Formation Flying performances simulator for the Shadow Position Sensors of the ESA PROBA-3 mission

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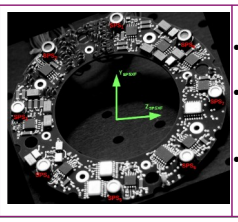
ABSTRACT

PROBA-3 (PRoject for OnBoard Autonomy) is an ESA mission to be launched on beginning of 2023 where a spacecraft is used as an external occulter (OSC-Occulter Spacecraft), to create an artificial solar eclipse as observed by a second spacecraft, the coronagraph (CSC-Coronagraph Spacecraft). The two spacecrafts (SCs) will orbit around the Earth, with a highly elliptic orbit (HEO), with the perigee at 600 km, the apogee at about 60530 km and an eccentricity of ≈ 0.81. The orbital period is of 19.7 hours and the precise formation flight (within 1 mm) will be maintained for about 6 hours over the apogee, in order to guarantee the observation of the solar corona with the required spatial resolution. The relative alignment of the two spacecrafts is obtained by combining information from several subsystems. One of the most accurate subsystems is the Shadow Position Sensors (SPS), composed of eight photo-multipliers installed around the entrance pupil of the CSC. The SPS will monitor the penumbra generated by the occulter spacecraft, whose intensity will change according to the relative position of the two satellites. A dedicated algorithm has been developed to retrieve the displacement of the spacecrafts from the measurements of the SPS. Several tests are required in order to evaluate the robustness of the algorithm and its performances/results for different possible configurations. A software simulator has been developed for this purpose. The simulator includes the possibility to generate synthetic 2-D penumbra profile maps or analyze measured profiles and run different versions of the retrieving algorithms, including the "on-board" version. In order to import the "as-built" algorithms, the software is coded using Matlab. The main aspects of the simulator, such as the results of the simulations, with the inclusion of some specific case studies, will be reported and discussed in this paper.

SIMULATOR CAPABILITIES

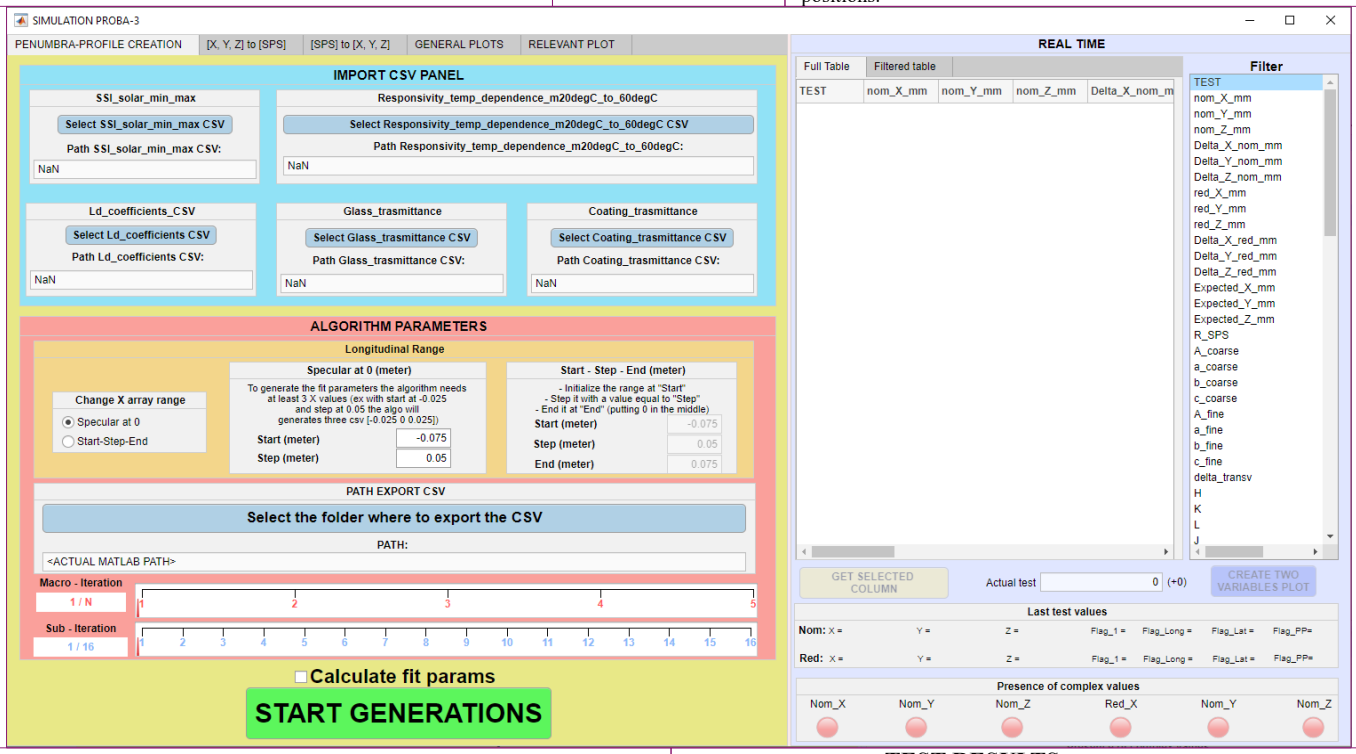
- Generate synthetic 2D penumbra maps;
- Evaluate the expected DNs and currents for a specific displacement;
- Evaluate the displacement from given DNs and penumbra profile;
- Import/Export data and results (CSV and PNG files);
- Real-time display of the results.

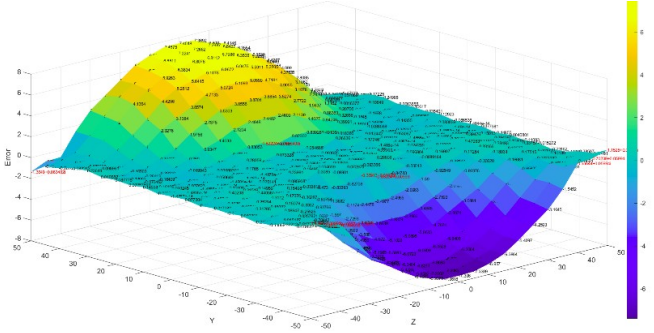
Each step is executed in a different tab.



SIMULATOR VALIDATION

- The "penumbra profile generation" module validation is in progress by using the full Sun disk data from SDO.
- The "expected output from the SiPMs" module has been validated by checking the conversion between irradiances and DNs generated by the SiPMs with the electronics design.
- The "spacecrafts Position Retrieval" has been validated by checking the results (i.e., X,Y and Z) provided by the simulator for known S/C positions.





TEST RESULTS

The simulator has been used for the SPS algorithm debugging and it is currently largely used for the SPS algorithm performances test. The main questions are:

- How much the algorithm is sensitive to the penumbra profile knowledge?
  We ran various tests by varying all the fitting parameters once at a time finding the exact range where the results start to give incorrect mathematical/physical results. Then we applied these ranges to run some Montecarlo simulations, obtaining that the penumbra profile is fitted with a precision of ±1%.
- How much the algorithm is sensitive to measurement errors?
  Since the SPS algorithm is based on differences between the readings of opposite SiPMs, this test evaluates the errors in the retrieved position introducing asymmetries in the measurements. We measured a variation of about 46 micron/DN.
- Are the SPS algorithm results still valid in some "exotic" S/Cs configurations?
  Several configurations have been tested by using the simulator. The results provided useful information about the limitations of algorithm to retrieve specific configurations.

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