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Risk-Reduction Autonomy Implementation to Enable NASA Artemis Missions

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Abstract

To achieve NASA's Artemis program mission objectives a high level of autonomy and ubiquitous autonomy throughout the systems that are being developed will be necessary. The autonomous systems of Artemis will require a distributed autonomy capability, with autonomous systems organized functionally in a hierarchical architecture, where systems at higher levels of the hierarchy have authority over systems at lower levels. The challenge of developing autonomy technologies and concepts of operations for Artemis has been undertaken by the NASA Gateway Working Group. This group has developed requirements, architectures, concepts of operations, and interface control documents, in the context of a hierarchical distributed architecture that includes the following: a Vehicle System Manager (VSM) that autonomously manages the entire Gateway; Module System Managers (MSMs) that autonomously manage each module; and System Managers (SMs) that autonomously manage systems within a module (i.e. ECLSS). A substantially high level of autonomy needs to be achieved by each element of the hierarchy (VSM, MSM, SM) to meet requirements for uncrewed operations; this includes conditions that will have minimal and/or delayed ground intervention (i.e. requirements for sustainability for months of operation without crew or ground support). To advance an implementation of this autonomy design (Gateway Autonomy Design – GAD), a collaboration was established between the Autonomous Systems Laboratory (ASL) at NASA Stennis Space Center and Lockheed Martin. The objectives of this partnership were the following: (1) to implement autonomy at the VSM, MSM, and SM levels; (2) to implement communications among a VSM, 2 MSMs, ORION (a visiting vehicle somewhat equivalent to a module) and 1 SM (a power system), and (3) test autonomous operations with representative use cases. A SM backed by a high-fidelity simulation was created to facilitate demonstrations of use cases that originated in a system of a module. Communication between the VSM and MSMs was implemented according to Concepts of Operations and Interface Control Documents (ICDs). Demonstrations were conducted to address nominal and off-nominal operations and multi-module interactions with VSM. Additionally, user interfaces were created to provide awareness about ongoing processes and results while enhancing the demonstration. Demonstrations included the following use cases: (1) Orion as visiting vehicle registers with VSM; (2) VSM reschedules a module's timelines when another module's MSM task fails; and (3) a module's Power System Manager (PSM) standalone demonstration that included component failure diagnostics, tracing component failure to effected components, which in turn, reports failure information up to the VSM for acknowledgement and display. This paper will describe the detailed technology and autonomous systems developed, and the integrated multi-module demonstrations conducted. Also, challenges that must be met to fully implement the GAD defined by Gateway will be addressed.