1 LONG TERM SIMULATIONS RESULTS

A series of long time simulations during imaging phases, one without the instrument in the loop and the others with different configurations of the instrument in science mode and considering also different AOCS units failures. The scheme of the initial conditions for the simulations are set in §**Error! Reference source not found.**.

These simulations starts from the satellite in ASH mode, goes to NM (to SUP submode by means of a rate bias manoeuvre) and then to CAP submode, via MAN submode using a bang-bang manoeuvre, in this state it continuous for more than 48 hours to finally return to SUP via another rate bias manoeuvre.

The main objective of these simulations is to provide to CHEOPS instrument team different files that represents the pointing behaviour that are expected in different satellite configurations. These files are attached to this document, besides the .txt file, a MATLAB file .mat is giving within a .m file script in order to generate the associated .txt. The following subchapters provide some graphics with interpretation of the results and a summary of the pointing error performance during the CAP phase.

The outputs of this "long-time" campaign will be numerical and will have the following data and format:

`Time [s]`	`isPIL`	`pldIsValid`	`X APE [arcsec]`	`Y APE [arcsec]`	`Z APE [arcsec]`
0.0000	0	0	146.718	-54.413	-269984.419

Where Time stands for the time of the simulation the beginning value will correspond with the beginning of CAP submode. `isPIL` is a flag value corresponding to validity flag of instrument if PSE is enable in CSW or to 0 if PSE is disabled. `pldIsValid` corresponds directly to the validity flag of the instrument. Note that only for the first "long-term" simulation (no instrument measurements) PSE would be disabled so for the rest the values of `isPIL` and `pldIsValid` will be the same.

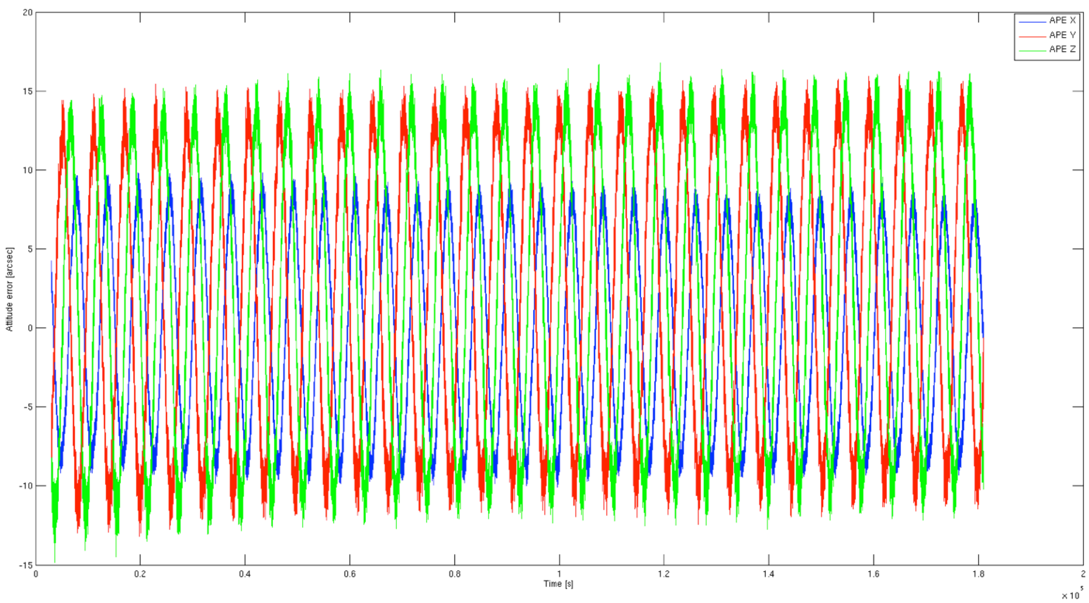
1.1 SIMULATION 1

This simulation assumes that no valid centroid is ever sent to AOCS. Then, in this simulation the thermos-elastic error is not corrected by means of instrument measurements and therefore are the main contributor to the pointing error.

CAP phase starts at 3000s from the initial time of simulation.

Following figure shows the pointing error for each axis during cap submode. It can be noted that the pointing error follows a sinusoidal function and that there are 30 cycles, that corresponds to a cycle per orbit (more or less 14.5 orbits per day).

As expected, the maximum pointing error for both Y and Z axis in satellite reference frame is about 15.1arcsec that corresponds to the input maximum thermos-elastic deformation.



Statistics Results

Percentage of time non-blinded during CAP: 100%

2D pointing error considering occultation periods

No Requirement on APE: at 68%

Performance : 13.3 arcsec at 68%

Performance : 13.3 arcsec at 68%. Considering blinded periods

No Requirement on APE: at 95%

Performance : 15.1 arcsec at 95%

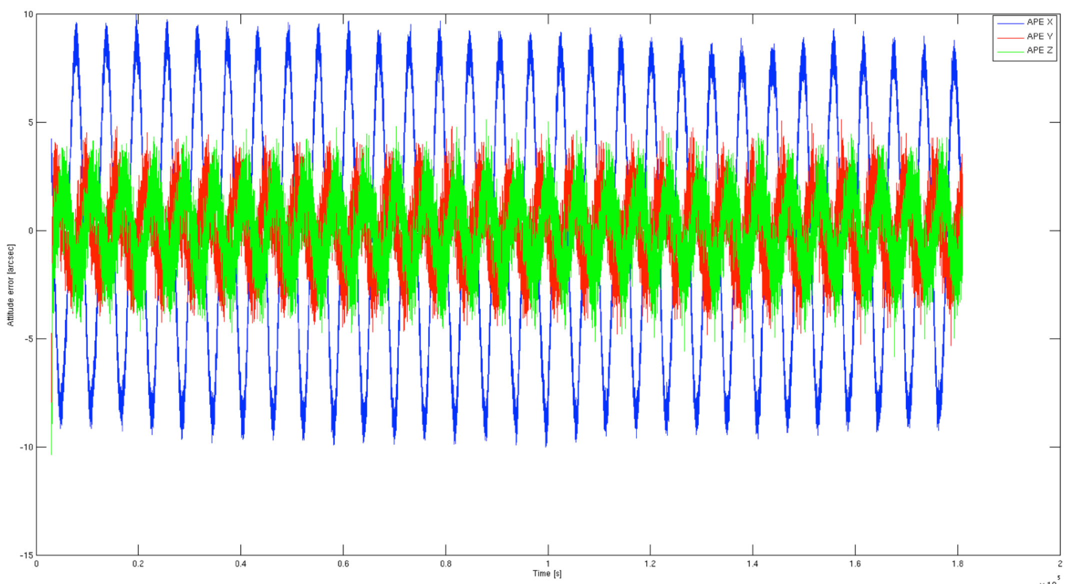
Performance : 15.1 arcsec at 95%. Considering blinded periods

1.2 SIMULATION 2

This simulation consists in an uninterrupted (not blinded) time series assuming a valid centroid cadence of 60sec, considering no equipment failure, i.e., 4RWs and 2STOHs.

CAP phase starts at 3000s from the initial time of simulation.

Following figure shows the pointing error for each axis during cap submode. It can be noted that the pointing error for both Y and Z axis has been drastically reduced. The sinusoidal function is still observable due to thermos-elastic error contribution between measurements of 60sec, the same frequency is kept as the maximum residual corresponds to the maximum thermos-elastic deformation.



Statistics Results
Percentage of time non-blinded during CAP: 100%

2D pointing error considering occultation periods
Requirement on APE: 4.00 arcsec at 68%
Performance : 2.47 arcsec at 68%
Performance : 2.47 arcsec at 68%. Considering blinded periods

Requirement on APE: 8.00 arcsec at 95%
Performance : 3.44 arcsec at 95%
Performance : 3.44 arcsec at 95%. Considering blinded periods

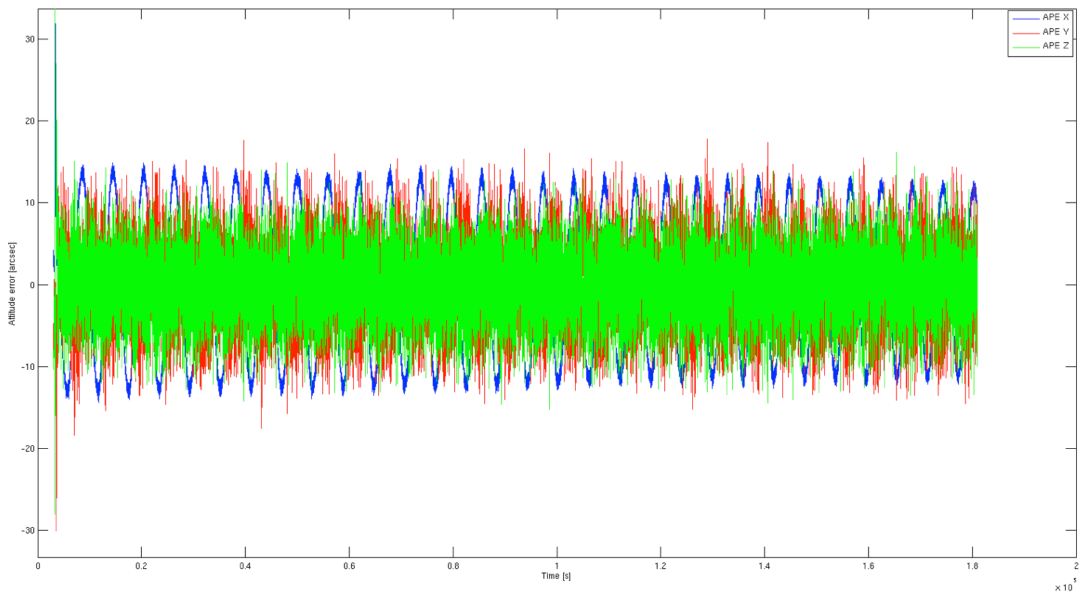
It can be seen that requirements are well fulfilled.

1.3 SIMULATION 3

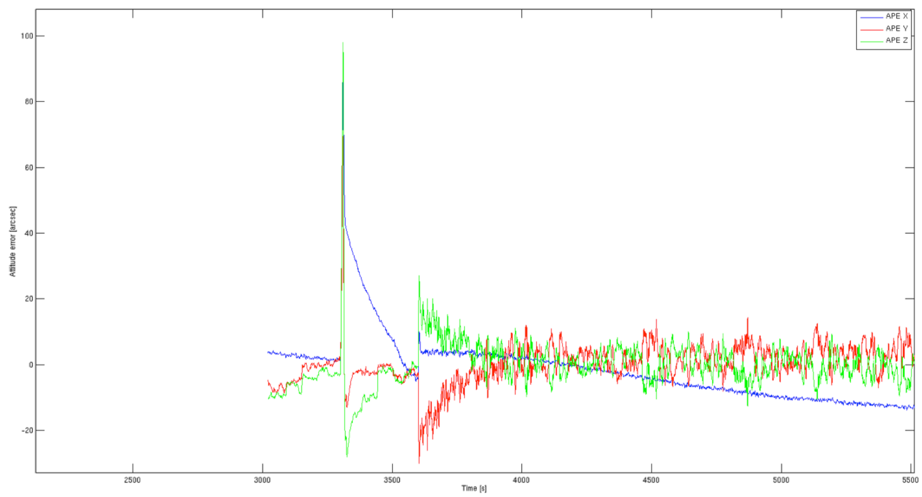
This simulation consists in an uninterrupted (not blinded) time series assuming a valid centroid cadence of 60sec, considering double equipment failure, i.e., 1RWs and 1STOH failure.

CAP phase starts at 3000s from the initial time of simulation.

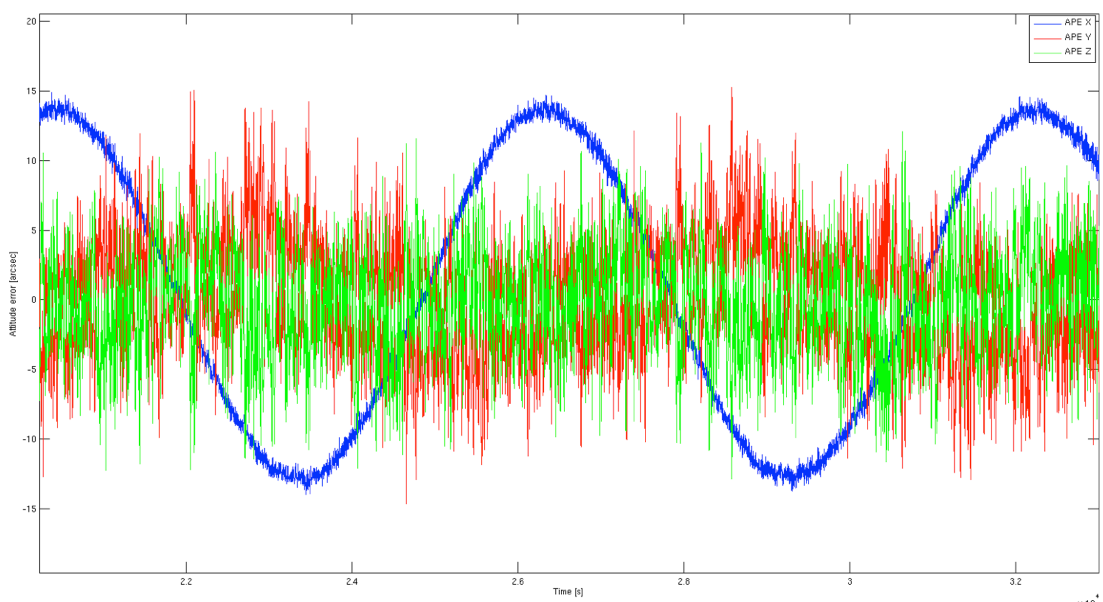
Following figure shows the pointing error for each axis during cap submode. The most noticeable change from SIMULATION2 is that the high frequency noise is larger due to the fact of losing one OH in both Y and Z axis. Error on X axis is not affected as the remaining OH is perpendicular to this axis.



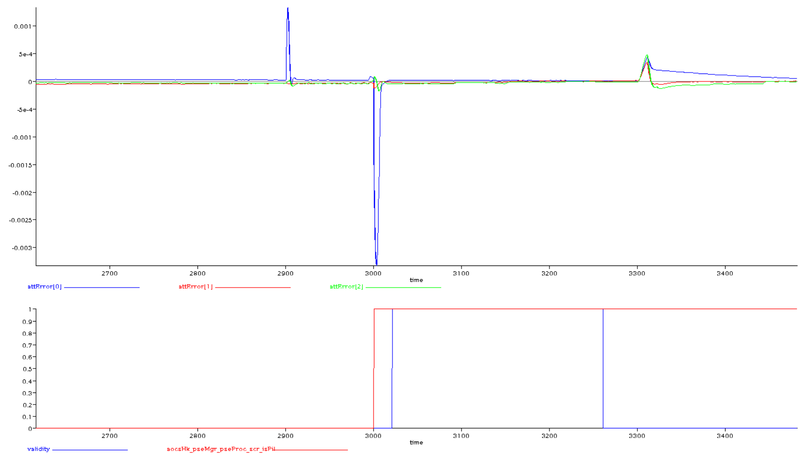
The failure of the wheel was forced once in CAP, at 3300s. The failure was modelled at RW model, so the CSW detected it and recover changing the appropriate parameters. The transient can be observed in the following figure. Besides, it can also be observed the fact of losing one OH. This was forced at time 3600s and the increase in the noise of the APE is clearly shown also in following figure.



The following figure shows a zoom of a couple of orbits during the stabilized phase of CAP. It is also note that the sinusoidal variation remains, although it is less visible due to the higher noise in the attitude estimation.



The flag pldIsValid (or validity in the figures) refers to the validity flag of the instrument AOCS report. It is set to 1 in case of full ccd, and to 0 in case of windows mode. The PSE is used in both cases (the same cadence of 60s was kept for both modes). In this simulation the instrument science mode started at 3020s, due to the internal parameter of "number of measurements within full CCD to pass to windows mode" (set to 4) it passed to windows mode at 3260s. This can be seen in the following figure:



Statistics Results

Percentage of time non-blinded during CAP: 100%

2D pointing error considering occultation periods

Requirement on APE: 8.00 arcsec at 68%

Performance : 5.48 arcsec at 68%

Performance : 5.48 arcsec at 68%. Considering blinded periods

Requirement on APE: 15.00 arcsec at 95%

Performance : 10.5 arcsec at 95%

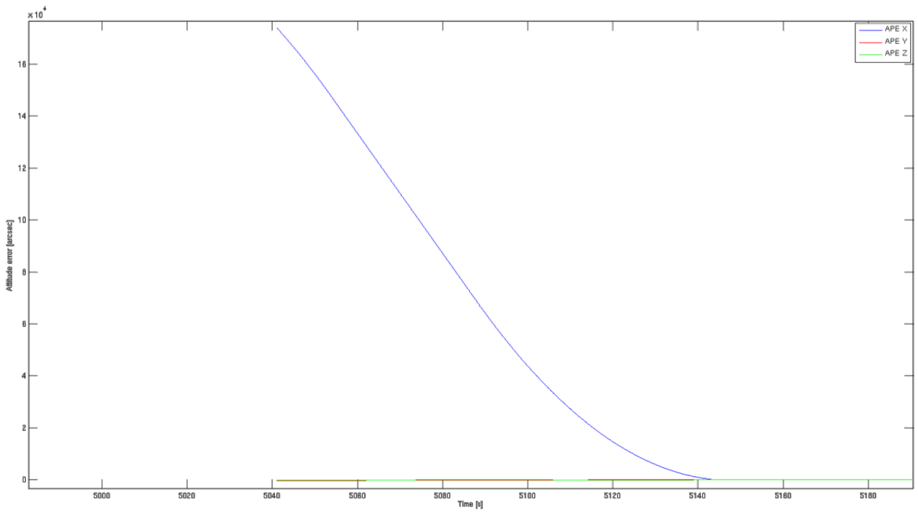
Performance : 10.5 arcsec at 95%. Considering blinded periods

This simulation shows compliance to the pointing requirements.

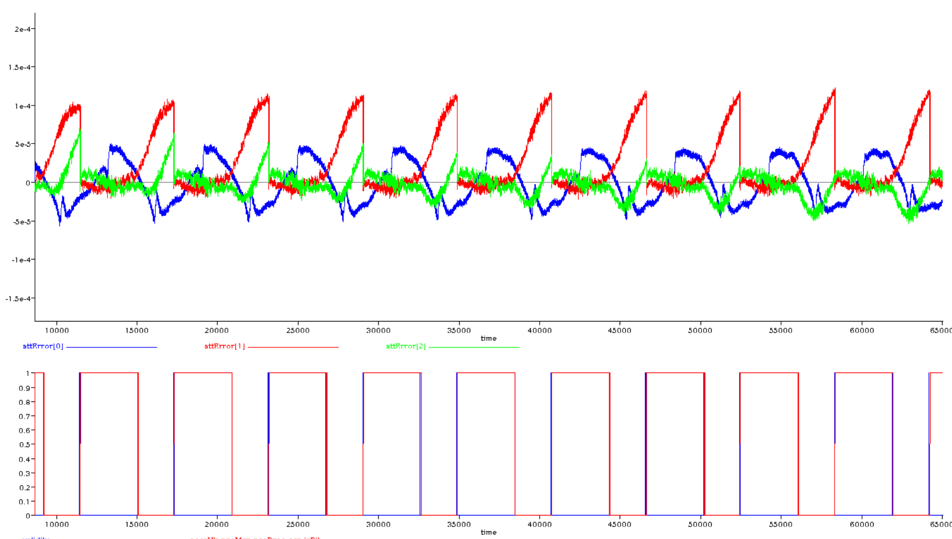
1.4 SIMULATION 4

This simulation consists in an interrupted (blinded) time series assuming a valid centroid cadence of 60sec. It considers maximum interruptions, continuous due to Earth occultation no valid centroid.

CAP phase starts at 5000s from the initial time of simulation. In this case an error in the tele-commanded quaternion was deliberately introduced in roll angle. So the initial error at CAP init was detected and corrected using a control base in rate-bias once the error was small enough it switch to the normal PID control during CAP. Following figure shows the roll error evolution at beginning of CAP.



Following figure shows the pointing error for each axis during part of CAP submode.



It can be noted that the pointing error smoothly increases during blinding periods while is suddenly corrected with each new measurement.

Statistics Results

Percentage of time non-blinded during CAP: 61%

2D pointing error considering occultation periods

Requirement on APE: 4.00 arcsec at 68%

Performance : 2.38 arcsec at 68%

Performance : 7.06 arcsec at 68%. Considering blinded periods

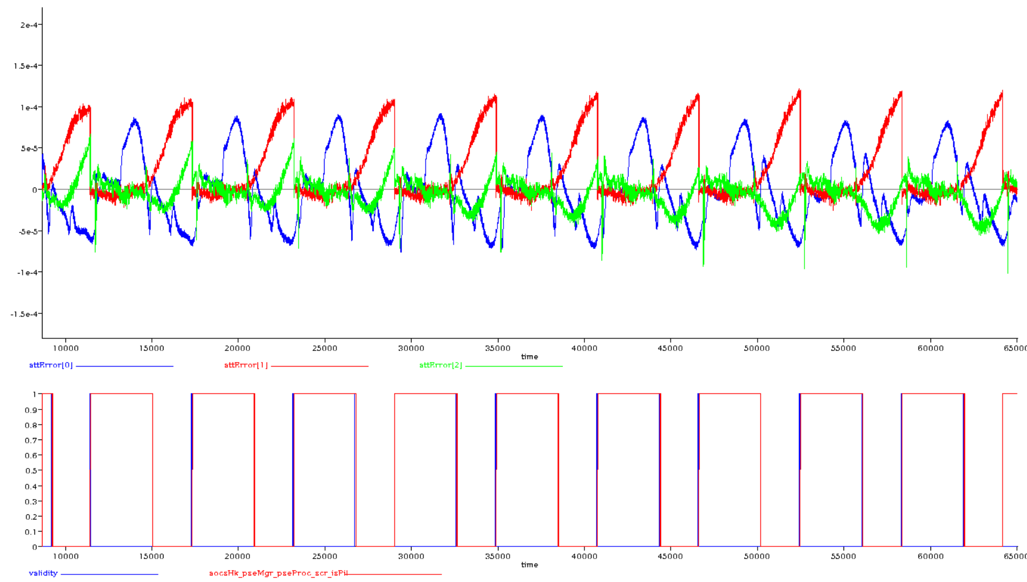
Requirement on APE: 8.00 arcsec at 95%

Performance : 3.49 arcsec at 95%

Performance : 22 arcsec at 95%. Considering blinded periods

1.5 SIMULATION 5

This simulation is similar to SIMULATION4 but with the addition of a failure of a reaction wheel. The results are really similar because there is enough control authority with 3RWs.



Statistics Results

Percentage of time non-blinded during CAP: 61%

2D pointing error considering occultation periods

Requirement on APE: 8.00 arcsec at 68%

Performance : 2.64 arcsec at 68%

Performance : 8.47 arcsec at 68%. Considering blinded periods

Requirement on APE: 15.00 arcsec at 95%

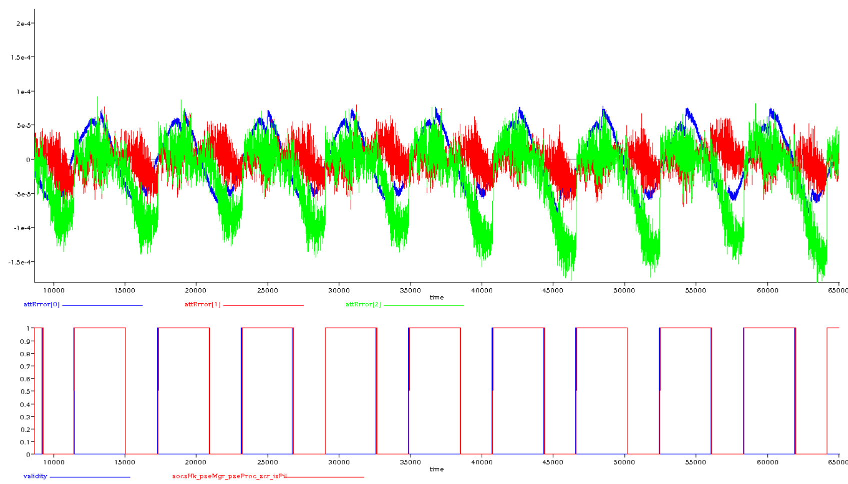
Performance : 4.87 arcsec at 95%

Performance : 22.6 arcsec at 95%. Considering blinded periods

Results are really similar to SIMULATION4, indeed it would be closer but the transition when losing the RW during CAP affects slightly to the performance at 68% (2.38 arcsec in SIMU4) and more to the performances at 95% (3.49 arcsec in SIMU4) as expected.

1.6 SIMULATION 6

This simulation is again based on SIMULATION4 but with the addition of a failure of a star tracker OH. The results are worst in this case as there is a higher noise in the estimation process.



Following figure shows the transient when losing the STR.

Statistics Results

Percentage of time non-blinded during CAP: 61%

2D pointing error considering occultation periods

Requirement on APE: 8.00 arcsec at 68%

Performance : 5.25 arcsec at 68%

Performance : 9.92 arcsec at 68%. Considering blinded periods

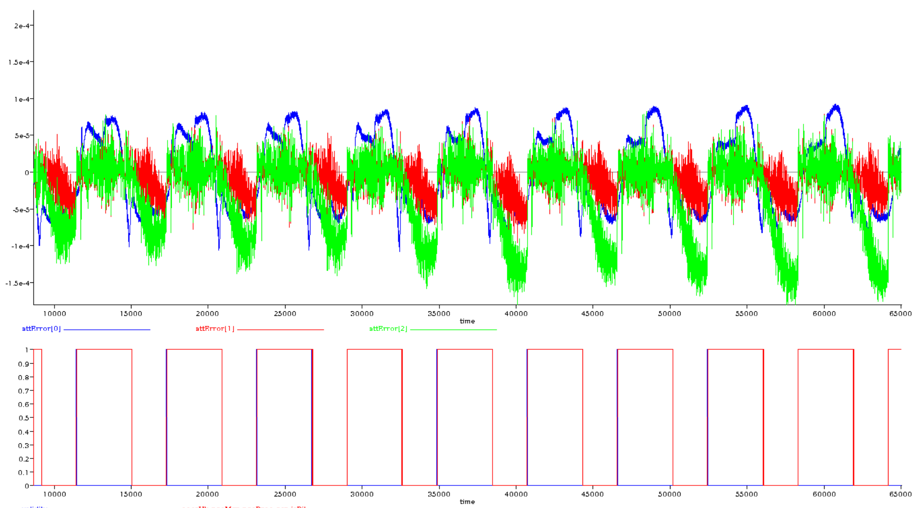
Requirement on APE: 15.00 arcsec at 95%

Performance : 10.9 arcsec at 95%

Performance : 26.5 arcsec at 95%. Considering blinded periods

1.7 SIMULATION 7

This simulation is again based on SIMULATION4 but with the addition of a failure of a star tracker OH and a RW. Besides, the cadence of the instrument is changed from 60s to 1s. The results are similar to SIMULATION6 when there was also the failure of one OH. The advantage of reducing the cadence of delivery of instrument measurements provides slights improvements with respect previous simulation that somehow are also blurred by the fact of the transient period of RW failure.



Statistics Results

Percentage of time non-blinded during CAP: 61%

2D pointing error considering occultation periods

Requirement on APE: 8.00 arcsec at 68%

Performance : 4.81 arcsec at 68%

Performance : 9.78 arcsec at 68%. Considering blinded periods

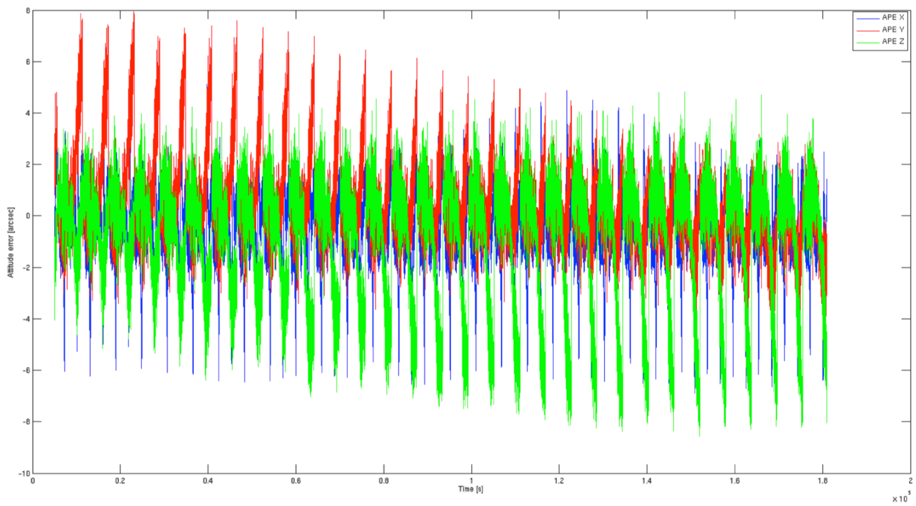
Requirement on APE: 15.00 arcsec at 95%

Performance : 10.3 arcsec at 95%

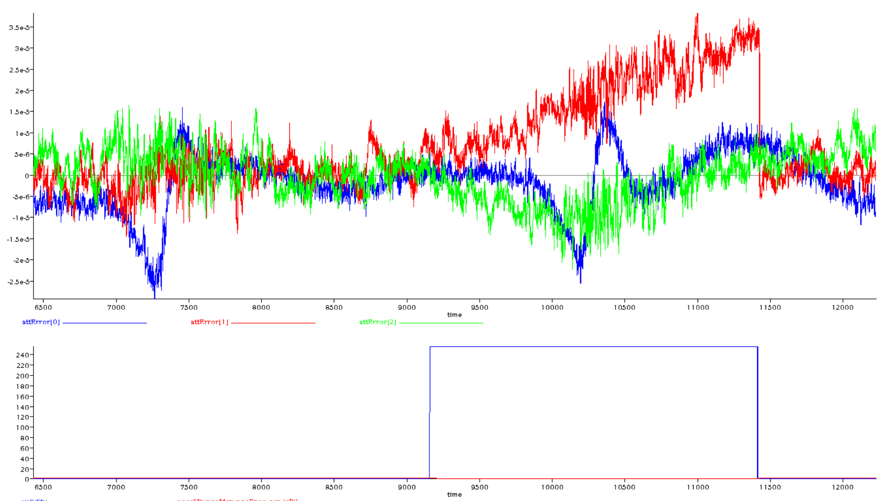
Performance : 26.4 arcsec at 95%. Considering blinded periods

1.8 SIMULATION 8

This simulation consists on an interrupted observation considering also maximum interruptions due to Earth occultation, with a centroid cadence of 60s and nominal AOCS unit equipment. In this case, the thermos-elastic perturbation is reduced to the expected operational values (+-1.75 arcsec x 2 margin = 3.5 arcsec (half-amplitude). Next figure shows the overall behaviour during CAP.



Next figure shows a zoom on the transient phase during an occultation and how the pointing performances are recovered as there is a new measurement.



Statistics Results

2D pointing error considering occultation periods

Requirement on APE: 4.00 arcsec at 68%

Performance	: 1.44 arcsec at 68%

Performance	: 2.47 arcsec at 68%. Considering blinded periods

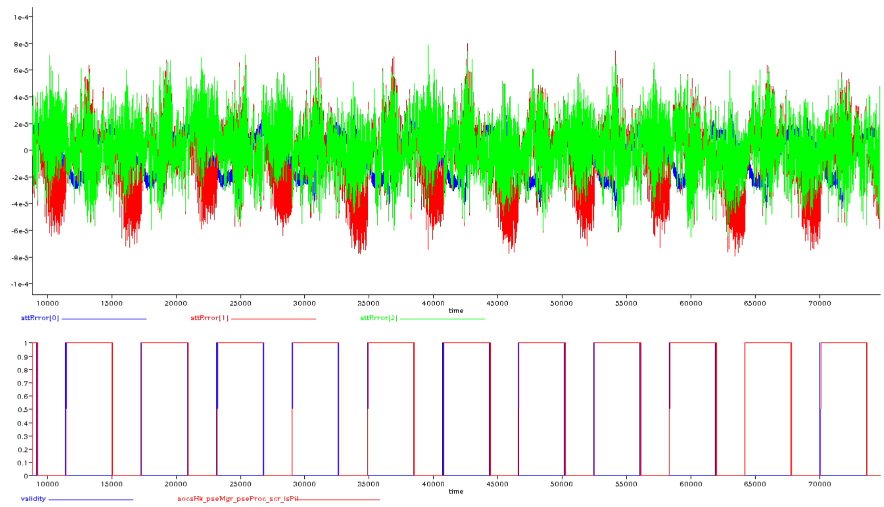
Requirement on APE: 8.00 arcsec at 95%

Performance	: 2.49 arcsec at 95%

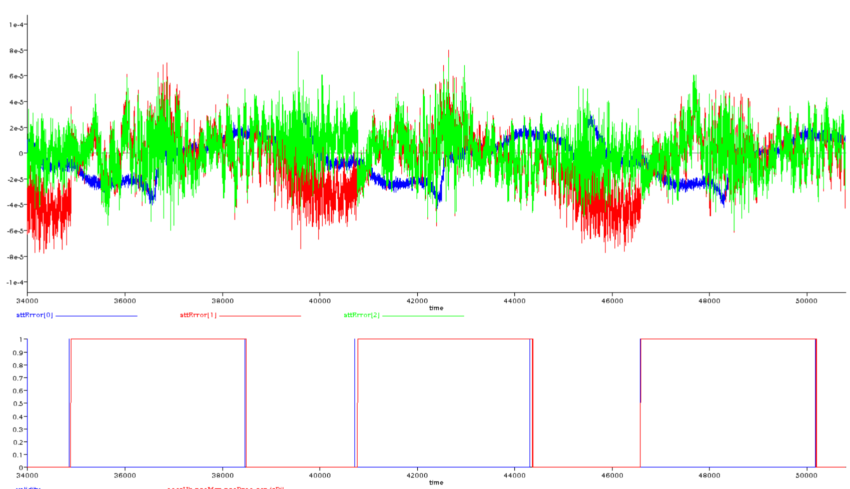
Performance	: 6.47 arcsec at 95%. Considering blinded periods

1.9 SIMULATION 9

This simulation is based on SIMULATION8 adding a failure of one OH. As expected, pointing performances are driven now by the error in the estimation due the OH noise.



Next figure shows a zoom on the transient phase during an occultation and how the pointing performances are recovered as there is a new measurement.



Statistics Results

Percentage of time non-blinded during CAP: 61%

2D pointing error considering occultation periods

Requirement on APE: 4.00 arcsec at 68%

Performance : 4.64 arcsec at 68%

Performance : 5.42 arcsec at 68%. Considering blinded periods

Requirement on APE: 8.00 arcsec at 95%

Performance : 9.54 arcsec at 95%

Performance : 10.2 arcsec at 95%. Considering blinded periods