Estimation of attitude dynamics for CubeSat

Research environment:

- Laboratory: **GIPSA-Lab, University Grenoble-Alpes, France** (http://www.gipsa-lab.fr/)
- Topic of research: SCAO, data fusion, estimation and control in nano-satellites
- Collaboration with **Hyperion Technologies, Netherlands** and **CSUG, Grenoble** (France)

Supervisors: Dr. Hassen Fourati, NeCS team, hassen.fourati@gipsa-lab.fr
Dr. Bogdan Robu, SYSCO team

Period: October 2018-Mars 2019 (for 6 months)

Required skills and knowledge: Background in Filtering and Estimation, Aerospace Dynamics, Optimization, Data Fusion.

Context of internship

The **CSUG (the Grenoble University Space Center**, https://www.csug.fr/) has set for itself the ambitious goal of developing CubeSats that distinguish themselves from other university-developed nanosatellites by a maximum scientific return. The second satellite consortium is recently established by the CSUG and started its preliminary Phase-0 study in September 2016. The "NanoBob quantum CubeSat" or NanoBob CubeSat mission wants to design a new CubeSat and use it to demonstrate the experimental feasibility of a free space full quantum communication link over a distance greater than 500km to exchange a cryptographic key. The ADCS is used on-board to keep NanoBob almost perfectly aligned with the transmitter source located in Vienna. In fact, the NanoBob satellite will need to be oriented towards the photon source during a sufficiently long section of its overpass of the ground station telescope. In order to have a successful transmission and receiving of the photons, the satellite and the ground station should be aligned with less than ~100 arcsec (~0.03°) error (dynamic pointing stability of the ADCS). However, a full quantum up-link experiment may require a tracking with ~1 arcsec (0.00027°) error from the ground station.

Controlling the satellite attitude requires sensors to first measure/estimate its orientation during flight by using of some specific on-board ADCS sensors. Many relative sensors generate outputs that reflect the rate of change in attitude such as gyroscopes. They require a known initial attitude, or external information, to use it in order to determine the current attitude. Many types of this class of sensors have noises leading to inaccuracies if not corrected by absolute attitude sensors such as: horizon sensor, sun sensor, star tracker, magnetometer, etc. The absolute attitude sensors feel the position or orientation of fields, objects or other phenomena outside the satellite. One of the first works related to this problem used least squares approach (Wahba, 1965). Later, various approaches are developed/tested, each one with some advantages and drawbacks (related to precision, complexity, robustness to noises, etc.), by using separately or combining relative and absolute sensors such as QUEST (QUaternion ESTimator) (Markley and Mortari, 2000), Extended QUaternion ESTimator (Psiaki, 2000), Kalman filters (Shuster, 1990 ; Lefferts et al., 1982), complementary filters (Mahony et al., 2008 ; Wu et al., 2016), observers (Koprubasi and Thein, 2006 ; McDuffie et Shtessel, 1997, Fourati et al., 2016), etc. The main conclusion is that attitude estimation for nanosatellites is still an open problem and an improvements on precision, complexity or robustness in presence of noises is still desirable. We will study the state-of-the-art on attitude estimation for nanosatellite, analyze recurrent problems (sensor bias, noise, magnetic perturbations) and develop (if necessary) new approaches that can improve attitude estimation precision with a better combination of sensors on-board of NanoBob, which will be beneficial later on for the control algorithms. According to the type of sensors that need to be used in each flight mode (detumbling, safe mode, nominal mode), specific algorithms will be devised.