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| Document Title | Simulation parameters |
| Document Number | E-MOS-TEC-ANR-0015 |
| Issue | V 1.2 |
| Date | 22-11-2016 |

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| --- | --- |
| Description | Define the parameters for the initial AO simulations (atmosphere, telescope, ..) |
| Distribution | MOSAIC SOSC WP & System Team |

**Change Record**

| Issue | Date | Changed by | Sections Affected | Change Description |
| --- | --- | --- | --- | --- |
| 0.0 | 10-05-2016 |  | All | Creation |
| 0.1 | 11-05-2016 | Gendron | many | comments from ali+tim, & discussion w jean-marc |
| 0.2 | 18-05-16 | Gendron | plenty of | noise formulae from JM. Conan,  NGS fields from Myriam |
| 0.3 |  | Gendron |  | NGS Field #3 reviewed  GOODS study asterism reviewed (shifted)  added 1 field from Candels paper (ali)  Magnitude definitions reviewed  new doc number  asterism plot corrected  turn some r0^5/3 into r0^-5/3 in text  Merge Tim’s comment to this doc (mail 8/7/16 14:39)  Included Ali’s option 1kx1k emccd at 75hz for NGS |
| 0.4 | 14-7-16 | Gendron | 6.2  6.6.4  8. (created)  TOC | alpao 60x60 does not exist 🡪changed into 64x64  NGS 75hz 🡪 83hz  new section 8.0: test case, summary of all parameters for a synthetic view  Table of contents now up-to-date (was wrong in 0.3)  Doc signed |
| 1.1 | 19-10-16 | Gendron | none | Passed in version 1.1 to make the doc applicable.  Version 1.0 was not compliant (wrong date, no change track)  Signed for approval+release. |
| 1.2 | 22-11-16 | Gendron | all pages  6.8.1, 6.8.2  6.8.3  6.8.3  6.6.3 | fancy footnote removed  photometry in ali asterism: added comment  asterisms rotated according to Carine  Ast F1-F2-F3-F4 now in unambiguous order  noise figure of NGS now correct (thanks JMarc!) |

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**List of Abbreviations**

Abbreviations used in this document can be found in the **MOSAIC Terminology, Definitions and Acronyms List**

**(E-MOS-MAN-LIS-0006)**

# Applicable and referenced documents

## Applicable Documents

| Ref No | Document Number and Document Title | Issue Number & Date |
| --- | --- | --- |
| AD1 | ESO-258292  Relevant Atmospheric Parameters for E-ELT AO Analysis and Simulations | Doc version: 2  2015-09-15 |
| AD4 | ESO-191766  E-ELT Environmental Conditions | version: 7  19 nov 2015 |
| AD2 | E-TRE-ESO-586-0252  EELT interfaces for scientific instruments | iss 3, 29 july 2010 |
| AD3 | E\_TRE-ESO-313-1000  EELT optical design report | issue 2, 19 sep 2012 |

## Referenced Documents

| Ref No | Document Number and Document Title | Issue Number & Date |
| --- | --- | --- |
| RD1 | E-SPE-ESO-276-0206  EELT AO design inputs: relevant atmospheric parameters | Issue 1 |
| RD2 | ESO-258292  Relevant Atmospheric Parameters for E-ELT AO Analysis and Simulations | Doc version: 1  2015-03-25 |
| RD3 | Bonaccini D., et al., “PM fiber lasers at 589nm: a 20W transportable laser system for LGS return flux studies”, SPIE 7736 (2010)  <http://cdsads.u-strasbg.fr/abs/2010SPIE.7736E..1UB> |  |
| RD4 | ESO-253082  Common ICD between the E-ELT Nasmyth Instruments and the Rest of the E-ELT System | version 1.12 |

# Introduction

This document is intended to provide some input parameters for AO simulations for MOSAIC that will be common to all the groups performing simulations.

We will define

* a basic parameter set, with a unique value for all possible parameter, called “**baseline**”.
* a set of possible values to be explored for each relevant parameter, called “**exploration**” set.
* conditions and situations to be explored

## Context

Start of phase A of MOSAIC.

## Scope of the document

Provide simulations with some input parameters, and range of variations.

Another goal is also to define kind of templates for making the simulation rather uniform between the different institutes.

This doc also contains provisions for parameters that may be used in future, more detailed end-to-end simulations, and that will be filled in later on.

# Atmospheric conditions from ESO documentation

The ESO document AD1 "ESO-258292 — *Relevant Atmospheric Parameters for E-ELT AO Analysis and Simulations*” defines seeing conditions.

Note: While writing the present report, the author discovered the release of the version n°2 of this ESO doc, AD1, which may possibly result in some slight inconsistencies in the text; apologies in advance.

Note2: the author has also discovered that the § atmospheric conditions can also be found in AD4, “ESO-191766 *E-ELT environmental conditions*, version 7, 19 nov 2015”.

## Armazones site

The E-ELT site is Armazones, at latitude = -24.5893°, longitude = 70.1917° W, altitude = 3046 m after flattening of the summit.

## Seeing

Seeing should be related to *r0* using:

or, given at *λ*=500 nm, with seeing and *r0* expressed in arcsec and cm

### A bit of history

ESO recommended (in RD1 and RD2) that in MOAO, “*robustness is the privileged dimensioning driver. In other words, the system design shall be tuned to ensure the required performance at the specified operating point and a reduced performance level over a wide range of conditions.*

* *Observation zenith angle: 30 degrees. Range: [0 - 60] degrees*
* *Seeing at zenith: optimization performed at 0.9”, i.e. 65th percentile at Armazones. Range: [0.4 - 1.5"].”*

However, this value of 0.9’’ corresponding to 65th percentile was valid for the previous version of the ESO document RD1 but was then inconsistent with the histogram from RD2, where the 65th percentile has moved to 0.78’’ at zenith (turning into 0.85’’ at z=30°). In RD2, the median seeing (0.67’’) was also inconsistent with the r0 of the median profile. Finally, this statement was suppressed from AD1 (the version 2 of doc RD2), plots of seeing histogram discarded and median seeing set to 0.644’’ now consistent with median profile. AD4 also exhibits a median seeing value of 0.67’’, with a description close to that of RD2 but with Cn2 profiles made of 31 layers, but superseded by AD1. However, those 31-layer profile exhibit at very high resolution up to 250m (25 layers), while considering only 6 layers for the rest of the atmosphere (>250m): this is not physical. These profiles won’t be used.

|  |
| --- |
| Figure 3‑1 Histogram of seeing at zenith taken from AD4. |

Seeing and *r0* at a given zenith angle *z* are computed using

MOSAIC consortium also expects to explore a range of seeing for the purpose of studying the impact of seeing on instrument efficiency.

## Seeing and profile: simulation parameters

We choose to simulate different seeing using different profiles, as stated in AD1.

We will select the seeing values corresponding to the 4 quartiles of seeing distribution of AD1.

We select as a baseline seeing the 3rd quartile, to be consistent with the fact that the MOS should rather be designed to be robust and cope with varying conditions, and also for “security”, as a median seeing of 0.64’’ is miraculous.

It is not sure however yet whether targeting same kind of conditions for HMM or HDM mode is rigorously adequate, however in any case the exploration of a range of seeing conditions is essential, so that it will serve both purpose at the end.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Baseline value | | Exploration | | Comment |
| zenith distance | 30° | | 30° | | No need to explore a range of *z*, as seeing range is explored anyway. |
| seeing & r0  at 500 nm given here at z=30° | 0.793’’ | 12.75 cm | 0.471’’  0.619’’  0.702’’  0.793’’  1.136’’ | 21.47 cm  16.33 cm  14.40 cm  12.75 cm  8.9 cm | All seeing values given here at z=30° |
| outer scale | 25 m for all layers | | 25 all layers,  25 m for 0<h<100 & 100 m for h>100 | |  |
|  |  | |  | |  |

Copied directly from AD1, the five 35-layer profiles are:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | %J  median | %J  Q1 | %J  Q2 | %J  Q3 | %J  Q4 |
| r0 (m)  zenith |  |  | 0.157 | 0.234 | 0.178 | 0.139 | 0.097 |
| r0 (m)  at 30° |  |  | 0.144 | 0.2147 | 0.1633 | 0.1275 | 0.089 |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Layer  # | Height  (m) | Wind  (m/s) | %J  median | %J  Q1 | %J  Q2 | %J  Q3 | %J  Q4 |
| 1 | 30 | 5.5 | 24.2 | 22.6 | 25.1 | 25.5 | 23.6 |
| 2 | 90 | 5.5 | 12 | 11.2 | 11.6 | 11.9 | 13.1 |
| 3 | 150 | 5.1 | 9.68 | 10.1 | 9.57 | 9.32 | 9.81 |
| 4 | 200 | 5.5 | 5.9 | 6.4 | 5.84 | 5.57 | 5.77 |
| 5 | 245 | 5.6 | 4.73 | 4.15 | 3.7 | 4.5 | 6.58 |
| 6 | 300 | 5.7 | 4.73 | 4.15 | 3.7 | 4.5 | 6.58 |
| 7 | 390 | 5.8 | 4.73 | 4.15 | 3.7 | 4.5 | 6.58 |
| 8 | 600 | 6 | 4.73 | 4.15 | 3.7 | 4.5 | 6.58 |
| 9 | 1130 | 6.5 | 3.99 | 3.1 | 3.25 | 4.19 | 5.4 |
| 10 | 1880 | 7 | 3.24 | 2.26 | 3.47 | 4.04 | 3.2 |
| 11 | 2630 | 7.5 | 1.62 | 1.13 | 1.74 | 2.02 | 1.6 |
| 12 | 3500 | 8.5 | 2.6 | 2.21 | 3 | 3.04 | 2.18 |
| 13 | 4500 | 9.5 | 1.56 | 1.33 | 1.8 | 1.82 | 1.31 |
| 14 | 5500 | 11.5 | 1.04 | 0.88 | 1.2 | 1.21 | 0.87 |
| 15 | 6500 | 17.5 | 1 | 1.47 | 1.3 | 0.86 | 0.37 |
| 16 | 7500 | 23 | 1.2 | 1.77 | 1.56 | 1.03 | 0.45 |
| 17 | 8500 | 26 | 0.4 | 0.59 | 0.52 | 0.34 | 0.15 |
| 18 | 9500 | 29 | 1.4 | 2.06 | 1.82 | 1.2 | 0.52 |
| 19 | 10500 | 32 | 1.3 | 1.92 | 1.7 | 1.11 | 0.49 |
| 20 | 11500 | 27 | 0.7 | 1.03 | 0.91 | 0.6 | 0.26 |
| 21 | 12500 | 22 | 1.6 | 2.3 | 1.87 | 1.43 | 0.8 |
| 22 | 13500 | 14.5 | 2.59 | 3.75 | 3.03 | 2.31 | 1.29 |
| 23 | 14500 | 9.5 | 1.9 | 2.76 | 2.23 | 1.7 | 0.95 |
| 24 | 15500 | 6.3 | 0.99 | 1.43 | 1.15 | 0.88 | 0.49 |
| 25 | 16500 | 5.5 | 0.62 | 0.89 | 0.72 | 0.55 | 0.31 |
| 26 | 17500 | 6 | 0.4 | 0.58 | 0.47 | 0.36 | 0.2 |
| 27 | 18500 | 6.5 | 0.25 | 0.36 | 0.3 | 0.22 | 0.12 |
| 28 | 19500 | 7 | 0.22 | 0.31 | 0.25 | 0.19 | 0.1 |
| 29 | 20500 | 7.5 | 0.19 | 0.27 | 0.22 | 0.17 | 0.09 |
| 30 | 21500 | 8 | 0.14 | 0.2 | 0.16 | 0.12 | 0.07 |
| 31 | 22500 | 8.5 | 0.11 | 0.16 | 0.13 | 0.1 | 0.06 |
| 32 | 23500 | 9 | 0.06 | 0.09 | 0.07 | 0.06 | 0.03 |
| 33 | 24500 | 9.5 | 0.09 | 0.12 | 0.11 | 0.08 | 0.05 |
| 34 | 25500 | 10 | 0.05 | 0.07 | 0.06 | 0.04 | 0.02 |
| 35 | 26500 | 10 | 0.04 | 0.06 | 0.05 | 0.04 | 0.02 |

They have been represented on the following plot, with units as *r0*-5/3 (m-5/3):



The altitude *h* of layers should be rescaled according to the zenith distance *z* following:

### Naming profiles

For the purpose of inserting the names in FITS headers:

‘ESO-35-median’

‘ESO-35-Q1’

‘ESO-35-Q2’

‘ESO-35-Q3’

‘ESO-35-Q4’

## Temporal evolution

Use ESO wind profile. Warning: as explained in AD1, the wind profile needs to be rescaled using a coefficient α, so that the wind profile matches the value of τ0 for each quartile.

Using this α-rescaling, and using formula



we find

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | %J  median | %J  Q1 | %J  Q2 | %J  Q3 | %J  Q4 |
| α |  |  | 1.052 | 0.925 | 0.968 | 1.079 | 1.37 |
| Vmean |  |  | 9.21 | 9.10 | 9.13 | 9.13 | 9.79 |
| τ0 (ms) |  |  | 5.35 | 8.08 | 6.12 | 4.78 | 3.11 |

# Atmospheric effects (other than turbulence)

## Dispersion

This parameter is not used (yet). If required one day, we suggest to use the IDL procedure that can be found at

<https://www.eso.org/gen-fac/pubs/astclim/lasilla/diff_atm_refr.pro>

which python translation is provided here:

import numpy as np

def DAR(Z,Lambda0,Lambda):

"""

Computes the diff atmosph dispersion for a given zenith distance

Z for different wavelengths "Lambda" wrt ref wavelength Lambda0.

ARGUMENTS

Z : The zenith distance in degrees

Lambda0 : The reference wavelength in microns

Lambda : array of wavelengths in microns

OUTPUT

The diff atmos dispersion in arcsecs wrt Lambda0

"""

#---------------------------------------------------------

# atmospheric parameters to edit (here given for Paranal)

#---------------------------------------------------------

T = 11.5 # Temperature [C]

HR = 14.5 # Relative Humidity [%]

P = 743.0 # Pressure [mbar]

ZD = Z\*np.pi/180

T = TC + 273.16

PS = -10474.0+116.43\*T-0.43284\*T\*\*2+0.00053840\*T\*\*3

Pw = HR/100.0\*PS #100 factor removed from Myriam’s as % already in decimals

Pa = P-Pw

#1+ instead of the 1- in Myriam’s

Da = Pa/T\*(1.0+Pa\*(57.90\*1.0E-8-(9.3250\*1.0E-4/T)+(0.25844/T\*\*2)))

Dw = Pw/T\*(1.0+Pw\*(1.0+3.7E-4\*P2)\*(-2.37321E-3+(2.23366/T)-

(710.792/T\*\*2)+(7.75141E4/T\*\*3)))

S0 = 1.0/Lambda0

S = 1.0/Lambda

N0\_1 = 1.0E-8\*((2371.34+683939.7/(130-S0\*\*2)+4547.3/(38.9-S0\*\*2))\*Da+

(6487.31+58.058\*S0\*\*2-0.71150\*S0\*\*4+0.08851\*S0\*\*6)\*Dw)

N\_1 = 1.0E-8\*((2371.34+683939.7/(130-S\*\*2)+4547.3/(38.9-S\*\*2))\*Da+

(6487.31+58.058\*S\*\*2-0.71150\*S\*\*4+0.08851\*S\*\*6)\*Dw)

DR = np.tan(ZD)\*(N0\_1-N\_1)\*206264.8

return DR

## Transmission, quantum efficiency, etc.

|  |  |  |
| --- | --- | --- |
| Element | Value | Comment |
| Atmosphere | 0.84 | In the visible, at z=30° ; average value.  Assumed to be constant over spectral range |
| Telescope (5 mirrors) | 0.70 | Average value from AD2, in the visible range. |
| Telescope (5 mirrors, in IR) | J:  H:  K: | Provision. Not needed now.  Just not to forget, if needed one day.. |
| Laser dichroic plates (reflect) | 0.90 |  |
| WFS optics | 0.85 |  |
| Detector QE | 0.85 |  |
| TOTAL (visible) | 0.382 (LGS) |  |
| 0.425 (NGS) |  |

# 

# Telescope

## Pupil

Pupil definition is a tricky problem on the EELT, as the telescope does not include any pupil stop valid for the whole 10 arcminute field.

### Baseline: hexagonal pupil

We will consider, as a baseline, that the “pupil” seen by the science channel is on-axis “illuminated area”, i.e. the full M1, because science channels do not provide any extra pupil stop (TBC ?).

|  |  |
| --- | --- |
| Pupil characteristics | Value |
| Pupil diameter | 38542 mm |
| Central obscuration | 11067 mm  (0.2871 normalised diameter) |
| Spiders | 530 mm width (6 spiders at 60°) |

The outer contour of the pupil is given by the coordinates, in mm:

X = [18452,18452,18798,18451,18451,18796,18448,18448,18792,18443,18443,18786,18436,18436,18778,18427,17735,17735,17383,17383,17724,17372,16677,16677,16323,16323,16665,16310,15614,15614,15258,15258,15599,15243,14545,14545,14188,14188,14529,14172,13473,13473,13115,12414,12414,12055,11353,11353,10994,10290,10290,9931,9226,9226,8867,8161,8161,7802,7096,7096,6737,6030,6030,5671,4964,4964,4606,3898,3547,3547,2838,2838,2481,1773,1419,1419,710,710,355,-355,-710,-710,-1419,-1419,-1773,-2481,-2838,-2838,-3547,-3547,-3898,-4606,-4964,-4964,-5671,-6030,-6030,-6737,-7096,-7096,-7802,-8161,-8161,-8867,-9226,-9226,-9931,-10290, -10290,-10994,-11353,-11353,-12055,-12414,-12414,-13115,-13473,-13473,-14172, -14529,-14188,-14188,-14545,-14545,-15243,-15599,-15258,-15258,-15613,-15613, -16310,-16664,-16323,-16323,-16677,-16677,-17372,-17724,-17383,-17383,-17735, -17735,-18427,-18778,-18436,-18436,-18786,-18443,-18443,-18792,-18448,-18448, -18796,-18451,-18451,-18798,-18452,-18452,-18798,-18451,-18451,-18796,-18448, -18448,-18792,-18443,-18443,-18786,-18436,-18436,-18778,-18427,-17735,-17735, -17383,-17383,-17724,-17372,-16677,-16677,-16323,-16323,-16664,-16310,-15613, -15613,-15258,-15258,-15599,-15243,-14545,-14545,-14188,-14188,-14529,-14172, -13473,-13473,-13115,-12414,-12414,-12055,-11353,-11353,-10994,-10290,-10290, -9931,-9226,-9226,-8867,-8161,-8161,-7802,-7096,-7096,-6737,-6030,-6030,-5671, -4964,-4964,-4606,-3898,-3547,-3547,-2838,-2838,-2481,-1773,-1419,-1419,-710, -710,-355,355,710,710,1419,1419,1773,2481,2838,2838,3547,3547,3898,4606,4964,4964,5671,6030,6030,6737,7096,7096,7802,8161,8161,8867,9226,9226,9931,10290,10290,10994,11353,11353,12055,12414,12414,13115,13473,13473,14172,14529,14188,14188,14545,14545,15243,15599,15258,15258,15614,15614,16310,16665,16323,16323,16677,16677,17372,17724,17383,17383,17735,17735,18427,18778,18436,18436,18786,18443,18443,18792,18448,18448,18796,18451,18451,18798]

Y = [0,0,614,1229,1229,1843,2458,2458,3071,3686,3686,4297,4913,4913,5523,6138,6144,6144,6759,6759,7368,7983,7990,7990,8605,8605,9212,9826,9834,9834,10448,10448,11053,11666,11675,11675,12287,12287,12890,13500,13510,13510,14120,14129,14129,14739,14748,14748,15356,15365,15365,15972,15980,15980,16587,16594,16594,17199,

17206,17206,17810,17815,17815,18418,18423,18423,19023,19028,18431,18431,18434,18434,19034,19036,18438,18438,18439,18439,19038,19038,18439,18439,18438,18438,19036,19034,18434,18434,18431,18431,19028,19023,18423,18423,18418,17815,17815,17810,17206,17206,17199,16594,16594,16587,15980,15980,15972,15365,15365,15356,14748,14748,14739,14129,14129,14120,13510,13510,13500,12890,12287,12287,11675,11675,11666,11053,10448,10448,9834,9834,9826,9212,8605,8605,7990,7990,7983,7368,6759,6759,6144,6144,6138,5523,4913,4913,4297,3686,3686,3071,2458,2458,1843,1229,1229,614,0,0,-614,-1229,-1229,-1843,-2458,-2458,-3071,-3686,-3686,-4297,-4913,-4913,-5523,-6138,-6144,-6144,-6759,-6759,-7368,-7983,-7990,-7990,-8605,-8605,-9212,-9826,-9834,-9834,-10448,-10448,-11053,-11666,-11675,-11675,-12287,-12287,-12890,-13500,-13510,-13510,-14120,-14129,-14129,-14739,-14748,-14748,-15356,-15365,-15365,-15972,-15980,-15980,-16587,-16594,-16594,-17199,-17206,-17206,-17809,-17815,-17815,-18418,-18423,-18423,-19023,-19027,-18431,-18431,-18434,-18434,-19034,-19036,-18438,-18438,-18439,-18439,-19038,-19038,-18439,-18439,-18438,-18438,-19036,-19034,-18434,-18434,-18431,-18431,-19027,-19023,-18423,-18423,-18418,-17815,-17815,-17809,-17206,-17206,-17199,-16594,-16594,-16587,-15980,-15980,-15972,-15365,-15365,-15356,-14748,-14748,-14739,-14129,-14129,-14120,-13510,-13510,-13500,-12890,-12287,-12287,-11675,-11675,-11666,-11053,-10448,-10448,-9834,-9834,-9826,-9212,-8605,-8605,-7990,-7990,-7983,-7368,-6759,-6759,-6144,-6144,-6138,-5523,-4913,-4913,-4297,-3686,-3686,-3071,-2458,-2458,-1843,-1229,-1229,-614]

The inner contour is:

X =

[5026,5026,4667,5025,5025,4667,5025,5025,4666,4666,3949,3590,3590,2872,2513,2513,1795,1436,1436,718,359,359,-359,-359,-718,-1436,-1436,-1795,-2513,-2513,-2872,-3590,-3590,-3949,-4666,-4666,-5025,-5025,-4667,-5025,-5025,-4667,-5026,-5026,-4667,-5025,-5025,-4667,-5025,-5025,-4666,-4666,-3949,-3590,-3590,-2872,-2513,-2513,-1795,-1436,-1436,-718,-359,-359,359,359,718,1436,1436,1795,2513,

2513,2872,3590,3590,3949,4666,4666,5025,5025,4667,5025,5025,4667]

Y=

[0,0,622,1243,1243,1865,2487,2487,3108,3108,3109,3730,3730,3731,4352,4352,4353,4974,4974,4974,5595,5595,5595,5595,4974,4974,4974,4353,4352,4352,3731,3730,3730,3109,3108,3108,2487,2487,1865,1243,1243,622,-1,-1,-622,-1243,-1243,-1865,-2487,-2487,-3108,-3108,-3109,-3730,-3730,-3731,-4352,-4352,-4353,-4974,-4974,-4974,-5595,-5595,-5595,-5595,-4974,-4974,-4974,-4353,-4352,-4352,-3731,-3730,-3730,-3109,-3108,-3108,-2487,-2487,-1865,-1243,-1243,-622]

### Variable pupil (advanced simulations)

When patrolling the 10 arcmin Ø field, a dark circular area coming from the lack of reflective surface at M4 centre will be seen wandering around and will mask the inner segments of M1. The union of all possible positions of “M4 hole” when observing everywhere over the Ø10 arcmin has a diameter of 11067 mm and is shown on the “pupil” recommended by ESO as a circular central obscuration:

|  |  |
| --- | --- |
|  | *Pupil recommended by ESO (Telescope data package).*  *This pupil mask ensures the instrument “sees” the same pupil, whatever the field angle. It avoids the instrument seeing the central obscuration created by the M4 central hole to move across with field angle.* |

|  |  |
| --- | --- |
| Pupil characteristics | Value |
| Pupil diameter | see contours coordinates below |
| Central obscuration | 11067 mm |
| Spiders | 530 mm width (6 spiders at 60°) |

ESO also distributed a data package that describes the pupil characteristics.

## M1

ESO has distributed in its data package some examples of numerous disturbances on M1. Static errors are:

polishing, structure gravity impact, temperature impact on structure, phasing errors, scalloping errors, segment AIV, coating stress, support stress, long-term temperature impact on segments.

### Baseline

Those errors are not taken into account.

### Advanced simulations

TBW

## M4

M4 has a total of 5316 degrees of freedom (886 per M4 petal). Due to the fact the centre of M4 is conjugated to 612.25 m above the ground (AD3), the actuators need to span an area much wider than M1 in order to cope with the 10 arcmin field of view. The pitch of M4 in M1 space is 53.5 cm (hexagonal), and there are about 4300 actuators in the pupil (Ø 38.542m).

We make an approximation for the baseline and decide to model M4 as a 75x75 actuator deformable mirror, square pattern, with a pitch of p = 38.542m / 74 = 0.52084 m.

|  |  |  |  |
| --- | --- | --- | --- |
| Param | Baseline | Exploration/Advanced | Comment |
| # actus | 75 x 75 | the real one |  |
| geometry | square pattern | hexagonal |  |
| pitch | 0.52084 m | 53.5 cm |  |
| conjugate to | 612 m | 612 m | important for GLAO ? |
| angle | 0 | tilted  TBD |  |

## Vibrations, windshake

Some examples of the influence of windshake have been provided by ESO to the consortia. However, details about the control are not (fully) known today, which make simulation conditions difficult to set.

Tip-tilt residuals are based on ESO estimations, taking in input current ESO Windshake temporal DSPs + double integrator loop at 500 Hz + M4/M5 bandwidth. This performance assumes the 3 guide probes of the telescope are located on 3 NGS in the technical field of the telescope.

In the case of cosmological fields, it remains to be checked that 3 NGS, bright enough, can actually be found in the telescope technical field.

HARMONI ran simulations showing that residuals of the order of ≈2mas in tip and tilt can be achieved. This is confirmed by MICADO-SCAO simulations. However, considering the particular case of star depleted fields where we will need to deal with faint stars, we should consider a lower frame rate and the impact of noise.

Impact of windshake can be added afterwards by convolving the AO PSFs with a Gaussian PSF simulating tip-tilt residuals.

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Baseline | Explore | Comment |
| Residual tip | 0 | 0  5 mas  20 mas | Margin w.r.t. simulations results (≈2mas) accounting for possibly reduced frame rate and increased noise. |
| Residual tilt | 0 | 0  5 mas  20 mas |  |

Note: As MOSAIC performance metric is EE on rather “large” box, this parameter should not impact too much anyway (TBC).

## Telescope throughput

See section 4.2.

# MOSAIC

## Frame rate & latency

|  |  |  |  |
| --- | --- | --- | --- |
|  | Baseline | Explore | Comment |
| Frame rate | 250 Hz | 250  125  62  31  16 | Different frame rates for NGS and LGS possible. |
| Latency | 1 frame  = 0.004 s | 0.004 s | Between the   * **END** of WFS integration * beginning of command application on DM |

## MOAO DM

Note: In the table below, the pitch is computed using:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Actuators | Pitch | Coupling | Geometry | Comment |
| Baseline | 64x64, square |  | 0.25 | square | Boston/ALPAO |
| Explore | 64x64  32x32 | 0.6118 m  1.2433 m | 0.25  0.25 | square  square | Boston/ALPAO  Boston |
| Explore optionally .. | 64x64  17x17 | 0.6118 m  2.4089 m | 0.4  0.4 | square  square | ALPAO  ALPAO |

The case 64x64 address both the Boston and ALPAO cases. They only differ by the coupling factor, which is a parameter that should not influence too much the performance of the system. Most interesting is to compare the 64x64 against 32x32.

Then, if one has some spare time, a more realistic simulation of the ALPAO case can be done using coupling factor of 0.4, as well as 17x17 (that should not be of a great interest...).

## Field of view

We assume that the dichroic plates for the LGS create a blind area for science and NGS wave-front sensing in the focal plane.

ESO’s worst case is a 20km FWHM at a mean altitude of 84km above the telescope. However, we consider this extreme case as pessimistic and we rather stick to more conventional values, taking into account the fact that the availability of the FoV is of prime importance for MOSAIC.

We will assume the lowest part of the LGS beacon altitude of 80 km with respect to sea level, i.e. 77 km from Armazones site. We then get a dichroic diameter of 103’’ (337 mm, using a plate scale of 3.267 mm/arcsec from AD3).

Assuming a surrounding mechanics envelope of 27.6 mm on the radius all around would make a total of 392.2 mm Ø, which is exactly 120’’ Ø (2 arcminutes Ø).

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Comment |
| Field of view diameter | Ø < 10 arcmin | For picking NGS.  NGS cannot be used “behind” LGS footprints in the focal plane. |
| Footprint of LGS | Ø 2 arcmin | centred on the LGS  That’s assuming we can pickoff in the focal plane and not in front. |

## Wavelengths (science)

For scientific reasons, it is confirmed that there is an interest to go as far as λ=370 nm, hence the value of 400 nm here. Even if the transmission is probably poor at that wavelength, the efficiency is dramatically superior to that of VLT.

The science wavelengths used for simulations should be:

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Baseline | Exploration | Comment |
| λ (nm) | 1650 nm | 400 nm  600 nm  800 nm (I)  1000 nm  1250 nm (J)  1650 nm (H)  2200 nm (K) | λ’s confirmed by science group. |

## LGS WFS

### LGS WFS Wavelength

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Baseline | Empty column | Comment |
| λ (nm) | λSodium = 589 nm |  | That one was easy |

### Sodium profile, beam profile

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Baseline | Exploration | Comment |
| Na profile | Gaussian distribution,  FWHM = 10 km | TBD later  ESO do provide a range of profiles to investigate in ESO-191766\_7 (E-ELT Environmental Conditions) |  |
| Na layer altitude | 90 km above sea level  = 87 km above Armazones  = 100 km at *z*=30° |  | To be rescaled with zenith distance |
| Laser beam width (upwards propag.) | 0.8’’ |  |  |

### LGS WFS Dimensioning

|  |  |  |
| --- | --- | --- |
| Parameter | Baseline | Exploration |
| pixel size | 0.70’’ | optimized, TBC later |
| pixels / sub-aperture | 16 x 16 | optimized, TBC later |
| RON | 3e- | 1 e-  2  3 |
| number of sub-apertures | 74 x 74 | TBD later  many .. |

### LGS WFS Photon return

|  |  |
| --- | --- |
|  | Extracted from RD3 (Bonaccini et al., SPIE 7736, 2010).  Return flux in 106 photons/s/m2, as a function of alt-az at Paranal. The plot centre is zenith, the edge the horizon. The plot takes into account the effect of air-mass, and an atmospheric transmission of 0.84 at zenith. The laser power is 16 W.  The plot peaks at ≈12.5 Mph/m2/s (incl. atmosphere). |

RD4 specifies a photon return flux to be larger than 5 Mph/m2/s including atmosphere, and AD1 specifies a range of 3–15 Mph/m2/s for sensitivity analysis including atmosphere.

As all numbers about LGS return flux are given including atmosphere, we define them here also including atmosphere, so that the transmission given in 4.2 is already applied (and should not be applied twice).

|  |  |  |  |
| --- | --- | --- | --- |
|  | Baseline | Explore | Comment |
| photon return at M1 (i.e. including atmosphere) | 7 106 photon/m2/s | 3 Mph/m2/s (1480 e-/sub/fr)  7 Mph/m2/s (3460 e-/sub/fr)  15 Mph /m2/s (7410 e-/sub/fr) | Conversion to e-/sub/fr given at 250 Hz for 74x74 subaps on 38.542m Ø pupil **at M1** |

### Noise figure for LGS WFS

For analytic simulations (ONERA GLAO, Paris) where the WFS is not simulated in detail (no end-to-end simulation), we will use a general law for scaling WFS noise with respect to flux and spot elongation based on equations (12), (15) and (16) from C. Robert, *et al*., "Tomographic wavefront error using multi-LGS constellation sensed with Shack–Hartmann wavefront sensors," J. Opt. Soc. Am. A **27**, A201-A215 (2010), slightly rewritten for our purpose. All the terms *Nwhatever* in these equations are expressed in pixels, but we can express them in any other unit, e.g. angles.

Defining σ as the rms value of the OPD between the opposite edges of a sub-aperture due to noise, we propose

with

* s the seeing angle at λSodium, (in radians),
* w the laser beam width (upward propagation) given in 6.5.2 (in radians),
* e the elongation (FWHM of the elongated plume) (in radians),
* d the size of the sub-aperture (same unit as σ)
* F the number of electrons per sub-aperture per frame
* RON the rms read-out noise in electrons per pixel
* z the pixel size (in radians)

The formula is intended to estimate the noise in the elongated direction (e), and in the perpendicular direction (using e=0). Finding the variance and covariances of noise for any arbitrary rotation of the spot in the sub-aperture requires to operate a rotation of the axes.

|  |  |
| --- | --- |
|  | *Example of application of above formula for s=1’’, w=0.8’’, e=0 and 15’’, z=0.7’’, RON=3e-, d=0.5m versus flux F.*  *Black: impact of read-out noise*  *Blue: impact of photon noise*  *Red: sum of both.*  *3 bottom plots: e=0’’*  *3 upper plots: e=15’’* |

*Note: At zero elongation (e=0), for the particular case of F=500 e-/subap/frame, we find ≈84 nm rms (0.9 rd2), which is close to the values considered for HARMONI studies.*

*Note2: Considering that the new ESO laser is ≈20Watts, the number F should rather be in the range1000-7000 e-, which make the photon noise dominant in most of cases.*

#### LGS WFS Uniform equivalent noise

For the Fourier model, a uniform noise has to be set in the simulations.

Based on studies done at ONERA for MAORY, it is proposed to set a uniform noise level, that will impact in the same manner as a variable one, taking:

### Laser Launch Telescopes

|  |  |  |
| --- | --- | --- |
|  | Baseline |  |
| number of LLT | 4 |  |
| distance from pupil centre to LLT | 22 m | At 45,135,225,315 degrees around pupil |
|  |  |  |

## NGS WFS

### NGSWFS Wavelength range

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Baseline | Explore | Comment |
| central λ (nm) | 650 nm (R band) |  | for WFS wavelength |
| width (nm) | 330 nm |  | Reflectivity of ELT changes quite a lot over this range. This throughput/bandwidth is an average value. |

### NGSWFS Photometry

Considering the NGS WFS peak sensitivity is centred around the R band, R star magnitudes should be used.

We will use:

log10(*N*(ph/s/cm2/Å)) = -0.4 *mR* + qR

The question is now to set the right value for qR. Depending on the magnitude system and the bibliographic reference different values may be found, as shown in this table:

|  |  |  |  |
| --- | --- | --- | --- |
| System | Band | value of qR | Comments |
| Johnson  (Vega) | R | 2.86 | (1)  <http://www.astro.utoronto.ca/~patton/astro/mags.html#flux>  <http://www.astro.umd.edu/~ssm/ASTR620/mags.html#flux>  <http://coolwiki.ipac.caltech.edu/index.php/Filters> |
| R | 2.85 | (2)  <http://www.astronomy.ohio-state.edu/~martini/usefuldata.html> |
| Rc (641nm) | 2.85 | (3)  <https://www.eso.org/sci/facilities/eelt/science/drm/tech_data/photdefs/> |
| r (670nm) | 3.00 | from links (1) |
| AB | true for any λ | 5.74 – log10(λ(nm)) | (4)  calculated by EG considering definition of AB=0 for 3631 Jy |
| R (640nm) | 2.93 | calculated by EG from links (1) & formula (4) |
| Rc (641nm) | 2.89 | from link (3) |
| r (670nm) | 2.91 | from links (1) |
| r (626nm) | 2.94 | from link (2) |

Getting an absolute estimation of the flux better than 10% would anyway require to have a complete, detailed knowledge of the spectral type and exact transmission curves of each mirrors, while on the on the other hand this would be useless considering the simple noise model we are using, and the error bars on all other parameters (profile, …).

For this reason, we propose using an “average” value of :

**qR = 2.90**

for any R, r, r’ magnitudes. This will **at very worst** give an approximate 20% variation in simulated flux w.r.t. real flux, which is good enough for our purpose. Comparisons have also been performed using a model (B. Neichel) from Pickles et al., which is in rather good agreement with the above value.

### Noise figure for NGS

For analytic simulations (ONERA GLAO, Paris), the WFS is not simulated in detail (no end-to-end simulation).

Defining σ as the rms value of the OPD between the opposite edges of a sub-aperture due to noise, we propose to use the same formula as for the laser spot, setting the spot width and elongation to w=e=0, i.e.

with

* s the seeing angle at λcentral, (in radians),
* d the size of the sub-aperture (same unit as σ)
* F the number of electrons per sub-aperture per frame
* RON the rms read-out noise in electrons per pixel
* z the pixel size (in radians)

|  |  |
| --- | --- |
|  | *Example, with r0(500 nm)=12.75cm (baseline seeing at 30°) with d=50cm, 0.4’’ pixels, 250 Hz, and RON=3e- rms/pixel.*  *Black: impact of read-out noise*  *Blue: impact of photon noise*  *Red: sum of both* |

### NGS WFS Dimensioning

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Baseline | Explored | Advanced |
| WFS type | SH, vis. | SH, vis. | other WFS? Pyramid? |
| pixel size | 0.4’’ | optimized, TBC later |  |
| pixels / subap | 10 x 10 | 10x10  6x6 (for case with RON=0.2e- see line below) |  |
| RON | 3 e- | 0.2 e- (1K2 EMCCD, 83 Hz, 6x6, Ali’s suggestion)  1 e-  2 e-  3 e- |  |
| Number of sub-apertures | 74x74 | (TBD .. many possible configs)  20x20  40x40  74x74 |  |

## LGS asterism

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Baseline | Explore | Comment |
| Number of beacons | 6 | 0  4  6 |  |
| LGS asterism diameter | Ø 7.4 arcmin | Ø 4  Ø 5.7  Ø 7.4 | (sorry.. I had put Ø2 in version v0.2, but I had confused radius and Ø)‼ |

## NGS asterism

### “Theoretical” asterism baseline

NGS asterism (GOODS study asterism 0):

Theta (arcsec), phi (degrees)

[(249.60001, 343.79001), (243.0, 331.42999),(168.60001, 14.07), (225.60001, 63.32),(192.0, 170.41)]

Fluxes (computed by Ali, long time ago with hypothesis *slightly* different from the baseline of this document, but not too far...)

[ 5.07868576, 7.31393862, 4.73970509, 73.34175873, 26.31184578] (electrons/subap/frame)

Which as r' magnitudes is:

15.7, 15.3, 15.8, 12.8, 13.9.

A rotation of 26° clockwise was applied. Values in arcminutes (projected onto tangent plane, directly usable in simulations, in arcminutes) are:



With -26° rotation:

|  |  |  |  |
| --- | --- | --- | --- |
| RA | DEC | magnitude r | Remark |
| 2.990185 | 2.279560 | 12.8 |  |
| -2.602248 | 1.862339 | 13.9 |  |
| 2.347816 | -3.300039 | 15.3 | not available |
| 3.081260 | -2.794895 | 15.7 |  |
| 2.749307 | -0.580873 | 15.8 |  |

### Tricky asterism from candels paper (Ali suggestion)

Asterism from Candels paper

Theta (arcsec), phi (Degrees):

[(239.39999, 270.07001),(152.39999, 221.46001)]

Flux: (computed by Ali, long time ago with hypothesis *slightly* different from the baseline of this document, but not too far...)

[36.42095566, 2.89835334]

R' magnitudes:

13.54, 16.288

Coordinates (rotated 1° clockwise, projected onto tangent plane, directly usable in simulations, in arcminutes) are:



|  |  |  |
| --- | --- | --- |
| RA | DEC | magnitude r |
| -0.064760 | -3.989474 | 13.54 |
| -1.932582 | -1.648249 | 16.288 |

### Real asterisms

These fields were gathered among the CANDELS cosmological field: GOODS, COSMOS and UDS.



They were selected in order to cover the distribution of NGS stars in typical cosmological fields:

* F1 - 1th quantile - 3 NGS (in a 10'diameter unvigneted fov)
* F2 - 2nd quantile - 6 NGS
* F3 - 3rd quantile - 7 NGS
* F4 - 4th quantile - 13 NGS

Stars were identified in the UCAC4 catalogue (Zacharias et al. 2013) and magnitudes were extracted from the American Association of Variable Star Observers (AAVSO) Photometric All-Sky Survey (APASS). The r-band magnitudes correspond to AB magnitude in the r' SDSS filter.

Each asterism has been rotated by an appropriate angle, chosen to maximise the number of NGS in the area which is not covered by the LGS dichoics.

All the stars provided by Myriam have been kept in the tables, but the stars that either lay out of the 10 arcmin Ø or lay within the LGS dichroics must be eliminated from the simulations, so that they have been tagged with a dark grey background in our tables below.

Coordinates (after rotation, projected onto tangent plane, directly usable in simulations, in arcminutes) are:

|  |  |
| --- | --- |
| Asterism F1 : |  |
|  | |  |  |  | | --- | --- | --- | | RA | DEC | magnitude r | | -2.157436 | -1.885051 | 13.835 | | 3.612384 | 1.703595 | 13.893 | | -1.454948 | 0.181456 | 15.125 |   (Rotation angle is 33° clockwise) |

|  |  |
| --- | --- |
| Asterism F2 : |  |
|  | |  |  |  | | --- | --- | --- | | RA | DEC | magnitude r | | 3.134590 | 2.642625 | 12.953 | | -4.715278 | -1.242124 | 13.098 | | -3.164782 | 2.270504 | 14.036 | | 1.922128 | -0.633274 | 14.418 | | -4.293015 | 2.009445 | 15.858 | | 3.018212 | 2.008235 | 15.880 | | -0.020217 | 0.411987 | 15.974 | | 1.942466 | -5.277747 | 15.982 | | 2.175896 | -2.189651 | 16.355 |   (Rotation angle is 11° clockwise) |

|  |  |
| --- | --- |
| Asterism F3: |  |
|  | |  |  |  | | --- | --- | --- | | RA | DEC | magnitude r | | 0.127423 | 0.802683 | 12.009 | | 2.709986 | -2.451394 | 12.78 | | -3.884450 | -2.159576 | 13.893 | | -1.063069 | 3.946519 | 14.309 | | 1.866629 | 0.975391 | 15.702 | | 2.783688 | -5.515496 | 15.754 | | -2.540207 | 4.401873 | 16.113 |   (Rotation angle is 28° clockwise) |

|  |  |
| --- | --- |
| Asterism F4: |  |
| (Rotation angle is 19° clockwise) | |  |  |  | | --- | --- | --- | | RA | DEC | magnitude r | | 1.833542 | -4.525972 | 11.935 | | -0.014879 | -1.819280 | 12.646 | | 1.200452 | -2.088818 | 12.908 | | 0.763823 | -0.743892 | 13.9 | | -0.052453 | -3.926005 | 13.954 | | -3.394710 | 1.250427 | 14.086 | | -1.770449 | 5.081438 | 14.293 | | -3.074838 | 2.655328 | 14.554 | | 0.910552 | 4.469363 | 14.58 | | -1.493931 | 3.885242 | 15.104 | | 0.496875 | 0.872459 | 15.535 | | -3.821120 | 0.128995 | 15.719 | | 3.547887 | -1.100186 | 15.765 | | 1.081755 | 0.652793 | 15.903 | | 3.122035 | -2.894965 | 16.168 | | 0.665460 | -1.896927 | 16.183 | |

## Performance criterion (SR, EE, box size, …)

Performance criterion should be the ensquared energy (EE).

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Baseline | Explore | Comment |
| EE | 150 mas | 50  75 mas  100 mas  150  200  250 | 75 mas just to compare with previous EAGLE points |

## PSF degradation due to slicer/fibre/spectro

A coefficient of 0.90 will/should be applied on the EE to take into account the degradations by the IFU, spectro optics, etc.

This degradation factor will NOT be simulated in the AO simulations; it will be applied by the science group analysis afterwards.

AO simulations do not take this degradation factor into account.

# Simulation cases

## Simulation output

### PSFs

PSFs should be exploited by the science group. They should be saved in FITS format, with header containing at least the following keywords:

NAXIS = 2 /

NAXIS1 = ... / 1st varying axis

NAXIS2 = ... / 2nd varying axis

OBSERVER= ‘durham’ / author of the PSF

INSTRUME=

ORIGIN = ‘e2e-dasp’ / ‘fourier’, ‘e2e-oomao’, ‘ana-covmat-1dm’ ... or anything

that describes which code was used, and type of

simulation

VERSION = 2.34 / version number of simulation code

PIXSIZE = 0.005 / pixel size in arcsec

TELDIAM = 38.542 / telescope diameter in metres

TELOBS = 0.283 / telescope central obscuration (normalised)

PUPIL = ‘circular’ / ‘circular’, ‘hexagonal’, ... ?

LAMBDA = 1650 / wavelength of PSF in nanometres

LTV1 = 513 / coord of central pixel of PSF in X (1-indexed)

LTV2 = 513 / coord of central pixel of PSF in Y (1-indexed)

LTM1\_1 = 200.0 / number of pixels per arcsec (1.0/PIXSIZE)

LTM1\_2 = 0.0 / (always 0.0)

LTM2\_1 = 0.0 / (always 0.0)

LTM2\_2 = 200.0 / (same as LTM1\_1)

SEEING = 0.793 / seeing in arcsec as seen by instrument

LAMSEE = 500.0 / wavelength of seeing

L0 = 25.0 / outer scale in metres

ZENANG = 30.0 / zenith angle in degrees

DISP = ??? / something about dispersion ? tim ? TBC

CN2H = ‘ESO-35-Q3’ / profile name referring to sect 3.3.1

MOAOACT = 64 / number of actuators of MOAO DM (0 if none)

M4ACT = 75 / number of actuators of M4

M4ALT = 0 / conjugate altitude of M4 in metres

M4GEO = ‘square’ / geometry of M4 actuators (‘square’,‘hexa’,‘fourier’...)

NAWIDTH = 10000 / FWHM of Na profile in metres

NADIST = 100000 / Na layer distance (as observed) in metres

LGSFLUX = 12e6 / number of photons/m2/s at M1

LGSRAD = 222.0 / radius of LGS constellation (arcsec)

LGSNB = 6 / number of LGS

LGSX1 = 192.2576 / X coord of LGS #1 in arcsec

LGSY1 = 111.0 / Y coord of LGS #1 in arcsec

LGSFL1 = 5675.2 / flux in electrons/subs/frame

LGSTYP1 = ‘sh’ / WFS type : ‘sh’, ‘pyr’, ...

LGSX2 = etc. for all LGSs

LGS... etc.

LGSNSSP = 74 / number of ssp for lgswfs across pupil diameter

LGSRON = 0.1 / read-out noise of LGS detector

LGSPIX = 0.70 / pixel size of LGSWFS (arcsec)

LGSNP = 16 / number of pixels per sub-aperture in LGSWFS

NGSFIELD= ‘GOODSS’ / something to know which field was considered

NGSNB = 3 / number of NGS

NGSX1 = -237.7 / X coord of NGS #1 in arcsec

NGSY1 = 21.3 / Y coord of NGS #1 in arcsec

NGSMAG1 = 14.2 / magnitude of NGS #1

NGSFL1 = 5675.2 / flux in electrons/subs/frame

NGSTYP1 = ‘sh’ / WFS type : ‘sh’, ‘pyr’, ‘sh-IR’, ...

NGSX2...

NGSNSSP = 40 / number of ssp for ngswfs across pupil diameter

NGSRON = 3.0 / read-out noise of NGS detector

NGSPIX = 0.25 / pixel size of NGSWFS (arcsec)

NGSNP = 16 / number of pixels per sub-aperture in ngswfs

TARGETX = 1.414 / coordinates of target galaxy in the field in X

TARGETY = 43.28 / same in Y

FREQ = 250.0 / sampling frequency

GAIN = 0.3 / loop gain (if relevant)

AOMODE = ‘glao’ / ‘glao’, ‘moao’, ‘telescope’, ...

Note: LTV and LTM keywords are standard ones that will allow most of FITS viewers to represent the image scaling in arcseconds.

PSF filenames:

MOS\_AO\_[Insititute]\_[yymmdd\_hhmmss].fits

Why the hell not? It’s all in the header anyway and at least each PSF filename should be unique!!

Or organise PSFs by folders ?

### Output results

Unless stated otherwise, for a given configuration, the simulation should output 3 graphs:

* a 2D map of the EE over the field from -5 to +5 arcminutes, sampled every ≈20’’ in both directions(about 30x30 points) limited to Ø5 arcminutes
  + main contour levels every multiple of 5% overplotted on the EE on the field (special contour EE=30% in red ?)
  + others contour levels where relevant, if needed
  + LGS blind areas (if any) marked on the plot
* histogram of EE, with bins of ΔEE=2.5%
* plot of Y versus X, with Y = (surface of the field where EE ≥ X). This is the *cumulative* version of the histogram, expressed as a field surface. All surfaces in arcmin.

Ideally, an EE map should also be a fits image containing

NAXIS = 3 / number of axis

NAXIS1 = 30 / field position along x

NAXIS2 = 30 / field position along y

NAXIS3 = 4 / box size (100, 150, 200, 250)

NAXIS4 = 6 / wavelengths (0.4, 0.8, 1, 1.25, 1.65, 2.2)

......

plus the same header than the PSFs.

## Baseline case

INPUT:

Baseline parameters + MOAO

## Exploration

The EE maps produced when exploring the parameter space should be done by

* using the baseline parameter
* for all science wavelengths and for all target positions in the field (so that to generate a cube of EE maps)
* and exploring the impact of each remaining parameter one by one

# Test case for comparison of simulation codes

Below is a summary of all baseline parameters through all this document.

The values have been copied from the previous “baseline” paragraphs of this document, they do not differ, and sections they refer to is shown (for more/detailed information)

This test case should allow us to compare on a fixed single case between simulations codes.

Two simulations cases should be done:

* MOAO case (i.e. using MOAO DM)
* GLAO case (using M4 only)

with the following summarised parameters:

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Refer to section … |
| zenith distance | 30° | 3.3 |
| seeing & r0 at 500 nm & 30° | 0.793’’  12.75 cm | 3.3 |
| L0 | 25 m | 3.3 |
| Profile | Q2, median, ESO 35 layers |  |
| Vmean  τ0 | 9.13 m/s, Q2 ESO  6.12 ms | 3.4 |
| Optical throughput (total) | 0.382 (LGS)  0.425 (NGS) | 4.2 |
| Telescope pupil | hexagonal | 5.1.1 |
| M1 polishing/phasing errors | not taken into account | 5.2.1 |
| M4 | 75x75, square pattern, pitch 0.52084 m, not tilted, conjugated to 612 m | 5.3 |
| Vibrations, windshake | 0 | 5.4 |
| Frame rate, latency | 250 Hz, 1 frame | 6.1 |
| MOAO DM | 64x64, square pattern, coupling 0.25 | 6.2 |
| FoV | 10 arcmin | 6.3 |
| Wavelength (science) | 1650 nm | 6.4 |
| LGS WFS  Wavelength  Na profile shape  Na profile fwhm  Na profile altitude  Laser beam width  pixel size  pixels/subap  RON  # sub-apertures  photon return at M1  Noise figure  laser launch telescopes | 589 nm  Gaussian  10 km  100 km (at 30°)  0.8’’  0.7’’  16x16  3 e-  74x74  7 Mph/m2/s  see § 6.5.5  4 at 22 metres | 6.5.1  6.5.2  “  “  “  6.5.3  “  “  “  6.5.4  6.5.5  6.5.6 |
| NGS WFS  wavelength  photometry  noise figure  pixel size  pixels/subap  RON  # sub-apertures | 650 nm  qr=2.90 see § 6.6.2  see § 6.6.3  0.4’’  10x10  3 e-  74x74 | 6.6.1  6.6.2  6.6.3  6.6.4  “  “ |
| LGS asterism | 6  Ø 7.4 arcmin | 6.7  “ |
| NGS asterism | Ali’s favourite  (GOODS study asterism 0) | 6.8.1  “ |
|  |  |  |