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Human-Systems Integration Needs Analysis for On-board Anomaly Resolution During Earth Independent Operations

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Future deep space exploration missions will require small crews to act with greater autonomy than in present or past missions. Limited communications (e.g., bandwidth, latency, etc.), lean sparing and re-supply, and delayed evacuation opportunities all reduce the level and speed of ground support. In times of safety critical operations—especially when anomalies or off-nominal conditions occur—the crew will have to independently and adequately respond to avert potentially severe outcomes. It will not always be sufficient or even possible to 'safe the system' and then wait upon ground intervention.

A Human-Systems Integration Architecture (HSIA) is a construct to describe the communication, coordination, and cooperation between humans and cyber-physical systems that must occur in order to accomplish an operation or mission, including managing critical events. The current HSIA for the ISS is ground-based and manpower-intensive, relying on many engineers and operators with broad and deep expertise; large, distributed datasets; and expansive analytical and computing power. While successful for near earth exploration, this model is not viable for long-term missions to the moon and beyond. The challenge then is how to engineer the future HSIA to marshal the required expertise, data, and computation for the small flight crew to enable them to perform the job that has traditionally been done by a much larger and well-equipped ground crew. This will require a fundamental rethinking of crew-vehicle integration, on-board problem-solving and decision-making, and crew-ground asynchronous collaboration.

The first step toward defining the next architecture is a needs analysis. Our research task is focused specifically on anomaly response—identifying requirements to enable on-board problem detection, diagnosis, resolution, and contingency management. To inform this work, we conducted systematic analyses of ISS system malfunctions and off-nominal operations as well as malfunctions that occurred during the Apollo Missions. We also observed (remotely) the investigations and deliberations of the ISS Mission Evaluation Room and Anomaly Resolution Teams in real-time; interviewed astronauts, flight controllers and instructors; reviewed flight and operation logs; and examined troubleshooting approaches taken in analogous domains.

This will provide a deeper understanding of how urgent diagnosis and resolution are currently done and what products are used to aid the process. The outcome of this task is a set of information and knowledge requirements critical to resolving potentially safety-critical anomalies and a breakdown of how the HFBP disciplines (HCI, TRAIN, HARI, and MPTASK) contribute to the provision of them in the design of onboard systems. Ultimately this information will enable prioritization of the data and expertise needed on-board to support the crew in performing anomaly investigation and sense-making in isolation.

The current presentation will review the IFI database to show 67 high priority IFIs from 2002 to 2019. 35 of the 67 are associated with malfunctions in vehicle subsystems, including active thermal control (ATCS), electrical power (EPS), environmental control and life support (ECLSS), guidance, navigation and control (GNC), and structures (S&M) subsystems. A systematic characterization and discussion of the types of anomalies that occur will also be included in this presentation.