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Author: Mr. Andreas Hornig
AerospaceResearch.net, Germany, andreas.hornig@aerospaceresearch.net

Prof. Dieter Fritsch
Institute for Photogrammetry (IFP), University of Stuttgart, Germany, dieter.fritsch@ifp.uni-stuttgart.de
Mr. Anthony Mallama
United States, anthony.mallama@gmail.com

TIME-SYNCHRONIZATION AND ACCURACY IMPACT ON THE OPTICAL OBSERVATION OF APPARENT BRIGHTNESS OF THE DIFFERENT STARLINK SATELLITE GENERATIONS AND VERSIONS

Abstract

In the wake of monitoring the apparent brightness of the different generations and versions of the Starlink satellites with a prototype optical groundstation (OGS), it became clear that the time-synchronization and accuracy has an impact on several levels of the data collection and processing. The impact are on levels such as localizing satellites on the optical image for brightness measurements, identifying this object by correlating it to a specific satellite by Cospar ID and gaining the timing offset between the the system's clock (stratum2 or higher) and a master clock (stratum0 or 1) for orbit determination. This effects all optical observations not just for the StarLink Satellites. In fact, it is of great importance for Space Situational Awareness (SSA) and Space Domain Awareness (SDA) as a whole. With Satellites in LEO the high relative speed can lead to several arcseconds of ambiguity of the satellites true location when the timing error is in the range of +-0.02 seconds.

For the prototype optical groundstation within the research topic of the Distributed Ground Station Network (DGSN), we applied time-synchronization methods used before for positioning signals in the radio-frequency communication domain on the optical sensor of the camera. This provided the video-observation with 25FPS a sub-frame accuracy of the absolute timing. This allowed the system to level up from a stratum4 level with +-20ms accuracy to a stratum1 level of accuracy in the range of +-2ms. The reference time source as stratum0 device is a combined GPS/Galileo/Beidou/GLONASS receiver. The paper shows the different synchronization modes how they are implemented on the OGS system itself. It shows the effects on the overlaid satellite trajectories defined with the most recent Two-Line Element (TLE) set that are used to find the nearest bright object and to identify it as a specific satellite. Further it shows how the timing is effecting the determination of the camera's attitude and direction of field-of-view, on sensor pixel level. This pixel-to-ra/dec mapping allows the correct overlay of the trajectory in the first place. And the paper concludes with the effects of the timing on the apparent brightness measurements of Starlink satellites themselves.

The DGSN project was started within the SmallSat-Design-Studies at the Institute of Space Systems (IRS) at the University of Stuttgart. It was part of several annual Google and ESA Summer of Code campaigns. It is a PhD-research topic at the Institute for Photogrammetry (IFP) at the University of Stuttgart.