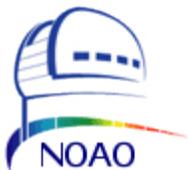


# Real-Time Software User's Manual

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## SOAR Adaptive Module (SAM)

Revision 1.9, May 2011



# Contents

## Getting Things Running

1.1 Hardware Setup.....	1
1.2 Starting the Real-Time Software.....	1
1.3 Stopping the Real-Time Software.....	2
1.4 Recovering from a VNC crush.....	2

## GUI Reference

2.1 MAIN>Operation Tab.....	4
2.1.1 MAIN>Operation>AOLoop Window.....	6
MAIN>AOLoop>File Menu.....	6
MAIN>AOLoop>Tools Menu.....	6
MAIN>AOLoop>Graphs Menu.....	7
MAIN>AOLoop>Loop Control Tab.....	7
MAIN>AOLoop>Interaction Matrix Tab.....	7
MAIN>AOLoop>Reconstructor Matrix Tab.....	8
MAIN>AOLoop>Reconstruction Error Tab.....	8
2.1.2 MAIN>Operation>WFS Window.....	8
MAIN>WFS>File Menu.....	8
MAIN>WFS>Tools Menu.....	9
MAIN>WFS>Graphs Menu.....	9
MAIN>WFS>WFS Configuration Tab.....	10
MAIN>WFS>Modal Estimation Tab.....	10
MAIN>WFS>Pockels Cell Tab.....	10
2.1.3 MAIN>Operation>WFS>Display Window.....	10
2.1.4 MAIN>Operation>TTLoop Window.....	11
MAIN>TTLoop>File Menu.....	11
MAIN>TTLoop>Tools Menu.....	11
MAIN>TTLoop>Graphs Menu.....	12
MAIN>TTLoop>Loop Control Tab.....	12
2.1.5 MAIN>Operation>DM Window.....	12
MAIN>DM>Voltages Tab.....	12
MAIN>DM>Graph Tab.....	13
2.2 MAIN>Historical Tab.....	13
2.3 MAIN>Maintenance Tab.....	13
2.4 MAIN>Comm-Server Tab.....	14
2.5 MAIN>Comm-Client Tab.....	14

## Common Operations

3.1 Calibrating the Wavefront Sensor.....	15
3.2 Obtaining the Reconstructor Matrix $H^*$ .....	15
3.3 Saving AO Loop Data Sequences.....	16
3.4 Examining the AO Loop Performance.....	16

3.5 Poking the DM Electrodes.....	17
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## Configuration Files and Macros

4.1 Configuration Files.....	19
4.1.1 rtsoft.cfg – real-time software parameters.....	20
4.1.2 camera.cfg – WFS CCD controller parameters.....	20
4.1.3 flattendm.cfg – voltage values to make de DM flat.....	21
4.1.4 positions.ini – WFS geometry and reference spot positions.....	21
4.1.5 positions_bgnd.ini – background subtraction box definitions.....	21
4.1.6 zstatic.ini – static aberrations.....	22
4.1.7 zlabel.ini – zernike mode label file.....	22
4.1.8 eltrdmap.ini – electrodes look up table.....	22
4.1.9 apdmap.ini – APD look up table.....	23
4.1.10 apdbias.ini – APD biases.....	23
4.1.11 soar_comms.ini – SOAR communicaton library parameters.....	23
4.1.12 faults.ini - faults definitions.....	23
4.2 Macros.....	24
4.3 FITS files.....	26
4.3.1 bim.fits.....	26
4.3.2 cmat.fits – Noll covariance matrix.....	26
4.3.3 imat.fits.....	26
4.3.4 rmat.fits and nas_rmat.fits.....	26
4.3.5 wfsbias.fits.....	26
4.3.6 mask.fits.....	27
badpix.fits.....	27
amps.fits.....	27
4.3.7 weight.fits, xgrid.fits, ygrid.fits.....	27

## Simulator Modes

5.1 Simulation at user space level.....	29
5.2 Simulation at kernel space level.....	29
5.3 Simulation Parameters.....	30
5.3.1 User defined pattern.....	30
5.3.2 5.3.2 FITS file.....	30
5.3.3 Zernike Modes.....	30
5.3.4 Kolmogorov.....	30

## Log Files

6.1 Type Alarm Events.....	31
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## Glossary

# Chapter 1: Getting Things Running

This user manual is intended to describe the use of the Real-Time Software (RTSOFT) from a user's point of view. It is not a programming manual. For implementation details please read the Real-Time Software Programmer Manual (RTSPM).

## 1.1 Hardware Setup

Before firing up the RTSOFT, and with the real-time computer turned off, there is a list of hardware that has to be powered up:

- a) Turn on the CCD controller power supply. Real-Time computer should be turned off at this time!
- b) Turn on the Peltier cooler power supply.
- c) Turn on the water pump.
- d) Turn on the high voltage amplifier of the DM.
- e) Turn on the PXI chassis. Real-Time computer should be turned off at this time!

**IMPORTANT:** The real-time computer should be turned off when powering up the CCD controller and the PXI chassis. This assures correct detection of the devices by their interface boards in the real-time computer.

## 1.2 Starting the Real-Time Software

Before you start the real-time software, make sure that all items in the checklist above were checked. It is very important to check the above list in order for the boot process to succeed.

- a) Turn on the real-time computer and wait for the system to boot.
- b) Start a VNC session connected to the real-time computer or alternatively log on as user **ao** and fire up the X windows system.
- c) Press the SAM RTC button in the toolbar or alternatively open a shell window and invoke the real-time software application with the following command:

```
% cd /home/ao/RTsoft  
% labview RTsoft.vi -- [ options]
```

Normally, you will invoke RTSOFT with no options. Options are reserved in case part of the hardware is not present and is wanted to be simulated by software. Valid option values are listed below:

- c No camera controller hardware is present.
- d No deformable mirror hardware is present.
- r Real-Time Core module not installed.

- tcs No connection to the TCS server
- lm No connection to the Laser Module server.

### 1.3 Stopping the Real-Time Software

To stop the RTSOFT application click the **EXIT** button. A dialog box will prompt for confirmation. Press YES.

### 1.4 Recovering from a VNC crush

If the VNC connection to the RTC is lost there are ways to recover:

1. Check first if it's only a VNC problem and not a system crush by pinging the machine.
2. If the machine is not responding, reboot the RTC and proceed as described in section 1.2 above.
3. If the machine is alive, ssh to the machine and type the following command to restart the VNC server

```
% bin/startvnc
```

4. Proceed as described in section 1.2 above paragraph c.

## Chapter 2: GUI Reference

When the application starts the user is presented with a single window containing the most relevant system status variables (Figure 2.1). If the boot process ended with no failures then the operational state is signaled and the application is ready to receive commands.

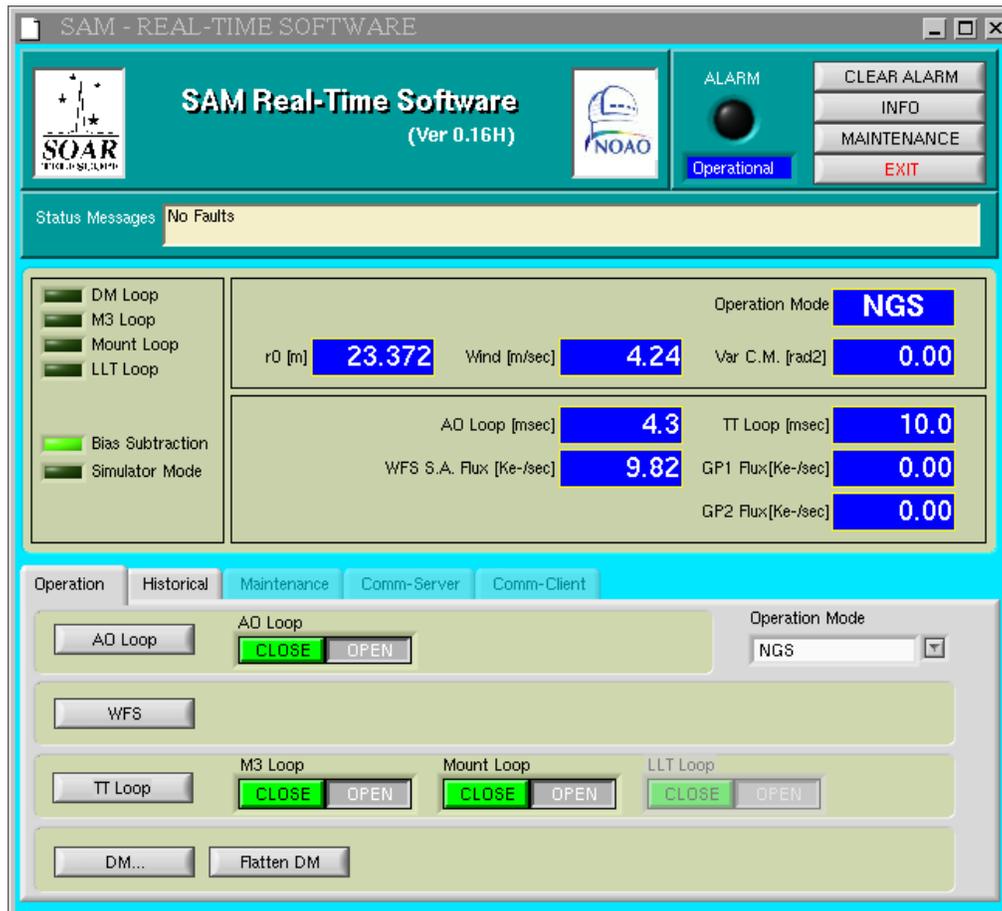


Figure 2.1: Main GUI. The most relevant status variables are displayed.

The application works in one of two levels of security: *user mode* and *maintenance mode*. In user mode a single pane is accessible to the operator and only safe operations are allowed. Under maintenance mode three more panes are available giving access to more advanced and risky features.

**CLEAR ALARM.** Allows the user to turn the alarm condition off.

**INFO.** Opens the info window with current configuration values.

**MAINTENANCE.** Prompts the user for a password to enter maintenance mode.

**EXIT.** Terminates the application.

**DM Loop.** Indicates whether the AO control loop is open or closed.

**M3 Loop.** Indicates whether the M3 control loop is open or closed.

**Mount Loop.** Indicates whether the Mount control loop is open or closed.

**LLT Loop.** Indicates whether the LLT loop is active or not. Available under LGS mode only.

**TT Loop.** Indicates whether the tip tilt loop is active or not. Available under LGS and NGS modes.

**Bias Subtraction.** Indicates that frame bias subtraction is active.

**Simulator Mode.** Indicates whether a simulator mode is active or not. See section 5 below for details on how the simulator modes work.

**Operation Mode.** Indicates what operation mode is active: TURSIM, NGS, TSLGS or LGS.

**r0 [m].** Seeing estimate.

**Wind [m/s].** Wind speed estimate.

**VAR C.M.[rad<sup>2</sup>].** Variance of the corrected modes in [rad<sup>2</sup>].

**AO Loop [ms].** Average AO loop period.

**WFS Flux [Ke-/s].** Wavefront sensor stellar flux in Kilo-photons per second per sub-aperture

**TT Loop [ms].** Average TT loop period in [ms].

**GP1 Flux [Ke-/s].** Guide probe 1 stellar flux in Kilo-photons per second.

**GP2 Flux [Ke-/s].** Guide probe 2 stellar flux in Kilo-photons per second.

## 2.1 MAIN>Operation Tab

The operation tab is the only pane that the operator will use under normal operation. Four lowered rounded boxes group the controls and indicators by functionality.

**AO Loop...** Opens the *AO Loop Control Window*. Read section 2.1.1 below.

**DM Loop.** Open/Close the DM control loop.

**Operation Mode.** List box to select the current operation mode:

**TSNGS.** TurSim natural guide star mode.

**NGS.** Natural guide star mode.

**TSLGS.** TurSim laser guide star mode

**LGS.** Laser guide star mode.

**WFS...** Opens the *WFS Control* and *WFS Display* windows. Read sections 2.1.2 and 2.1.3 below.

**TT Loop...** Opens the *TT Loop Control Window*. Read section 2.1.4 below.

**M3 Loop.** Open/Close the M3 control loop.

**Mount Loop.** Open/Close the Mount control loop.

**LLT Loop.** Open/Close the LLT control loop.

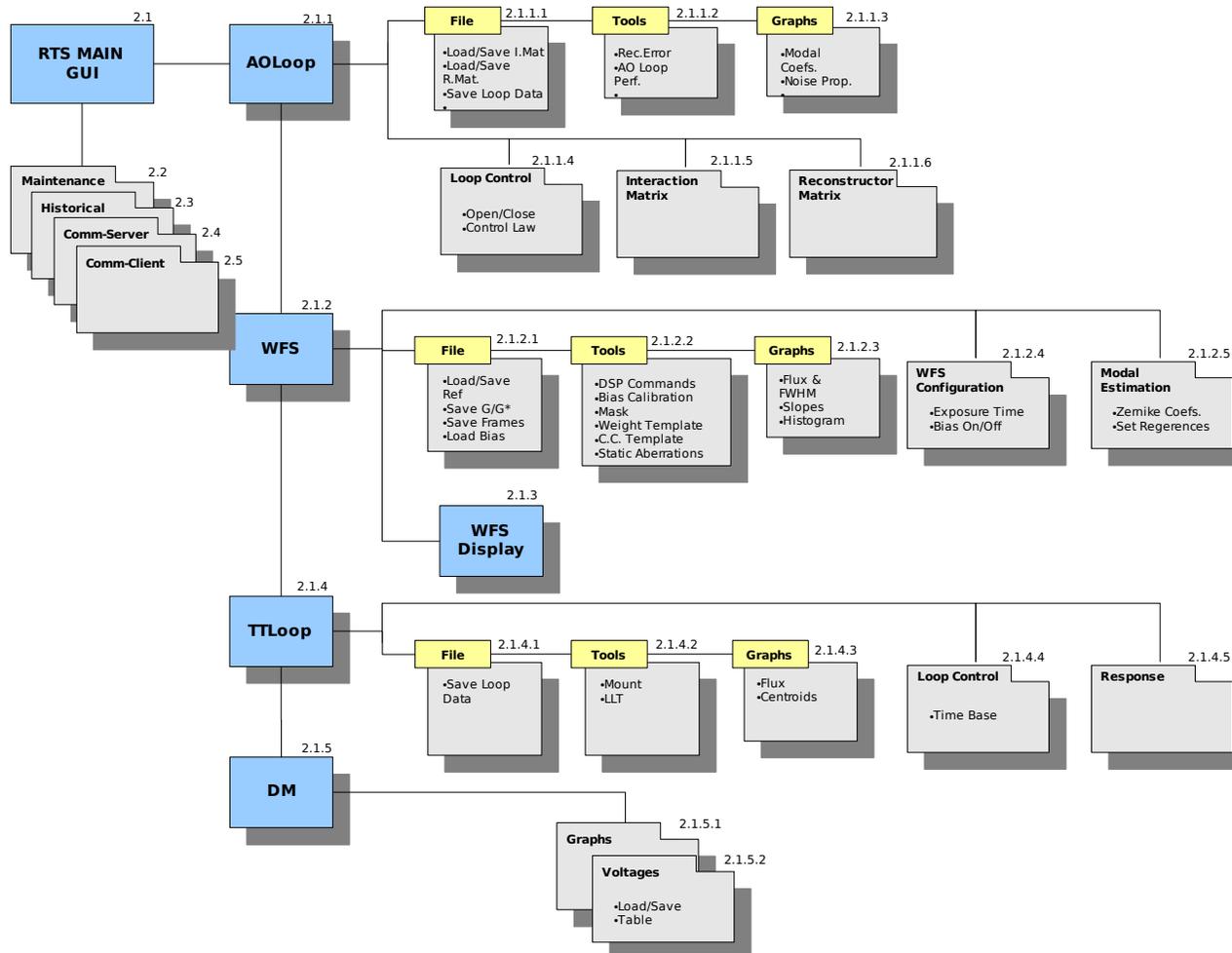


Figure 2.2: User Interface Navigation Map

**DM...** Opens the *DM Window*. Read section 2.1.5 below.

**STATIC FLAT.** Loads and applies the voltages stored in the file *flattendm.cfg* to the DM.

**ROT FLAT.** Loads and applies the voltages stored in the file *flattendm.cfg* including a correction factor based on the current rotator angle.

## 2.1.1 MAIN>Operation>AOLoop Window

### 2.1.1.1 MAIN>AOLoop>File Menu

**Load Interaction Matrix.** Allows for loading a previously saved interaction matrix. The matrix to load is expected to be in standard FITS file format.

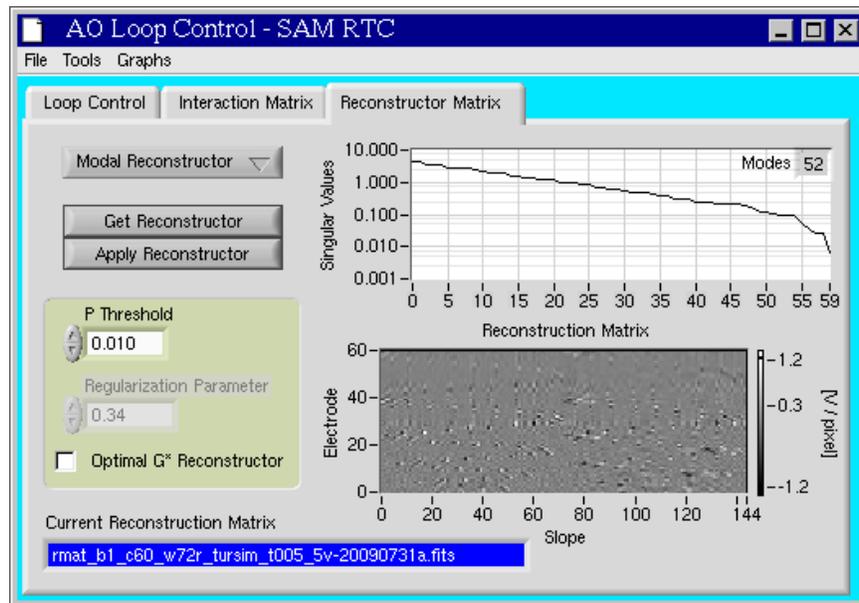


Figure 2.3: Loop Control GUI. This window is used to obtain reconstructor matrix.

**Save Interaction Matrix.** Allows for saving the current interaction matrix. The matrix is saved in standard FITS file format as *imat.fits* and *imat-<current date>.fits*

**Load Reconstructor Matrix.** Load FITS file containing reconstructor matrix definition. The matrix is loaded into memory only.

**Save Reconstructor Matrix.** Save the current reconstructor matrix to disk in FITS file format in the *RTsoft/ConfigFiles/* directory.

**Save Loop Data Sequence.** Save real-time sequences of slopes and voltages to disk. Read section 3.3 below.

### 2.1.1.2 MAIN>AOLoop>Tools Menu

**Reconstruction Error Analysis.** Chart presenting the reconstruction error and effective

compensation order for the currently applied reconstructor<sup>1</sup>.

**AO Loop Performance.** Window presenting the user with atmospheric and loop performance estimates and graphs. This window is intended to be used as diagnostic tool to study AO loop compensation of the atmospheric disturbances. Read section 3.4 for more details on how to use this tool.

#### 2.1.1.3 MAIN>AOLoop>Graphs Menu

**Modal Coefficients Charts.** Set of charts presenting real-time sequences of slopes and modal coefficients.

**Noise Propagation Coefficients.** Graph presenting the noise propagation coefficients for the current reconstructor matrix.

#### 2.1.1.4 MAIN>AOLoop>Loop Control Tab

**AO Loop.** Open close the AO loop control.

**Tilt Subtraction.** Indicator showing if tilt component subtraction from residual measurements is active.

**Operation Mode.** Indicates what operation mode is active: TURSIM, NGS, TSNGS or LGS.

**Loop Time.** Average AO loop period in [ms].

**r0 [m].** Seeing estimate.

**Wind [m/s].** Wind speed estimate.

**Time Constant.**

**VAR C.M.[rad<sup>2</sup>].** Variance of the corrected modes in rad<sup>2</sup>.

**Control Law.** Allows the user to select between Smith predictor and pure integrator as the control law for the AO loop. Depending on selection the right parameter values are shown.

**K.** Pure integrator and Smith predictor gain.

**KL.** Leaky constant.

**KS.** Smith predictor constant. Visible only when SP control law has been selected.

**AO Loop.** Open/Close the DM control loop.

#### 2.1.1.5 MAIN>AOLoop>Interaction Matrix Tab

**Get Interaction Matrix.** Pops up the “Interaction Matrix Measurement” window. Read section 3.2 below.

**Mid Voltage [V].** Mid range voltage value. This value is typically 0 as defined in the *rtsoft.cfg*

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<sup>1</sup> Detailed information on this analysis can be found in document SDN1107 and in the RTSPM.

configuration file (see section 4.1.1 below).

**SD to Average.** Number of slope values to average when measuring the interaction matrix as defined in the *rtsoft.cfg* configuration file (see section 4.1.1 below).

**Current Interaction Matrix Graph.** Gray level intensity graph presenting the current interaction matrix in units of [pixel/V].

#### 2.1.1.6 MAIN>AOLoop>Reconstructor Matrix Tab

**Modal/SVD Reconstructor.** Select the type of reconstructor to produce. Upon selecting each option, appropriate controls are shown.

**P Threshold.** Threshold in the SVD inversion of the P matrix. This parameters is visible only if type Modal Reconstructor has been selected.

**Regularization Parameter.** This is the alpha parameter for the optimized reconstructor<sup>2</sup>. Set this parameter to the desired value before obtaining a reconstructor matrix (see section 3.2 below). This parameters is visible only if type Modal Reconstructor has been selected.

**Optimal G\* Reconstructor.** Select this check box to use the optimal G\* when calculating H\*. Selecting this box enables the Regularization Parameter. This parameters is visible only if type Modal Reconstructor has been selected.

**H Threshold.** Threshold when doing the SVD inversion of H. This parameters is visible only if type SVD Reconstructor has been selected.

**Get Reconstructor.** Calculates the H\* matrix out of the P and G matrices. If optimal G\* reconstructor check box is selected, then the optimal G\* matrix is used when obtaining H\*.

**Apply Reconstructor.** Apply the reconstructor matrix to the RTCORE. If a reconstructor matrix has been loaded and not applied, this button will blink.

**Current Reconstructor Matrix.** Name of the currently loaded matrix. If a reconstructor matrix has been just produced the indicator is set to “Not Saved”.

#### 2.1.1.7 MAIN>AOLoop>Reconstruction Error Tab

**Reconstruction Error Analysis.** Chart presenting the reconstruction error and effective compensation order for the currently applied reconstructor<sup>3</sup>.

### 2.1.2 MAIN>Operation>WFS Window

#### 2.1.2.1 MAIN>WFS>File Menu

**Load Reference Positions File.** Loads the reference spots positions from disk and then apply them to the RTCORE (see section 4.1.4 below).

**Save Reference Positions File.** Save the WFS geometry to disk.

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<sup>2</sup> Details on this parameter in SDN1113.

<sup>3</sup> Detailed information on this analysis can be found in document SDN1107 and in the RTSPM.

**Save Gradient Matrix.** Save the current gradient matrix G to disk in FITS file format. The matrix is non dimensional (e.g. gradient is 2 for tip tilt). The matrix is calculated when the real-time software first run and its value depends on the WFS geometry definition and the max number of modes selected.

**Save Inverse Gradient Matrix.** Save the current inverse gradient matrix G to disk in FITS file format. The matrix is non dimensional.

**Save Zernike Coefficients.** Allows the user to save the current Zernike coefficients estimation.

**Save Frames.** Allows the user to save single CCD frames in FITS format or frame sequences in raw format (unsigned integer 16 bit long).

**Load Bias (1x1).** Allows the user to load a FITS file containing a bias reference frame. When Bias subtraction is turned on the frame will be subtracted pixel to pixel before running the centroiding algorithm.

### 2.1.2.2 MAIN>WFS>Tools Menu

**DSP Commands.** Allows the use to send direct commands to the CCD controller. Use at your own risk. Inappropriate use of this commands can cause the application to crash and the computer to hang.

**Bias Calibration.** Allows the user to take a bias reference frame, save it to disk and use it in the real-time centroid calculations. Once applied the bias calibration frame will be pixel-to-pixel subtracted from each sub-aperture prior to slope calculations. This frame is set as the default bias reference frame and loaded on boot time (see section 4.1.1 below).

**Mask.** Tool to create/customize the bit-wise frame mask used in centroid calculations. Each element is a 16 bit number with bit fields defining sub-aperture ID, amplifier, status (good or bad), and background. The information contained in this mask is used when doing centroid calculations. It is possible to set the default mask frame by editing the *rtsoft.cfg* file (see section 4.1.1 below).

**Weighted Centroid Mask.** Allows the user to define a weight template for the WCoG centroid method, out of a WFS geometry definition file, save it to disk and apply it to the RTCORE.

**Cross Correlation Template.** Allows the user to define the template used in the cross correlation centroid method.

**Static Aberrations.** Allows the user to add non-common path aberrations to the reference spot positions.

### 2.1.2.3 MAIN>WFS>Graphs Menu

**Flux & FWHM Monitor.** Set of charts presenting the flux, background and spot size for each sub-aperture.

**Slopes Statistics.** Set of charts presenting the x-y slope min/max/average and standard deviation for each sub-aperture.

**Histogram.** Snapshot presenting the current image histogram.

#### 2.1.2.4 MAIN>WFS>WFS Configuration Tab

**Bias Subtraction.** Turn on/off the bias subtraction. Normally this mode should be on. The default bias frame to use can be specified in the *rtsoft.cfg* configuration file (see section 4.1.1 below).

**Background Subtraction.** Turn on/off the background subtraction. Normally this mode should be on.

**Exposure Time.** Exposure time parameter for the CCD controller. Normally set to 0 [ms]. Under SAM readout mode, this time will be added to the readout time.

#### 2.1.2.5 MAIN>WFS>Modal Estimation Tab

**Zernike Coefficients.** Standard Zernike coefficients representing the estimate for the current wavefront aberrations.

**Residual Aberration.** Check this option to only present the Zernike coefficients for the residual aberrations versus the open loop aberrations.

**Set All References.** Use this button to measure the reference spot positions. The software will average several measurements and then apply the new reference positions to the RTCORE. See section 2.1.2.1 for saving the new reference positions.

#### 2.1.2.6 MAIN>WFS>Pockels Cell Tab

**ARM/DISARM.** Use this radio button to start producing the synchronization pulses that open and close the LGS WFS shutter.

**LGS/TSLGS.** Use this radio button to select between the LGS and TSLGS pulse generation mechanisms. LGS mode needs the LASER output trigger to be connected to the PXI chassis.

**Delay.** Under LGS mode is the time between the falling edge of the trigger pulse and the rising edge of the ON pulse to the shutter. This number is typically adjusted depending on the distance to the laser guide star.

**Separation.** Under LGS and TSLGS mode is the distance between the ON pulse rising edge and the OFF pulse rising edge to the shutter.

**Pulse Width.** Is the width of the ON and OFF pulses to the shutter. This is typically 200[ns].

**Period.** Is the period of the ON and OFF pulse train. This is typically 100[us].

#### 2.1.3 MAIN>Operation>WFS>Display Window

**Linear Auto-contrast** Select this option to use min/max values to map the full frame range to the full display range.

**Freeze Auto-contrast** Select this option to stop updating the frame statistics used to map the frame intensity range to the display range.

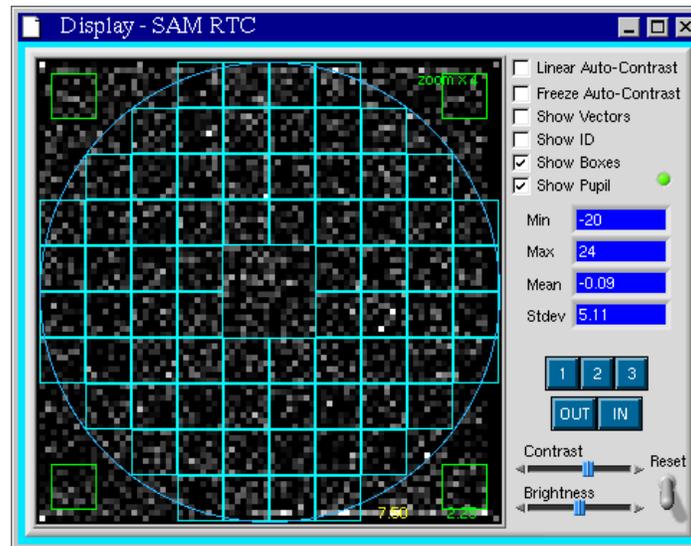


Figure 2.4: WFS Display. Each box represents the calculation grid for each sub-aperture.

**Show Vectors.** Draw small vectors representing the average slope value for each sub-aperture

**Show ID.** Draw the ID number for each sub-aperture

**Show Boxes.** Draw the calculation grid for each sub-aperture defining the WFS geometry as defined in the *positions.ini* file (see section 4.1.4).

**Show Pupil.** Draw a circle representing the pupil size and position as defined in the *rtsoft.cfg* file.

**Contrast.** Use the slider to adjust the display contrast.

**Brightness.** Use the slider to adjust the display brightness.

**Reset.** Reset the contrast and brightness to default values.

**Zoom.** Use the zoom buttons to zoom in and out.

## 2.1.4 MAIN>Operation>TTLoop Window

### 2.1.4.1 MAIN>TTLoop>File Menu

**Save Loop Data Sequence.** Save real-time sequences of tip tilt errors and M3 commands to disk.

### 2.1.4.2 MAIN>TTLoop>Tools Menu

**TT Loop Performance.** Window presenting the user with loop performance graphs. The window is intended to be used as a diagnostic tool to study the tip-tilt compensation.

**Mount Corrections.** Charts presenting the corrections sent to the mount servo.

**LLT Corrections.** Charts presenting the corrections sent to the LLT servo.

#### 2.1.4.3 MAIN>TTLoop>Graphs Menu

**Centroid Charts.** Charts presenting real-time sequences of tip tilt errors plus statistics.

**APD Flux Charts.** Two charts presenting sequences of average flux values for each APD module/channel.

**Bias Calibration Button.** Use the calibration button to calibrate the bias level for each APD channel. Is up to the user to make sure that the APD signal is adequate for such calibration.

#### 2.1.4.4 MAIN>TTLoop>Loop Control Tab

**M3 Loop Square LED.** Indicator showing the current state of the M3 control loop.

**LLT Loop Square LED.** Indicator showing the current state of the LLT control loop.

**Mount Loop Square LED.** Indicator showing the current state of the Mount control loop.

**APDs Bias Square LED.** Indicator showing the current state of the bias subtraction to the APD signal.

**Operation Mode String Indicator.** Current operation mode: TSNGS, NGS, TSLGS or LGS.

**Error Source String Indicator.** Current tilt error signal source: WFS or Probes.

**Loop Time Numeric Indicator.** Average tilt probes sampling period in [ms].

**Rotation Numeric Indicator.** Current rotator mechanical angle in degrees.

**M3 Elevation Numeric Indicator.** Current SOAR M3 elevation in units of [ADU]

**M3 Azimuth Numeric Indicator.** Current SOAR M3 azimuth in units of [ADU]

**KC1 Numeric Control.** Set the SOAR M3 controller gain.

**M3 Loop Push Button.** Open/Close the SOAR M3 control loop.

**Time base x 10ms Numeric Control.** The value entered multiplies the 5ms time base of the tip-tilt real-time task to change the photon count period.

**Lock GP1|GP2 Push Button.** Activate the use of the selected probe to close the SOAR M3 loop on its signal.

**KC2 Numeric Control.** Set the SOAR mount controller gain.

**Mount Loop.** Open/Close the SOAR mount control loop.

**KC3 Numeric Control.** Set the LLT M3 controller gain.

**LLT Loop Push Button.** Open/Close the LLT M3 control loop.

## 2.1.5 MAIN>Operation>DM Window

### 2.1.5.1 MAIN>DM>Voltages Tab

**ROT FLAT.** Load and apply the voltages stored in the file *flattendm.cfg* including a correction factor based on the current rotator angle.

**STATIC FLAT.** Load and apply the voltages stored in the file *flattendm.cfg* to the DM.

**REC FLAT.** Save the currently applied DM voltages to disk using the protected name *flattendm.cfg* and *flattendm-YYYYMMDDTHHMMSS.cfg*.

**Load Voltages.** Load predefined sets of voltages from disk to the *Loaded* voltages column in the *Voltages Table*.

**Save Voltages.** Save the currently applied DM voltages to disk.

**Reset To Value.** Set *Loaded* voltages column in the *Voltages Table* to a user defined value.

**Value.** User defined voltage.

**Apply Voltages.** Write *Loaded* voltages to the DM.

**delay.** Send voltages to DM with a delay of 1 second.

**Voltages Table.** Table displaying voltage data updated once a second. Each row corresponds to an actuator. Double click a row to open a pop-up window and load a new voltage value.

### 2.1.5.2 MAIN>DM>Graph Tab

The Graphs tab presents a typebar graph showing the voltage applied to each electrode. The values are normalized [1,1]. This typebar representation is useful to detect saturation.

## 2.2 MAIN>Historical Tab

From this pane it is possible to examine the last five system faults and to check the faults chart.

**Last Faults.** Last five faults encountered by the application.

**Faults.** List with all the defined fault conditions and their current state. See the section 4.1.12 below for customizing this list.

**REFRESH.** Allows the user to update the faults list on demand.

## 2.3 MAIN>Maintenance Tab

The Maintenance tab is only accessible after entering maintenance mode. From this pane it is possible to route direct commands to several software/hardware RTC modules and to have access to some low level functionality.

**Command.** Input box to enter string commands. For a complete list of the available string commands read the RTSPM.

**Response.** Reply to the last command sent to a software/hardware module.

**Send.** Write the command entered in the *Command* input box to a software/hardware module.

**Base Path.** Real-Time software root directory.

**Simulator Modes.** Cluster indicator showing active simulator modes.

**Simulator Engine.** Open the *rtsoft\_simulator\_engine.vi*. This VI holds parameters to create an artificial frame pattern, when the command line option *-c* has been selected. Read the RTSPM for details on how the simulator engine works.

**AO Loop Data.** Open the *rtsoft\_task\_loop\_data.vi*. This low level VI serves as a back door to troubleshoot the software. More details in the RTSPM.

**TT Loop Data.** Open the *rtsoft\_task\_tt\_loop\_data.vi*. This low level VI serves as a back door to troubleshoot the software. More details in the RTSPM.

**Frame Data.** Open the *rtsoft\_task\_frame\_data.vi*. This low level VI serves as a back door to troubleshoot the software. More details in the RTSPM.

**DONE.** Exits the maintenance mode. The Maintenance, Comm-Server and Comm-Client panes will be closed as well.

## 2.4 MAIN>Comm-Server Tab

The *Comm-Server* tab is only accessible after entering maintenance mode (MAINTENANCE button) . From this pane it is possible to monitor the single connection provided by the RTSOFT.

**RTC Server Name.** Key identifying the peer to peer connection in the configuration file *soar\_comms.ini*.

**RTC Server Address.** IP address where the RTC computer listens for incoming connections. It must match the real-time computer IP address. The address is defined in the configuration file *soar\_comms.ini*.

**RTC Local Port.** Port at which the RTC computer listens for incoming connections. Defined in the configuration file *soar\_comms.ini*.

**Incoming Commands.** Queries and replies are showed here.

**CLEAR.** Clear the *Incoming Commands* list.

## 2.5 MAIN>Comm-Client Tab

The *Comm-Client* tab is only accessible after entering maintenance mode (MAINTENANCE button) . From this pane it is possible to monitor the two client connections provided by the RTSOFT: TCS and LM.

**TCS Manager.** Open the TCS manager task window. The window presents the messages going back and forth between the TCS and the RTSOFT.

**LM Manager.** Open the LM manager task window. The window presents the messages going back and forth between the Lase Module and the RTSOFT.

## Chapter 3: Common Operations

Most of the time the real-time software will be ready to use on startup because the loaded configuration files will set all typical operation parameters, (e.g. reference spot positions, reconstructor matrix, etc.). This section outlines some common procedures involved in changing or redefining those parameters when needed.

### 3.1 Calibrating the Wavefront Sensor

Calibrating the WFS involves three major steps: setting the exposure time, taking a bias reference and setting the reference spot positions.

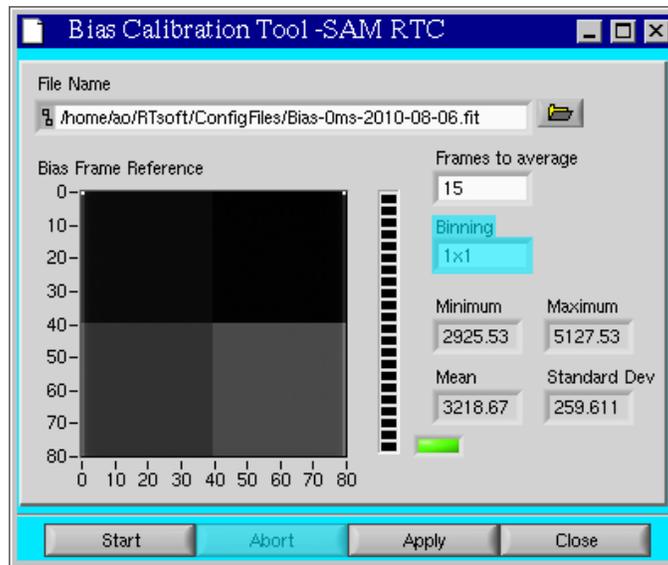


Figure 3.1: Bias Calibration Tool

To set the exposure time open the WFS GUI in the *Control* tab and enter a exposure time value. Normally this value will be set to 0 [ms]. Then take a bias reference frame using the *Bias Calibration* tool (Main>WFS>Tools>Bias Calibration, Figure 3.1). Finally set the reference spot positions. Select the *Modal Estimation* tab in the WFS GUI (Main>WFS) and press the *Set All References* button. Check the new references by looking at the Zernike Coefficients table; all coefficients should be close to 0. The OPD representation should look flat.

**IMPORTANT:** The reference spot positions should be measured at the same exposure time that will be used under closed loop operation. Otherwise spot position offset effect can distort the slopes measurement.

### 3.2 Obtaining the Reconstructor Matrix $H^*$

The process of obtaining the reconstructor matrix  $H^*$  starts by measuring the interaction matrix  $H$ . To measure  $H$ , open the Loop GUI in the *Interaction Matrix* tab. Then select *Get Interaction Matrix* to

open the measurement window. Enter the test voltage (typical value is 5 volts) and press start. Wait while the program poke each DM electrode and average the slope measurements on each sub-aperture. This might take a bit more than a minute. When the process ends the new H Matrix will be loaded into memory. Save it for later use.

The next step depends on what type of reconstructor is to be used: Modal or SVD. Normally, the modal reconstructor will be used. Select the *Modal Reconstructor* tab and press *Get Modal Reconstructor* to obtain the H\* matrix. If happy with the result apply it by selecting *Apply reconstructor Matrix*.

### 3.3 Saving AO Loop Data Sequences

An important feature of the real-time software is the tool for saving loop data sequences to disk. To save loop data sequences open the Loop GUI and select *Save Loop Data Sequence* from the *File* menu (Main>Loop>File>Save Loop Data Sequence). The Loop Data Recorder window pops up. Enter a file name and press *REC* to start recording data. The *Time Recording* indicator shows the elapsed time and the *File Size* indicator shows how many Kbytes have been recorded so far. Press *Stop* to quit recording data.

### 3.4 Examining the AO Loop Performance

The Loop Performance window is available to examine in detail the AO loop performance. Open the Loop GUI and select the *Loop Performance* tool from the *Tools* menu (Main>Loop>Tools>Loop Performance).

The software task behind the scenes continuously collects loop data (slopes and voltages) to estimate atmospheric parameters and loop performance. When sufficient samples have been collected, the several estimates are calculated and the collecting cycle starts over again. A progress bar indicator to the right gives feedback to the user on the state of the samples collection cycle. The duration of each cycle will depend on the loop frequency but in general it should take a few seconds to finish.

The *Power Spectrum* pane presents the user with a graph of the averaged power spectrum for both the compensated and uncompensated signal for the currently selected mode. A control to the top allows to select the displayed mode.

The *ACF* pane presents the autocorrelation function corresponding to the averaged power-spectrum for both the compensated and uncompensated signal, for the currently selected mode. The displayed mode is again selected with the selector control to the top of the window.

The crosses on top of the solid line representing the ACF for the uncompensated signal (e.g. atmospheric disturbance) represent the extrapolation of the ACF to zero to estimate the WFS noise contribution. Right now the parameters for this extrapolation (starting point and polynomial fit order) are hard coded but suitable controls have been provided to allow for testing.

The graph in the *Residual* pane presents the estimates for the atmospheric variance, the residual variance of the corrected modes and the WFS noise variance, versus mode number.

The graph in *r0 and V* pane presents the ratio between atmospheric variance and Noll variance for each mode. The average of this values is used to obtain the seeing estimate  $r_0$ .

### 3.5 Poking the DM Electrodes

The DM GUI is accessible from the Main GUI. When opened it presents the user with a table containing the current voltages applied to the DM. To poke an electrode double click in the table line corresponding to the electrode voltage you want to modify (first column lists the electrode number). A small window will pop-up to enter the new voltage. Enter the new electrode voltage and press OK. Now the voltage is listed in the *Loaded* column. Press the *Apply* button to actually write the voltage to the DM.

## Chapter 4: Configuration Files and Macros

Configuration files provide a mean to set multiple system parameters to some predefined value. Some of the parameters can be changed by the user during run-time (exposure time, reference spot positions, etc), others will remain fixed and can only be changed by editing the files and restarting the real-time software application (WFS pupil size, number of DM actuators, etc.). A detailed description of the configuration files, macros, and their parameters follows.

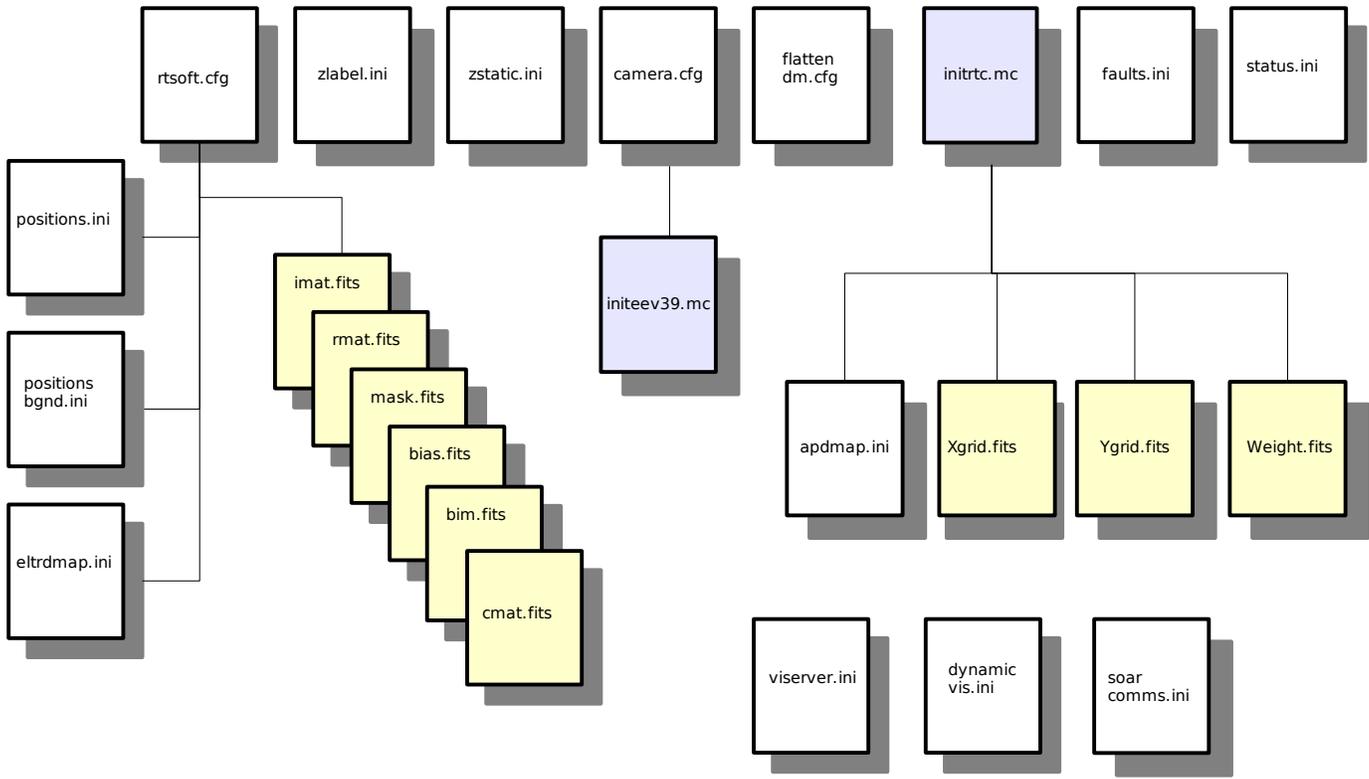


Figure 4.1: Configuration files and macros dependencies

### 4.1 Configuration Files

Most configuration files follow a common format. Files are divided in multiple sections, each one beginning with a keyword enclosed in square brackets. Each section lists a parameter name followed by an equal sign and its value. A semicolon marks the beginning of a short parameter description.

```
[Section Keyword]
Parameter = Value ; this is the parameter description
```

Other files are ordinary text files containing a list of space separated fields. The name and path of these files is fixed and can not be modified since they are hard coded in the real-time software. Some of these files have keywords to point to other configuration files which can have user defined names. All configuration files are expected to live in the directory */home/ao/RTsoft/ConfigFiles*.

#### 4.1.1 rtsoft.cfg – real-time software parameters

This file is currently composed of three self-explanatory sections: General, RTCORE and Simulator. The user can hand-edit this file to modify parameter values and the name of some definition files (interaction matrix, reconstructor matrix, bias, frame mask, reference spot positions, electrodes map, influence functions). The following is a typical example of how this file looks like.

```
[General]
TELESCOPED_M=4.1           ;Telescope diameter in [m]
LAMMDA=0.5E-6             ;Wavelength in [m] for calculations
MODES=56                  ;Modal estimator max Zernike mode (Mz + 1)
PUPILX=40                 ;Pupil center on CCD in x [pixels]
PUPILY=40                 ;Pupil center on CCD in y [pixels]
PUPILD=80                 ;Pupil diameter on CCD [pixels]
LENSLETDM=8               ;Lenslet diameter on CCD [pixels]
LENSLETDM=200E-6          ;Lenslet diameter [m]
LENSLETFM=5E-3            ;Lenslet focal distance [m]
PIXELM=24E-6              ;Pixel size [m]
SD_AVERAGE=20            ;Values to average for H matrix measurement
TOLERANCE=0.05           ;Default tolerance for inverting H (SVD)
GAIN=1.17                 ;Gain in electrons per ADU
PROBESCALE=1.0           ;Translate probe centroid to arc-seconds
M3ELSCALE=                ;M3 elevation scale in [asec/ADU]
M3AZSCALE=                ;M3 azimuth scale in [asec/ADU]

[RTCore]
MODE=TSNGS                ;Operation mode: TSNGS, NGS, TSLGS, LGS.
FRAMESIDE=80              ;Frame side in pixels
FRAMESIZE=6400            ;Frame size in pixels
SUBX=8                    ;Sub-aperture side in X [pixels]
SUBY=8                    ;Sub-aperture side in Y [pixels]
MIRROR=CILAS              ;Mirror type [CILAS|OKOTECH]
AV=60                     ;Number of actuators. Max is 60.
MINV=-10.0                ;Min low voltage in DM DAC
MIDV=0.0                  ;Mid low voltage in DM DAC
MAXV=10.0                 ;Max low voltage in DM DAC
AOFIFOSIZE=               ;Size of the A0 data FIFO buffer
TTFIFOSIZE=               ;Size of the TT data FIFO buffer

[Simulator]
GRIDSIZE=80               ;Size of the sim-engine arrays [samples]
SPUPILX=40
SPUPILY=40
SPUPILD=80
NXSUB=10                  ;Number of sub-apertures per side
INFXFILE=                 ;Influence functions
```

For example, when doing tests with DM37 the parameter AV, number of DM actuators, was set to 37; for DM60 AV is now set to 60.

#### 4.1.2 camera.cfg – WFS CCD controller parameters

The RTSOFT partially recycles software modules written for other SOAR applications. That is the

case for the CCD controller Labview interface module, originally written as part of the ArcView code. The *camera.cfg* is the configuration file for that software module.

```
[CAMERA]
asmpath=                ;Path to the boot files (files with .lod extension)
macropath=              ;Path to the start up configuration macro
initmacro=              ;Name of the start up configuration macro file

[IMAGE]
ImagePath=              ;Default path to save frames
ImageRootName=          ;Root name for saved frames
ImageNumber=            ;Default frame number suffix
```

The first section specifies where the low level binary code for the CCD controller and its interface board lives. It also defines where the camera initialization macro lives and the name of such macro. The second section keeps track of the path, root-name and suffix number of the last saved frame.

#### 4.1.3 flattendm.cfg – voltage values to make de DM flat

#### 4.1.4 positions.ini – WFS geometry and reference spot positions

This file is a regular text file with each line defining a sub-aperture related parameter. The file contains as many lines as defined sub-apertures exist.

```
28.000 4.000 -0.213 0.500 1.900 1.900
36.000 4.000 -0.100 0.452 1.900 1.900
44.000 4.000 -0.200 0.432 1.900 1.900
52.000 4.000 -0.235 0.345 1.900 1.900
20.000 12.000 -0.075 0.574 1.900 1.900
28.000 12.000 -0.254 0.522 1.900 1.900
36.000 12.000 -0.113 0.471 1.900 1.900
44.000 12.000 -0.324 0.478 1.900 1.900
52.000 12.000 -0.230 0.469 1.900 1.900
.....
```

The first and second fields represent the x-y position of the sub-aperture center in units of CCD pixels. The third and fourth fields are the x-y reference spot position measured from the center of the sub-aperture box. The fifth and sixth fields are the x-y size of the spot for the weighted center of gravity template.

During run-time this file can be edited and reloaded from the Main>WFS>File menu (see section 2.1.2). Typically the user will measure the reference spot positions and save them to this file.

#### 4.1.5 positions\_bgnd.ini – background subtraction box definitions

This file is a regular four lines text file with each line defining a box. Box definition in line 0 is for estimating the background in CCD quadrant 0, line 1 for quadrant 1, etc.

#### 4.1.6 zstatic.ini – static aberrations

If the user has selected to apply static aberrations to the reference spot positions, then the magnitude of the aberrations for each Zernike mode will be extracted from this file.

The file is a regular text file with each line indicating the magnitude of the aberration for a given Zernike mode. The line contains as many lines as defined Zernikes exist, but the number of them to be considered by the software is defined by the maximum number of modes as defined by the MODES keyword in the *rtsoft.cfg* file (read section 4.1.1 above). If the number of Zernikes defined is smaller than the maximum number of modes, then the missing Zernike aberrations will be assumed to be zero.

The first field in each line is the Zernike mode number, and the second field is the standard coefficient value for the Zernike in units of microns.

#### 4.1.7 zlabel.ini – zernike mode label file

This is an ordinary text file listing a text label associated with each Zernike mode. Several GUIs use this list to present Zernike related data, like the modal estimation coefficients for example. It is recommended to match the size of this list with the number of modes specified in the *rtsoft.cfg* file in section 4.1.1

```
TiltY(a2)
TiltX(a3)
Defocus(a4)
Astig45(a5)
Astig0(a6)
Comma(a7)
Comma(a8)
Trefoil(a9)
Trefoil(a10)
Spherical(a11)
Astigm.5th(a12)
Astrigm.5th(a13)
....
```

#### 4.1.8 eltrdmap.ini – electrodes look up table

The real-time computer has two DAC boards installed to generate the DM electrode voltages. This configuration file defines the look-up table that maps DAC board channel to DM electrode. Each section in the file has a label with the electrode number. The section entries specify the correspondent board (0 or 1) and channel (0 to 31), upper and lower limit for that electrode and its initialization value.

```
[General]
Name="Electrodes Look-Up Table" ; User defined label
[0] ; Electrode Number
Board=0 ; Board number
Channel=0 ; Channel Number
UpperLimit=10 ; Channel upper limit [V]
LowerLimit=-10 ; Channel lower limit [V]
Value=0 ; Default value [V]
```

When the real-time software starts each electrode is set to its default value<sup>4</sup>.

#### 4.1.9 apdmap.ini – APD look up table

The real-time computer has a counter board installed to read the photon counts produced by each APD channel. This configuration file defines the look up table that maps counter board channel to APD channel and micro-lens quadrant. The section entries specify the correspondent APD box, APD channel, tip-tilt probe, and probe quadrant<sup>5</sup>.

```
[General]
Name="Counter Look-Up Table" ; User defined label
[0] ; Counter board channel
Box= ; APD Box 0 or 1
APD= ; APD Channel 0,1,2 or 3
Probe= ; Probe 1 or 2
Quadrant= ; Probe quadrant 1,2,3 or 4
```

#### 4.1.10 apdbias.ini – APD biases

Loaded on boot and updated every time a bias calibration is made.

```
[0] ; Counter board channel
Bias= ; APD Bias in photon counts
```

#### 4.1.11 soar\_comms.ini – SOAR communication library parameters

The real-time software communication infrastructure is built upon the SOAR communication library (SCLN). The SCLN is an implementation of a network communication layer that suites the interoperability requirements of the SOAR telescope environment. Each section in the configuration file for this software module defines a client-server pair with the corresponding listening port.

```
[CommLib]
Version= ;Version for which this configuration is usable
[RTC]
IP_Server= ;IP address of the server
IP_Client= ;IP address of the client
IP_Port= ;Remote port number
```

For more information on the SCLN and its protocol read the document “SOAR Communication Library New” available at the SAM web site archive.

#### 4.1.12 faults.ini - faults definitions

The real-time software logging and error handling infrastructure is built upon the *HistoryLib* software module. The configuration file for that module defines error codes and their corresponding error messages.

```
[0]
ID= ;Fault identification number
What= ;Short description of the fault
```

<sup>4</sup> For information on voltage generation read the RTSPM.

<sup>5</sup> The convention for quadrants follows that one described in SDN2306.

```
Limit=           ;Number of occurrences to raise an alarm. -1 to ignore.  
LogAlways=       ;Log even when there's no error condition.
```

The error code assignment to a certain fault condition is hard coded in the software and the configuration file makes possible to hand edit the error message content.

## 4.2 Macros

The real-time software executes two initialization macros when it first starts. The first macro is defined in the *camera.cfg* parameter file (see section 4.1.2) and is the CCD controller initialization macro. The macro initialize things such as the detector geometry, exposure time, pixel time and readout mode<sup>6</sup>.

```
# SOAR TTG Initialization Macro  
  
# Download the PCI board file  
ldf pci /home/ao/RTsoft/Boot/pci+int.lod  
  
# Reset the controller  
reset controller  
  
# Stop camera idle  
readout stop-idle  
  
# Download the Timing board file  
ldf tim /home/ao/RTsoft/Boot/tim.lod  
  
# Power on  
power on  
  
# Detector geometry  
set size 80 80  
  
# Detector Geometry and readout mode  
readmode 11_12_21_22  
  
# Exposure time  
set exposure 0  
  
# Adjust the offset of quadrant 0-3  
# Guider Display: Q0 - Q1  
# Q3 - Q2  
# SBN Card# DAC# VID=0x564944 DAC_Value 0-0xFFF  
# Add 1 or 2 Counts to make Darker / Subtract goes Lighter  
mancmd SBN 0 2 0x564944 0x7f2 # Quadrant 0  
mancmd SBN 1 2 0x564944 0x7ea # Quadrant 2  
mancmd SBN 1 3 0x564944 0x7d1 # Quadrant 3  
  
# Adjust the pixel time. Default value is 0x180000 for  
# 2.5us per pixel.  
mancmd SPT 0x18
```

---

<sup>6</sup> For details on the macro contents and macro commands read SDN8215.

```

# Continuous readout. 2048 represents the number of
# frames in the ring buffer. 8388607 (0x7FFFFFF) is
# the number of frames to capture.
##
NOTE: the number of frames multiplied by the detector
# size (80x80) and by the bytes per pixel (2 bytes)
# CAN'T exceed the high memory allocated. Look for
# BUFFER_SIZE in Memory.c in the astropciAPI_LIB
# library for the current value. Last time I look
# it was 4000x4000x2 = 30.5Mb
#
set frames 2048
set readout 8388607
exposure start
EOF

```

The second macro is the real-time software initialization macro *initrtc.mc*. This macro is the last initialization done by the real-time software before it enters operational mode. So it is the appropriate place to set parameters or override some default parameter values<sup>7</sup>. Right now the *initrtc.mc* macro is the place for setting the centroid algorithm and defining the loop control law.

```

# Real-Time Computer Software Initialization Macro

# Reset the RTCORE
rt aofg reset

# Load APD map
load apdmap /home/ao/RTsoft/ConfigFiles/apdmap.ini

# Load the weight matrix
load wmat /home/ao/RTsoft/ConfigFiles/Weights.fits 1

# Load the x grid matrix
load xgrid /home/ao/RTsoft/ConfigFiles/XGrid.fits 1

# Load the y grid matrix
load ygrid /home/ao/RTsoft/ConfigFiles/YGrid.fits 1

# Set digital controller parameters
rt aofg di k 0.25
rt aofg di kl 0.999
rt aofg sp k 1.0
rt aofg sp kl 0.999
rt aofg sp ks 0.7
rt aofg sp on

# Set the centroid algorithm (1=WCoG, 5=CC). CC pattern
# size is 2.0 pixel (sigma 0.85)
rt cc algorithm 5
rt cc ref8 1000 0.85

```

---

<sup>7</sup> For details on the macro contents and macro commands read the RTSPM

```
# Size of the spot and size of the weighting function for
# the WCoG. This values will set the gamma factor.
rt cc NT 1.1
rt cc Nw 2.0

# Readout Noise in ADU (1.696 ADU for 1.06 us/pixel; 5.011 ADU
# for 2.5 us/pixel)
rt cc Nr 5.011

# Turn the bias subtraction on
bias on

# Turn background subtraction on
rt cc bgnd 1
```

### 4.3 FITS files

Many of the program variables of the real-time software have a matrix representation. This includes the interaction matrix  $H$ , the reconstructor matrix  $H^*$ , the DM influence functions, the centroid grids, the centroid weights, the bias frame and the Noll covariance matrix.

All these type matrix variables are stored in disk using the FITS file format. The data is kept in the *RTsoft/ConfigFiles* directory. For historical reasons the names of the FITS files containing default matrix data are defined both by suitable keyword values in the *rtsoft.cfg* parameter file (see section 4.1.1), and by direct loading in the initialization macro *inirtc.mc*.

#### 4.3.1 bim.fits

Influence matrix. Loaded at boot time as defined by the INFXFILE keyword in the SIMULATOR section of the *rtsoft.cfg* configuration file.

#### 4.3.2 cmat.fits – Noll covariance matrix

#### 4.3.3 imat.fits

The interaction matrix file is loaded at boot time and lives in the *RTsoft/ConfigFiles* directory. It is produced from the AO Loop Control window described in section 2.1.1.1

#### 4.3.4 rmat.fits and nas\_rmat.fits

The *rmat.fits* file contains the reconstructor matrix elements. Is loaded at boot time along with the *nas\_rmat.fits*. The *nas\_rmat.fits* file contains the reconstructor with the average slopes subtracted and its creation is automatically handled by the RTSOFT when a new reconstructor is obtained out of an interaction matrix.

#### 4.3.5 wfsbias.fits

The WFS bias calibration file is loaded at boot time and lives in the *RTsoft/ConfigFiles* directory. It is produced by the WFS bias calibration tool described in section 2.1.2.2.

### 4.3.6 mask.fits

This is a matrix of dimension 80x80 in which each pixel is a 16 bit integer. Bits 15 to 8 represent the sub-aperture ID. Bits 7,6 represent the amplifier number. Bit 4 represents the type of pixel (0 regular, 1 background). Bit 0 represents the pixel status (0 bad, 1 good).

New masks can be created using the WFS>Mask Tool (see section 2.1.2.2) and files *background.ini*, *badpix.fits* and *amps.fits*.

#### 4.3.6.1 badpix.fits

This is matrix of dimension 80x80 in which good pixels are represented by a 1 and bad pixels by a zero. The file is loaded automatically by the WFS>Mask Tool when the user creates a new bitwise frame mask (see section 2.1.2.2)

#### 4.3.6.2 amps.fits

This is matrix of dimension 80x80 in which each pixel has a value of 0, 1, 2 or 3 depending on the readout amplifier they belong to. The file is loaded automatically by the WFS>Mask Tool when the user creates a new bitwise frame mask (see section 2.1.2.2)

### 4.3.7 weight.fits, xgrid.fits, ygrid.fits

Weighted center of gravity definitions. All loaded at boot time by the *inirtc.mc* macro.

## Chapter 5: Simulator Modes

The RTSOFT has basically two layers of simulation: a user space simulation layer and a kernel space simulation layer. Without getting into the internals of the real-time software we can say that the user space simulation layer involves having all the simulation done by the Labview part of the real-time software. The kernel space simulation layer involves having the simulation done by the Labview part plus the RTCORE<sup>8</sup>.

The active simulation modes are selected by command line options. Table 5.1 summarizes the available options. So for example, if the RTCORE is not available, by giving option `-r` the real-time software will start and will not complain on not finding the RTCORE present, and its functionality will be emulated by the Labview part of the RTSOFT, that is, simulation will take place at the user space layer.

*Table 1: Command line options to the realsoftware.*

Option	Description
<code>-r</code>	Emulate real-time core (RTCORE) functionality
<code>-c</code>	Emulate WFS camera. An artificial pattern is generated and passed to the RTCORE
<code>-d</code>	Emulate DM. Electrodes voltages are not written to the DAC boards.
<code>-tcs</code>	No connection to the TCS server.
<code>-lm</code>	No connection to the LM server.

### 5.1 Simulation at user space level

The command line option `-r` has been passed to the real-time software at startup. At this level the RTCORE (and hardware if the `-c` or `-d` have been given) is emulated in the Labview part of the real-time software.

With the `-r` option active, the slope measurements and electrode commands calculations normally done by the RTCORE, are done at the emulation layer. If the `-c` option has been passed, the calculations are done using an artificial pattern; otherwise actual CCD frames are used. If the `-d` option has been passed, electrode voltages are calculated but never written to the DAC board.

### 5.2 Simulation at kernel space level

The command line option `-r` has not been passed to the real-time software. At this level the RTCORE is fully operational but some or all the hardware is not available (`-c` or `-d` options have been passed).

If the `-c` option has been given to the RTSOFT, the emulation layer continuously produces artificial patterns which are passed to the RTCORE for processing. The RTCORE measures the slopes and

<sup>8</sup> For background on the internals of the real-time software read the RTSPM and document SDN8211.

voltages as under real operation. If the -d option is given, the electrode voltages are calculated but never written to the DAC board.

## 5.3 Simulation Parameters

Some of the simulation engine parameters are available at the *rtsoft.cfg* configuration file (see section 4.1.1 above). Other parameters can be changed by the user from the Maintenance>Simulator Engine window under maintenance mode (see section 2.3 above).

The simulator engine includes a model of the deformable mirror (DM) based on the influence functions defined in the FITS file given in *rtsoft.cfg*.

The emulated electrode voltage together with the user defined mode selected (Zernike, FITS file, etc.) define the characteristics of the generated artificial pattern. This calculations can be intensive in CPU resources so be aware of the lower frame rates obtained when under simulator mode.

**Noise.** Add white noise to the artificial pattern using the readout noise number given in the RTSOFT configuration file.

**Gain.** Multiplying factor to the artificial pattern generated it can be tuned to obtained the desired amount of flux in each subaperture.

**Zernikes.** Standar Zernike coefficients used to add aberration to a perfectly flat wavefront.

**File.** Name of a FITS containing a CCD frame.

**Dark.** Add the bias frame to the generate pattern to emulate the CCD bias pattern.

**Mode.** Read below.

### 5.3.1 User defined pattern

When this mode is selected the user is free to defined the values in the array representing a CCD frame. The user can poke values and then see the results in the WFS display window. This can be very useful when it is necessary to give a known value to a pixel.

### 5.3.2 5.3.2 FITS file

When this mode is selected, a user defined FITS file containing a CCD frame is loaded and used as artificial pattern.

### 5.3.3 Zernike Modes

In this mode the user specifies a set of standard Zernike coefficients to add known aberrations to a perfectly flat wavefront.

### 5.3.4 Kolmogorov

In this mode the spectrum of the artificial pattern follows the Kolmogorov law for atmospheric turbulence. Correlation between successive frames is not supported though.

## Chapter 6: Log Files

When the RTSOFT first runs, it opens a regular text file to save log messages describing runtime events. Events can be of several types including type alarm, type command, type status, and type simple-event. For details on the implementation of the logging mechanism read the RTSPM.

The events and the conditions in which a log message is generated is hard-coded into the RTSOFT, but certain flexibility exists when it comes to define error messages associated to error codes. A configuration file called *faults.ini* (section 4.1.12) exists that serves as a look up table between error codes and error messages. The logging engine, when given an error code, searches the right error message and then produces the corresponding log message.

The actual log file can be found under directory *RTsoft/Logs* which is typically a link to a user defined directory (right now */home/ao/Logs*). Each line in the log file starts with a timestamp that includes date and time in *YYMMDD HH:MM:SS* format. Then a label describes what type of event (alarm, status, etc.) the log message refers to. A second label states the name of the “originator”, that is, the piece of software code that produced the event. This second label is most useful for debug purposes. The line ends with the log message describing the event. This last message does not follow a predefined format.

We use the system utility log rotate to manage the ICS log file. The configuration file is in */etc/logrotate.d/icsoft*.

```
% cat /etc/logrotate.d/icsoft
/home/ao/ICsoft/Logs/*.log {
compress
daily
rotate 7
}
```

The above keeps the last seven days logs in compressed format. The logrotate utility is executed as a crontab job by the cron daemon on a daily basis (see */etc/cron.daily/* directory for logrotate). We adjusted to run at midday

```
% cat /etc/crontab
# run parts
01 * * * * root run_parts /etc/cron.hourly
00 12 * * * root run_parts /etc/cron.daily
22 12 * * 0 root run_parts /etc/cron.weekly
42 12 1 * * root run_parts /etc/cron.monthly
```

**NOTE:** The whatis database update has to be removed!!

### 6.1 Type Alarm Events

Events of type alarm produced by the real-time software can trigger the alarm flag. Each error code defined in the *faults.ini* configuration file has an associated counter that keeps track of consecutive type alarm events. When three alarm messages in a row for a given error code are detected, the global alarm flag is raised. The number of type alarm events in a row is actually configurable in the *faults.ini* configuration file (see section 4.1.12 above).

## Chapter 7: Glossary

AO	Adaptive Optics.
AOSOFT	SAM Adaptive Optics Software. Supervisory control application that handles the bussiness logic of the SAM instrument.
DM	Deformable Mirror.
DSP	Digital Signal Processing.
DAQ	Data Acquisition.
Effective Compensation	Maximum order compensation for a given reconstructor matrix.
FITS	Flexible Image Transport Format.
FWHM	Full Width at Half Max.
GLC	Ground Layer Compensation
G Matrix	Slopes in x and y are related to aberrations by the gradient matrix G.
G* Matrix	Inverse of the gradient matrix G.
H Matrix	Interaction matrix.
H* Matrix	Reconstructor matrix.
Integrator	Digital controller. Measured residuals are added to the previous signal with some gain.
Interaction Matrix	The relation between the WFS and the DM in an AO system is characterized by the interaction matrix H.
Kolmogorov Law	The Kolmogorov model of the turbulence distortions prescribes the specific form of the phase structure function for the optical wave.
LGS	Laser Guide Star
LLT	Laser Launch Telescope
Modal Coefficients	Zernike mode coefficients
Modal Reconstructor	Error signal delivered by the WFS is converted into modal amplitudes by matrix G*. Amplitudes are weighted and transformed to voltages by matrix P*.
NGS	Natural Guide Star
Noise Propagation	Noise propagation is described by the covariance matrix of Zernike noise coefficients.
Optimal G* Reconstructor	Optimal modal reconstructor. Takes into account the information on the statistics of the input disturbance contained in the Noll covariance matrix, and correlated centroid noise.
P	Matrix Aberrations are related to DM voltages by the projection matrix P.
P*	Matrix Inverse of the protection matrix P.
PXI	Modular instrumentation standard based on CompactPCI developed by National Instruments with enhancements for instrumentation

Chapter 7:Glossary

Reconstructor Matrix	Inverse of the interaction matrix H.
Regularization Parameter	Setting this parameter $> 0$ helps balancing the noise and input signal in case when the noise is strong. The reconstructor with the right choice of this parameter gives the smallest RMS wavefront error.
RTC	Real Time Computer
RTCORE	Real Time Core
RTSOFT	Real Time Software
RTSPM	Real Time Software Programmer Manual
SAM	SOAR Adaptive Module
Slope	Gradient averaged within the sub-aperture and expressed in units of phase difference between the edges of sub-aperture.
Smith Predictor	Digital controller that counter acts the effect of delay in the loop.
SVD	Singular Value Decomposition
SVD Reconstructor	The interaction matrix is inverted using SVD. Singular values below some threshold are set to zero.
TTP	Tip Tilt Probe
TURSIM	Turbulence Simulator
WFS	Wavefront Sensor
WCoG Method	Weighted Center of Gravity. Improved center of gravity with different weight to each pixel depending on their flux.
Zernike Coefficients	Input disturbance, correction and residuals are represented as coefficients of Zernike modes.