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Corresponding author: COURTEVILLE Florian
e-mail of corresponding author: flo.courteville@gmail.com
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Title

Cold gas roll control for a 30kg experimental rocket

Authors

Florian COURTEVILLE [1], Enrico Mario GIOVANARDI [2], Elouan PETERAU [3], Thomas BESSON [4]

[1] Student, 4 Avenue Edouard Belin TOULOUSE, France, flo.courteville@gmail.com
[2] Student, Enrico-mario.GIOVANARDI@student.isae-supaero.fr
[3] Student, Elouan.PETEREAU@student.isae-supaero.fr
[4] Student, Thomas.BESSON@student.isae-supaero.fr

Abstract

PERSEUS is a European project led by students and operated by CNES, the French space agency. The aim is to allow students to engage in space related activities and gain valuable experience that will train them prior to beginning their professional activities in the sector. Within the framework of PERSEUS, SUPAERO SPACE SECTION works since September 2021 on the development of a cold gas roll control system for experimental rockets. Those rockets are crafted with the collaboration of other French engineering schools. The first version of the system was launched on the rocket CERES at the 2022 C'Space. A refined version of the system will be launched on the 30kg experimental rocket SERENDIPITY at the 2023 C'Space. This paper describes the development of the roll control system that can be broken down in four parts: pneumatics, control, electronics and mechanical structure.

The pneumatic system feeds separately two pairs of nozzles, one for each rotational direction, to provide the moment needed for the control. The air is stocked under high pressure (about 200 bar) then decompressed to 5 bar before ejection through nozzles. The system includes electric valves able to direct the air flow to one of the pair of nozzles. However, the system is under very restrictive constraints: a launch at C'Space imposes that all elements of the pneumatic circuit are certified to withstand 2 times the pressure at which they will work, and the system's weight must not exceed 5kg. Furthermore, to be able to correctly control the roll, the electric valves need a low response time, and the nozzles must provide a high thrust, which imposes a high flow rate. Regulators and control valves that satisfy those constraints are rare and expensive. The first solution considered consists of using quick exhaust valves controlled with small solenoid valves, as they can handle high flow rates. The second solution considered is the creation of a flow deviator commanded with pressurized air or by a step motor. For the regulator, the solution considered is the creation of a component that lowers the pressure of the flowing air using pressure drops and small light regulators downstream once the pressure is reduced. This solution needs to put a valve upstream near the tank as it needs the air to circulate. Having on/off actuators with a minimum impulse bit imposed by the valve's response time, a convergence to a specific roll angle is not possible. However, limit cycles can be identified around the desired roll angle and they are reached through a PD controller feeding a Schmitt trigger. The tuning of the controller gains is performed through the first harmonic method, linearizing the system around each velocity configuration, thus obtaining adaptive gains. Regarding the electronics, a microcontroller is used to implement the control law. However, solenoid valves need 24V provided by the rocket battery, so the microcontroller uses mosfets to control them. Finally, the integration in the rocket is performed through PLA 3D printed discs, which hold the tank and nozzles in place.