Increasing the Automation and Autonomy for Spacecraft Operations with Criteria Action Table

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Focus Issues: Automation and Integrated Services and Emerging ground system technologies

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The Criteria Action Table (CAT) is an automation tool developed for monitoring real time system messages for specific events and processes in order to take user defined actions based on a set of user-defined rules. CAT was developed by Lockheed Martin Space Operations as a part of a larger NASA effort at the Goddard Space Flight Center (GSFC) to create a component-based, middleware-based, and standard-based general purpose ground system architecture referred as GMSEC – the GSFC Mission Services Evolution Center. CAT has been integrated into the upgraded ground systems for Tropical Rainfall Measuring Mission (TRMM) and Small Explorer (SMEX) satellites and it plays the central role in their automation effort to reduce the cost and increase the reliability for spacecraft operations.

The GMSEC architecture provides a standard communication interface and protocol for components to publish/subscribe messages to an information bus. It also provides a standard message definition so components can send and receive messages to the bus interface rather than each other, thus reducing the component-to-component coupling, interface, protocols, and link (socket) management. With the GMSEC architecture, components can publish standard event messages to the bus for all nominal, significant, and surprising events in regard to satellite, celestial, ground system, or any other activity. In addition to sending standard event messages, each GMSEC compliant component is required to accept and process GMSEC directive request messages.

With a rich supply of information in a standard event message format, CAT subscribes to all published event messages on the information bus in order to analyze them for possible action according to pre-defined rules. The functional steps CAT performs are essentially a decision making process. It first collects the data and information from the system and environments, and culls the desired information from the event messages. CAT then correlates the disparate pieces of information and provides a contextual analysis of the events. Finally it carries out a course of action according to a set of pre-defined rules. Thus, CAT can monitor the health and safety of space and ground assets as well as the status of ongoing operations. Components are charged with reporting status and information within their specialized area of functionality. CAT is charged with analyzing and correlating this information to determine what action, if any, is required. Upon the satisfaction or triggering of a pre-defined rule, CAT can initiate an automated action, in real-time, by sending a standard directive message and/or event message to a specific component for further action. The action may take the form of prevention, correction, or a call for assistance. Removing the analysis from the specialized components and allowing them to simply report on activities allows more sophisticated and comprehensive analysis to be performed. CAT can provide more context in its analysis since it can take into account all reported activities.

The task of analysis and monitoring for activities and anomalies are performed by intelligent agents managed by CAT. The agents are created dynamically, and CAT provides the mechanism for agents to communicate and collaborate with each other. Agents are created by the pool manager based on user-defined triggers, and stay alive until a user defined termination. Each agent is given a task of monitoring a particular activity or processes, such as pass, limit violation, and heart beat monitoring. While

agents associated with monitoring anomalies (such as limit violations) are activated only when anomalies occur, users may also configure permanent agents that stay alive indefinitely for monitoring regular events (such as passes, and heart-beats), or for keeping track of state variables.

CAT is a generic, flexible, and highly configurable tool. The implementation separates the mission specific features from the generic. The mission specific features and attributes are defined in an xml schema as the CAT configuration. The CAT configuration allows users to specify how the attribute values should be extracted from messages and how the event messages should be monitored and filtered. The rules in CAT consist of the logical elements, and each logical element represents the relationship between the critical values in the configuration and the attribute values obtained from the event and resource monitoring subsystem. A single rule could involve many attributes, which corresponds to more complex operational scenarios. Each rule is associated with specific actions, and the actions in the CAT configuration are defined as standard GMSEC messages that are sent to a specific component as a directive, or broadcasted as general event log messages. With a user friendly GUI, CAT provides an expandable, extensive, and flexible configuration. Thus, new automation ideas can be easily accommodated without requiring additional software development

CAT has been deployed as the central component for the TRMM automation effort. The objective of the TRMM Re-engineering effort is to reduce the operation costs by 50 percent by the end of 2004. This is achieved by increasing the automation and autonomy of the spacecraft operations to allow lights-out operations for the night shifts. The routine pass activities are automated with the scenario schedulers using the GMSEC directive request messages. The event triggered activities for the ground system are automated by CAT, which is used to monitor the spacecraft limit violations and the heartbeat (or keep alive) messages from each component in the ground system. The actions taken by CAT include sending the directive message to Alert Notification System Router (ANSR) that sends the paging to the FOT personnel in the case of the system anomalies. CAT also initiates a failover operation in case of a component failure by sending the directive messages to the backup equipment. The experience in integrating CAT into the ground system for TRMM and SMEX has shown that CAT is a very flexible, easy to use and general automation tool that covers wide ranges of operational scenarios. The flight operation team with the support of CAT has entered the CAT rules for TRMM automation.

Further enhancements of CAT are planned to ensure the easier integration to a ground system, and to add new capabilities for more intelligent information gathering, decision making, and action planning. The application of GMSEC architecture and the automation of the spacecraft operations with CAT are also planned for other missions within GFSC in the near future.

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To whom it may concern:

Enclosed is the abstract for plenary presentation at GSAW workshop.

Sincerely

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