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UNEXPECTED CONTROL STRUCTURE INTERACTION ON INTERNATIONAL SPACE STATION

Abstract

On June 23, 2011, the International Space Station (ISS) was performing a routine 180 degree yaw maneuver in support of a Russian vehicle docking when the on board Russian Segment (RS) software unexpectedly declared two attitude thrusters failed and switched thruster configurations in response to unanticipated ISS dynamic motion. Flight data analysis after the maneuver indicated that higher than predicted structural loads had been induced at various locations on the United States (U.S.) segment of the ISS. Further analysis revealed that the attitude control system was firing thrusters in response to both structural flex and rigid body rates, which resonated the structure and caused high loads and fatigue cycles. It was later determined that the thruster themselves were healthy. The Russian segment software logic, which was intended to react to thruster failures, had instead been triggered by interaction between the control system and structural flex. This paper will discuss the technical aspects of the control structure interaction problem that led to the RS control system firing thrusters in response to structural flex, the factors that led to insufficient preflight analysis of the rigid body thruster firings, and the ramifications the event had on the ISS. The immediate consequence included limiting which thrusters could be used for attitude control, which was operationally restrictive. This complicated the planning of on-orbit thruster events and necessitated the use of suboptimal thruster configurations that increased propellant usage and caused thruster lifetime usage concerns. In addition to the technical aspects of the problem, the team dynamics and communication shortcomings that lead to such an event happening in an environment where extensive analysis is performed in support of human space flight on a highly complex vehicle will also be examined. Finally, the technical solution will be presented, which required a multidisciplinary effort between the U.S. and Russian control system engineers and loads and dynamics structural engineers to develop and implement an extensive modification in the RS software logic for ISS attitude control thruster firings.