Anomaly Monitoring Inductive Software System

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Johnson Space Center is collaborating with the NASA Ames Research Center (ARC) to develop, adapt, and deploy the Anomaly Monitoring Inductive Software System (AMISS) in support of International Space Station (ISS) flight operations. AMISS, which is based on the Inductive Monitoring System (IMS) software developed at ARC, complements current mission control practices by augmenting the health-monitoring capabilities in the Flight Control Room for real-time ISS systems. AMISS also allows for off-line analysis of archived data to detect unusual events in previous system behavior (figure 1).

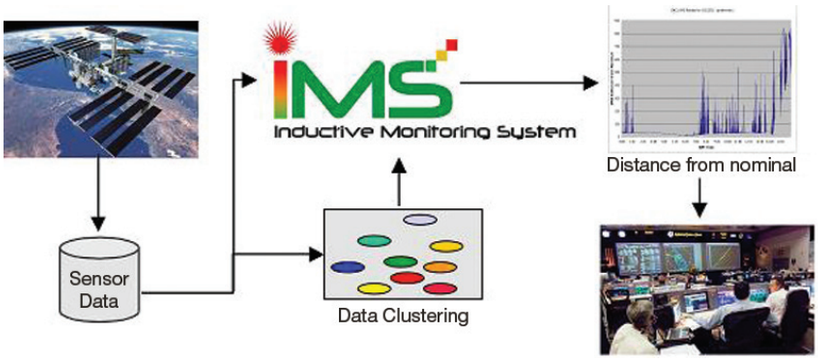

Fig. 1. *During off-line training, AMISS/IMS analyzes archived system data to model how a system normally behaves. In real time, AMISS/IMS alerts the operator if the monitored system behaves differently than expected.*

The AMISS software uses techniques derived from model-based reasoning, machine learning, and data mining to build system monitoring knowledge bases from archived sensor telemetry data. Unlike many other machine learning techniques, AMISS does not require examples of anomalous or failure behavior, which are often scarce or unavailable. It automatically analyzes archived nominal system data to form general classes of expected system sensor values, relationships, and interactions. This process enables the software to inductively learn and model nominal system behavior. The generated data classes are then used to build a monitoring knowledge base, or nominal system model, that is deployed on the flight control console. AMISS employs this knowledge base to perform real-time telemetry monitoring on the console. It compares concurrent vectors of incoming telemetry values to the model, determines the degree of deviation from historic nominal performance, and publishes the result for display or analysis by other software tools. Significant deviations or trends in AMISS monitoring results indicate out-of-family system behavior, which may be caused by system degradation or an incipient failure.

AMISS has been certified and deployed to monitor the control moment gyroscopes (CMGs) used to provide non-propulsive attitude control for the ISS. In off-line analysis of a previous CMG failure, AMISS detected early symptoms more than 15 hours before the CMG required deactivation due to excessive vibration (figure 2). We have also developed AMISS monitoring systems for the ISS thermal control, rotation rate laser gyro, and carbon dioxide removal systems. The thermal and rate gyroscope monitors are scheduled for certified mission control deployment in mid-2009.

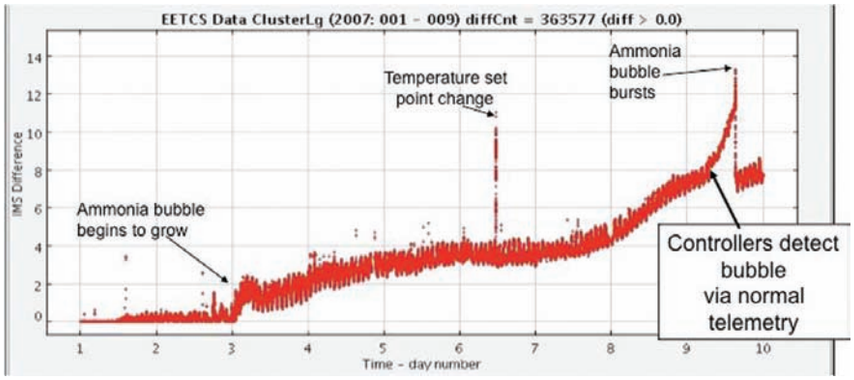

Fig. 2. *AMISS analysis indicated the formation of a gaseous bubble in the ISS Early External Thermal Control System liquid ammonia cooling loop nearly 6 days before mission controllers detected it via standard telemetry data.*

AMISS also supports the future ISS operations concept. Since new operators will not have the experience and insight that comes with many years of data observation, this tool will help them understand whether observed data trends are expected and nominal. If an unexpected data signature occurs, a concurrent, large AMISS degree of deviation will provide supporting evidence to the operator or specialist that something anomalous may be occurring and further investigation is warranted. For system specialists and engineering analysts, this tool provides an efficient method of reviewing a past day/week/month of system data vs. manually inspecting and comparing individual parameters.

The techniques used by AMISS are applicable to many instrumented systems with consistent behavior patterns. In addition to ISS system monitoring, AMISS techniques have been applied to space shuttle propulsion and impact detection systems, aircraft engine and flight control systems, and commercial electrical power systems. We have identified several additional ISS subsystems as candidates for AMISS monitoring, and ongoing AMISS research and development activity will provide additional system health monitoring and analysis capability.

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