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1. Introduction

ERIS, the Enhanced Resolution Imager and Spectrograph, is an IR instrument, observing in the wavelength range 1-5 μm, installed at the Cassegrain focus of UT4/VLT, equipped with the Adaptive Optics Facility (AOF). ERIS uses and depends on the AOF infrastructure to perform the AO correction. The AO corrections are provided by the AOF Deformable Secondary Mirror (DSM) and with the aid of the artificial Laser Guide Stars (LGSs) that are generated by the 4LGSF system. The WFSs inside of ERIS form the feedback loop with the AOF.

ERIS consists of three main instrumental modules:

- the **AO module** provides NGS and LGS wavefront sensing and real-time computing capabilities and interfaces to the AOF.
- two scientific instruments, the **imager NIX** and the **spectrograph SPIFFIER**, only one of which at a time can fed by the AO module through a dichroic beamsplitter.
- **NIX** provides diffraction limited imaging, sparse aperture masking (SAM) and pupil plane coronagraphy capabilities from 1-5 μm (i.e. J-Mp bands), either in “standard” observing mode or with “pupil tracking” and “burst” (or “cube”) readout mode.
- **SPIFFIER** is an upgraded version of SPIFFI, the 1-2.5 μm integral field unit used on-board SINFONI, modified to be integrated into ERIS. Its observing modes are identical to those of SINFONI, additionally including high resolution grating configuration.

1.1 Scope

This document contains the overall ERIS Calibration Plan, which includes all subsystems: ERIS-AO, ERIS-NIX, and ERIS-SPIFFIER. For each of the calibration procedures documented information is provided that includes an explanation of the purpose of the procedure, the expected frequency and duration, and the output products of the procedure.

1.2 Definitions, Acronyms and Abbreviations

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

AO	Adaptive Optics
AT	Acquisition Template
CT	Calibration Template
ESO	European Southern Observatory
ERIS	Enhanced Resolution Imager and Spectrometer
IFU	Integral Field Unit
MPE	Max-Planck-Institut für extraterrestrische Physik
NA	Not Applicable
NIX	Near Infrared Camera
OB	Observation Block
OS	Observation Software
OT	Observation Template
P2PP	Phase II Proposal Preparation
PDR	Preliminary Design Review

QC	Quality Control
SNR	Signal-to-noise ratio
SPIFFIER	Spectrometer for Infrared Faint Field Imaging Enhanced Resolution
SO	Science Operations
TBC	To Be Confirmed
TBD	To Be Defined
UK ATC	United Kingdom Astronomy Technology Centre
VLT	Very Large Telescope

2. Related Documents

2.1 Applicable Documents

The following documents, of the exact version shown, form part of this document to the extent specified herein. In the event of conflict between the documents referenced herein and the content of this document, the content of this document shall be considered as superseding.

AD1 ERIS Common definitions and acronyms;
VLT-LIS-ESO-14400-5937

AD2 ERIS Applicable and Reference Document List;
VLT-LIS-ESO-14400-5944

2.2 Reference Documents

The following documents, of the exact version shown herein, are listed as background references only. They are not to be construed as a binding complement to the present document.

RD1 ERIS Instrument Software Functional Specification;
VLT-SPE-ERI-14401-1702

RD2 ERIS Sub-System Design & Performance Report - Calibration Unit;
VLT-TRE-ERI-14404-5001

RD3 Data Reduction Library Specifications;
VLT-SPE-ERI-14400-4801

3. Calibration Plan

3.1 Classes of calibration procedures

Two classes of calibrations are defined: *science calibrations (SCI),* and *instrument monitoring (MON).* The classification is done according to the following guidelines:

- *Science calibrations* are taken within a predefined time interval of the science observations and cover the instrument setup relevant for the corresponding science observation. All such calibrations should be available on the day following the science observation in order to allow data reduction to begin.
- *Instrument monitoring calibrations* are carried out routinely at a lower rate (typically weekly, though for some calibrations, daily) and are basically concerned with individual instrumental parts (e.g. detectors) whose performance and "health" is monitored over long periods of time. They are useful for instrument monitoring and to initiate preventive maintenance. These lead to the creation of numerous Quality Control (QC) parameters to monitor the instrument's health. These are not detailed here at this stage of the calibration plan's development, but will be elaborated for FDR, after the complete list of QC parameters has been determined.
- Science calibrations are taken at either: 1) night and cover a parameter range close or restricted to the one used in actual science observations or 2) carried out in daytime and cover a larger or even complete range of the offered instrument setups and parameters.

3.2 Glossary of Terms used in calibration procedures

Acquisition: Accurate positioning of the telescope and instrument to position the targets for the observations. Preset the telescope to the target coordinates, setup the instrument (NIX or SPIFFIER), perform the AO sequence acquisition, and then position the target in the field for observations.

Calibration: Procedures to remove the instrumental signature from the scientific data.

Dark frame: Integration of specified duration with the shutter closed. The registered number of electrons per pixel includes the bias, dark current, and read noise from the detector, and the thermal background of the cryostat.

Daytime calibrations: Usually, calibrations are done during daytime following the night of observations. This implies a typical time delay of a few hours between science observations and daytime calibrations.

Flatfield: Exposure of a calibration light source with featureless spatial and spectral energy distribution, or a twilight flat sky exposure. The registered signal provides information about the response of the detector as a function of position, allowing a determination of the variation in sensitivity from pixel to pixel, the vignetting function, the presence of bad pixels on the detector, linearity of pixel response, etc.

Guide Star (GS): A point source used for accurate tracking (and active control of the telescope mirrors).

Image Slicer: is located in a focal plane of SPIFFI and dissects the 2D image into strips, using a 3D image slicer to have higher efficiency, using a tip-angle. The strips are rearranged to form a pseudo long-slit while preserving for each slitlet the pupil position and size.

Nighttime calibrations: Upon request, calibrations taken during the night of observations can be performed in form of so-called ``attached calibrations'' for high precision observations. These calibrations also include telluric and standard star observations. Their execution time is charged to the time allocation of the science program.

Observation Block: A logical unit of exposures needed to obtain a coherent set of data. An OB is made up of templates, and it encompasses all relevant information for a successful data acquisition on a target or set of targets. It consists of target information, a set of templates, parameter files for the templates, conditions, requirements, and comments concerning the specified observations. It represents the entity the short-term scheduler deals with. Constructing Observations Blocks is part of the Phase II Proposal Preparation process.

Quality Control: This includes a set of parameters (Quality Control level 1, or QC1 parameters) produced by an instrument pipeline for the purpose of trends analysis and instrument monitoring. The QC1 parameters are defined in the instrument QC dictionary, which will be defined by PAE.

Template: A set of instructions for the execution of a standard operation on the instrument and detector setups. The templates represent specially devised sequences for frequently used instrument operations and calibrations.

Template Signature File: A description of a template and its parameters. It contains information about the type and allowed ranges of the parameters. Some of the parameters have to be set by the observer.

Wavelength Calibration: Spectrum obtained from an emission line source. The wavelengths of the emission lines are accurately known and are used to transform pixel space along the spectral dimension into wavelength space.

3.3 Calibration procedure description

For each defined calibration, we give the following information:

Procedure ID: ERIS-XXX-##, where XXX identifies the calibration class (SCI or MON), and ## is a numerical index (for traceability and cross-referencing purposes)

Responsible group to carry out the calibration (science, engineer, observer, ...)

Phase: when the calibration has to be carried out (day or night time)

Frequency: how often the calibration task has to be carried out.

Purpose: reason for performing the calibration

Expected accuracy: accuracy required to be able to monitor the corresponding requirement during the project's life. Note that this is not relevant for all procedures, and also exact numbers have not been included here at this stage – currently the requirement documents should be the reference for this type of information.

Procedure: the description of the operations when the calibration is carried out. Reference to a pre-defined procedure is OK.

Set-up: actual setup of instrument functions that INS has to apply. In many cases these will be the same as the templates. Any additional settings are noted here though.

User defined parameters: list of the parameters that should be defined by the user when preparing the OB.

Calibration Hardware Devices: list of the calibration devices to be used for the calibrations (e.g. lamps). Detailed requirements for each device are described in RD2.

INS template: the INS template for the described calibration in RD1.

DRL Recipe (pipeline): where appropriate the associated pipeline routine required to process the data, and produce the calibration frames used in the analysis is given. More information about pipeline routines can be found in RD3.

Outputs: the pipeline data products, the Quality Control (QC) parameters and/or the keywords entered into the VLT engineering data stream produced by the calibration task.

Duration: an estimate of the time required to execute the task.

Prerequisites: possible dependencies on instrumental or sky conditions and/or on other calibration tasks.

Remarks: additional remarks, names of other documents when specific complementary information is required for instance if some parameter is very severe (accuracy, frequency...) and is justified in an analysis report.

4. Calibration Plan – Science Calibrations

4.1 ERIS-NIX Science Calibrations

4.1.1 Dark frames

Procedure ID	ERIS_IMG_SCI_001
Responsible	Science Operations
Phase	Day
Frequency	1/1 day, for matching DIT/NDIT and readout mode used while observing.
Purpose	Create master dark frames for science exposures
Accuracy	
Procedure	Take five dark images in a requested configuration with NXIS in dark position
Set-up	As defined by ERIS_nix_cal_Darks
Calibration Hardware devices	-
Template	ERIS_nix_cal_Darks Provides: DARK (DET.SEQ1.DIT, DET.NDIT, DET.READ.CURNAME)
DRL Recipe	eris_nix_dark
Outputs	MASTER_DARK_IMG (w/ matching DET.SEQ1.DIT, DET.NDIT, DET.READ.CURNAME) QC.READ.NOISE QC.READ.NOISE.VAR QC.DARK.MED QC.DARK.MEAN QC.DARK.RMS QC.NUMBER.HOT.PIXEL
Duration	Dependent on the number and duration of exposure times used for the science observations.
Pre-requisites	GAIN_INFO (matching DET.READ.CURNAME)
Remarks	Note that it is likely that ERIS could restrict the possible exposure times so that fewer daytime darks have to be taken.

4.1.2 Lamp Flats

Procedure ID	ERIS_IMG_SCI_006
Responsible	Science Operations
Phase	Day
Frequency	1/1 day for each combination of NXCW, NXPW, NXFW used in science observations.
Purpose	Provide flat field exposures for the correction of pixel-to-pixel sensitivity of each detector in each instrument configuration.
Accuracy	With an aim to reach at least 100 SNR per exposure, 300 SNR in the final products (count level 4000-5000 ADU in slow mode with gain=5.2 e-/ADU)
Procedure	5 exposures with the QTH lamp at the requested instrument configuration and 5 exposures at dark configuration matching the detector configuration of bright frames;
Set-up	As defined by ERIS_nixIMG_cal_LampFlats
Calibration Hardware devices	CU, QTH lamp
Template	ERIS_nixIMG_cal_LampFlats Provides: FLAT_LAMP_ON FLAT_LAMP_OFF
DRL Recipe	eris_nix_lamp_flat
Outputs	MASTER_FLAT_LAMP_LOFREQ (w/ matching DET.READ.CURNAME, NXCW, NXPW, NXFW) QC.FLAT.LAMP.MED QC.FLAT.LAMP.MEAN QC.FLAT.LAMP.RMS QC.NUMBER.COLD.PIXELS MASTER_FLAT_LAMP_HIFREQ (w/ matching DET.READ.CURNAME, NXCW, NXPW, NXFW) QC.FLAT.LAMP.MED QC.FLAT.LAMP.MEAN QC.FLAT.LAMP.RMS QC.NUMBER.COLD.PIXELS MASTER_BPM_LAMP (w/ matching DET.READ.CURNAME,NXCW, NXPW, NXFW)
Duration	Dependent on the number of different science observation settings.

Pre-requisites	MASTER_DARK_IMG (w/ matching DET.SEQ1.DIT, DET.READ.CURNAME) GAIN_INFO (DET.READ.CURNAME) COEFFS_CUBE (DET.READ.CURNAME) BP_MAP_NL (DET.READ.CURNAME)
Remarks	The ERIS calibration unit allows flat fielding only up to 2.5µm. L and M band wavelengths therefore require sky flats. The resulting BPM is different enough between FAST_UNCORR and SLOW_GR_UTR. It is better to match the readout mode of the observations. In APP mode, the Consortium recommends matching (NXCW, NXFW) nominal imaging flats, i.e. APP not in the beam.

4.1.3 Twilight Flats

Procedure ID	ERIS_IMG_SCI_011
Responsible	Science Operations, User
Phase	Twilight
Frequency	Once every two weeks at selected configurations (NXPW=JHK-pupil): NXCW=13mas-JHK, NXFW=J,H,Ks NXCW=27mas-JHK, NXFW-J,H,Ks *Depending on the observing demand in given configurations, regular monitoring interval can be kept longer (~monthly). Narrow-band filters and blocking if there is requested observation.*
Purpose	Full flat field in broad band filters (telescope+instrument) Accuracy assessment of low frequency flat fields with CU
Accuracy	The aim is to reach flux contrast about a factor of ~2 around 1/3th of the full well.
Procedure	Right after the sunset wait for switch to ERIS focus. Telescope points at zenith. Manually setup the instrument for a given twilight flat configuration. When the counts are around 11k-12k ADU, start recording images with the twilight flat template. Allow about 5 minutes for the recording part.
Set-up	As defined by ERIS_nixIMG_cal_TwFlats
Calibration Hardware devices	Telescope
Template	ERIS_nixIMG_cal_TwFlats Provides: FLAT_TWILIGHT
DRL Recipe	eris_nix_flat_twilight
Outputs	MASTER_FLAT_TWILIGHT_LOFREQ (w/ matching NXFW,NXCW,NXPW) QC.FLAT.TWILIGHT.MED QC.FLAT.TWILIGHT.MEAN QC.FLAT.TWILIGHT.RMS QC.NUMBER.COLD.PIXELS
Duration	At the worst case, one configuration per TW (which is easy, ~10 mins). The consortium will provide analysis to achieve 2 configs per TW.
Pre-requisites	MASTER_DARK_IMG (w/ matching DET.SEQ1.DIT, READ.CURNAME) MASTER_BPM_LAMP (w/ matching NXCW, NXPW, NXFW)

	GAIN_INFO (w/ matching DET.READ.CURNAME) C OEFFS_CUBE (w/ matching DET.READ.CURNAME) BP_MAP_NL (w/ matching DET.READ.CURNAME) MASTER_BPM_LAMP (w/ matching NXCW, NXPW, NXFW)

4.1.4 Sky Flats

Procedure ID	ERIS_IMG_SCI_016
Responsible	Science Operations, User
Phase	Late twilight, night time
Frequency	Once every L and M filters with 13mas-LM camera *Depending on the observing demand in given configurations, regular monitoring interval can be kept longer (~monthly). The consortium recommends associating Lp flats for >2.5um narrow-band filers.*
Purpose	Provide flat field exposures for the correction of pixel-to-pixel sensitivity of each detector in each instrument configuration of L and M band.
Accuracy	About 100 SNR in the final products. This requires about 1e7 e- in total assuming 5% difference in two airmass
Procedure	Autojitter (NOFF>=5) at least two airmasses (about 1, 2) optionally another one at a lower airmass (~2.5). DIT is limited by the sky background (DIT=0.2/0.05 in Lp/Mp as a guide). Adjust NDIT to reach the desired SNR.
Set-up	As defined by ERIS_nixIMG_cal_SkyFlats
Calibration Hardware devices	Telescope
Template	ERIS_nixIMG_cal_SkyFlats Provides: FLAT_SKY
DRL Recipe	eris_nix_flat_sky
Outputs	MASTER_FLAT_SKY_LOFREQ (w/ matching NXCW, NXPW, NXFW) QC.FLAT.LAMP.MED QC.FLAT.LAMP.MEAN QC.FLAT.LAMP.RMS QC.NUMBER.COLD.PIXELS MASTER_FLAT_SKY_HIFREQ (w/ matching NXCW, NXPW, NXFW) QC.FLAT.LAMP.MED QC.FLAT.LAMP.MEAN QC.FLAT.LAMP.RMS QC.NUMBER.COLD.PIXELS MASTER_BPM_SKY (w/ matching NXCW, NXPW, NXFW)
Duration	Dependent on the number of different science observation settings during the night.

Pre-requisites	MASTER_DARK_IMG (w/ matching DET.SEQ1.DIT, READ.CURNAME) GAIN_INFO (w/ matching DET.READ.CURNAME) COEFFS_CUBE (w/ matching DET.READ.CURNAME) BP_MAP_NL (w/ matching DET.READ.CURNAME)
Remarks	In APP mode, the Consortium recommends matching (NXCW, NXFW) nominal imaging flats, i.e. APP not in the beam.

4.1.5 Standard Star Observation

Procedure ID	ERIS_IMG_SCI_026
Responsible	Science Operations, User
Phase	Night
Frequency	Science operations: • Assessment of transparency classification for a given night, two standard stars low/high airmasses (J/H/Ks 27mas – TBC) • If a science OB requests clear conditions, a standard star observation prior to science OB (NXCW, NXFW, NXPW, READ.CURNAME)* • If a science OB requests photometric conditions, standard star observations before/after the science OB (NXCW, NXFW, NXPW, READ.CURNAME)* * Only applies to broad band filters (J,H,Ks,Lp,Mp) User: • For other situations, it is the responsibility of user to request for a standard observation applicable to their programme
Purpose	Photometric calibration
Accuracy	
Procedure	Take observations of a standard star, typically N exposures on source and N exposures off-source for background subtraction, depending on the star's brightness; same instrumental configuration as for science target (if applicable);
Set-up	As defined for ERIS_nixIMG_cal_StandardStar
Calibration Hardware devices	Telescope
Template	ERIS_nixIMG_cal_StandardStar
DRL Recipe	eris_nix_img_cal_and_stack
Outputs	IMG_STD_COMBINED QC.BACKGD.MEAN QC.BACKGD.SIGMA QC.FWHM QC.ELLIPTICITY QC.STREHL QC.LIMITING_MAG QC.SKYBRIGHT QC.MAGZPT

	QC.MAGZERR QC.MAGNZPT QC.MAGZPT.ELECTRON QC.MAGZPT.ELECTRON.ERR QC.STD.FWHM QC.STD.ELLIPTICITY QC.STD.STREHL QC.STD.AIRMASS QC.AMBI.SEEING
Duration	5-10 min (+acquisition)
Pre-requisites	MASTER_DARK_IMG (w/ matching DET.SEQ1.DIT, DET.READ.CURNAME) GAIN_INFO (DET.READ.CURNAME) COEFFS_CUBE (DET.READ.CURNAME) BP_MAP_NL (DET.READ.CURNAME) If NXCW=13mas-LM: • MASTER_FLAT_SKY_LOFREQ (w/ matching NXCW, NXPW, NXFW) • MASTER_FLAT_SKY_HIFREQ (w/ matching NXCW, NXPW, NXFW) • MASTER_BPM_SKY (w/ matching NXCW, NXPW, NXFW) If NXCW=13mas-JHK, 27mas-JHK: • MASTER_FLAT_LAMP_LOFREQ (w/ matching NXCW, NXPW, NXFW) • MASTER_FLAT_LAMP_HIFREQ (w/ matching NXCW, NXPW, NXFW) • MASTER_BPM_SKY (w/ matching NXCW, NXPW, NXFW)
Remarks	Replace MASTER_FLAT_LAMP_LOFREQ with MASTER_FLAT_TWILIGHT_LOFREQ if there is matching configuration within 2 weeks. We don't observe standards in HCI modes.

4.1.6 Standard Star Observation (LSS)

Procedure ID	ERIS_IMG_SCI_031
Responsible	Science Operations, User
Phase	Night
Frequency	1/1 for each band and airmass range of OB of the science observations, depending on need.
Purpose	Observe a calibration standard in long slit spectroscopy mode
Accuracy	
Procedure	Take observations of a standard star, typically N exposures along the long slit
Set-up	As defined for ERIS_nixLSS_cal_StandardStar
Calibration Hardware devices	Telescope
Template	ERIS_nixLSS_cal_StandardStar
DRL Recipe	eris_nix_spec_cal_and_stack
Outputs	A multi-extension FITS file of type SPEC_STD_COMBINED. QC1 parameters: QC.FWHM QC.STREHL QC.STD.AIRMASS QC.AMBI.SEEING
Duration	5-10 min (+acquisition)
Pre-requisites	GAIN_LINEARITY MASTER_DARK MASTER_FLAT_LAMP MASTER_FLAT_TWILIGHT
Remarks	TBD

4.2 ERIS-SPIFFIER Science Calibrations

4.2.1 Dark frames

Procedure ID	ERIS_IFS_SCI_001
Responsible	Science Operations
Phase	Day
Frequency	1/1 day, for matching DIT used while observing
Purpose	Create master dark frames for science exposures
Accuracy	
Procedure	Take five dark exposures in a requested configuration with the instrument shutter closed (SPFW in closed position)
Set-up	As defined by ERIS_ifs_cal_Darks
Calibration Hardware devices	-
Template	ERIS_ifs_cal_Darks
DRL Recipe	eris_ifu_dark
Outputs	MASTER_DARK_IFU (with matching DET.SEQ1.DIT) BPM_DARK (associated bad pixel mask) QC.DARK.NBADPIX QC.DARKMED.AVE QC.DARKMED.STDEV QC.RON QC.RONRMS QC.DARKFPN QC.RON1 QC.RON2 QC.RON3 QC.RON4 QC.MASTERDARK MEAN QC.MASTERDARK STDEV
Duration	Dependent on the number and duration of exposure times used for the science observations.
Pre-requisites	-
Remarks	

4.2.2 Flat fielding

Procedure ID	ERIS_IFS_SCI_006
Responsible	Science Operations
Phase	Day
Frequency	1/1 day for each combination of SPFW, SPGW, SPXW used in science observations.
Purpose	Provide high SNR flat field exposures for the correction of pixel-to-pixel sensitivity of each detector in each band.
Accuracy	With an aim to reach at least 100 SNR per exposure, 300 SNR in the final products (i.e. 10k ADU or above per exposure)
Procedure	Five exposures with the QTH lamp on at the requested instrument configuration and five exposures with the QTH lamp off matching the detector configuration of bright frames.
Set-up	As defined by ERIS_ifs_cal_LampFlats
Calibration Hardware devices	CU, QTH lamp
Template	ERIS_ifs_cal_LampFlats Provides: FLAT_LAMP
DRL Recipe	eris_ifu_flat
Outputs	MASTER_FLAT (with matching SPFW, SPGW, SPXW) BPM_FLAT (updated bad pixel mask) QC.FLAT.SAT.NCOUNTS QC.SPECFLAT.OFFFLUX QC.SPECFLAT.NCNTSAVG QC.SPECFLAT.NCNTSSTD QC.LFLAT.FPN1 QC.LFLAT.FPN2
Duration	Depends on the number of different science observations settings.
Pre-requisites	BPM_DARK BPM_DETLIN BPM_DIST
Remarks	

4.2.3 Atmospheric transmission and photometric calibration

Procedure ID	ERIS_IFS_SCI_011
Responsible	User
Phase	Night
Frequency	On user request only. Should match SPXW. SPGW, SPFW of the observations.
Purpose	Correct for the atmospheric (and instrument) transmission in the observed science data. Photometric calibration is achieved by using telluric standards of known magnitudes.
Accuracy	
Procedure	Take observations of a standard star, typically 1 exposure on source and 1 exposure off-source for sky background subtraction.
Set-up	As defined for ERIS_ifs_cal_StandardStar
Calibration Hardware devices	None
Template	ERIS_ifs_cal_StandardStar Provides: STD, SKY_STD
DRL Recipe	eris_ifu_jitter
Outputs	OBJECT_CUBE (reconstructed sky-corrected object exposure for a given SPGW, SPXW, SPFW configuration) QC.LAMBDA.SHIFT QC.LAMBDA.SHIFT.PIXEL
Duration	5-10 min
Pre-requisites	DISTORTION (with matching SPFW, SPGW, SPXW) WAVE_MAP (with matching SPFW, SPGW, SPXW) MASTER_DARK (with matching DET.SEQ1.DIT) MASTER_FLAT (with matching SPFW, SPGW, SPXW) BPM_DARK BPM_FLAT BPM_LINEARITY OH_SPEC
Remarks	The user has the responsibility on this and wide selection of stars are available here (section 5.2.3 for the photometric monitoring): https://www.eso.org/sci/facilities/paranal/instruments/kmos/tools/Specphot_KMOS.html

4.2.4 Calibration of point spread function

Procedure ID	ERIS_IFS_SCI_016
Responsible	User
Phase	Night
Frequency	On user request only. Should match SPXW. SPGW, SPFW of the observations.
Purpose	Determine instrument/AO point spread function
Accuracy	
Procedure	Take observations of a PSF standard, typically 1 exposure on source and 1 exposure off-source for sky background subtraction.
Set-up	As defined for ERIS_ifs_cal_PSF
Calibration Hardware devices	None
Template	ERIS_ifs_cal_PSF Provides: PSF_CALIBRATOR SKY_PSF_CALIBRATOR
DRL Recipe	eris_ifu_jitter
Outputs	OBJECT_CUBE (reconstructed sky-corrected object exposure for a given SPGW, SPXW, SPFW configuration) QC.LAMBDA.SHIFT QC.LAMBDA.SHIFT.PIXEL
Duration	5-10 min
Pre-requisites	Same as 6.2.3
Remarks	

4.2.5 Wavelength calibration

Procedure ID	ERIS_IFS_SCI_021
Responsible	Science Operations
Phase	Day
Frequency	1/1 day for each SPFW, SPGW, SPXW configuration used for the science observations.
Purpose	Acquire emission-line lamp spectra to determine the wavelength solution for each spatial pixel.
Accuracy	1/10th of a spectral pixel
Procedure	Take calibration spectra of combinations of Ne, Ar, Kr and Xe pen ray lampsThe required pen ray lamps and DIT are automatically selected by the template according to the BAND (SPFW+SPGW) and SPXW setting.
Set-up	As defined by ERIS_ifs_cal_Arcs
Calibration Hardware devices	CU, Pen ray lamps (Ne, Ar, Kr and Xe)
Template	ERIS_ifs_cal_Arcs Provides: WAVE_LAMP
DRL Recipe	eris_ifu_wavecal
Outputs	WAVE_MAP (for a given SPGW, SPFW, SPXW configuration) QC.COEF0.AVG QC.COEF0.MED QC.COEF1.AVG QC.COEF1.MED QC.COEF2.AVG QC.COEF2.MED QC.COEF3.AVG QC.COEF3.MED QC.FWHM.AVG QC.FWHM.MED QC.POSER. AVG QC.POSERR.MED QC.POSERR.CLEAN.AVG QC.POSERR.CLEAN.MED QC.POSERR.AVG.ABS

	QC.POSERR.MED.ABS QC.POSERR.CLEAN.AVG.ABS QC.POSERR.CLEAN.MED.ABS
Duration	Depends on the number of different science observations settings.
Pre-requisites	DISTORTION (with matching SPFW, SPGW, SPXW) REF_LINE_ARC WAVE_SETUP SLITLET_POS MASTER_FLAT (with matching SPFW, SPGW, SPXW) BPM_FLAT
Remarks	

4.2.6 Image distortion

Procedure ID	ERIS_IFS_SCI_026
Responsible	Science Operations
Phase	day
Frequency	1 per month for all combinations of BAND (SPFW+SPGW) and SPXW configurations.
Purpose	Determine distortion correction map.
Accuracy	1/10th of a spatial pixel
Procedure	For each requested band and pixel scale: • A single slit mask in upright rotation exposure and a corresponding dark exposure • One or more pen pen ray lamp exposure with the corresponding dark images • A flat exposure with its corresponding dark image The required pen ray lamps, QHT lamp intensity and DIT are automatically selected by the template according to the BAND (SPFW+SPGW) and SPXW setting.
Set-up	As defined by ERIS_ifs_tec_NorthSouth
Calibration Hardware devices	Pen ray lamps (Ne, Ar, Kr, Xe), QTH lamp, integrating sphere, slit masks
Template	ERIS_ifs_tec_NorthSouth Provides: FIBRE_NS FLAT_NS WAVE_NS DARK_NS
DRL Recipe	eris_ifu_distortion
Outputs	For each combination of spectral band and pixel scale: DISTANCES (table with slitlet distances) BPM_DIST (bad pixel frame) SLITLET_POS (table with slitlet edge positions) DISTORTION (table with distortion correction parameters)
Duration	Depends on pixel scale and spectral band configurations.
Pre-requisites	
Remarks	

4.3 ERIS-AO Science Calibrations

No specific calibrations of the AO system are required to calibrate the scientific data. (TBD)

4.4 Summary of ERIS Science Calibrations

This table is per instrument setting (i.e. Band, SAM/APP configuration if relevant).

Duration estimates include overheads for on-sky calibrations.

N: number to be defined by user

o.r.: on request, corresponding OBs to be provided by user.

System	Calibration	Number	Frequency (1/day)	Purpose	Estimated Time
NIX	Dark frames	5/DIT	1/1	Master dark frame, preliminary bad pixel map	Variable, depends on exposure times
NIX	Lamp flats	5/setup	1/1 (where applicable)	Master flat field, pixel-to-pixel sensitivity, final bad pixel mask, lamp efficiency, saturation	5 min/setup
NIX	Twilight flats	N/setup	1/2 weeks	Check relative quality of lamp flats and on request twilight flats for users	TBD
NIX	Sky flats	N/setup	1/2 weeks	Alternative flats where lamp flats are not applicable	TBD
NIX	Standard Star	N	SO – 1 per nightly run User – o.r.	Atmospheric transmission and absolute flux calibration	20 min/setup
SPIFFIER	Dark frames	5/DIT	1/1	Master dark frame, preliminary bad pixel map	Variable, depends on exposure times

SPIFFIER	Flat field (with calibration unit or twilight)	5/setup (filter, grating, pixel scale)	1/1	Master flat field, pixel-to-pixel sensitivity, final bad pixel mask, lamp efficiency, saturation	5 min/setup
SPIFFIER	PSF	N	o.r.	Calibration PSF of system	-
SPIFFIER	Distortion correction	1	1/1 month	Slitlet postitions, spatial scaling differences	45 min/band.
SPIFFIER	Telluric (and photometric) standard	N	SO – 1 per nightly run User – o.r.	Atmospheric transmission and absolute flux calibration	-
SPIFFIER	Wavelength Calibration	1/ setup (filter, grating, pixel scale)	1/1	Dispersion solution, resolving power, lamp efficiency, saturation	5 min/setup.

5. Calibration Plan – Instrument Monitoring

This section of the ERIS Calibration Plan describes which instrument calibration data has to be collected, and at which frequency, to allow trend analysis of the instrument health and to initiate preventive maintenance.

5.1 ERIS-NIX Instrument Monitoring

5.1.1 Detector Linearity

Procedure ID	ERIS_IMG_MON_001
Responsible	Engineering Operations
Phase	Monthly
Frequency	1 per month
Purpose	Take a series of flat fields with increasing DIT, to determine read-out noise, gain, detector linearity, bad pixel map.
Accuracy	
Procedure	Take N exposures at different DIT (2 of each) with the calibration unit set towards the flat lamp switched on and N exposures in dark configuration. Note: two sets needed. One for slow and one for fast readout mode.
Set-up	As defined by ERIS_nix_tec_GainLinearity
User defined parameters	n/a
Calibration Hardware devices	CU, QTH lamp
Template	ERIS_nix_tec_GainLinearity
DRL Recipe	detmon_ir_lg (from DETMON)
Outputs	As described in the DETMON manual
Duration	40 minutes
Pre-requisites	-
Remarks	The consortium recommends single filter combination for each SLOW_GR_UTR and FAST_UNCORR.

5.1.2 Alignment Check with Calibration Unit

Procedure ID	ERIS_IMG_MON_006
Responsible	Engineering Operations
Phase	Day
Frequency	Monthly or after each instrument intervention
Purpose	Monitor (or verify after an intervention) internal alignment of NIX to CU
Accuracy	TBD
Procedure	Take an image of fibre source illuminated pupil of CU with NIX while Crosshairs in the pupil wheel. Scroll through 3 camera positions and use Ks band. CU is not transmitting in L band.
Set-up	As defined for ERIS_nix_tec_CheckPupil
User defined parameters	Camera, Mask, Filter, DIT + NDIT,
Calibration Hardware devices	Fibre source
Template	ERIS_nix_tec_CheckPupil
DRL Recipe	
Outputs	-
Duration	Few minutes
Pre-requisites	
Remarks	The test is proposed Ks since L, M band is not provided by the calibration unit.

5.1.3 Mask Alignment Check on Sky

Procedure ID	ERIS_IMG_MON_011
Responsible	Science Operations
Phase	Night
Frequency	Monthly or after each instrument intervention
Purpose	Monitor (or verify after an intervention) alignment of NIX to the telescope and assess the impact on pupil sensitive masks (SAM, APP, Lyot) if there is a suspected misalignment
Accuracy	APP, Lyot and SAM masks must cover the telescope spiders for modes to be operable
Procedure	For monitoring, record telescope pupil at 13mas-LM/Lp on-sky with NXPW at Crosshairs. If relative alignment of the crosshairs to the telescope spiders is the same, no need to proceed further. But, if not or in case of major intervention, each mask must be checked on-sky both in 13mas-JHK/13mas-LM (for FPC only the latter is usable): • Rotate the rotator to a configured angle (SAM=136, Lyot=135, APP=36 deg) • Record an image with NXCW=Open1 configuration • Record an image with the relevant pupil mask in • Overlaid images will show the spider positioning behind the mask
Set-up	As defined for ERIS_nix_tec_CheckPupil
Calibration Hardware devices	-
Template	ERIS_nix_tec_CheckPupil
DRL Recipe	-
Outputs	-
Duration	Depending on the configurations
Pre-requisites	
Remarks	This needs to be done on-sky and at zenith. Typical DIT for Lp is 0.05 and is 5 for Ks.

5.1.4 Astrometry, Plate Scale and Orientation

Procedure ID	ERIS_IMG_MON_021
Responsible	Science Operations
Phase	Night
Frequency	Monthly for each camera (13mas-JHK/H,27mas-JHK/H,13mas-LM/Lp)
Purpose	Monitor plate scale, orientation (and image distortion)
Accuracy	Initially, at least with accuracy in pixel scale of 0.1 mas/pix and orientation of 0.1 deg
Procedure	Observe reference astrometric fields ideally overlapping with HST observations or other ESO instruments
Set-up	As defined by ERIS_nixIMG_obs_GenericOffset
Calibration Hardware devices	None
Template	ERIS_nixIMG_obs_GenericOffset
DRL Recipe	eris_nix_img_cal_wcs The recipe only provides linear transformation (orientation and plate scale)
Outputs	
Duration	15 mins per config (typically enough per camera)
Pre-requisites	-
Remarks	Omega Cen, 47 Tuc are the suggested targets.

5.1.5 Persistence Characterization Monitoring

Procedure ID	ERIS_IMG_MON_036
Responsible	Engineering Operations
Phase	Day
Frequency	Monthly (initially, if stable enough quarterly)
Purpose	Monitor the stability of the persistence characteristics of NIX detector
Accuracy	
Procedure	- Baseline darks / 3 x Dark with DIT=300s - Illuminated flat frame / 1 x Flat with DIT=300s filling 80% well-depth - Darks to monitor persistence decay / 12 x Dark with DIT=300s
Set-up	NXPW=ND, NXFW=K-peak, NXCW=13mas-JHK, QTH=10.5% (TBC)
Calibration Hardware devices	CU, QTH lamp
Template	ERIS_nix_cal_Darks, ERIS_nixIMG_cal_LampFlats
DRL Recipe	-
Outputs	
Duration	~ 1.5 hours
Pre-requisites	
Remarks	

5.1.6 Persistence Event Detection

Procedure ID	ERIS_IMG_MON_041
Responsible	Science operations
Phase	Day/Night
Frequency	Before each nightly run and/or after execution of a science OB in which there is a suspicion of a persistence event (TBC)
Purpose	Either to confirm that NIX detector is not suffering from a persistence event before a nightly run and/or to perform a quick analysis on the detector during night if there is a reason to believe that a persistence event has occurred during a science OB.
Accuracy	
Procedure	3 x Dark with DIT=300s
Set-up	DIT=300, NDIT=1, NEXPO=3
Calibration Hardware devices	
Template	ERIS_nix_cal_Darks
DRL Recipe	Analysis using a dedicated local script (provided by ESO)
Outputs	
Duration	~15 minutes
Pre-requisites	
Remarks	

5.2 ERIS-SPIFFIER Instrument Monitoring

5.2.1 Detector Characterization

Procedure ID	ERIS_IFS_MON_001
Responsible	Engineering Operations
Phase	Monthly
Frequency	1 per month
Purpose	Take a series of flat fields with increasing DIT, to determine read-out noise, gain, detector linearity, bad pixel map
Accuracy	
Procedure	Take 2 exposures at different DIT (2, 5, 10, 20, 30, 40, 50, and 60 s) using the CU QTH lamp and repeat with lamp off.
Set-up	Same as ERIS_ifs_tec_GainLinearity
Calibration Hardware devices	CU, QTH lamp
Template	ERIS_ifs_tec_GainLinearity Provides: LINEARITY_LAMP
DRL Recipe	eris_ifu_detlin
Outputs	BPM_DETLIN (badpixel map) BPM_DETLIN_FILT (filtered badpixel map) QC parameters TBD
Duration	~20 min
Pre-requisites	
Remarks	SPIFFIER data is not linearity corrected. Hence, the Consortium recommends single instrument configuration for monitoring purposes and bad pixel map.

5.2.2 Pupil Image

Procedure ID	ERIS_IFS_MON_006
Responsible	Engineering Operations
Phase	Monthly
Frequency	1 per month
Purpose	Take an image of the pupil to ensure it remains in the correct position
Accuracy	The accuracy of the pupil alignment due to the overall optical alignment is 1% (about half a pixel shift).
Procedure	Take an image of the CU pupil illuminated with the calibration unit LDLS.
Set-up	As defined by ERIS_ifs_tec_CheckPupil
Calibration Hardware devices	CU LDLS
Template	ERIS_ifs_tec_CheckPupil
DRL Recipe	eris_ifu_jitter
Outputs	TBD
Duration	5 min
Pre-requisites	
Remarks	

5.2.3 Throughput response

Procedure ID	ERIS_IFS_MON_011
Responsible	Science Operations
Phase	night
Frequency	1 per month
Purpose	Throughput monitoring of SPIFFIER using spectrophotometric standards of known magnitudes and profile, which are listed in the remarks.
Accuracy	
Procedure	Take observations of a standard star, typically 1 exposure on source and 1 exposure off-source for sky background subtraction.
Set-up	As defined for ERIS_ifs_cal_StandardStar
Calibration Hardware devices	None
Template	ERIS_ifs_cal_StandardStar Provides: STD SKY_STD
DRL Recipe	eris_ifu_jitter
Outputs	OBJECT_CUBE (reconstructed sky-corrected object exposure for a given SPGW, SPXW, SPFW configuration) QC.LAMBDA.SHIFT QC.LAMBDA.SHIFT.PIXEL
Duration	5-10 min
Pre-requisites	DISTORTION (with matching SPFW, SPGW, SPXW) WAVE_MAP (with matching SPFW, SPGW, SPXW) MASTER_DARK (with matching DET.SEQ1.DIT) MASTER_FLAT (with matching SPFW, SPGW, SPXW) BPM_DARK BPM_FLAT BPM_LINEARITY OH_SPEC
Remarks	Standard Stars to be used: GD 71, LTT 3218, GD 153, EG 274, LTT 7987, Feige 110.

5.2.4 Persistence Characterization Monitoring

Procedure ID	ERIS_IFS_MON_016
Responsible	Engineering Operations
Phase	Day
Frequency	Monthly (initially, if stable enough quarterly)
Purpose	Monitor the stability of the persistence characteristics of SPIFFIER detector
Accuracy	
Procedure	- Baseline darks / 3 x Dark with DIT=300s - Illuminated flat frame / 1 x Flat with DIT=300s filling 80% well-depth - Darks to monitor persistence decay / 12 x Dark with DIT=300s
Set-up	BAND=K-middle, SCALE=25mas, QTH=9.8% (TBC)
Calibration Hardware devices	CU, QTH lamp
Template	ERIS_ifs_cal_Darks, ERIS_ifs_cal_LampFlats
DRL Recipe	-
Outputs	
Duration	~ 1.5 hours
Pre-requisites	
Remarks	

5.2.5 Persistence Event Detection

Procedure ID	ERIS_IMG_MON_021
Responsible	Science operations
Phase	Day/Night
Frequency	Before each nightly run and/or after execution of a science OB in which there is a suspicion of a persistence event (TBC)
Purpose	Either to confirm that SPIFFIER detector is not suffering from a persistence event before a nightly run and/or to perform a quick analysis on the detector during night if there is a reason to believe that a persistence event has occurred during a science OB.
Accuracy	
Procedure	3 x Dark with DIT=300s
Set-up	DIT=300, NDIT=1, NEXPO=3
User defined parameters	None
Calibration Hardware devices	
Template	ERIS_ifs_cal_Darks
DRL Recipe	Analysis using a dedicated local script (provided by ESO)
Outputs	
Duration	~15 minutes
Pre-requisites	
Remarks	

5.3 ERIS-AO Instrument Monitoring

This section describes the calibration procedures to acquire and monitor the most relevant parameters for the operation of the NGS WFS, LGS WFS and AO loops.

5.3.1 AO WFSs

Most of the following calibrations apply to multiple WFSs (NGS, LGS, and NGS in LO mode). Where this is the case, multiple templates are listed in the “Template” section.

Due to the overhead of switching between NGS and LGS configuration, the calibration OBs will be implemented with all the NGS mode calibrations in a single block, followed by all the LGS mode calibrations.

5.3.1.1 WFS Camera RON

Procedure ID	ERIS_AO_MON_001
Responsible	Science Operations
Phase	Day
Frequency	1/7 days
Purpose	Compute RON average and 2D map statistics from a set of WFS EMCCD frames. Compare with expected values and trends.
Accuracy	Average RON accuracy ~ 1/240 counts (considering an average over 240x240 pixels, no stray light, 1000 frames).
Procedure	Set the Filter Wheel/Shutter in BLOCK position. Take a series of EMCCD NDIT frames at minimal DIT available. Compute for each pixel the STDEV of the counts over the NDIT frames, and compute the average stdev over the whole frame. Value is compared with a quality threshold and an error is raised if the threshold is exceed.
Set-up	As defined by the measurement template
User defined parameters	EMCCD gain (default 400) NDIT (default 1000)
Calibration Hardware devices	None
Template	ERIS_ao_tec_NGSCcdRon ERIS_ao_tec_LGSCcdRon
DRL Recipe	No pipeline recipe, computation done in template code.
Outputs	RON average value and RON 2D map (240x240).
Duration	2-3 minutes for each WFS (LGS/NGS)
Pre-requisites	None
Remarks	

5.3.1.2 WFS camera counts vs. gain

Procedure ID	ERIS_AO_MON_006
Responsible	Science Operations
Phase	Day
Frequency	1/7 days
Purpose	Measure the ADU/e- ratio of the WFS cameras, compare with expected values and trends.
Accuracy	0.1 ADU/e- fitting residual (TBC)
Procedure	Illuminate WFS with using the CU. Setting a fixed EMCCD gain value, iterate over a series of different framerates and acquire a series of frames for each one. For each framerate, compute the average and stdev of each pixel in the series. Fit a line on the average vs. stdev relation across all framerates, the fitted slope is the measured value.
Set-up	As defined by the measurement template
User defined parameters	EMCCD gain value vector, framerate list, frame series length.
Calibration Hardware devices	CU using QTH lamp
Template	ERIS_ao_tec_NGSCcdGain ERIS_ao_tec_LGSCcdGain
DRL Recipe	No pipeline recipe, computation done in template code.
Outputs	ADU/e- ratio average value.
Duration	5 minutes for each WFS (LGS/NGS)
Pre-requisites	None
Remarks	

5.3.1.3 Acquisition camera dark frame

Procedure ID	ERIS_AO_MON_011
Responsible	Science Operations, user
Phase	Day
Frequency	1/1 day
Purpose	Measure dark frame of acquisition camera vs. integration time.
Accuracy	Fraction of count.
Procedure	Setup acquisition camera with the wanted DIT, NDIT, X and Y binnings, acquire and save a dark frame. Repeat for a list of DIT, NDIT, X and Y binnigs combinations covering all cases needed for TA templates.
Set-up	As defined by the measurement template
User defined parameters	None
Calibration Hardware devices	None
Template	ERIS_ao_tec_NGSAcDark
DRL Recipe	No need for a pipeline recipe: data is acquired and saved without further processing.
Outputs	Acquisition camera dark frames saved in $INS_ROOT.
Duration	Depends on the list of frames to be acquired, typically 2-3 minutes.
Pre-requisites	None
Remarks	The list of DIT and binning combinations is computed scanning the AO configuration tables when the calibration template is run, to ensure that all possible cases are covered.

5.3.1.4 WFS camera dark frame

Procedure ID	ERIS_AO_MON_016
Responsible	Science Operations
Phase	Day
Frequency	1/1 day
Purpose	Prepare dark frames of WFS cameras to be used during TA templates.
Accuracy	Fraction of count.
Procedure	Set the Filter Wheel/Shutter in BLOCK position. For each possible framerate, acquire a series of NDIT frames and save the averaged frame.
Set-up	As defined by measurement template
User defined parameters	NDIT camera frames to be averages for each measurement
Calibration Hardware devices	None
Template	ERIS_ao_tec_NGSCcdDark ERIS_ao_tec_LGSCcdDark
DRL Recipe	No need for a pipeline recipe: avearage is done in the template code, data is saved without further processing.
Outputs	WFS camera dark frames for each framerate, saved in $INS_ROOT
Duration	Depends on the list of framerates to be acquired, typically 2-3 minutes for each WFS (LGS/NGS)
Pre-requisites	None
Remarks	The list of framerates is computed scanning the AO configuration tables when the calibration template is run, to ensure that all possible cases are covered.

5.3.1.5 WFS pupil image and spots wobble vs. k-glass rotation

Procedure ID	ERIS_AO_MON_021
Responsible	Science Operations
Phase	Day
Frequency	1/7 days
Purpose	Measure, as a function of the k-glass rotation angle, (a) pupil image center position over the SH lenslet array, (b) SH spots average displacement (X & Y).
Accuracy	Fraction of SH pixel.
Procedure	Setup a reference position of AO WFS and CU. Take NDIT SH frames for each k-glass rotation angle (from 0deg to 360deg in steps) (a) Measure center coordinates for each spot in each frame Average the center coordinates per each sub-aperture and K-glass rotation angle (b) Get the pupil center position for each K-glass rotation angle as measured by SPARTA (xp,yp) The p2v value of spots center coordinates and pupil position is computed and saved into FITS logs. If the p2v values are higher than a threshold, an error is raised.
Set-up	As defined by the measurement template
User defined parameters	Angle start, end, step: k-glass angle to be scanned (default 0-360 degrees in steps of 30 degrees) NDIT: # of WFS camera frames to be averaged Threshold for pupil wobbling check Threshold for spots wobbling check
Calibration Hardware devices	CU with LDLS lamp.
Template	ERIS_ao_tec_NGSRotShWobble ERIS_ao_tec_LGSRotShWobble
DRL Recipe	No pipeline recipe, computation done in template code.
Outputs	(a) Pupil center Xp & Yp coordinates vs. k-glass rotation, p2v value (b) spots displacement (X & Y) vs. k-glass rotation, p2v value
Duration	5 minutes for each WFS (LGS/NGS)
Pre-requisites	None
Remarks	This is the same template that measures the k-glass wobbling compensation LUT, with different parameters to just execute a check

5.3.1.6 WFS pupil image and spots wobble vs.ADC rotation

Procedure ID	ERIS_AO_MON_026
Responsible	Science Operations
Phase	Day
Frequency	1/7 days
Purpose	Measure, as a function of the ADC rotation angle, (a) pupil image center position over the SH lenslet array, (b) SH spots average displacement (X & Y).
Accuracy	Fraction of SH pixel.
Procedure	Setup a reference position of AO WFS and CU. Take NDIT SH frames for each ADC rotation angle (from 0deg to 360deg in steps) (a) Measure center coordinates for each spot in each frame Average the center coordinates per each sub-aperture and ADC rotation angle (b) Get the pupil center position for each ADC rotation angle as measured by SPARTA (xp,yp) The p2v value of spots center coordinates and pupil position is computed and saved into FITS logs. If the p2v values are higher than a threshold, an error is raised.
Set-up	As defined by the measurement template
User defined parameters	Angle start, end, step: ADC angle to be scanned (default 0-360 degrees in steps of 30 degrees) NDIT: # of WFS camera frames to be averaged Threshold for pupil wobbling check Threshold for spots wobbling check
Calibration Hardware devices	CU with LDLS lamp.
Template	ERIS_ao_tec_NGSAdcShWobble
DRL Recipe	No pipeline recipe, computation done in template code.
Outputs	(a) Pupil center Xp & Yp coordinates vs. k-glass rotation, p2v value (b) spots displacement (X & Y) vs. k-glass rotation, p2v value
Duration	10 minutes
Pre-requisites	None
Remarks	This is the same template that measures the ADCs wobbling compensation LUT, with different parameters to just execute a check

5.3.1.7 Pupil mirror actuator interaction matrix

Procedure ID	ERIS_AO_MON_031
Responsible	Science Operations
Phase	Day
Frequency	1/7 days
Purpose	Measure how much the pupil and spots position change on the WFS cameras as a result of a given pupil mirror actuator command. Compare with previous measurements to detect any aging of the actuator.
Accuracy	
Procedure	Setup a reference position of AO WFS and CU. Move the pupil mirror (PM) piezo actuators following a list of dX, dY positions. At each position: (a) Measure center coordinates for each spot in each frame Average the center coordinates per each sub-aperture (b) Get the pupil center position as measured by SPARTA (xp,yp) After all measurements have been done, compute an interaction matrix for both the spots center coordinate and pupil position vs. the pupil mirror commands. From the 2x2 IM values of x/y scaling, shear and rotation are derived and saved into FITS lots.
Set-up	As defined by the measurement template
User defined parameters	List of dX, dY positions NDIT: # of WFS camera frames to be averaged at each position
Calibration Hardware devices	CU with LDLS lamp.
Template	ERIS_ao_tec_NGSPmPsf ERIS_ao_tec_LGSPmPsf
DRL Recipe	No pipeline recipe, computation done in template code.
Outputs	x/y scaling, shear and rotation for pupil mirror actuator command vs. pupil position, and vs. spot motion.
Duration	5 minutes for each WFS (LGS/NGS)
Pre-requisites	None
Remarks	This is the same template that measures the PM/pupil position reconstructor, with different parameters to just execute a check

5.3.1.8 Reference slopes and weighting masks

Procedure ID	ERIS_AO_MON_036
Responsible	Science Operations
Phase	Day
Frequency	1/7 days
Purpose	Measure refence slopes and weighting masks for the AO WFSs.
Accuracy	
Procedure	Scan the K-glass rotation angle at user-defined steps, get an averaged frame of WFS slopes at each step. Keep the pupil loop closed throughout the measurement. Project the slopes into vectors of low-order modes, fit each mode with a sin/cos series to detect any rotating component. Remove the fitted rotated modes from the slopes Average the residual slopes at each angle, and save the result as the reference slope frame. Generate a series of weighting masks with different diameters (from 3 to 10 pixels TBC), centered on the spots positions found with a similar algorithm: remove periodic sin/cos components and average the residuals.
Set-up	As defined by the measurement template
User defined parameters	Angle start, end, step: K-glass angle to be scanned (default 0-360 degrees in steps of 30 degrees) NDIT: # of WFS camera frames to be averaged
Calibration Hardware devices	CU with LDLS lamp.
Template	ERIS_ao_tec_NGSRefSlopes ERIS_ao_tec_LGSRefSlopes ERIS_ao_tec_LORefSlopes
DRL Recipe	No pipeline recipe, computation done in template code.
Outputs	Reference slopes frame Weighting masks
Duration	5 minutes for each WFS (LGS/NGS/LO)
Pre-requisites	None
Remarks	

5.3.1.9 Quick health check

Procedure ID	ERIS_AO_MON_041
Responsible	Science Operations
Phase	Day
Frequency	1/1 day
Purpose	Verify that the system alignment is within specifications. After setting a reference CU configuration: pupil position within limits spots position within limits and slopes p2v/stdev within limits all subapertures are illuminated spot on AC camera close to hotspot
Accuracy	
Procedure	Setup a reference position for all devices through assemblies Center pupils, storing the TT mirror delta command Verify that piezo mirror delta comand is within limits Verify that average, p2V and stdev slope signal of well illuminated subaps is within limits Remove tip/tilt/focus using the CU stages Verify that average, p2V and stdev slope signal of well illuminated subaps is within limits Gets the list of well illuminated subaps at reference angle Rotate the pupil by 45 deg and center it back (to avoid K-prism wobbling) and repeat step 3.2 Performs an unique union of the two lists of subaps (to avoid underillumination due to CU spiders) Verifies that exactly all valid subaps are well illuminated Check that current PSF on acquisition camera is within limits compared to reference hotspot.
Set-up	As defined by measurement templates
User defined parameters	NDIT: # of acquisition camera frames to be averaged (default 1000). EMCCD gain to be used Thresholds for all checks
Calibration Hardware devices	CU with LDLS lamp
Template	ERIS_ao_tec_QuickHealthChk
DRL Recipe	No pipeline recipe, all computations done in template code.

Outputs	pass/fail
Duration	5 minutes
Pre-requisites	None
Remarks	

5.3.2 AO loop

This section describes the calibration procedures to acquire and monitor the most relevant parameters for the operation of the AO loops.

5.3.2.1 DSM flat command

Procedure ID	ERIS_AO_MON_046
Responsible	Science Operations
Phase	Night
Frequency	1/7 days (TBC)
Purpose	Measure the average value of DSM best actuators position in closed loop.
Accuracy	
Procedure	After the loop has been closed with a TA template, average a series of DSM actuator positions from the SPARTA recorders. The averaged positions define a new reference actuator frame that is applied to SPARTA. Remove tip/tilt/focus from the averaged frame.
Set-up	Run a NIX or SPIFFIER TA template in NGS configuration with magR<8 at zenith distance <15deg (max number of controlled modes)
User defined parameters	NDIT: number of of SPARTA telemetry DSM commands to average (default 10000)
Calibration Hardware devices	None
Template	ERIS_ao_tec_DsmFlatteningCmd
DRL Recipe	No pipeline recipe, computation done in template code
Outputs	DSM command vector (actuator positions)
Duration	1 minute
Pre-requisites	AO loop running in closed loop as described in the Set-up section
Remarks	The goodness of the system DSM flat is relevant especially when a lower # of modes than maximum DSM modes is corrected.

5.3.2.2 WFS subapertures mask verification

Procedure ID	ERIS_AO_MON_051
Responsible	Science Operations
Phase	Night
Frequency	1/7 days (TBC)
Purpose	Verify that all subapertures are correctly illuminated during closed loop operation on-sky
Accuracy	Fraction of counts
Procedure	Take a series of closed loop telemetry data and compute average and rms of subaperture intensity with bright reference star (in NGS mode) or the LGS reference star. Compare intensity vector with a threshold, identify illuminated subapertures, and compare with the list of valid subapertures in the current SPARTA configuration. Raise an error to the user if some subapertures are not illuminated.
Set-up	NGS case: HO NGS loop successfully closed on a NGS with 1<magR<8 at zenith distance <15deg (max number of controlled modes) LGS case: Full AO (LGS + LO NGS) loop successfully closed on LGS and a co-located NGS with 7<magR<10 at zenith distance <15deg (max number of controlled modes)
User defined parameters	Time of SPARTA telemetry data to average (default 10s), NGS or LGS check
Calibration Hardware devices	None
Template	ERIS_ao_tec_NGSCheckPupil.seq ERIS_ao_tec_LGSCheckPupil.seq
DRL Recipe	No pipeline recipe, computation done in template code.
Outputs	2D subaperture map
Duration	1 minute.
Pre-requisites	AO loop running in closed loop as described in the Set-up section
Remarks	

5.3.2.3 NGS best focus position

Procedure ID	ERIS_AO_MON_56
Responsible	Science Operations
Phase	Night
Frequency	1/month (TBC) for the three WFS modes and a TBD set of NIX and SPIFFIER filters at first 2/yr (TBC) after seasonal behaviour is verified.
Purpose	Measure the NGS WFS stage position that results in the best focus position on the science detector.
Accuracy	0.1 mm (TBC)
Procedure	Define a movement range and step size for the NGS or LGS WFS focus stage. Scan the movement range in steps. At each step, acquire an image with the NIX or SPIFFIER detector, perform a 2d gaussian fitting to detect the PSF, and repeat for all steps. Fit the gaussian peaks with a parabola and set the position corresponding to the parabola peak as the best focus one. If the best focus position is close to the beginning or the end of the movement range, offer the operator to shift the range by half in that direction, and repeat the procedure. Procedure must be repeated for in NGS, LGS and SE AO modes, and for a list of NIX/SPIFFIER wavelengths.
Set-up	NGS case: HO NGS loop successfully closed on a NGS with 1<magR<8 at zenith distance <15deg (max number of controlled modes) LGS case: Full AO (LGS + LO NGS) loop successfully closed on LGS and a co-located NGS with 7<magR<10 at zenith distance <15deg (max number of controlled modes) NIX: filter(s), DIT and NDIT in order to have an unsaturated image on the detector (same for SPIFFIER)
User defined parameters	Movement range in mm Step size in mm Filter(s), DIT, NDIT for science detector NIX or SPIFFIER
Calibration Hardware devices	None
Template	ERIS_ao_tec_NGSFocus ERIS_ao_tec_LGSFocus ERIS_ao_tec_LOFocus
DRL Recipe	No pipeline recipe, data reduction done in template code.

Outputs	WFS focus stage position
Duration	Depends on DIT, NDIT and movement range. Typically 10 minutes per measurement.
Pre-requisites	AO system running in closed loop as described in the Set-up section
Remarks	

5.4 Summary of ERIS Monitoring Calibrations

System	Calibration	Number	Frequency (1/x)	Purpose
NIX	Detector Linearity	2 sets for fast and slow	1/Month	Monitor read-out noise, gain, detector linearity, bad pixel map
NIX	Mask Alignment Check with Calibration Unit	N	1/Month	Verify that there is no vignetting when the SAM/APP mask is put in place
NIX	Mask Alignment Check on Sky	N	1/Month	Verify optimum position of APP mask
NIX	Mask Orientation	N	1/Month	Verify alignment of SAM/APP mask with respect to telescope spiders
NIX	Distortion Correction	N	1/Week	Distortion correction matrix, angular deviation, Field orientation.
NIX	Illumination	N	2/Year	Master illumination correction
NIX	Spectral Monitoring	N	1/TBD	Determine/monitor the geometry and wavelength calibration in long slit spectroscopy
NIX	Persistence Characterization Monitoring	-	Monthly	Monitor persistence characteristics of NIX detector
NIX	Persistence Event Detection	-	1/1	Verify the detector is not suffering from a persistence event before nightly run
SPIFFIER	Detector Linearity	1	1/Month	Monitor read-out noise, gain, detector linearity, bad pixel map
SPIFFIER	Pupil Image	1	1/Month	Monitor stability of the pupil image
SPIFFIER	Throughput Response	N	1/Month	Monitor the atmospheric and instrument transmission
SPIFFIER	Persistence Characterization Monitoring	-	Monthly	Monitor persistence characteristics of SPIFFIER detector
SPIFFIER	Persistence Event Detection	-	1/1	Verify the detector is not suffering from a persistence event before nightly run
AO WFS	WFS Camera RON	N/2WFSs	1/7	Monitor detector read-out noise
AO WFS	WFS camera counts vs. gain	frmrt/N /2WFSs	1/7	Monitor detector ADU/e- ratio
AO WFS	Acquisition camera dark frame	auto	1/1	Measure dark frame of acquisition camera vs.

				integration time/binning
AO WFS	WFS camera dark frame	N/frmrt /2WFSs	1/1	Measure dark frame of WFS camera vs. integration time.
AO WFS	WFS pupil image and spots wobble vs. k-glass rotation	N/DANG /2WFSs	1/7	Measure, as a function of the k-glass rotation angle, (a) pupil image centre position over the SH lenslet array, (b) SH spots average displacement (X & Y)
AO WFS	WFS pupil image and spots wobble vs. ADC rotation	N/DANG	1/7	Measure, as a function of the ADC rotation angle,(a) pupil image centre position over the SH lenslet array, (b) SH spots average displacement (X & Y)
AO WFS	Pupil mirror actuator interaction matrix	5/2WFSs	1/7	Measure how much the pupil and spots position change on the WFS cameras as a result of a given pupil mirror actuator command. Compare with previous measurements to detect any aging of the actuator.
AO WFS	Reference slopes and weighing masks	N/DANG /3WFSs	1/7	Measure refence slopes and weighting masks for the AO WFSs.
AO WFS	Quick health check	3	1/1	Verify that the system alignment is within specifications
AO loop	DSM flat command	N	1/7	Measure the average value of DSM best actuators position in closed loop
AO loop	WFS subapertures mask verification	N	1/7	Verify that all subapertures are correctly illuminated during closed loop operation on-sky
AO loop	NGS best focus position	N/STEP /3WFSs	1/Month	Measure the NGS WFS stage position that results in the best focus position on the science detector.

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