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## Orbit Determination Using the SatNOGS network and Orekit

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The SatNOGS network is a global network of open-source ground stations that allows users to track, monitor, receive telemetry, and command satellites without the need to build their own network of stations. This helps to reduce the costs and complexity of operating and communicating with a spacecraft, which is especially important for CubeSat missions which are usually run by small teams with limited resources.

Orekit is an open-source spaceflight-dynamics library that is widely used across the space ecosystem to carry out mission analysis, studies, and in operational systems. It provides many low level features such as frame conversions, orbit propagation and more. Orekit also provides a very high level feature in the form of a complete orbit determination system.

Currently many CubeSat projects make use of the publicly available TLEs provided by SpaceTrack and online pass predictors to schedule connections to their satellites. TLEs are by their nature low accuracy and if accurate predictions are to be made using them the prediction model used must introduce periodic variations in the same manner that they were removed, otherwise a less accurate prediction will be produced.

Orbital position predictions based on TLEs are sufficient for simple data access but they break down for more ambitious missions.

The complexity of CubeSat missions have been increasing as a result of the ever expanding capabilities of CubeSats, and this is a trend that is expected to continue for the foreseeable future. As such the spacecraft location needs to be known to a greater degree of accuracy, both to improve the scheduling of connections to the satellite for telemetry and data retrieval by its operators as well as to improve the geo-location of measurements and imaging from the onboard instruments. The access to improved orbital models also allows mission planners and operators to more accurately schedule observing runs if they are interested in a particular region of the planet surface below or space above.

As part of the ESA SOCIS 2019 programme a project was carried out to investigate the feasibility of using Doppler Shifts from the SatNOGS network to carry out orbit determinations in an Orekit-based system. If possible it would mean the SatNOGS network could provide a large set of measurements from around the globe that would allow for more accurate orbital determinations to be carried out and could allow for multiple determinations to be carried out per day. The work on this project primarily focused on determining the accuracy of SatNOGS Doppler measurements that would be required for metre-level precision orbital determinations to be carried out successfully.

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