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HAL-5: HIGH AUTONOMY LEVEL -5 SMART DATA MANAGEMENT ABOARD THE ISS

Abstract

The International Space Station (ISS) faces significant challenges in managing its limited communication bandwidth, which supports a diverse array of data streams, including crew health monitoring, scientific experiments, system situational awareness, and allied diagnostics. While existing systems such as NASA's Tracking and Data Relay Satellite (TDRS) System, data compression techniques, and mission data management protocols help with data transmission, they primarily focus on predefined, manual configurations and lack real-time, adaptive bandwidth allocation management. There is currently no integrated system aboard the ISS that autonomously prioritizes data, dynamically adjusts transmission based on real-time network conditions, or uses AI-driven algorithms to optimize uplink and downlink efficiency. To address these gaps, the development of a system called 'High Autonomy Level - 5' or 'HAL-5' is proposed. The HAL-5 concept architecture would use AI through a Smart Data Management System (SDMS) to classify data into priority categories, dynamically allocate bandwidth, and apply advanced compression techniques for more efficient communication. It would also incorporate edge processing and onboard storage capabilities, allowing the ISS to temporarily store non-critical data during periods of degraded communication and only transmit essential or pre-processed information. By incorporating a telemetry feedback loop, the system could continuously adjust to changing conditions, ensuring that mission-critical data, such as crew health or system diagnostics, always takes precedence. This relegation of ISS maintenance tasks through incorporating the SDMS is aimed at improving and enhancing ISS crew productivity. Ground-based mission control is looped into the HAL-5 during the early phases of deployment of this AI-enhanced architecture to ensure optimum system performance that evolves to accommodate a growing set of automated tasks. The current systems lack several key features that the HAL-5 would address: (1) automatic data classification and prioritization using AI, (2) real-time, dynamic bandwidth management based on system health and mission needs, (3) adaptive compression and pre-processing for scientific data, and (4) edge computing for local data storage and processing. Developing this comprehensive, intelligent system would not only improve data efficiency aboard the ISS but also provide a framework for future missions to the Moon, Mars, and beyond, where communication bandwidth will be even more constrained and the need for autonomy is needed due to factors including power and time delay parameters.