LBT-ADOPT
TECHNICAL REPORT

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A O S
Functional Description

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ABSTRACT

In this memo we describe the functionalities required to AOS (the TCS Subsystem which manages interaction with the Adaptive Optics) in order to perform all the operations related to the LBT Adaptive Optics.

Contents

Glossary of terms and acronyms

ADC. Atmospheric Dispersion Corrector.

AdSec. The Adaptive Secondary Mirror. In this context usually refers to the software subsystem controlling the hardware devices related to the secondary mirror.

AO System. The hardware and software components of the LBT first light Adaptive Optics System. Includes the Wavefront Sensor, the Adaptive Secondary Mirror, the AO Computer and some auxiliary devices (such as networking hardware).

AO-CI. The AO Software Command Interpreter: a component of AO-SW which can execute scripts.

AO Computer. The computer (or farm of computers) running the AO-SW.

AO Console. The operator console of the AO Computer.

AO-SS. the script executed to start-up the AO-SW.

AO-SW. The software dedicated to the managements of the Adaptive Optics System. Its main component is the Supervisor.

AOS. A part (subsystem) of TCS dedicated to interaction with the AO-SW.

AO Supervisor. The software system which manages all the components of the AO System

DD. Data Dictionary, the TCS own variable repository.

IIF. Instrument Interface, the set of commands provided by TCS to instrument software [6].

MsgD. Message Dispatcher, the AO Supervisor message dispatching utility.

OSS. Optical Support System, the TCS subsystem which manages optical devices (Secondary mirror, Tertiary mirror).

PCS. Point Control System, the TCS subsystem which manages pointing and tracking of the telescope.

PSF. PSF Control System, the TCS subsystem which manages the control of the optical PSF.

RTDB. AO Real Time Database, the AO Supervisor own variable repository.

TCS. Telescope Control System. The software dedicated to the management of the LBT telescope.

TCS Computer. The Computer (or farm of computers) running the TCS.

Technical Viewer. An auxiliary CCD used by the Wavefront Sensor to acquire the reference star.

WFS. The Wavefront Sensor. In this context usually refers to the software subsystem controlling the hardware devices related to the wavefront sensor.

1 Introduction

1.1 System Architecture

The Adaptive Optics Subsystem (AOS) is the subsystem of TCS providing all the functionalities needed for interaction between the LBT Adaptive Optics system and the rest of the telescope, including instruments.

General issues about the interaction between AO System and the TCS have been discussed in [1] and in figure 1 the relationships between relevant software components are shown.

From the AO System side, the interaction with TCS is managed by a specific process the "Ao Arbitrator", whose main function is to receive commands from the TCS and coordinate the execution of needed function by sending subcommands to the processes controlling the WFS and the AdSec.

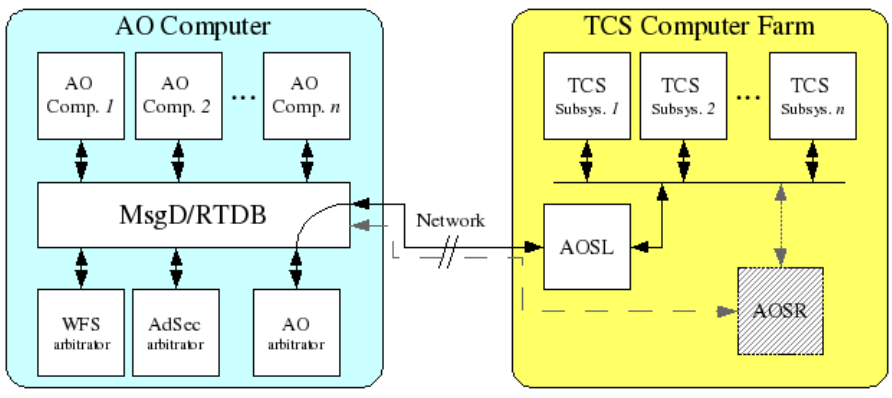

Figure 1: Interaction between the TCS and the AO Software

In general, communication between AOS and the AO Supervisor will be based on the two mechanisms defined in AO-Sup: access to `RTDB` variables and direct messages sent through the `MsgD` to some AO-Sup component.

AOS will maintain a subset of the TCS status variables reflected in the `RTDB` so that AO-Sup component have them available, and will have read access to the full set of AO-Sup status variables.

1.2 Supervisor Service States

AO-Sup supports four "Service States", indicating the mode of interaction with the TCS.

1. STANDALONE, when the AO system is operational but will neither request nor accept interaction with the TCS. All communications from AOS will be simply ignored. AOS anyway is allowed to read the `AOServStat` variable holding the current service status of the AO System (see also sect. 5.1).
2. ENGINEERING, when the AO system is performing calibration or maintenance functions which require services from the TCS (to operate telescope devices or to point a suitable reference star).
3. READY, when the AO system has successfully completed the automatic bootstrap procedure and is waiting for one of the following events to happen: 1) the TCS sends a request to start OBSERVATION state (see sect. 2.1) an operator at the AO console issues one of the state change commands: shutdown, or change service status to either STANDALONE or ENGINEERING.
4. OBSERVATION, when the AO System is supporting an observation.

Notably AO-Sup, in its interaction with TCS, will operate as master when in ENGINEERING service status and as slave when in OBSERVATION service status[1].

1.3 AO System Operating Modes

When operating in support of an observation the AO System will provide four modes of operation [2].

- **FIX-AO**. Fixed Mode Operation. It is the seeing limited mode where the Adaptive Secondary mirror holds a fixed "flat" shape defined by a pre-calibrated vector of mirror commands. Depending on the particular kind of observation a specific "flat" vector may be selected.
- **TTM-AO**. Tip-Tilt Mode Operation. It is an AO mode with only tip-tilt correction performed by the secondary mirror.
- **ACE-AO**. Auto Configured Adaptive Optics Operation. It is the full AO corrected mode, with AO loop parameters automatically selected by the AO System based on reference source characteristics.
- **ICE-AO**. Interactively Configured Adaptive Optics Operation. It is a full AO corrected mode where the observer is given the possibility to adjust AO loop parameters.

[1]Note that master operation here means that operation requests are originated by AO-Sup; but TCS will be able, anyway, to send a limited number of requests to AO-Sup too. And vice-versa, when operating as slave AO-Sup will mainly wait for requests from the TCS, but will anyway send a limited number of requests to TCS.

2 AOS Operational Functions

AOS, being an interfacing layer between the TCS and AO-Sup will both define commands to be used by other subsystems of the TCS to operate the AO System and, on the other side, it will receive messages from AO-Sup and translate them into proper commands to be executed by TCS[2].

In the following two sections we describe two set of operational commands in some deeper details: the first set is for commands which are received by the AOS from other TCS subsystem and are converted in messages to be sent to the AO-Sup; the second set refers to messages coming from the AO-Sup and received by the AOS. The description is essentially from the point of view of messages exchanged between the AOS and the AO-Sup. E.g : it may happen that an AO-Sup command to the AOS is entirely managed within the AOS itself (e.g.: by simply setting the value of a DD variable), or that it might result in a short sequence of commands sent to different subsystems of the TCS; on the other side some function executed by the AOS as the result of a command issued by another TCS subsystem, may result in a short sequence of messages exchanged with the AO-Sup.

2.1 Commands accepted by AOS from other TCS subsystems

Commands to be used by instruments during observation, which are translated by AOS into commands for the AO-Sup are listed in table 1 and are described in some details in the following paragraphs. Prior of sending the command message to AO-Sup, AOS will check the "status precondition".

Note that whenever necessary for each command the required parameters have been listed. This doesn't necessarily imply that the corresponding values will be sent together with the command: in some cases required values can be available as variables which are continuosly mirrored betwen the AO-Sup and AOS (see section 3.1).

2.1.1 StartObs

This command is used by the TCS to request the AO System to move from READY service status to OBSERVATION service status, this must be done at the beginning of an observation.

No parameters are required.

AOS will send the request message to AO-Sup and wait for an acknowledge. AO-Sup will perform the required checks and operations (e.g.: it will modify the behavior of the engineering interface at the AO Console) and acknowledge the request. At the end AOS will properly update the value in DD.

2.1.2 PresetFlat

This command is issued in OBSERVATION service status in order to request the AO System to prepare itself for the FIX-AO[3] mode of observation.

[2]The identification of the set of functions is the result of discussions with various people both from Arcetri and from Tucson: N. Cushing, M. De La Pena, S. Esposito, R. Green, J. Kraus, A. Riccardi, P. Salinari, M. Wagner, with a special mention to J. Hill.

[3]See sect 1.3.

Command	Status precond.	Description
StartObs	READY	Start an observation
PresetFlat	OBSERVATION	Preset AO System for seeing limited operation
PresetAO	OBSERVATION	Preset AO System for adaptive operation
CheckRefAO	OBSERVATION	Returns offset values between reference star actual and nominal position
AcquireRefAO	OBSERVATION	Acquire the reference star and become ready for closing the AO loop
RefineAO	OBSERVATION	Perform optimization of AO loop parameters
ModifyAO	OBSERVATION	Modify some AO loop parameter
StartAO	OBSERVATION	Start the AO mode (i.e.: close the AO loop)
OffsetXY	OBSERVATION	Offset AO pointing
OffsetZ	OBSERVATION	Offset AO focus
CorrectModes	OBSERVATION	Apply mirror shape correction
GetSnap	OBSERVATION	Get a snapshot image of the AO field of view
Stop	OBSERVATION	Stop current operation
Pause	OBSERVATION	Temporarily suspend current operation.
Resume	OBSERVATION	Resume suspended operation.
Terminate	OBSERVATION	Terminate an observation.
UserPanic	OBSERVATION ENGINEERING READY	Emergency shutdown request

Table 1: Commands accepted by AOS from TCS

This mode doesn't require a reference star, but it will be possible to select among several different "flats" depending on the type of observation.

`PresetFlat` Command Parameters

Name	Type	Units	Comment
`FlatSpec`	string		Specification of the desired "flat"

After sending the command to AO-Sup the AOS will wait for a status change of the corresponding AO variable. It will then reflect the service status into `DD`.

2.1.3 PresetAO

This command is issued in OBSERVATION service status in order to prepare the AO System for an observation in adaptive mode, i.e.: one of TTM-AO, ACE-AO, ICE-AO[3].

Following this command the AO System will perform all set up operations needed to prepare for the acquisition of a reference star[4].

[4]The setup operation has been split in two steps (`PresetAO` followd by a mixture of `AcquireRefAO` `RefineAO` and

When the PresetAO command has been completed and the telescope has reached the pointing position and is tracking, a command AcquireRefAO or CheckRefAO may follow.

The command must specify all parameters needed to set up the AO System for the requested operating mode as detailed in the following table.

PresetAO Command Parameters[a]

Name	Type	Units	Comment
AOMode	string		Either "TTM" or "ACE"
WFS	string		Specifies the source of WFS data
SOCoords	float[2]	mm	Position of the scientific object in focal plane coordinates
ROCoords	float[2]	mm	Position of the reference object in focal plane coordinates
Elevation	float	radians	Telescope elevation[b]
RotAngle	float	radians	Angular position of rotator[b]
GravAngle	float	radians	Angular position of rotator with respect to gravity[b]
Mag	float	TBD	Magnitude of reference star
Color	float	TBD	Color Index of reference star
R0	float	TBD	Estimated value of R0 (optional)
SkyBrghtn	float	TBD	Sky brightness (optional)
WindSp	float	TBD	Wind speed (optional)
WindDir	float	TBD	Wind direction (optional)

[a]The AO-Sup will also need some environment parameters, such as wind speed and direction, but will get values from the set of variables mirrored from the DD (See sect. 3.1).

[b]This is the estimated value when the pointing position is reached. This value may be used to select the proper look-up table and to preset the ADC.

After sending the command to AO-Sup, AOS will wait for a change of the corresponding AO variable. It will then reflect the new value into DD.

The AO system is expected to perform all set up operation needed except acquiring the reference object, which will be performed when the subsequent AcquireRefAO command will be issued.

At the end of preset the AO System will send an acknowledge to the AOS.

2.1.4 AcquireRefAO

The AcquireRefAO command is issued after a PresetAO in order to request the AO System to proceed to reference object acquisition by moving it's internal stages.

Before issuing this command the AOS must check both that the previous PresetAO command has been successfully completed and that the telescope has reached the pointing position and the guiding system is operating.

CheckRefAO) in order to allow the AO System to perform potentially time consuming adjustments (such as moving the mechanical assets of the WFS) while the telescope is slewing to point the source.

If the above preconditions are fulfilled, the AO System must find the reference star within the field of view of the Technical Viewer and thus is able to adjust the mechanical position of the WFS to put the reference star in the right spot. Then it will compute parameters needed for optimization of the AO loop and set up all the needed optical devices.

During the execution of the command some indication of partial completion of the operation will be sent back to the AOS[5].

The command requires no arguments.

After successful completion, the function will send back the computed AO loop parameters as detailed in the following table.

Parameters sent back by `AcquireRefAO` command

Name	Type	Units	Comment
`CompStatus`	string		Completion status. Either OK or an error message
ΔXY	float[2]	mm	Pyramid X,Y displacement with respect to nominal position
`NModes`	integer		Number of corrected modes
`Itime`	float	s	CCD integration time
`Nbins`	integer[2]		CCD binning (row wise,column wise)
`TTMod`	float	TBD	Tip-Tilt internal mirror modulation
`F1spec`	string		Selected position of filter wheel # 1
`F2spec`	string		Selected position of filter wheel # 2
`Strehl`	float[3]	TBD	Measured Strehl ratio in J,H,K bands
`R0`	float	TBD	Measured R0
`MSNratio`	float[672]	TBD	Measured S/N per mode
`TVframe`	T.B.D.		Snapshot of the stellar field from the Technical Viewer

After receiving the parameter block, the AOS will usually issue either a `StartAO` or a `RefineAO` command.

Note the ΔXY return values which are the amount of displacement of the WFS stages needed to put the source on top of the pyramid: in this mode they can be used to evaluate the errors in the pointing model and, possibly, to correct it.

2.1.5 CheckRefAO

This command can be used to obtain the centering of the reference star by adjusting the pointing of the telescope (instead of the WFS stages). Because it requires more complex interaction with the telescope, it will need a few steps.

After the `PresetAO` command a `CheckRefAO` command is sent. The AO-Sup will take an image with the technical viewer compute the ΔXY value and return it back. Based on that value the TCS can offset the telescope of the right amount and then can send an `AcquireRefAO` command to the AO-Sup. After that the WFS will actually perform the acquisition of the reference star.

[5]Note that the AO setup procedure may require several seconds to be completed.

2.1.6 RefineAO

The `RefineAO` command is used to request the AO system to perform better estimation of the AO loop parameters. It may be issued after the `AcquireRefAO` and will start the AO-Sup procedure[6] to optimize the selection of parameters.

The command has a single argument which selects the specific optimization method.

`RefineAO` command parameters

Name	Type	Units	Comment
`Method`	string		Optimization method

This command can be issued only in reply to the successful completion of a previous `AcquireRefAO` command. It is thus assumed that the reference object selected in the previous `PresetAO` command is still correctly positioned.

AO-Sup will perform the optimization procedure and reply with the same parameter block described for the `AcquireRefAO` command (see sect. 2.1.4).

2.1.7 ModifyAO

The `ModifyAO` command is used to support the ICE-AO operating mode. It may be used to request the AO System to modify the value of some AO loop parameter before closing the AO Loop. The command must specify the set of AO loop parameters selected by the observer as detailed in the following table[7].

`ModifyAO` command parameters

Name	Type	Units	Comment
`NModes`	integer		Number of corrected modes
`Itime`	float	s	CCD integration time
`Nbins`	integer		CCD binning
`TTMod`	float	TBD	Tip-Tilt internal mirror modulation
`F1spec`	string		Selected position of filter wheel # 1
`F2spec`	string		Selected position of filter wheel # 2

This command can be issued only in reply to the successful completion of a previous `AcquireRefAO` and/or `RefineAO` command. It is thus assumed that the reference object selected in the previous `PresetAO` command is still correctly positioned.

[6]The AO loop parameters optimization procedure evaluates the performances of the AO for a small interval of parameters values in order to determine the optimal set. It may require several minutes to complete, so it is offered as an optional function.

[7]The capability to specify some 'free" parameters (i.e.: parameters which can be optimized by the AO system, and not forced to specified values) will be provided.

AO-Sup will perform check of the validity of parameters[8], recompute the optimization values, and will reply with the same parameter block described for the `AcquireRefAO` command (see sect. 2.1.4).

The AOS can in principle issue an arbitrary number of `ModifyAO` commands before requesting the closing of the AO loop with a `StartAO` command.

2.1.8 StartAO

The `StartAO` command is issued by AOS to request the closing of the AO loop. It doesn't require any parameter in that it is only needed to synchronize the AO operation with the scientific instrument operation and when it is issued the AO System must be fully ready to close the AO loop.

After sending the corresponding command to AO-Sup, AOS will wait for a change of the corresponding AO variable.

It will then reflect the value into `DD`. The instrument software will thus be able to know from this status variable when the AO system is ready to start scientific data acquisition.

2.1.9 OffsetXY

This command is issued in OBSERVATION service status in order to offset pointing of the AO System (i.e.: by moving the WFS stages). The command is meaningful only when the AO System is operating in closed loop mode: the secondary mirror will follow the offset, so that this operation results in an offset of the field on the scientific camera.

The command requires two delta position values:

`OffsetXY` command parameters

Name	Type	Units	Comment
`DeltaXY`	float[2]	mm	Requested position offset

2.1.10 OffsetZ

This command is issued in OBSERVATION service status in order to offset the focus position of the AO System (i.e.: by moving the WFS stages). The command is meaningful only when the AO System is operating in closed loop mode: the secondary mirror will follow the offset, so that this operation results in a change of focus on the scientific camera.

The command requires one delta value:

`OffsetZ` command parameters

Name	Type	Units	Comment
`DeltaZ`	float	mm	Requested focus offset

[8] Parameter checking will be particularly strict for this command in order to ensure safe operation od the AO system.

2.1.11 CorrectModes

This command is used in OBSERVATION service status to apply a modal correction to mirror shape (e.g.: to make active optics corrections in seeing limited mode). A vector of Δ values must be specified.

`CorrectModes` command parameters

Name	Type	Units	Comment
`DeltaM`	float[672]	TBD	Modes correction vector

AOS will send the related request message to AO-Sup. No reply is expected to this command. Possible error conditions are notified by AO-Sup with the proper message.

2.1.12 GetSnap

The `GetSnap` command may be used to get a snapshot of the current field of view of the AO subsystem[9]. The image may be used e.g.: for displaying the AO field to the operator console.

2.1.13 Stop

This command will be issued to stop the current operation. After this command any setting defined by a previous `PresetAO` command will be canceled. The command requires a string parameter containing a description of the reason for stopping (see also sect. 2.1.17).

`Stop` command parameters

Name	Type	Units	Comment
`Msg`	string		Reason for stopping

AOS will send the request message to AO-Sup and wait for acknowledge. Then it will properly update the related variable in `DD`.

2.1.14 Pause

Temporarily suspend current operation; the AO System must remain ready to resume the suspended operation. AOS will send the related request message and wait for acknowledge, then it will reflect the status in `DD`. AO-Sup will take the proper action (e.g.: open the AO loop) and then acknowledge the request. The command may be followed by either the `Resume` or the `Stop` command.

[9]This actually corresponds to the readout of the Technical Viewer

2.1.15 Resume

Resume suspended operation after a `Pause`. AOS will send the related request message and wait for acknowledge, then it will reflect the status in `DD`. AO-Sup will resume the operation and acknowledge the request.

2.1.16 Terminate

This command is issued at the end of an observation night to terminate operations. After the command the AO-Sup will properly put all devices into safe conditions and go back to READY service status. The actual shutdown of AO hardware, and possibly of the AO-Sup and AO Computer can then be performed by the operator at the AO-Console.

2.1.17 UserPanic

This command is issued whenever some TCS subsystem (including an instrument) detects any dangerous conditions and decides to to perform a fast shutdown; the command may be also fired by the observer or operator at some user interface. AOS will send the corresponding request message to AO-Sup and Immediately close the connection. AO-Sup will will do its best to shutdown as soon as possible. After the acknowledge no other interaction will be possible between AOS and AO-Sup; i.e.: the command cannot be canceled. The command requires a string parameter containing a description of the event which caused it (see also sect. 2.1.13).

`Panic` command parameters

Name	Type	Units	Comment
`Msg`	string		Reason for panic

2.2 Commands issued by AO-Sup to request services from TCS

Commands sent by AO-Sup to AOS in order to request services from the Telescope are subdivided into three subset. The first subset includes housekeeping commands listed in table 2.

The second set of commands, listed in table 3, are used when the AO System is performing engineering operations which do not require pointing and tracking in the sky. In this mode of operation the AO System may need to directly control devices such as the hexapod or the rotator.

The third subset of commands, listed in table 4, are used when the AO System is performing engineering operations which require pointing a suitable object and tracking on it. In this mode of operation AO-Sup will behave much like an instrument and will not be able to directly control devices such as the hexapod or the rotator because they are under the control of PCS.

Command	State	Description
LogItem	ENGINEERING OBSERVATION	Requests to log some piece of information into the TCS Logging System.
LogOn	ENGINEERING OBSERVATION	Activate mirroring to `MsgD` of AOS generated log Messages.
LogOff	ENGINEERING OBSERVATION	Deactivate mirroring to `MsgD` of AOS generated log Messages.
DbgLevel	ENGINEERING OBSERVATION	Set debug level of AOS
Warning	ENGINEERING OBSERVATION	Notify warning condition
Error	ENGINEERING OBSERVATION	Notify error condition
Panic	ENGINEERING OBSERVATION	Notify AO System panic condition

Table 2: Commands Issued by AO-Sup. I - Housekeeping commands and messages

Command	State	Description
RequestService	ENGINEERING	Request service from TCS
EndOfService	ENGINEERING	Notifies to the rest of TCS that AO System has finished with AO engineering operations, and releases telescope resources.
Stop	ENGINEERING	Terminate current operation
Sync	ENGINEERING	Wait for synchronization
SetAltAz	ENGINEERING	Set telescope position (alt-azimuth, not tracking)
SetHexapod	ENGINEERING	Set hexapod position
SetRotator	ENGINEERING	Set rotator angle
SetTertiary	ENGINEERING	Set tertiary position.

Table 3: Commands Issued by AO-Sup. II - Low level commands

2.2.1 LogItem

Requests to log some piece of information into the TCS Telemetry System.

AO-Sup will have it's own logging system to be used for troubleshooting and engineering tasks. A selected subset of the log data will be stored in the TCS log system by means of `LogItem` commands.

2.2.2 LogOn/LogOff

Activate/deactivate the mirroring of AOS generated log messages to the `MsgD`.

After activation all the log messages[10] generated by the AOS other than being logged via the standard TCS logging mechanism, will also be echoed to the `MsgD` in order to be merged with Ao-Sup specific

[10]Except for messages explicitly logged to TCS Syslog by the `LogItem` command.

Command	State	Description
ActivatePreset	ENGINEERING	Activate telescope preset GUI
PointTelescope	ENGINEERING	Point telescope and start tracking (this is a simplified version of the PresetTelescope function of IIF)
OffsetPointing	ENGINEERING	Request a pointing offset to the telescope
OffloadModes	ENGINEERING	Offload accumulated errors.

Table 4: Commands Issued by AO-Sup. III - Pointing commands

logs. This will help in the maintenance of the system by allowing to easily correlate the relevant log messages.

2.2.3 DbgLevel

Activate/deactivate the AOS log messages. This command may be used ad debugging tool to increase/decrease the verbosity of messages generated by AOS. Under normal condition logging should be off (`DbgLevel=0`).

Note that if a LogOn command has also been sent, all logs will be mirrored in the `MsgD` log file.

2.2.4 Warning

This command is used by AO-Sup to notify that it has detected some condition which may potentially cause an error (e.g.: some mechanical device is close to a limit position). In ENGINEERING mode AOS will simply update the proper variables, while in OBSERVATION mode it will also notify the operator on the telescope console. Actions to be performed by AOS following a `Warning` command vary, depending on the reason why the warning was generated.

The AOS, when receiving the `Warning` command, will simply fire a specific event.

2.2.5 Error

This command is used by AO-Sup to notify that it has detected some error condition (possibly because a previous warning notification has not been properly managed) and has stopped the current operation. In ENGINEERING mode AOS will simply update the corresponding variables, while in OBSERVATION mode it will also notify the operator on the telescope console.

2.2.6 Panic

This command notifies that AO-Sup has detected a dangerous error condition and has initiated a shutdown procedure. AOS will stop any current operation and provide that a notification is displayed on the operator's console. After this the AO System will be set in a safe status and it may be necessary that an operator go to the AO engineering console to further investigate the problem and take proper actions.

2.2.7 RequestService

Notifies that the AO System wants to start engineering operation and needs service from some telescope subsystem. AOS will first check that the telescope is in suitable status (e.g.: no instrument has currently authorization to operate the telescope). If the request is accepted AOS will set a proper flag into the telescope status so that other subsystem will not receive authorization to control TCS functions and will request the TCS to activate the related focal station; then it will acknowledge the command to AO-Sup. The authorization status variable will be checked by AO-Sup prior of issuing any other request to AOS.

2.2.8 EndOfService

Notifies to the rest of TCS that AO System has finished with AO engineering operations, and releases telescope resources.

2.2.9 Stop

Request AOS to stop current operation.

2.2.10 Sync

This command is used to provide a means of synchronization between the AO System and an instrument.

After getting the command[11] the AOS must wait for the synchronization event and then return to the AO-Sup an acknowledgment. A negative acknowledgment will be returned if synchronization is not possible.

2.2.11 SetAltAz

This command is used in ENGINEERING service status to request TCS to set telescope position in alt-azimuth coordinates when the telescope is not tracking. AOS will issue the proper command to the MCS. The current position value and operation status will be reflected in the related variables in `RTDB`.

2.2.12 SetHexapod

This command is used in ENGINEERING service status to set hexapod position. AOS will issue the proper commands to the OSS. The current hexapod position and command completion status will be reflected in the corresponding variables in `RTDB`.

[11] Implementation details for this function are yet to be defined. The idea is to make it possible from a procedure running within the AO-Sup environment to request a snapshot to the scientific instrument and to be notified when the snapshot is available, maybe in the form of a FITS file on some shared disk area.

2.2.13 SetRotator

This command is used in ENGINEERING service status to control the rotator position. AOS will issue the proper commands to PCS to get the desired rotator angle. The current rotator position and command completion status will be reflected in the corresponding variable in `RTDB`.

2.2.14 SetTertiary

This command is used in ENGINEERING service status to set the position of Tertiary mirror. AOS will issue the proper commands to OSS to get the desired tertiary position. The current tertiary position and command completion status will be reflected in the corresponding variables in `RTDB`.

2.2.15 ActivatePreset

This request[12] is used in ENGINEERING service status to activate the TCS Preset GUI by which an operator can select a suitable reference star for AO operation. The preset GUI must allow the AO engineer to control all details of telescope presetting: setting and authorizing the proper focal station, selecting a suitable star from a catalog, pointing, start tracking, etc.

When the preset operation is terminated, AOS is notified and it will send to AO-Sup the same request message used for the `PresetAO` operation. AO-Sup will thus be able to acquire the reference star and proceed with engineering operations.

2.2.16 PointTelescope

This request is used to request pointing of the telescope to a given sky position and start tracking.

2.2.17 OffsetPointing

This command is used to request a pointing offset to the telescope. AOS will issue the proper commands to fulfill the request. No acknowledge will be provided (AO-Sup will be able to check the pointing status in the related variables as soon as they are updated by AOS).

2.2.18 OffloadModes

This command is issued by the AO System to request the TCS Arbitrator to offload accumulated errors[13]. AOS will issue the proper commands to the TCS.

[12] The exact meaning of this command depends on various operational aspects and is yet to be defined; it is quite possible that it will be no need to implement this function in the code, because it may be performed by means of commands given from the operator at the telescope control console.

[13] Note that this is specific of ENGINEERING service status. See section 2.2.4.

Variable	Type	Description
AOSVersion	String	A string specifying the version of AOS software.
TelStatus	Struct	Status of the telescope. This is a block of data representing the telescope status as recorded in the TCS. AO-Sup will use this value to know which operations are allowed at any time.
TelPointingEqu	Float	Current pointing equatorial coordinates. These include both "target" and "achieved" AR and DEC.
TelPointingAlt	Float	Current pointing alt-azimuth coordinates.
HexapodPos	Float	Current hexapod position
RotatorPos	Float	Current rotator angle
TertiaryPos	Float	Current tertiary position
Environment	Struct	A block of data with current environment and weather information (temperature, pressure, humidity wind speed and direction, and the like)

Table 5: Variables in RTDB

3 Variables

3.1 TCS variables reflected in RTDB

AOS will maintain a number of variables updated into RTDB (see table 5), providing proper refresh when needed. Variable update will be implemented by polling the DD at a constant rate of approximately 2 Hz.

Note that most of the variables names actually correspond to data structures including several items.

3.2 AO System variables reflected in DD

The set of variables which describe the status of the AO system are listed in table 6. They are updated as needed by AOS by means of the variable change notification mechanism provided by RTDB.

3.3 Special variables

A number variables will be defined for special purposes:

OffloadExecuted	Int	This variable is updated in RTDB whenever TCS executes a mode offload. AO-Sup can thus register to be notified of this event.

4 Watchdog security

For the reliability of the communication, it is important that both sides (i.e.: the AO-Sup and the AOS) will be promptly aware of any failure in the communication.

Variable	Type	Description
AOVersion	String	Version of AO-Sup
AOServStat	String	Current AO service status. TCS subsystems may use this value to know whether they are allowed to operate the AO System. One of the values of this variable will be STANDALONE which means that AOS must not attempt to do any operation on the AO System.
AOStatus	String	Current AO System operating status. It specifies current mode of operation and related parameters.
ImageQuality	Float	Image quality statistics. They are meaningful only while operating in close loop.
OffModes	Float	Low order modes which could be offloaded by some telescope device. These values may be used by instrument software to command TCS to adjust the pointing when needed (see also section 2.2.4).
Offload	Integer	Offload request hint. When greater than 0 indicates that it's time to offload modes. Increasing values in the range 1..3 correspond to incrasing strenght of the request. When the value of this variable becomes greater than zero a suitable event is fired by AOS.

Table 6: Variables in DD

In order to cope with possible failures either in the software or in the hardware (e.g.: in the network connections) AO-Sup and AOS will periodically send each other a special echo request and wait for a reply with a suitable timeout. If the request is not replied within the given time frame both AO-Sup and AOS will go into error condition and take proper safe actions. This, obviously, will happen only when the current service status involves communication between AO-Sup and AOS (i.e.: in OBSERVATION and ENGINEERING service modes).

5 Status transitions

In the following sections we describe the steps followed by both AO-Sup and AOS to initiate (or reply to) a change of service status.

5.1 Initial Rendez-vous

Because AO-Sup and AOS are loosely coupled and there is the need to operate AO-Sup without a working TCS and vice-versa, to avoid deadlocks the initial rendez-vous will proceed as follows:

1. AO-Sup is normally waiting for connections from clients. So it will accept a request for connection from AOS at any time, independently on its current service status. Any AO-Sup component which may request service from AOS must anyway check that AOS is ready before proceeding.
2. When starting the AO-Sup will create an AOServStat variable in RTDB with an initial value STANDALONE.

3. AOS at start will connect to `MsgD` and wait for `AOServStat` to be created. When the variable becomes available it will read the value. As long as the service status is not OBSERVATION AOS must simply wait for a change of variable value.

4. When AO-Sup is ready to proceed (i.e.: has performed all initial checks and initializations of the hardware devices) it will go to READY service status. This is actually a "point of switch" from where the AO system may proceed to either the OBSERVATION status (following a request issued by the AOS) or to some servicing status: ENGINEERING or STANDALONE (following a request from the operator at the AO Console).

5. As soon as AOS is notified by AO-Sup of service status change to either ENGINEERING or OBSERVATION, it will create the TCS variables into `RTDB`, copy the initial values of AO-Sup variables into `DD` and then will notify to `MsgD` that it is ready.

After this initialization AO-Sup and AOS will start performing the required tasks.

5.2 Driving AO-Sup in READY service status

During normal operation, after initialization, the AO System will proceed to READY service status in order to be ready either for a request from the operator at the AO Console or for a `StartAO` request issued by AOS.

The READY service status will also be restored when the AOS will issue a `Terminate` command at the end of an observation.

Finally an operator at the AO Console will be able to return the system to READY status at the end of maintenance operations, performed in either STANDALONE or ENGINEERING mode.

5.3 Shutting down TCS

Whenever the TCS must shut down, for any reason it will send either a `Terminate` command or a `UserPanic` command to AO-Sup (see sect 2.1), according to the reason for TCS shutdown.

The AO System will perform the operations necessary to properly stop current work and return to READY status.

A Typical AO Command Sequences

For a better understanding of the overall AO operations, in figure 2 we show the sequence of commands which must be issued to implement the various ways of functioning of the AO system when supporting an observation.

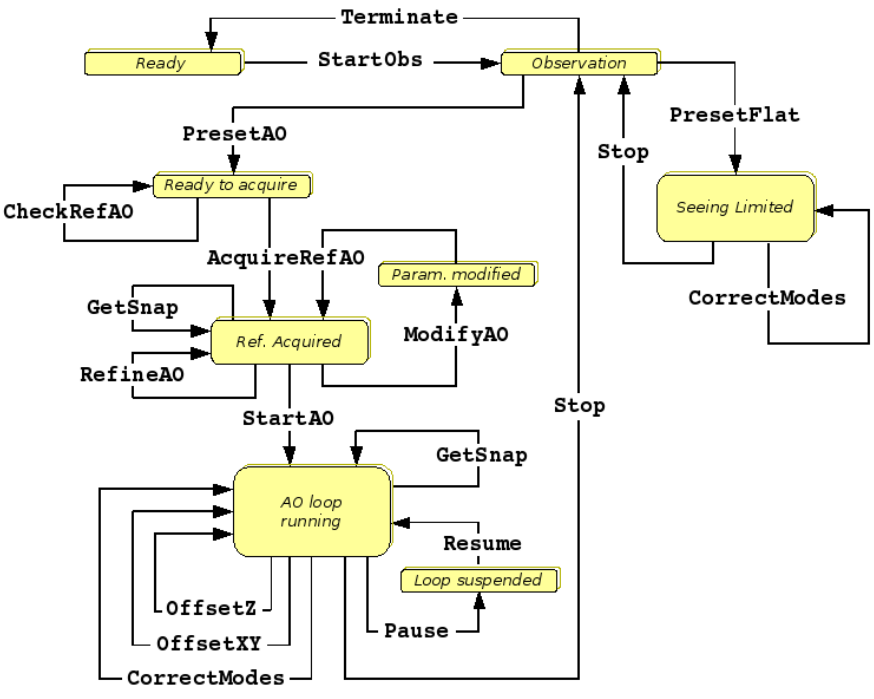

Figure 2: Command flow for AO operations

Here follows a few examples of possible implementations of some operating modes of the AO system.

A.1 Example 1: ACE-AO Implementation

The following steps will be performed by the instrument software to perform an observation in AO mode with optimization of the AO loop parameters[14]:

[14]The procedure includes only the essential steps: security related checks and asynchronous events which may interrupt or modify the sequence of operations have been omitted for clarity purposes.

AO Command	Tel. command	comment
PresetAO	Preset Telescope	*Telescope starts slewing while instrument is presetting AO starts adjusting stages. AOS waits for acknowlegment and returns.*
Event: telescope is tracking on target.		
AcquireRefAO		*AO adjusts pointing on the ref.star. AOS waits for acknowlegment and returns.*
RefineAO		*AO performs the optimization procedure. AOS waits for acknowlegment and returns.*
Event: instrument is ready.		
StartAO		*AO closes the loop. AOS waits for acknowlegment and returns.* *Instrument starts integration.*
Event: instrument integration finished.		
Stop		*AO opens the loop and remains ready for a new observation step.*

A.2 Example 2: ICE-AO Implementation

The following steps will be performed by the instrument software to perform an observation in AO mode with interactive selection of the AO loop parameters[14]:

AO Command	Tel. command	comment
PresetAO	Preset Telescope	*Telescope starts slewing while instrument is presetting. AO starts adjusting stages. AOS waits for acknowlegment and returns.*
Event: telescope is tracking on target.		
AcquireRefAO		*AO adjusts pointing on the ref.star. AOS waits for acknowlegment and returns. The instrument SW activates the AO parameter selection GUI.*
ModifyAO		*AO modifies parameters. AOS waits for acknowlegment and returns.*
Event: instrument is ready, AO parameter selection is confirmed.		
StartAO		*AO closes the loop. AOS waits for acknowlegment and returns.* *Instrument starts integration.*
Event: instrument integration finished.		
Stop		*AO opens the loop and remains ready for a new observation step.*

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