OPERATIONAL CONCEPTS REFINEMENT FOR THE ORBIT DETERMINATION OF METEOSAT THIRD GENERATION

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ABSTRACT

The Meteosat Third Generation (MTG) System of EUMETSAT will provide continuous high spatial, spectral and temporal resolution observations and geophysical parameters of the Earth/Atmosphere System, from direct measurements of its emitted and reflected radiation from geostationary orbit. The mission will comprise 6 satellites: 4 imaging and 2 sounding satellites, based on 3-axes stabilized platforms. The full operational capability foresees one Imager and one Sounder in the same longitude slot at 0° (±0.1° width) with another Imager at 9.5° East; the system has the capability to co-locate up to 4 satellites in the same slot. The program is currently in Phase-B, during Preliminary Design Review; the first launch is scheduled for 2018.

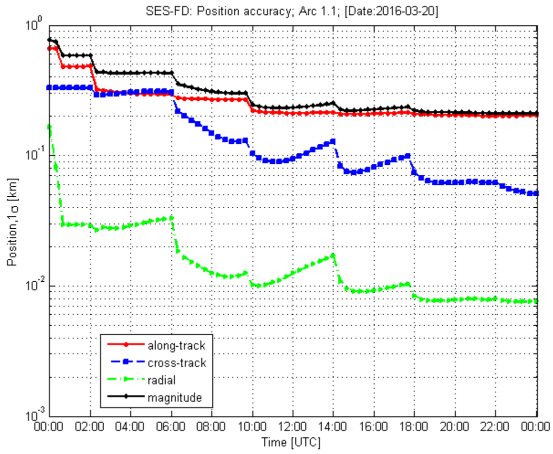
MTG has stringent accuracy requirements for instrument data navigation and rectification; this necessitate direct Instrument Data Processing (IDP) for combined orbit/attitude determination, matching known landmarks to the payload data and using star-trackers attitude information.

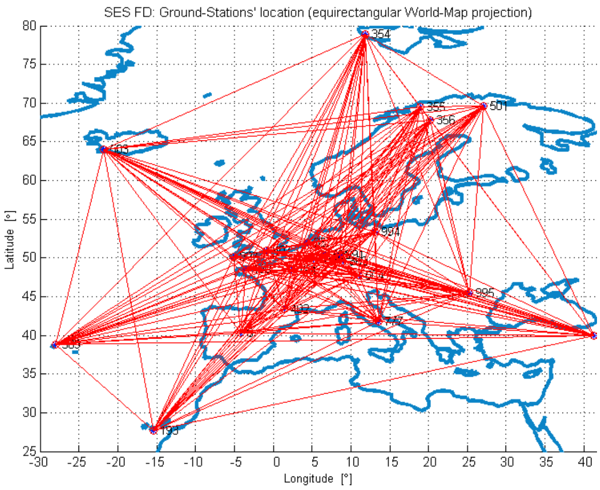
To support the image taking on-board, the Flight Dynamics System has to determine the orbit and to update its prediction regularly. For MTG, this task is dependent on the availability of Image Navigation and Registration (INR) data from IDP, as time-stamped orbital state vectors:

- INR data not available: orbit determination and predictions are based on ranging from 2 different S-band ground-stations, with frequent swaps (down to 3 hours) and measurements. This is done to re-initialize IDP (during payload off periods, safe mode and in the spacecraft commissioning phase), or in case of INR degraded accuracy (such as during orbit manoeuvres).
- INR data available: this is the nominal routine scenario, with orbit determination and predictions based INR data, together with ranging from a single station. A second ranging station is used as cold back-up, with less frequent swaps (typically one week) for maintenance and station bias calibration.

In both cases, the current operations' baseline requires a near real-time orbit determination accuracy from the Flight Dynamics System of better than 1500m/500m/50m in the along-track/cross-track/radial directions, at 3-sigma confidence level, with the ranging stations located on the territory of EUMETSAT member states. It is possible to achieve high accuracy of the orbit determination process based on dual-ranging techniques, properly selecting the ground-station geographical location (i.e. increasing their relative distance), the frequency of the measurements and swaps between stations, or reducing the uncertainty in the process, such as measurement noise. These have an opposite impact on the cost, maintenance and operational effort for the selected design. This paper will describe the methods adopted within MTG project, for a trade-off and refinement of the operational concepts for orbit determination.

The simulation concept is based on the use of high accuracy models for orbit propagation and measurements generation, including local terrain displacement of stations, ionosphere and troposphere's effects, INR and tracking noise, ground stations and spacecraft transponder delays. The solution for the trajectory determination is implemented by means of covariance analysis with a square-root information filter (SRIF); this allows batch of pure sequential filtering, with covariance matrix evolving, as more and more measurements are available during the mapping times. An example of 1-sigma position accuracy evolution is shown in the plot up-right for dual ranging of one specific baseline and tracking schedule (semi-logarithmic scale). The SRIF estimation process includes not only the modelling of the dynamic variables (as defined by their equations and partial derivatives), but also the effects of exponentially correlated random variables and considered biases. The estimation process additionally computes the state evolution from simulated real measurements, and it can be also implemented in Monte Carlo sense, to obtain empirical statistics of the system knowledge and dispersion. This also allows simulating other kinds of typical measurements errors, like sine waves for INR data. The analysis involves all possible baselines for a wide range of existing ground stations in Europe (see picture on the left), each with a combination of stations's swap schedule (i.e. every 3, 6, 12, 24 hours) and ranging interval (i.e. every 20, 60, 180 min).





For each baseline, the results are collected as function of key parameters, such as longitude/latitude separation of the stations (see the example plots below on the right: 1-sigma radial position accuracy for all baselines at given tracking schedule). The paper will also present a sensitivity analysis of the orbit determination accuracy with respect to the uncertainty of the initial state, the solved-for parameters (such as Solar Radiation Pressure coefficients or station biases), the level of noise of the processed ranging measurements, the INR data frequency and quality, the duration of the arc when the measurements are taken, the spacecraft longitude slot and resonances of the stations' swap scheme with the orbital period.