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SAFEGUARDING FOR CONTINGENCY DEORBIT CAPABILITY AFTER AN ISS DEPRESSURIZATION FAILURE

Abstract

International Space Station (ISS) has addressed the risk of a micro-meteoroid orbital debris (MMOD) penetration that could potentially lead to an irreparable cabin depressurization, requiring emergency crew evacuation and de-orbit. ISS de-orbit operation demands access to several tons of propellant on short notice. However, preliminary assessments showed that rapid depressurization could lead to loss of thermal control within the Functional Cargo Block (FGB), which holds most of the ISS propellant reserves. The ISS Propulsion System, managed by the Russian Segment, makes use of Unsymmetrical Dimethylhydrazine (UDMH) as fuel and Nitrogen Tetroxide (N2O4) as oxidizer. With nearly six tons of propellant storage capacity, FGB serves as a large reservoir of ISS propellants. The thermal control system loops, which use Triol as the coolant, keep the propellants within the operating range. Freezing points of N2O4 at -11 and Triol at -7 drive the response time during this contingency. In order to accommodate an aggressive program schedule, requirement to operate FGB systems in vacuum environment had been removed from the module specifications during the original design phase. This meant that when the cabin is depressurized, some components that are essential to support propellant supply might fail to work. For instance, loss of convection resulting from cabin depressurization could cause failure of convection cooled avionics boxes, resulting in cascading failures within the electrical power system (EPS), command and data handling (CDH), thermal control system (TCS), etc. Failure of EPS could bring all the operations to a standstill. Also, a loss of CDH functionality could prevent the valve commands required to support propellant supply during the deorbit operation. Similarly, if the environmental conditions result in freezing, TCS pumps cannot work until Triol thaws. Nonfunctional TCS loops could lead to N2O4 freezing; subsequent freeze thaw cycles could cause propellant lines to rupture. Although most of the FGB systems were expected to survive depressurized conditions, thermal management of the FGB require additional assessments with detailed analysis and testing to develop safe operational procedures. Due to the time criticality, automatic procedures will be required to quickly transition critical systems to a safe configuration in order to preserve the capability to safely deorbit the ISS. This paper describes the assessments performed to address failure modes and identify the operational constraints to characterize the capabilities of the FGB systems. It also provides an overview of the special procedures developed to ensure fail-safe operations during depressurization and the deorbit phase.