Project team

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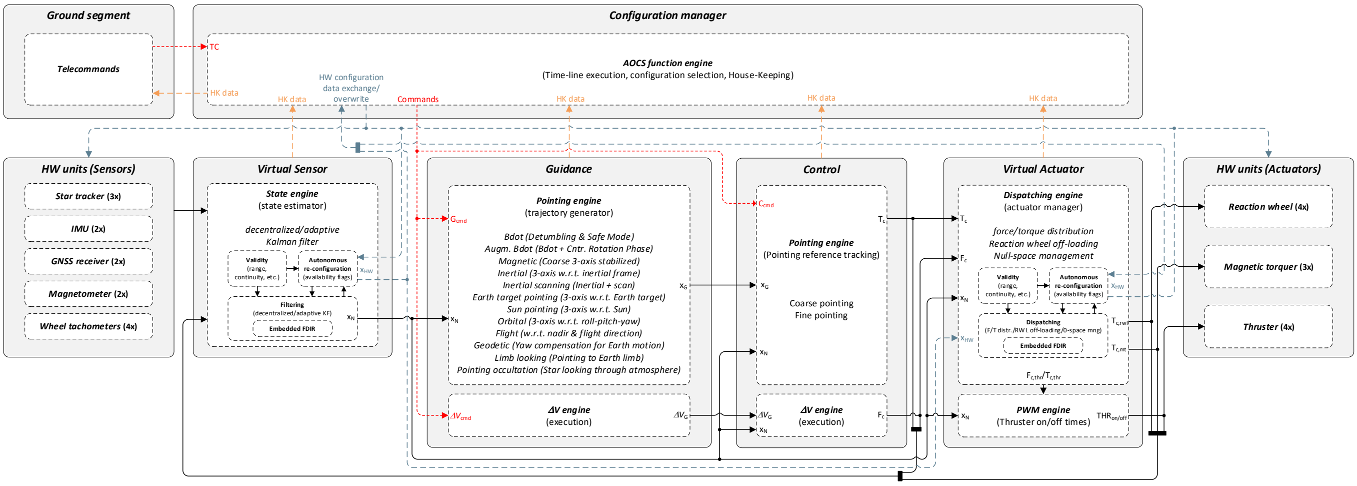
Abstract: Virtual sensors and actuators for all-in-one mode AOCS

Classical AOCS software typically employs several modes applicable to different mission (sub-)phases and manoeuvres to cover the range of required control functionality of the satellite. Ostensibly, however, all these modes often provide similar low-level functionality —namely the suitable control of satellite attitude (and rates), or translational positions (and velocities)—, which motivates the investigation of alternative AOCS architectures.

To this end, the aim of this activity was to exploit these similarities to investigate and mature a novel AOCS architecture consisting of only a single mode. Different spacecraft configurations and tasks are then to be accounted for using so-called virtual sensor and actuator abstractions, as well as advanced control techniques allowing for adaptations to different mission phases and spacecraft configurations.

This has resulted in a novel single mode AOCS architecture consisting of five main units as shown in the following figure.



- **Configuration manager:** The configuration manager is responsible for (re)configuring the system according to the available hardware units, assigning tasks via telecommands (targets), and monitoring safety (and realize a safe configuration if required).
- **Virtual sensor (VS):** The VS is an overarching state estimator that estimates the full system state during all tasks and for all possible configurations covering all possible scenarios including sensor outages due to blindings/occultations and hardware unit failures. The design includes a decentralized no-reset federated Kalman filter (FKF) for multi-sensor hybridization with snapshot filter fusion. Moreover, it includes several FDIR functionalities to detect, isolate, and discard any inconsistent propagation of measurements.
- **Virtual actuator (VA):** The VA is a state-of-the-art generic optimization-based actuator manager unit that takes care of distribution of control commands over the available actuators. The unit also takes care of several other tasks including thruster dispatching, RWL null-space management, RWL off-loading, actuator constraints, among other things.
- **Guidance:** The guidance consists of an optimization-based (sequential convex program (SCP)) pointing engine which autonomously generates trajectories that smoothly guide the spacecraft from its current state towards a desired target, while, for example, avoiding star tracker blindings. Also, it processes DeltaV commands. Essentially, this unit is agnostic to its surroundings irrespective of the spacecraft configuration and task to be performed.
- **Control:** The control unit was developed by means of advanced control design and analysis techniques (H_∞-synthesis, μ-analysis). Subsequently, the controllers were re-parameterized based on a state-of-the-art Youla-based technique that facilitates smooth transitioning between the different tasks with guarantees for stability. Also this unit is agnostic to its surroundings.

Together, these five units make up the single mode AOCS. The architecture was implemented for a representative benchmark study case derived the ALTIUS mission: (A)tmospheric (L)imb (T)racker for (I)nvestigation of the (U)pcoming (S)tratosphere. The corresponding spacecraft consists of a rich set of sensors and actuators, and the mission covers a wide range of science as well as various other objectives which makes it well suited to demonstrate the single mode AOCS concepts.

The design was extensively tested following a detailed validation campaign demonstrating several benefits of the approach when compared to conventional multi-mode AOCS approaches:

1. A decrease in verification and testing efforts due to the reduction of AOCS (sub-)modes and, as consequence, the reduction of the number of test scenarios versus hardware units.
2. An enhanced hardware modularity through the simplification of a replacement of one hardware unit by another, as the virtual sensor and actuator abstract layers in the AOCS only need to be parametrically adapted to different unit types and configuration.
3. A reduction in the number of hardware units thanks to a different redundancy approach through the virtual sensor and actuator concept.
4. A simplified FDIR design and verification, potentially less monitors and recovery actions (no mode dependencies).
5. Simplified operations: a smaller number of TCs, procedures, operational constraints.
6. Facilitation of the re-use of the AOCS design by means of the genericity of the virtual sensor and actuator abstractions.
7. Increase of the spacecraft's autonomy.

Besides this, the developed single mode AOCS units are generic and most of them can be easily re-used in other missions of similar nature and potentially be extended with additional functionalities.

In this "paper", we will further elaborate on the technical concepts and present a selected overview of simulation results.