Principal Design of GNSS Integrity Monitoring from Low Earth Orbit using a CubeSat Mission

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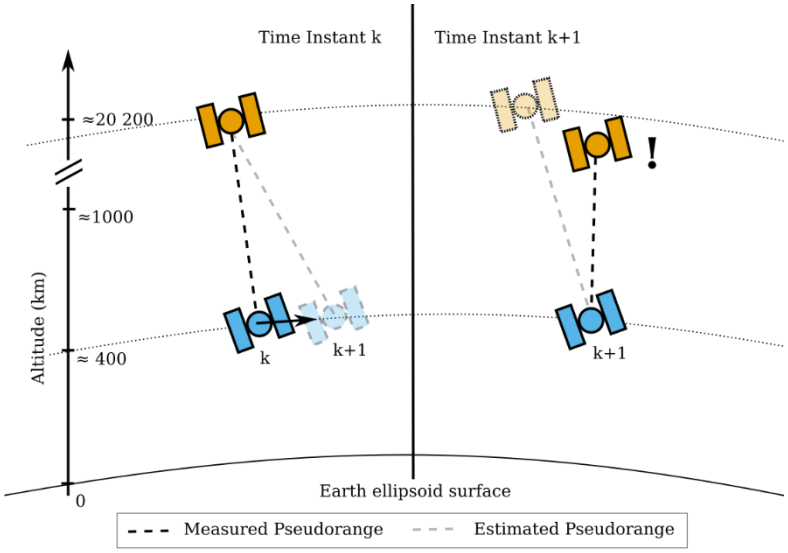


Figure 1: A simplified diagram showcasing a potential GNSS (orange satellite) failure detection, identified via the mismatch of the estimated pseudorange from the measurement onboard a LEO satellite (blue)

Global Navigation Satellite Systems (GNSS) have become an indispensable part of modern societies. This is largely due to simple, yet profound promises of GNSS: accuracy, availability, integrity, and continuity of the provided PNT services. In aviation and maritime navigation, GNSS are essential for certain operations such as landings with severely restricted visibility or docking maneuvers. In the automotive, railway, and urbain air mobility sector reliance on GNSS is not only trending, but a necessity for the realization of certain concepts. The above-mentioned applications fall under the so-called safety of life (SoL) or safety-critical designation. Spearheaded by strict requirements in civil aviation, recent decades have seen the rise of space-based and ground-based augmentation systems (SBAS and GBAS respectively). SBAS is a regional system of geostationary satellites relaying GNSS fault detection and correction information from a ground-based reference station network. GBAS installations are limited locally to airports and consist of two or more GNSS receivers. Both systems are confined to a certain area and entail significant infrastructure costs. With the rise of autonomous applications, tightening of the accuracy and integrity bounds, a need in increasing the performance of GNSS integrity monitoring and augmentation is becoming apparent.

The trend towards providing PNT via low Earth orbit (LEO) constellations may bring significant benefits. A more direct in-space monitoring of GNSS signals may be performed, with negligible distortion caused by atmospheric effects. A global augmentation service can be offered, with minimal ground infrastructure, and potentially faster dissemination of alerts lowering the guaranteed time-to-alert (TTA). The German Aerospace Center (DLR) and the Centre National d'Etudes Spatiales (CNES) are currently investigating in a project named GAUSS (GNSS Augmentation Satellite System) the concept of such a system. An in-orbit validation mission using two CubeSats under the name GERMAIN is also currently in planning.

In this work, we investigate and review the principal design of the integrity monitoring of GNSS via low Earth orbiting satellites. Our focus lies in developing strategies and concepts for processing GNSS observables, providing fault detection and exclusion algorithms for on-board GNSS receivers. We focus our findings to work with minimal resources that can be provided by CubeSats. Crucially, we emulate synthetic GNSS observables and compare the results with the in-situ observations made available via open repositories of LEO mission data. As a result of our work, we identify the open challenges in the field of integrity monitoring from LEO and showcase the capabilities that can be achieved by utilizing existing datasets.