Attitude Determination and Control System for the Micro-Spacecraft Lunarsat

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LunarSat, Lunar Academic and Research Satellite, is a micro-spacecraft that will be sent into an orbit around the Moon to perform scientific investigations concerning the lunar environment and its characteristics. The first objective of the LunarSat mission is to serve as an educational and outreach project. LunarSat is designed by young engineers, scientists, and students from around Europe, with support by numerous institutions. It shall be launched as an auxiliary payload on an Ariane 5 ASAP platform and will have a mass of 100 kg in GTO. LunarSat will orbit the Moon on a highly elliptical polar orbit with its perilune above the lunar South Pole area. This orbital strategy yields the possibility to obtain images of the lunar South Pole region with a resolution never achieved before. Further measurements shall provide further evidence regarding the existence of water ice in the lunar polar craters. LunarSat should be the first European orbiter to the Moon, the first spacecraft of this size to reach a Moon orbit from a standard Ariane 5 GTO.

The LunarSat project is being developed by the Division of Astronautics at the Technical University of Munich (Germany) in collaboration with the University of Surrey (England), the Surrey Satellite Technology Limited, the Swedish Institute of Space Physics in Uppsala and other several institutions all over Europe.

The Attitude Determination and Control System baseline shows a 3-axis stabilised satellite during all the phases of the mission. During orbital insertions the control is achieved by off-pulsing the 4 main engines. This leads to slightly increased fuel consumption but also to a very effective control of the spacecraft during these critical phases. The ADCS is planned to have different autonomous modes that follow the mission phases and tasks. The mission requirements imply de-tumble manoeuvres, Sun pointing for the body mounted solar arrays, Earth pointing for the high gain antenna and for the wide angle camera and fine Moon pointing for the high resolution camera, as well. In order to achieve all these tasks actuators like reaction wheels, attitude thrusters and main engine thrusters were sized and chosen. Sensors like laser gyros, Sun sensor and a star sensor perform the attitude determination. The reaction wheels are employed in order to reject external and internal disturbances and to accomplish LunarSat frequent slews. Different algorithms were implemented in order to keep pointing accuracy and stability under required limit, to command slews, to accomplish de-tumble manoeuvres and to desaturate the reaction wheels accumulated angular momentum.

Different control algorithms have been developed and implemented with the Matlab/Simumink™ platform: Target pointing, Slewing, Desaturation of the Reaction Wheels, Firing and Detumble.

The firing phases algorithms require the main engines and the attitude thrusters as actuators meanwhile for inertial Sun, Earth and Moon pointings reaction wheels are used. The detumble command employ all the actuators: first using the thrusters to damp the angular speed then using the reaction wheel to completely stop the spacecraft. A master simulation model in Simulink that integrates all of the algorithms is being designed, it contains:

- Attitude dynamics and Kinematics of the spacecraft,
- Models of the hardware used for the attitude determination and control (Thrusters, Reaction Wheels, Gyros, Sun and star sensors),
- Observers with filters for the Gyros and state-assemblers,
- Controllers.

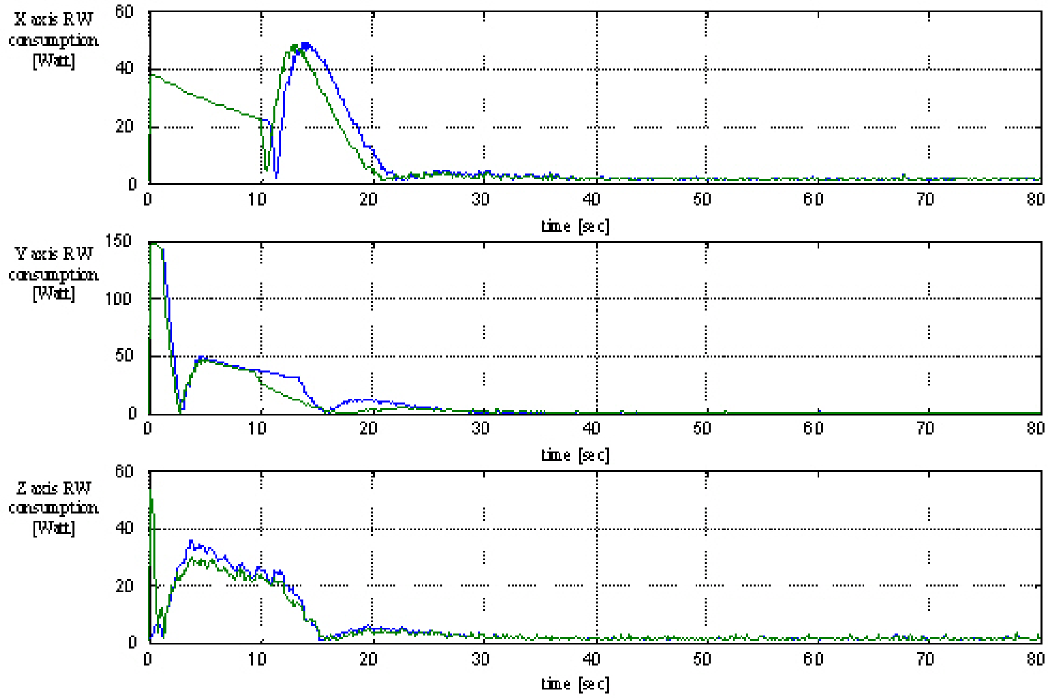

Figure 1: Optimum controller and optimum PID comparison

The controllers are developed with the modern optimal control approach. A comparison with classical theory PID controllers, separately developed, is done. Simulations demonstrated the superiority of the modern Optimum control methodology. The optimum controllers shown to be able to fulfil all the mission requirements while several lacks is found in the classical PID controllers. Optimum controllers minimise a cost function that takes into account the performance requested and the allowed control action. The resulting gain matrices have the peculiarity of better dosing the control signal. This lead to a noticeable power safe in confront of the PID controllers, when performing the same pointing manoeuvre with the reaction wheels. It is to remember that one of the most stringent requirements on the pointing manoeuvres is based on power consumption. In order to demonstrate this Optimum controller power-safe capability, a comparison between an Optimum controller and an optimum PID (obtained by the diagonal of the Optimum control gain matrix) was conducted. The simulation of Figure 1 was done for a Moon pointing manoeuvre, starting with null angular speed and an angular error of phi(3)=0, theta(1)=5 deg and psi(2)=5 deg (Euler angle parameterisation 312). The resulting power-safe was estimated to be the 7.8%, the 16.7% and the 5.56% on the X, Y and Z axis reaction wheel respectively.