observer the possible L3CCD modes of operation. The L3CCD detector can run in these modes:

- Unity Gain Mode: The L3CCD operates as a classical CCD, with the gain is set to unity. In general a slow readout is required (300KPix/second) to obtain low read noise (4 electrons would be typical).
- High Gain Mode: The gain is set to a high value to make noise in the readout amplifier of the CCD negligible.
- Photon Counting Mode: Gain is again set high but the video waveform is passed through a comparator. Each trigger of the comparator is then treated as a single photo-electron of equal weight. Multiplication noise is thus eliminated. Risk of coincidence losses at higher illumination levels.

The parameters that are common to all the modes are the following:

- total time of exposure;
- scanning wavelength;
- number of channels (z-frames);
- frame rate;
- binning;
- others (name of the image, description, comment, path image, observer, etc).

And the necessary parameters for each mode are described in Table 6. Note that don't appears nothing for the gain unity mode, because is enough for this mode the parameters described above.

Table 6: Summary of parameters of L3CCD modes operation

Mode	Parameter	Description and Comments
High Gain	gain	The user can adjust the gain, and in the “background”, the

		program will calculate the corresponding value of the high voltage clock for the controller
Photon Counting	gain	Same as above
	threshold	The user can adjust the threshold value which determines a photon event above or equal to this value.

5.2 – Graphical Interface during a Observation

When the observer makes a observation, he needs that in the graphical interface appears all the important informations regarding to the observation. The Table 7 lists the most important informations in the GUI for the observer.

Table 7: Summary of observer graphical interface requirements

Requirement ID	Requirement	Description
REQ-85.03	status information	shows: <ul style="list-style-type: none"> - the status of the detector; - the status of the connection to the server; - the current L3CCD mode operation; - the parameters entered for the current data cube; - coordinates: the coordinates will come from the TCS (right ascension, UTC, airmass, etc); - progress of exposure, readout and writer; - temperature and pressure.
REQ-85.04	operations	<ul style="list-style-type: none"> - selection of the L3CCD mode operation; - picture parameters; - take exposure; - stop exposure and save; - stop exposure and discard;

5.3 – Others Graphical Interfaces

In the ICS, will be available other interfaces, for the technical staff (telescope operator, technician, engineer and developer). Table 8 shows it.

Table 8: Summary of other graphical interfaces requirements

Requirement ID	Requirement	Description
REQ-85.05	Engineering Graphical Interface	This interface should show: <ul style="list-style-type: none"> - Current Setup: current setup information (location of the temperature sensors, number and location of detectors, positioning of the Fabry-Perot etalon and angle of VPH) - View Log file of everything happening on the instrument - Readings from temperature sensors in the cameras - A field to enter low level commands