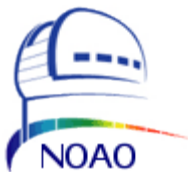


IC Software Programmer's Manual

SOAR Adaptive Module (SAM)

Revision Rev 3.6.4, February 2015



Change Record

Version	Date	Description	Owner Name
3.5	March 14, 2013	Modulate command documented	RCR
3.6	March 25, 2013		RCR
3.6.1	June 7, 2013	Add reference for LM M4 command	RCR
3.6.2	December 2, 2013	Refinements in section 4.1	RCR
3.6.3	February 12, 2015	Add missing RTC LLT options in section 3.1	RCR
3.6.4	February 17, 2015	Add reference to RMFAULTS command	RCR

Table of Contents

Chapter 1: Overview.....	1
1.1Introduction.....	1
1.2Software Architecture.....	2
1.3Source Code.....	2
Chapter 2: Manager Modules.....	4
2.1RTSOFT Control Manager.....	4
2.2AOMSOFT Control Manager.....	5
2.3SLGMSOFT Manager.....	6
2.3.1Status Poll.....	6
2.4TCS Manager.....	9
2.5Execution Threads.....	9
Chapter 3: Scripting.....	11
3.1Local Commands.....	11
3.2Remote Commands.....	20
3.2.1Instrument Command Handler.....	21
3.2.2GMAP Command Handler.....	21
Chapter 4: Guide Star Acquisition.....	23
4.1Interactive star selection in LGS Mode.....	23
Chapter 5: Range Gate.....	26
Chapter 6: Atmospheric Dispersion Correction.....	27
Chapter 7: Telemetry.....	29
APPENDIX A: North-East coordinates to Up-Left coordinates for Gnomonic Projection.....	30
APPENDIX B: Up-Left coordinates to SAM Guide Probe coordinates.....	33
APPENDIX C: Dispersion Orientation Angle.....	37

Chapter 1: Overview

1.1 Introduction

The SAM software suite of applications comprises a set of programs that differentiate themselves by the mission they serve [SDN-8201]. The suite includes the SAM Instrument Control Software (ICSOFT), the SAM Imager Software (SAMI), the SAM Motion Control Software (AOMSOFT), the SAM Laser Guide-Star Motion Control Software Module (SLGMSOFT), the Laser Clearance House software and the SAM Real-Time Software (RTSOFT).

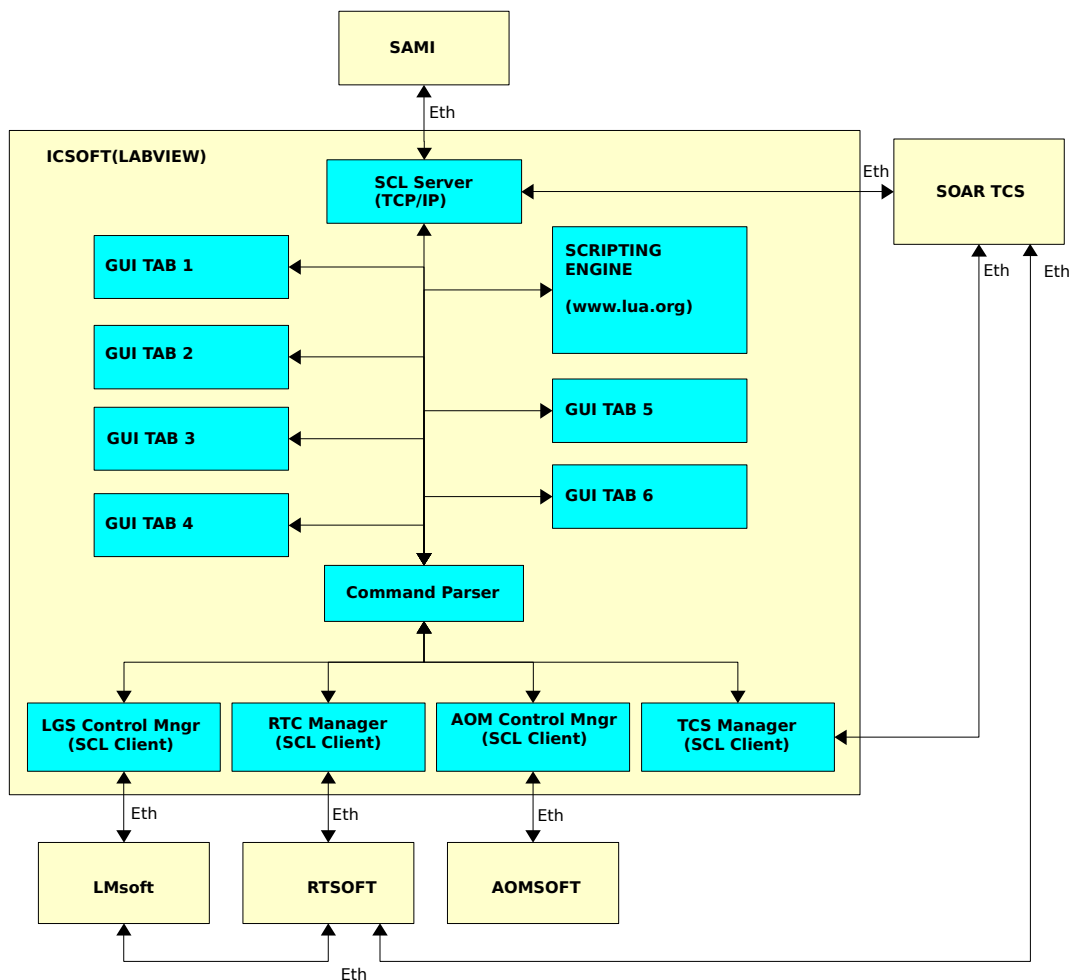


Figure 1: Block diagram of the Instrument Control Software. Managers handle the remote systems and AO subsystems. Managers are TCP/IP clients using the SOAR Communication Library

This manual covers implementation details of the Instrument Control Software (ICSOFT). The manual is not focused on operational aspects of the software. For an operational focus please read the Instrument Control Software User Manual instead.

1.2 Software Architecture

The ICSOFT is a Labview application running as a supervisory control application (Figure 1). It is based in several GUIs and managers. The GUIs deal with the operator while the managers handle the remote systems and SAM subsystems (RTSOFT, AOMSOFT, SLGMSOFT, and TCS). Remote client connections are also allowed by means of communication server tasks.

The managers act as clients using the SOAR Communication Library (SCL) infrastructure. The managers encapsulate all what's specific to each system/subsystem: status polling loops, command routing, etc. All managers follow the same state machine logic; the manager keeps running while connected to its server. If the connection is broken the manager enters the re-connection state until it re-connects or the application is terminated

The ICSOFT is capable of accepting remote procedure calls (RPC) from other systems acting as a server using SCL over TCP/IP . The command interface is of the type: <command> <arg1> <arg2> ... <argN>.

The ICSOFT provides several GUIs. A command parser routes the local commands from the GUIs and script engine, as well as remote commands received by the SCL server, to the managers for actions and status information.

1.3 Source Code

The ICSOFT software can be found in the Instrument Control Computer machine, installed in the ao user home directory */home/ao* under root directory *ICsoft*. The Labview application code lives under subdirectory *modules* with its main VI living alone in the root directory *ICsoft*.

Executables and shared libraries produced can be found under directory *bin* and *lib*. Configuration files, data files under directory *config*.

Copies of the ICSOFT are kept in the SOAR public repository. Access is possible through local accounts on machine *ctioll*. The path to the copies is */home/public/SOAR/SAM*.

The following is a tree view of the directory structure of the software:

```
Icsoft
|--bin
|--config
|--data
|--doc
|--lib
|--logs
|--modules
|   |--AOMLib
|   |--AstroLib
|   |--HistoryLib
|   |--ICSoftLib
|   |--LGSLib
|   |--ParseLib
|   |--RTCLib
|   |--SCLN
|   `--TCSLib
```

```
|--macro  
\--scrips
```

To access the code is recommended to start by opening the main VI first

```
% cd /home/ao/ICsoft  
% labview Icsoft.vi
```

Chapter 2: Manager Modules

Managers modules encapsulate all the specifics involved in the interaction with each SAM subsystem: connection integrity, status polling loops, command routing, etc. All managers act as clients using the SOAR Communication Library (SCL) infrastructure, and follow the same state machine logic; the manager keeps running while connected to its server. If the connection is broken the manager enters the re-connection state until it re-connects or the application is terminated. A status task within the manager is in charge of continuously polling for status data from the server. The polling can be activated/deactivated from the GUI for debugging purposes though. If a timeout occurs while waiting for a status response from the server, the link to the server is automatically closed and a reconnection cycle to the server starts up. Otherwise the response is passed to a parser VI that de-serializes the data using a configuration file as a data mode definition. Each de-serialized sample is then analyzed to set warnings and alarms accordingly.

FIXME: FILL HERE THE MISSING COMMAND ROUTING MECHANISM

2.1 RTSOFT Control Manager

The status task for the RTSOFT Control Manager (RTCM) polls for status every 1 second. The configuration file defining the data structure exchanged between the RTSOFT and the ICSOFT is *rtc_status.cfg*. The two files live in the *Icsoft/config* directory. Not all of the elements are considered. A short description of the selected fields follows.

FIXME: FILL HERE THE MISSING FIELDS

[RGATE]

STATUS – ON or OFF.

MODE – AUTO or LASER.

DELAY – A fractional value in units of [ns]

DISTANCE – A fractional value in units of [ns]

PWIDTH – A fractional value in units of [ns]

PERIOD – A fractional value in units of [ns]

[LLT]

LOOP – ON or OFF.

PZT1OFFSET – A fractional value in units of [V].

PZT2OFFSET – A fractional value in units of [V].

.

FILL HERE THE MISSING FIELDS

.

.

2.2 AOMSOFT Control Manager

The status task for the AOMSOFT Control Manager (AOMCM) polls for status every 1 second. The configuration files defining the data structures exchanged between the AOMSOFT and the ICSOFT are *AOM_MechanismStatus_Default.cfg* and *SAM_TelemetryStatus_Default.cfg*. The two files live in the *Icsoft/config* directory. Not all of the elements are considered. A short description of the selected fields follows.

.

.

FILL HERE THE MISSING FIELDS

.

.

[G_Dimmer_P1]

power – One of the strings ON or OFF.

status – One of the strings ENABLED or TBD.

dimmer - A numeric string between 0 and 100.

[G_Dimmer_P2]

power – One of the strings ON or OFF.

status – One of the strings ENABLED or TBD.

dimmer - A numeric string between 0 and 100.

[TS_Dimmer]

power – One of the strings ON or OFF.

status – One of the strings ENABLED or TBD.

dimmer - A numeric string between 0 and 100.

[WFS_Ref_Beam]

status – One of the strings “DONE”, “ACTIVE”, DISABLED” or TBD.

abs_position – One of the strings “IN”, “OUT” or “NONE”.

[WFS_f/10_Adj]

position – A fractional string expressing the current position in [mm].

status – One of the strings “DONE”, “ACTIVE”, DISABLED” or TBD.

[WFS_Dimmer]

power – One of the strings ON or OFF.

status – One of the strings ENABLED or TBD.

dimmer - A numeric string between 0 and 100.

.
.

FILL HERE THE MISSING FIELDS

.
.

[Sam_Cover]

position - One of the words OPEN, OUT OF TBD, or CLOSE

status - One of the strings ENABLED or TBD.

2.3 SLGMSOFT Manager

VI Name: *lm_manager*

Module Name: *LMLib*

2.3.1 Status Poll

VI Name: *lm_manager_status_poll*

The status task for the SLGMSOFT Manager (SLGMM) polls for status every 1 second. The configuration file defining the data structure exchanged between the SLGMSOFT and the ICSoft is *LGS_Full_Status.cfg*. The file lives in the *ICsoft/config* directory. Not all of the elements are considered to be stored in type II global variables. A short description of the selected fields follows.

[LASER]

Diode On/Off (Standby) – One of the strings “ON”, “OFF” or “STANDBY” describing the status of the LASER diode.

Laser Power – A fractional string with the LASER power in units of [WATT]

Fault Status – One of the strings TBD describing fault conditions.

Chiller Temperature – A fractional string with the chiller working temperature.

Shutter – One of the strings TBD describing the state of the LASER shutter.

[M1_X]

position_X – A fractional string expressing the LLT M1 current x position in [mm].

status – One of the strings “DONE”, “ACTIVE”, DISABLED” or TBD.

[M1_Y]

position_Y – A fractional string expressing the LLT M1 current y position in [mm].

status – One of the strings “DONE”, “ACTIVE”, DISABLED” or TBD.

[M2_Focus]

position – A fractional string expressing the LLT M2 current position in [mm]

status – One of the strings “DONE”, “ACTIVE”, DISABLED” or TBD.

[LLT_Cover]

position – A fractional string expressing the LLT cover current position in TBD units.

status – One of the strings “DONE”, “ACTIVE”, DISABLED” or TBD (TBC)

abs_position – One of the strings “OPEN” or “CLOSED”.

[LaserSelect]

status - One of the strings DONE, ACTIVE, DISABLED or TBD indicating the status of the LASER selector mechanism.

abs_position – One of the strings IN or OUT indicating the position of the mechanism.

[LLTDigitalIO]

Prosilica – One of the strings ON or OFF indicating the state of the LLT ATP camera.

LaserDiode – One of the strings ON or OFF indicating the state of the LLT LASER diode.

LLTMotors – One of the strings ON or OFF indicating the LLT motors power supply status.

FANPower – One of the strings ON or OFF indicating the LLT fan status.

status – One of the strings DONE or TBD.

[LLTAnalogInput]

LLT_Temp – A fractional string expressing the current LLT temperature in units of [C]

Prosilica – A fractional string expressing the current voltage applied to the camera in units of [V].

LaserDiode – A fractional string expressing the current voltage applied to the LLT LASER diode in units of [V].

status – One of the strings “DONE” or TBD.

[LaserDigitalIO_B]

Interlock – One of the strings TBD or TBD indicating if an interlock has been engaged.

Heater – One of the strings ON or OFF indicating the state of the LASER box heater.

SafetyShutter_In – Laser box safety shutter IN limit switch status.

SafetyShutter_Out – Laser box safety shutter OUT limit switch status.

[PiezoAnalogInput]

PZT1 – A fractional string expressing the current voltage applied to the PZT1 in units of [V]

Input1 – A fractional string

PZT2 – A fractional string expressing the current voltage applied to the PZT2 in units of [V]

Input2 – A fractional string

PZT3 – A fractional string expressing the current voltage applied to the PZT3 in units of [V]

Input3 – A fractional string

status – One of the strings DONE, DISABLE or TBD.

[TempLaserBox]

temperature – A fractional string expressing the current temperature inside the laser box.

[IBOOT]

state – One of the strings ON or OFF indicating the state of the LASER box 220[V] remote power outlet.

2.4 TCS Manager

INFO

ROTSPOS RMA IAA GUI_XY CCD_XY M3_POS

Rotator mechanical angle

Instrument Position Angle

Instrument Alignment Angle

Angulo del guider con respecto al rotador

Angulo del CCD con respecto al rotador

Position del M3 (1 Nasmyth Right (infrared), 2 Bent Cass 1, 3 CWFS Bent Cass 2, 4 SOI Bent Cass 3, 5 Nasmyth Left (vosible))

2.5 Execution Threads

Table 1 lists the ICSOFT VIs and their execution thread and priority. The descendant VIs are all marked to run in the execution thread of their parents.

Chapter 2: Manager Modules

Table 1: Execution thread and priority assignments. Descendants are marked to run in the execution thread of their parents.

Vi Name	Queue	Running	Thread	Priority	Description
ICsoft	1	Always	User Interface	Normal	Main VI
hist_task		Always	User Interface	Normal	Log alarms and events
parse_task		Always	User Interface	Normal	Parse and execute string commands
icsoft_task_update_connections		Always	User Interface	Normal	Poll for all remote connection status
icsoft_task_command_servers	2, 3	Always	User Interface	Normal	Incoming connections
icsoft_task_adc_logic	ADC	Always	Standard	Normal	ADC corrections
tcs_task_manager_launcher	Mq1	Always	Data Acquisition	Normal	TCS manager
aom_task_manager_launcher	Mq2	Always	Data Acquisition	Normal	AOM manager
rtc_task_manager_launcher	Mq3	Always	Data Acquisition	Normal	RTC manager
lm_task_manager_launcher	Mq4	Always	Data Acquisition	Normal	LGS manager

Chapter 3: Scripting

The ICSoft integrates the LuaView engine (luaview.esi-cit.com) to handle scripting. For details on the LUA scripting language visit the web site www.lua.org.

The LUA interface provides just two commands: *sam.command* and *sam.wait_until_end*. [Read section 3.1 below for a list of the available commands to be passed as arguments to the LUA interface.](#) Here is part of the GP1-tune.lua script for reference on how to use them

```
% cat /home/ICsoft/scripts/GP1tune.lua

-- Test GP1 centering

ok, flux = sam.command("GET RTC TT GP1F")
sam.command("LOG GP1flux is " .. flux)

fluxmin = 5.
if (flux + 0) < fluxmin then
  sam.command("LOG Flux less than " .. fluxmin ..", returning")
  return
end
.
.
.
-- Move the GP and take error signals
sam.command("LOG Moving probe to " .. x2 .. " " .. y2)
sam.wait_until_end("AOM GUIDERP1 MOVE " .. x2 .. " " .. y2, 25000)
ok, ex2 = sam.command("GET RTC TT GP1X")
.
.
.
```

3.1 Local Commands

ADC <MOVE | ENABLE | DISABLE>

MOVE <INNER> <OUTER> - With no arguments use mount elevation angle to obtain the prism angles.

AOM <GUIDERP1 | GUIDERP2> - Forward Guide Probe commands to AOMSOFT.

GUIDERP<N> STOP

GUIDERP<N> MOVE XP YP <ZP>

GUIDERP<N> DIMMER [ON | OFF]

GUIDERP<N> DIMMER MOVE [0-100]

AOM TURSIM - Forward TURSIM commands to AOMSOFT.

TURSIM PHSCREEN<N> MOVE [IN | OUT]

TURSIM PHPLATE<N> MOVE [0-100]

TURSIM INJARM MOVE [IN | OUT]

TURSIM DIMMER [ON | OFF]

TURSIM DIMMER MOVE [0-100]

TURSIM SJOGX [0 | 1]

TURSIM SJOGY [0 | 1]

AOM WFS - Forward Wave Front Sensor commands to AOMSOFT.

WFS FOCUS MOVE FP

WFS REFBEAM MOVE [IN | OUT]

WFS DIMMER [ON | OFF]

WFS DIMMER MOVE [0 – 100]

AOM <ESHUTTER | ADC | OUTSEL> - Environmental shutter, Atmospheric Dispersion Correction, and Output Selector Mirror.

ESHUTTER MOVE [OPEN | CLOSE]

ADC MOVE [IN | OUT | STOP]

ADC MOVE INNER OUTER

OUTSEL MOVE [IN | OUT]

AOM <APD | ACAM | HV > - Avalanche Photo Diodes, Acquisition Camera, and Pockell Cell High Voltage.

APD<N> [ON | OFF | RESET]

ACAM [ON|OFF] – Turn the WFS acquisition camera power on-off.

HV [ON|OFF] – Turn the Pockel-Cell high voltage on-off.

AOM <STATUS | TELEMETRY>

STATUS

TELEMETRY

ECHO <ARG₁> <ARG₂> ... <ARG_N> - Simply returns the arguments back to the originator.

GET RTC

RTC RTC [FAULT | LSFAULT | SIMM | MODE|STATE]

RTC WFS [RGATE | RGDELAY | STATUS | MIN | MAX | MEAN | STDEV | ETIME |

MEANFLUX | BIAS | BGND]

RTC AO [LOOP | LTIME | R0 | V | VCM]

RTC TT [LOOP | CTRLR | FULLBW | LTIME | GP1F | GP2F | GP1W | GP2W | GP1X | GP1Y | GP2X | GP2Y | GP1LOCK | GP2LOCK]

RTC MOUNT [LOOP]

RTC LLT [LOOP | CTRLR | PZT1OFFSET | PZT2OFFSET]

GET AOMS¹

AOMS Guider_P1_X [position|pos_zpoint|status]

AOMS Guider_P1_Y [position|pos_zpoint|status]

AOMS Guider_P2_X [position|pos_zpoint|status]

AOMS Guider_P2_Y [position|pos_zpoint|status]

AOMS Focus_P1 [position|status|init]

AOMS Focus_P2 [position|status|init]

AOMS G_Dimmer_P1 [power|status|dimmer]

AOMS G_Dimmer_P2 [power|status|dimmer]

AOMS Output_Selector [position|status|abs_position|trajectory|init]

AOMS TS_Ph_Screen_1 [position|status|abs_position]

AOMS TS_Ph_Screen_2 [position|status|abs_position]

AOMS TS_Source_Adj_X [position|status|abs_position]

AOMS TS_Source_Adj_Y [position|status|abs_position]

AOMS TS_Dimmer [power|status|dimmer]

AOMS TS_Phase_Plate [ph_plate1_status|ph_plate1_vel]

AOMS TS_Phase_Plate [ph_plate2_status|ph_plate2_vel]

AOMS TS_Phase_Screen [screen1_pos|screen2_pos|power1|power2|status1|status2]

AOMS TS_Source_Adj [s_adjx_status|s_adjy_status|sourcex_vel|sourcey_vel]

AOMS TS_Inj_Arm [position|power|status]

AOMS Filter_Wheel [position|status]

AOMS WFS-Focus [position|status|abs_position|init]

AOMS WFS_Ref_Beam [position|power|status]

¹ The parameters listed here correspond to the status definition contained in configuration file AOM_MechanismStatus_Default.cfg

AOMS WFS-Dimmer [power|status|dimmer]
AOMS ADC-Inner [position|status|init]
AOMS ADC-Outer [position|status|init]
AOMS ADC_Position [position|abs_position|status|init]
AOMS Fabri-Perot [position|abs_position|status|init]
AOMS Sam_Cover [position|status]
AOMS SHUTTER [position|status]

GET AOMT²

AOMT PowerSupply
[Telemetry|APD1_30V|APD2_30V|APD_5V|APD_2V|Reserved_01]
AOMT PowerSupply [Prosilica_12V|Prosilica|Reserved_03|Control|APD1|APD2]
AOMT PowerSupply [Overcurrent_APD1| Overcurrent_APD2]
AOMT HV [Pockels_Power_supply|HV_value|HV_Error]
AOMT HV [status]
AOMT Temperatures [Glycol|OAP1_area|DM_area|OAP2_area|ADC_area]
AOMT Temperatures [Tursim_area | status]

GET LMS³

LMS LASER [Diode On/Off (Standby) | Laser Power | Interlock | Fault Status]
LMS LASER [Diode Current Setting | Diode Temperature Sense]
LMS LASER [Chiller Temperature | Shutter | RF Level]
LMS LASER [Flow Switch | Set Trigger Mode]
LMS M4_Axis_1 [position | status | init]
LMS M4_Axis_2 [position | status | init]
LMS M1_X [position | position_X | status | init]
LMS M1_Y [position | position_Y | status | init]
LMS M2_Focus [position | status | init]
LMS LLT_Cover [position | status | init | abs_position]
LMS LaserSelect [position | status | init | abs_position]

² The parameters listed here correspond to the status definition contained in configuration file SAM_TelemetryStatus_Default.cfg

³ The parameters listed here correspond to the status definition contained in configuration file LGS_Full_Status.cfg

LMS LLTDigitalIO [Prosilica | LaserDiode | status]
LMS LLTDigitalIO [LLTMotors] – LLT motors power supply status [ON | OFF]
LMS LLTDigitalIO [FANPower] – LLT fan status [ON | OFF]
LMS LLTAnalogInput [PhM1-X1 | PhM1-X2 | PhM1-Y1 | PhM1-Y2 | PhM2]
LMS LLTAnalogInput [LLT_Temp | Prosilica | LaserDiode | LLTMotors | FANPower]
LMS LLTAnalogInput [status]
LMS LaserDigitalIO_A [FloodDetector | EmergencyChiller | EmergencyLaserDoor]
LMS LaserDigitalIO_A [EmergencyConsole | SLCHCommFail | RS485CommFail]
LMS LaserDigitalIO_A [status]
LMS LaserDigitalIO_B [Key_interlock | Interlock]
LMS LaserDigitalIO_B [SafetyShutter_In] – Laser box safety shutter status
LMS LaserDigitalIO_B [SafetyShutter_Out] – Laser box safety shutter status
LMS LaserDigitalIO_B [Watchdog_Monitoring | Heater | GreenLaser | status]
LMS IBOOT [state] – Remote power outlet status [ON | OFF]
LMS PiezoAnalogInput [PZT1 | Input1 | Voltage | PZT2 | Input2 | PZT3 | Input3]
LMS PiezoAnalogInput [status]
LMS TempLaserBox [temperature | setpoint | status | heater]

GET TCS

TCS POSANG	Position angle in degrees
TCS RMA	Rotator mechanical angle in degrees
TCS M3POS	M3 turret position.
TCS RA	Telescope right ascension
TCS DEC	Telescope declination
TCS HA	Telescope hour angle
TCS AZ	Telescope azimuth
TCS ZD	Telescope zenith distance
TCS EL	Telescope elevation
TCS EPOCH	Coordinates epoch
TCS LST	Siderial time
TCS DITHER	Dither value in numeric control.

TCS FOFFSET Telescope offset value in numeric control.

INFO - This command will return a string of the form “DONE VAR1=VAL1 VAR2=VAL2” containing status information of the SAM instrument. The data included is

OPMODE	SAM operation mode: TSNGS, NGS, TSLGS or LGS
R0	Estimated Fried parameter in [m]
WSPEED	Estimated wind speed in [m/s]
VARCM	Variance of corrected modes in [rad^2]
INSTRMT	Name of selected instrument: SAMI, VISITOR, etc.
DMLOOP	DM mirror loop ON or OFF
FTIME	Frame time in [ms]
WFSFLX	WFS flux in [Ke-/s] per sub-aperture
WFSFOC	WFS focus in [mm]
M3LOOP	M3 mirror loop ON or OFF
APDTIME	APDs sample time in [ms]
APDHV	APDs high voltage ON or OFF
P1LIGHT	Guide probe 1 light ON or OFF
P2LIGHT	Guide probe 2 light ON or OFF
MNTLOOP	Mount loop ON or OFF
LLTLOOP	LLT loop ON or OFF
RGPOWER	Range gate power ON or OFF
RGDELAY	Range gate delay in [ns]
LGSDIST	Laser guide star distance in [Km]
LQUALTY	Laser quality
LPOWER	Laser power ON or OFF
LSHUT	Laser intra cavity shutter OPEN or CLOSE
LLTDOOR	Launch laser telescope environmental door OPEN or CLOSE
ADC	ADC compensation ON or OFF
ADCIN	ADC inner element position
ADCOUT	ADC outer element position
VIFOLD	Visitor instrument fold IN or OUT

REFLIGHT WFS reference light ON or OFF
REFARM WFS reference arm IN or OUT
TSDISK TURSIM disk rotation ON or OFF
TSFOLD TURSIM fold IN or OUT
TSLIGHT TURSIM light ON or OFF
MODDOOR Environmental module door OPEN or CLOSE

LM <M1 | ... > - Forwards commands to the LMSOFT.

ATP [ON | OFF]

M1 MOVE <M1X> <M1Y> - M1X and M1Y in units of [mm]

M2 MOVE <VALUE> - VALUE in units of [mm]

M4 MOVE <A1> <A2> - A1 and A2 in the range [-1, 1]

SAFETYSHUTTER MOVE [IN | OUT]

LM LLT - Forward Laser Launch Telescope commands to LMSOFT.

LLT FAN [ON | OFF]

LLT POWERSUPPLY [ON | OFF]

LLT SHUTTER [OPEN | CLOSE]

LM LASER - Forward Laser Box commands to LMSOFT.

LASER DIODE [ON | OFF]

LASER POWERSUPPLY [ON | OFF]

LASER SHUTTER [OPEN | CLOSE]

LOG <ARG₁> <ARG₂> ... <ARG_N> - Log the arguments to the ICSOFT log file and to the *Events and Messages* display.

RMFAULTS – Use this command to clear all faults latched by the system. If the ALARM led indicator in the ICSOFT is lite, it will have the effect of turning that light off.

RTC <AO | DM | TT | ... > - Forwards commands to the RTSOFT.

AO <OPEN | CLOSE | STATE > - Open/Close the AO loop.

BGND <ON | OFF> - WFS background subtraction.

BIAS <ON | OFF | ACQ | APPLY | STATE > - WFS bias subtraction control.

ACQ <frames> - Takes a WFS bias calibration by averaging *frames* number of frames and then save the result to disk using two names: the protected name *wfsbias.fits* and the date formatted name *wfsbias-YYYYMMDDTHHMMSS.fits*

APPLY – Loads the file *wfsbias.fits* from disk and sets the RTCORE to use it.

CAMERA <exposure | ldf | power | readout | reset | set | mancmd | STATE >

exposure [stop|abort]

ldf [util|pci|tim]

power [on|off]

readout[abort|stop-idle]

set binning <val1> <val2>

set exposure <val>

set frames <val>

set gs <val1> <val2>

set readout <val>

set size <val1> <val2>

set trigger <val>

set roi <val1> <val2> <val3> <val4>

set panoramic]

DM <APPLY | FLATTEN | RECFLAT | ROTFLAT | STATE>

FLATTEN – Load and apply the voltages stored in the file *flattendm.cfg* to the DM.

APPLY <V₀ V₁ V₂ V₅₉> – Apply the given voltages to the DM.

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

ROTFLAT – Load and apply the voltages stored in the file *flattendm.cfg* including a correction factor based on the current Nasmyth rotator mechanical angle, and coefficients in file *DMflat_rot.txt*. See the RTSOFT programmer's manual for a detailed description.

ECHO <ARG₁> <ARG₂> ... <ARG_N> - Return all arguments.

EXEC <MACRO> - execute the specified macro.

FLATTEN – Deprecated, use “DM FLATTEN” instead.

LOAD [APDMAP | WMAT | XGRID | YGRID]

APDBIAS <FILENAME> - Load the bias for each APD.

APDMAP <FILENAME> - Loads the quad sensor geometry

WMAT <FILENAME> - Load the weights for WcoG.

XGRID <FILENAME> - Load x relative positions for WcoG.

YGRID <FILENAME> - Load y relative position for WcoG.

LLTM1 <CLOSE | OPEN> - LLT M1 loop control.

LLTM3 <CLOSE | DISABLE | ENABLE | OPEN> - LLT M3 loop control.

M3 <CLOSE | DISABLE | ENABLE | OPEN> - M3 loop control.

MODE <TSNGS | NGS | TSLGS | LGS> - Set RTC operation mode.

MODULATE RADIUS PERIOD CYCLES -

MOUNT <CLOSE | OPEN> - Mount loop control.

REC FRAMES AOPERIOD TTPERIOD – Use this command to record FRAMES number of wavefront sensor frames, AOPERIOD seconds of AO loop data, and TTPERIOD seconds of tip tilt loop data. With no arguments the default values are used. Set argument to a negative number to skip recording data for it. The command produce four files:

WF-YYYYMMDDTHHMMSS.RAW

WF-YYYYMMDDTHHMMSS.FITS

AO-YYYYMMDDTHHMMSS.DAT

TT-YYYYMMDDTHHMMSS.DAT

The files are saved to an automatically generated subdirectory located in a root directory set in the RTSOFT configuration file.

RGATE <ON | OFF | MODE | DELAY | DISTANCE | PWIDTH | PPERIOD>

MODE <AUTO | LASER> - Use to select between AUTO and LASER sync modes for ON/OFF pulse generation.

DELAY <VALUE> - In LGS mode the delay in [ns] between the falling edge of the TRIGGER OUT signal and the ON pulse to the Pockels Cell high-voltage driver.

DISTANCE <VALUE> - The delay in [ns] between the falling edge of the ON pulse and the rising edge of the OFF pulse to the Pockels Cell high voltage driver.

PWIDTH <VALUE> - The width on [ns] for the ON and OFF pulses to the Pockels Cell high-voltage driver.

PPERIOD <VALUE> - In TSLGS mode the time period in [ns] of the

pulse-train.

RMFAULT – Clear alarms.

RNOISE <ADU> - Set the readout noise value in the RTCORE. If the max value in a sub-aperture is smaller than three times this value, then the slopes are discarded and zero is returned instead.

RT <ARG₁> <ARG₂> ... <ARG_N> - RTCORE interface.

SDSU <ARG₁> <ARG₂> ... <ARG_N> - LEACH II controller interface.

SETREF < REVERT | OFFSET> - Without arguments attempts to measure the reference positions for each sub aperture.

REVERT - Use the revert option to remove all user applied offsets to the measured reference positions.

OFFSET < ID | ID_N-ID_M >

ID <OX> <OY> - Add a user defined offset to sub aperture ID. Without arguments return the current offset by subtracting the measured reference position to the current reference position value.

ID_N-ID_M <OX> <OY> - Add a user defined offset to a range of sub apertures starting at ID_N and ending at ID_M.

SLEEP <VALUE> - Wait a number of milliseconds and return.

SYTEM <ARG₁> <ARG₂> ... <ARG_N> - RTC OS command.

TT <PSCALE | PWEIGHT | LOCK>

PSCALE <VALUE> - Set the seeing dependent coefficient that relates TT probes error signals to actual displacements in arc-seconds.

PWEIGHT <VALUE> <VALUE> - Set the weight for each guide probe error signal.

LOCK <0 | 1> <0 | 1> - Control guide probe locking.

TTBIAS < ON | OFF | WHO | STATE >

<WHO> <SAMPLES> – Use to select the number of counts to average to estimate the APD bias. Max number is 6000 and min number is 50. Valid values for argument WHO are 0: BOTH, 1: GP1 only, 2: GP2 only.

TTP1, TTP2 [OPEN | CLOSE] Open/Close the TT loop for probe 1 or 2.

ROTFLAT <ANGLE> - Flatten the DM according to the specified rotator angle. With no arguments it uses the current rotator angle as published by the TCS. If the TCS is not available a rotator angle of 0 is used instead.

TCS <ARG₁> <ARG₂> ... <ARG_N> - Forward commands to the TCS.

TCS GET

3.2 Remote Commands

These are command available only to remote applications connecting to the ICSOFT through one of its **three** command servers. Two of the servers have at their core the *parse-service-instrument-command* VI. The third one is GMAP⁴ specific and implemented by the *parse-service-gmap-command* VI.

3.2.1 Instrument Command Handler

VI Name : parse-service-instrument-command

Module : PARSELIB

Default behavior is to forward the command to the ICSOFT command parser in *parse_task.vi* and return immediately with the response.

AO [OPEN | CLOSE] - Open/Close the AO loop by executing the script *aoloop_close.lua* and *aoloop_open.lua*

AOM [P1 | P2] - Return the current X-Y coordinates for guide probe 1 or 2.

ECHO - see section 3.1 above for a complete description.

GET - see section 3.1 above for a complete description.

INFO - see section 3.1 above for a complete description.

PING - replies the string “**SAM INSTRUMENT CONTROL APPLICATION**”

SOFFSET SX SY [SAMI] – set the offset between a reference star and the center of the field in units of arc-seconds in the X-Y GP coordinate frame . Parameters SX and SY are in units of arc-seconds. If the third argument SAMI is specified SX and SY are assumed to be X-Y SAMI CCD coordinates in units of pixels (no binning), and translated to X-Y GP coordinates. See section 4.1 below for more details on how this command is implemented.

3.2.2 GMAP Command Handler

ECHO - see section 3.1 above for a complete description.

GC - Returns the current RA-DEC mount coordinates.

GP - Returns the current Rotator Mechanical Angle.

GPOFFSET <XOFFSET> <YOFFSET> - Set the offset in arc-seconds between the mount coordinates and the center of the field.

P1 [XYSTATUS | COORDS]

P2 [XYSTATUS | COORDS]

XYSTATUS - X-Y coordinates of guide probe 1 in arc-seconds using the GMAP X-Y reference system. In that frame X_{GMAP} is flipped with respect to X_{SAM} . The XYSTATUS command account for that flip and returns the correct sign to GMAP.

4 Guide Star Selection Tool

COORDS *HH:MM:SS DD:MM:SS Epoch* – Set the ICSoft next object RA-DEC-EPOCH variables. The next object coordinates can be then be used for guide star acquisition see section TBD.

SOFFSET SX SY [SAMI] – set the offset between a reference star and the center of the field in units of arc-seconds in the X-Y GP coordinate frame . Parameters SX and SY are in units of arc-seconds. If the third argument SAMI is specified SX and SY are assumed to be X-Y SAMI CCD coordinates in units of pixels (no binning), and translated to X-Y GP coordinates. See section 4.1 below for more details on how this command is implemented.

Chapter 4: Guide Star Acquisition

Guide star acquisition involves transforming RA-Dec coordinates to X-Y stages coordinates in [mm]⁵. The required functionality for doing the transformations is provided by the ASTROLIB library of VIs. The library was contributed by SOAR and is part of the SOAR TCS application suite.

The ICS accepts target coordinates for the probe expressed in RA-Dec plus epoch. The transformations are encapsulated in [icsoft_general_GRA_GXY.vi](#). The VI accepts as input the target RA-Dec coordinates and returns as output the X-Y coordinates of the guide star.

The process starts by moving the input coordinates to the epoch reported by the TCS. The resulting RA-Dec coordinates along with the Mount coordinates are used to obtain the gnomonic projection coordinates ξ and η (ξ is in the east axis and η is in the north axis).

Then the transformations that account for the optical system of the telescope are applied [see appendix A below]. Here those transformation are presented in their matrix form

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} \cos(ROT) & -\sin(ROT) \\ \sin(ROT) & \cos(ROT) \end{bmatrix} \begin{bmatrix} \cos(-EL) & -\sin(-EL) \\ \sin(-EL) & \cos(-EL) \end{bmatrix} \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix} \begin{bmatrix} \cos(\theta) & -\sin(\theta) \\ \sin(\theta) & \cos(\theta) \end{bmatrix} \begin{bmatrix} \xi \\ \eta \end{bmatrix}$$

The coordinates in units of [mm] are obtained multiplying x and y by the focal length of the telescope. Finally the field center⁶ offset and the quad sensor offsets are added.

While the field center offset changes depending on how bad the mount pointing is, the quad sensor offsets are fixed.

4.1 Interactive star selection in LGS Mode

In LGS mode we use SAMI to help calibrate the guide star selection tool GMAP. SAMI allows to interactively select a star from an image and send its coordinates to the ICSOFT. By using the known coordinates of the field-center in SAMI plus the field rotation and the scale, the ICSOFT calculates the offset between the selected star and the field-center in units of arc-seconds in the X-Y GP coordinate frame.

$$\begin{aligned} DX &= SAMISCALE \times (STARX - SAMIFCX) \\ DY &= SAMISCALE \times (STARY - SAMIFCY) \\ SOFFSETX &= DX \times \cos(SAMIROT) - DY \times \sin(SAMIROT) \\ SOFFSETY &= DX \times \sin(SAMIROT) + DY \times \cos(SAMIROT) \end{aligned} \tag{4.1}$$

⁵ Looking SAM from the ISB, X is parallel to the bench and positive right. Y is perpendicular to the bench and positive up.

⁶ Distance between the position where the mount is pointing and the position where the WFS field center is.

SAMI send the star coordinates issuing the SOFFSET command with the SAMI option at the end to accept SAMI CCD coordinates. Upon receiving that command the ICISOFT calculates the offset between the field center and the star (SOFFSETX, SOFFSETY) using the values stored in the *icsoft.ini* configuration file: SAMIFCX, SAMIFCY, SAMIROT and SAMISCALE (4.1).

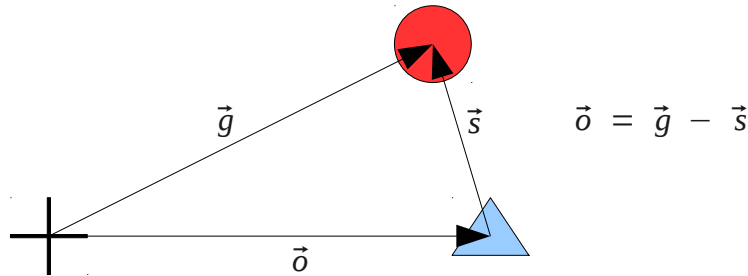


Figure 2: The cross mark the telescope coordinates in the sky-map. The circle is the selected star. The triangle is the field center.

The user has to set GMAP sky map to display the observed field and find the selected star to click in it. Correct identification of the selected star is critical to a good result. Then by pressing the FO button, GMAP interrogates ICISOFT on the current value of (SOFFSETX, SOFFSETY), calculates the offset between the mount and the field-center (GPOFFSETX, GPOFFSETY) and sends that value back to the ICISOFT. Next time you command ICISOFT to acquire a star the following transformation will be made to obtain the exact X-Y GP coordinates:

$$\begin{aligned} GPX' &= FLENGTH \times \{ \chi \cos(SAMPA) - \eta \sin(SAMPA) \} \\ GPY' &= FLENGTH \times \{ \chi \sin(SAMPA) + \eta \cos(SAMPA) \} \end{aligned} \quad (4.2)$$

$$\begin{aligned} GPX &= GP1X' + GPOFFSETX + GPAPDX + OPOFFSETX \\ GPY &= GP1Y' + GPOFFSETY + GPAPDY + OPOFFSETY \end{aligned} \quad (4.3)$$

The keywords FLENGTH, GPAPDX, GPAPDY, OPOFFSETX and OPOFFSETY are defined in the *icsoft.ini* configuration file. It is possible to GET/SET them on the fly via the GET/SET interface commands.

Chapter 5: Range Gate

Here is how the Range Gate parameters are calculated from the two parameters LGS Distance d and LGS Gate g (Figure 3) in units of [Km]

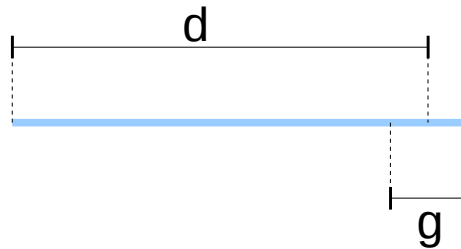


Figure 3: Range Gate parameters are calculated from the two parameters LGS Distance d and LGS Gate g .

From the RTSOFT programmer manual, we need to set the *DELAY* and *DISTANCE* parameters. *DELAY* is the delay in [ns] between the falling edge of the LASER sync pulse and the ON pulse to the Pockels Cell driver. *DELAY* is obtained then as

$$DELAY = \frac{2}{c} \times (d - \frac{g}{2}) \quad (5.1)$$

where c is the speed of light in units of [Km/ns].

DISTANCE is the delay between the falling edge of the ON pulse and the rising edge of the OFF pulse to the Pockels Cell driver.

$$DISTANCE = 2 \times \frac{g}{c} - Pulse\ Width \quad (5.2)$$

Since the Pockels Cell opens on rising edge the *Pulse Width* has to be taken into account.

Chapter 6: Atmospheric Dispersion Correction

The ADC task is implemented by the *icsoft_task_adc_logic* VI. The VI loops waiting for input in the *ADC Task Queue*. If the MOVE command arrives, the task searches for two arguments containing the target positions for the prisms. The arguments are used to build the command “AOM ADC MOVE ARG1 ARG2” and the resulting string is then sent to the AOMSOFT.

If the GO command arrives instead, the task uses the current telescope elevation (EL) and Nasmyth rotator mechanical angle (ROT), as stated by the TCS, to obtain the target position for the prisms. The process starts in the VI *icsoft_calculate_dispersion_angle* by obtaining the dispersion orientation angle (DA) for the ADC [see Appendix C].

The dispersion orientation angle along with the zenith distance ($ZD = 90 - EL$) is then passed to the VI *icsoft_compute_adc_elements_position* to obtain the final target positions for the inner element (INNER) and the outer element (OUTER) of the ADC as

```

if (STRENGTH*tan(zd) < 1)
    ANGLE = 90.0 - RAD2DEG( asin(STRENGTH*tan(zd)) );
else
    ANGLE = 90.0

DA    = DA0 * SIGN + OFFSET;

INNER = DA - ANGLE;
OUTER = DA + ANGLE;

```

The two angles are then used to build the command “AOM ADC MOVE INNER OUTER” and the resulting string is sent to the AOMSOFT. OFFSET, SIGN and STRENGTH are user defined parameters obtained from the *icsoft.ini* configuration file.

When ADC compensation is enabled, the GO command executes every TIMEOUT seconds, triggered by a loop in the VI *icsoft_task_control_manager*. TIMEOUT is a user defined parameter obtained from the *icsoft.ini* configuration file.

Chapter 7: Telemetry

The `icsoft_task_telemetry` VI runs every second and checks for every test-point if `LTIME` seconds have elapsed since the last check. The list of test-points to check is defined in the `telemetry.ini` file and `LTIME` is a test-point user defined parameter.

Each test-point in the `telemetry.ini` file has an ID. The assignment between ID and telemetry channel is hardwired into the code (Table 2)

Table 2: Test-point ID assignments

ID	Global Variable	Telemetry Keyword
0	TCHANNEL 00	30V Power Supply
1	TCHANNEL 01	30V APD 1
2	TCHANNEL 02	30V APD 2
3	TCHANNEL 03	5V APD
4	TCHANNEL 04	2V APD
5	TCHANNEL 05	Glycol
6	TCHANNEL 06	OAP1
7	TCHANNEL 07	DM
8	TCHANNEL 08	OAP2
9	TCHANNEL 09	ADC
10	TCHANNEL 10	TURSIM
11	TCHANNEL 11	PROSILICA 12V
12	TCHANNEL 12	Pockels-Cell High-Voltage
13		ATP 12V
14		LLT LASER Diode

APPENDIX A: North-East coordinates to Up-Left coordinates for Gnomonic Projection

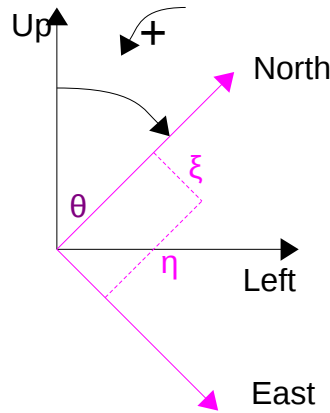


Figure 4: View of the celestial sphere from the outside. θ is the angle between the plane containing the major circle of the reference RA and major circle of the reference AZ.

The east-north coordinates (ξ is east) for the gnomonic projection of an object (α, δ) near the reference coordinate (α_z, δ_z) is given by

$$\begin{aligned} \cos(c) &= \sin(\delta)\sin(\delta_z) + \cos(\delta)\cos(\delta_z)\cos(\alpha - \alpha_z) \\ \xi &= \frac{\cos(\delta)\sin(\alpha - \alpha_z)}{\cos(c)} \\ \eta &= \frac{\sin(\delta)\cos(\delta_z) - \cos(\delta)\sin(\delta_z)\cos(\alpha - \alpha_z)}{\cos(c)} \end{aligned} \tag{1}$$

To move the above coordinates to the Up-Left reference frame, they have to be rotated by the angle θ between the North and Up vectors. That angle is obtained using the following algorithm for a given geographic latitud φ , refence declination δ_z and reference hour angle H

$$\vec{z} = (\cos(\varphi), 0, \sin(\varphi)), \vec{m} = (\cos(-H)\cos(\delta_z), \sin(-H)\cos(\delta_z), \sin(\delta_z)), \vec{p} = (0, 0, 1)$$

Vector \mathbf{z} is the zenith, \mathbf{m} is the reference and \mathbf{p} is the pole. Vector \mathbf{l} is the normal vector defining the plane containing the major circle of AZ. Vector \mathbf{e} is the normal vector defining the plane containing the major circle of RA.

Using the cross and dot product between the two normal we obtain the tangent of angle θ .

$$\begin{aligned}
 \vec{l} &= \vec{z} \times \vec{m} \\
 \vec{e} &= \vec{p} \times \vec{m} \\
 \tan(\theta) &= \frac{\|\vec{l} \times \vec{e}\|}{\vec{l} \cdot \vec{e}} \\
 \vec{m} \cdot (\vec{l} \times \vec{e}) &> 0 \Rightarrow \theta = 2\pi - \theta
 \end{aligned} \tag{2}$$

Then, the transformation is obtained by multiplying the north-east coordinates by the rotation matrix

$$\begin{bmatrix} \cos(\theta) & -\sin(\theta) \\ \sin(\theta) & \cos(\theta) \end{bmatrix} .$$

APPENDIX B: Up-Left coordinates to SAM Guide Probe coordinates

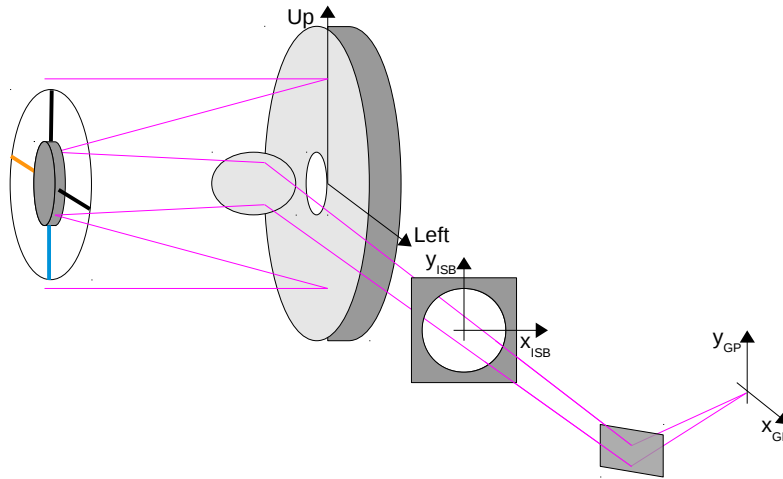
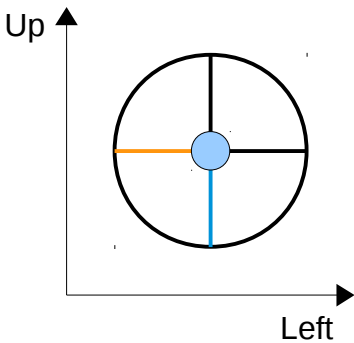
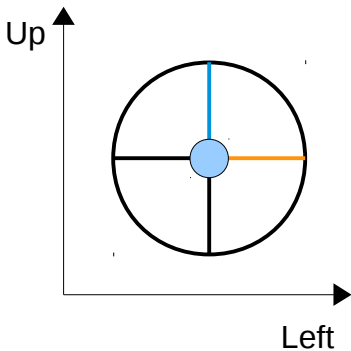


Figure 5: Telescope pointing to the horizon and rotator angle 0°.



The image to the left is the telescope spider. The reference axes match the alt-azimuth telescope Up and Left reference frame. Colored lines has been added to better visualize the flips and rotations introduced by the telescope optical system.



The M1 primary mirror introduces a vertical and a horizontal flip and the M2 secondary mirror introduces no change. The transformation is obtained by multiplying the x-y coordinates by $\begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix}$.

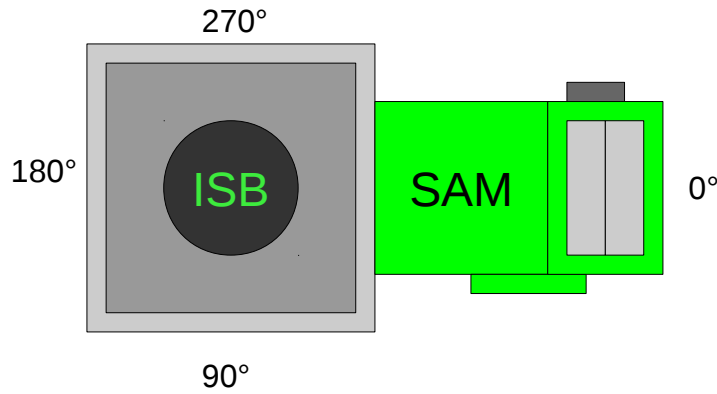
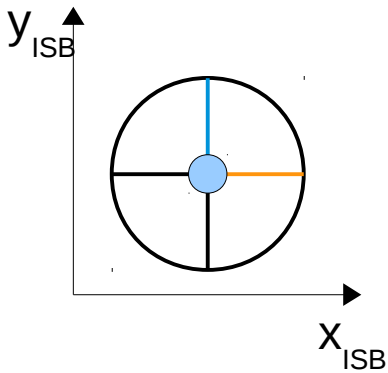
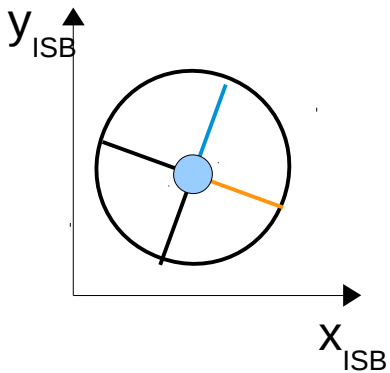


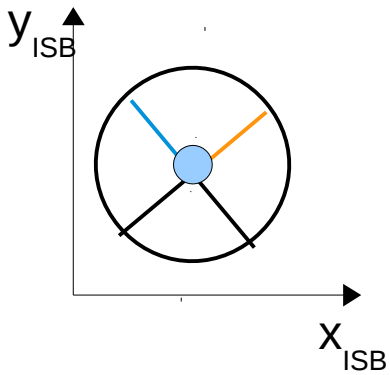
Figure 6: When the rotator angle is 0° SAM points to the right. Changes in rotator position introduce a rotation in plus the rotator angle ROT. $ROT \in [0^\circ, 360^\circ]$.



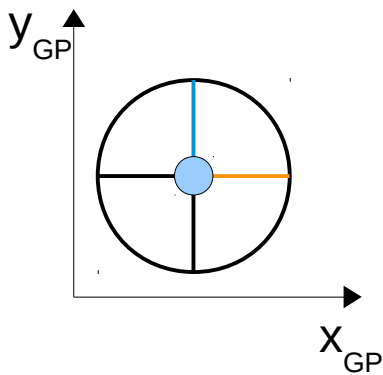
To reference the M3 tertiary mirror effect, we use reference axes fixed to the ISB [Figure 5]. With the elevation ring pointing to the horizon ($EL=0^\circ$) and the Nasmyth rotator (ROT) at its 0° angle position, M3 introduces no change.



Changes in elevation introduce a rotation in minus telescope elevation angle. The transformation is obtained by multiplying by $\begin{bmatrix} \cos(-EL) & -\sin(-EL) \\ \sin(-EL) & \cos(-EL) \end{bmatrix}$, with $EL \in [0^\circ, 90^\circ]$.



Changes in rotator position introduce a rotation in plus the rotator angle. The transformation is expressed by multiplying by $\begin{bmatrix} \cos(ROT) & -\sin(ROT) \\ \sin(ROT) & \cos(ROT) \end{bmatrix}$, with $ROT \in [0^\circ, 360^\circ]$.



To reference the M4 flat mirror effect, we use the reference axes of the SAM guide probes. With the elevation ring pointing to the horizon ($EL=0^\circ$) and the Nasmyth rotator (ROT) at its 0° angle position, M4 introduces no change.

APPENDIX C: Dispersion Orientation Angle

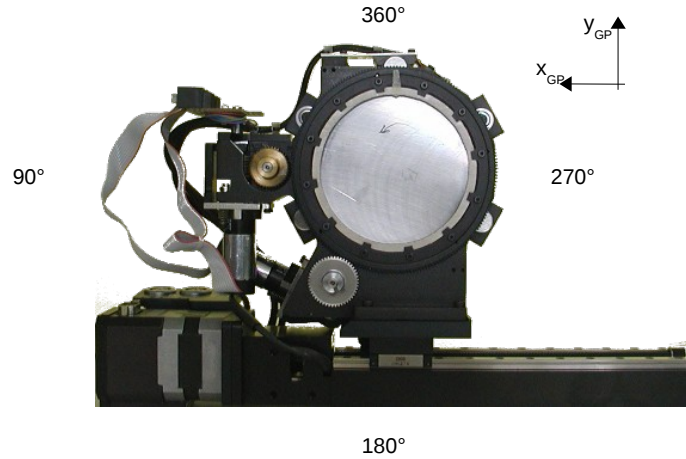


Figure 7: A final transformation is necessary to match the ADC mechanism convention for its prism angles.

The dispersion orientation angle (DA) matches the Down axis of the telescope at all times, that is (0, -1) in Up-Left coordinates. Applying the transformations explained in the previous appendix it is possible to obtain its position over SAM focal plane in X_{GP} - Y_{GP} coordinates as

$$\begin{bmatrix} DA_x \\ DA_y \end{bmatrix} = \begin{bmatrix} \cos(ROT) & -\sin(ROT) \\ \sin(ROT) & \cos(ROT) \end{bmatrix} \begin{bmatrix} \cos(-EL) & -\sin(-EL) \\ \sin(-EL) & \cos(-EL) \end{bmatrix} \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix} \begin{bmatrix} 0 \\ -1 \end{bmatrix} = \begin{bmatrix} -\sin(ROT - EL) \\ \cos(ROT - EL) \end{bmatrix}$$

Light goes behind the SOAR focal plane, reflects in OAP1, then goes down and to the right, reflects in the deformable mirror and hits the ADC. The net effect is only a small fixed rotation of $\sim 2^\circ$ degrees.

The dispersion angle can be obtained using an $ATAN2(DA_y, DA_x)$ type of function, to obtain a solution in the range $[-180^\circ, 180^\circ]$. A final transformation is necessary to match the ADC convention for the prism angles (see Figure 7)

APPENDIX C: Dispersion Orientation Angle

$$DA_{ADC} = 90^\circ - DA_{GP} \quad (1)$$