RACS Stability Analysis for VEGA FPSA Program

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Abstract

This paper describes the detailed stability analysis of the RACS (Roll and Attitude Control System) for VEGA launcher vehicle (LV), in the frame of the development of an Alternative Flight Program Software (FPSA). The analysis has been done with an automatic tool that consider a linear RACS model, the results have been validated comparing them with the practical stability margins obtained in 6-dof time domain simulations.

The stability results are only linked to the selected algorithm tuning cause it is independent from the different LV missionization. The independence of the closed loop dynamic behaviour from the LV inertia is guaranteed by a generic characterization of the control gains, valid and applicable for all mission types. In particular, the desired linear dynamic behaviour is obtained by tuning the proportional and derivative gain as function of damping ratio and natural frequency of an equivalent linear second order system.

The control law of the proposed Quaternion Feedback Regulator (QFR) algorithm consists of linear error-quaternion feedback (proportional action), linear body-rate feedback with a feed-forward term (introducing an artificial damping factor, i.e. derivative action), and a nonlinear body-rate feedback term that counteracts the gyroscopic coupling torque. The quaternion error, considered in the control torque computation, represents the rotation that the LV shall perform to obtain the programmed quaternion. Both the control action gains can be related to the full inertia matrix and for this reason, the QFR algorithm presents fully MIMO characteristics.

Each RACS flight phase has a specific tuning and all of that can be analyzed with the linear stability tool. The longer and most critical flight phases have been analyzed in this paper. The linear and practical stability margin and the phase specific Nichols plots are presented.