SPACE TRANSPORTATION SOLUTIONS AND INNOVATIONS SYMPOSIUM (D2)
Future Space Transportation Systems Technologies (5)

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PRECISE MARGINS TO OPERATIONAL LIMITS OF THE RACS TAKING INTO ACCOUNT THE PWM IMPLEMENTATION

Abstract

For the VEGA launcher, the Roll control during the propelled phases and Attitude control during the ballistic phases is performed by a digital Control System known by the acronym “RACS”. Although based on a globally stable control law, experience says that the PWM implementation is such that the RACS is not globally stable. Before this work, the only known way of obtaining precise stability margins of the RACS was to perform iterative simulations. The extraction of a single stability margin for a single flight phase takes approximately 20 min or less, depending on the solicited precision. There is a set of combinations of parameters as inertia moments and tuning gains such that the system is not stable, but as these parameters are varied, other undesired behaviors as persistent relatively high-frequency chaotic oscillations are verified. The presented work is the result of a heuristic time-domain approach carried out ad hoc to device a practical method that simplified the task of finding margins to these operational situations. Elementary behavioral characteristics are used to instantly calculate precise margins, potentially constituting a sensible efficiency increase in the overall missionization activities and/or, more importantly, providing flexibility in the general management of the RACS during the missionization campaign. The RACS is based on the Quaternion Feedback Regulation (QFR) control law (RACS QFR Algorithm for VEGA FPSA program, 2012). QFR consist basically of a feedback proportional action on the error quaternion complemented by a feedback proportional action on the error angular velocity and a compensation for gyroscopic coupling. This has been proven (Wie, et al., 1989) to be globally stable practically for any tuning possibility. However, experience demonstrates that the RACS is not globally stable and that necessarily-introduced hard nonlinearities in the control loop play a fundamental role in the behavior of the system. The key observation that leads to the presented approach is that the saturation applied to the commands entails a saturation effect on the modal behavior of the system. In other words, given that, because of saturation, the command can only take a finite set of values (ON time lengths), also the modes of the system, intended as a series of periodic commands, conform a finite set. The calculation of any margin (e.g. the stability margin) consists simply of the calculation of the margin to the saturation limit that corresponds to the mode that is to be avoided.