IGARSS Topic: Innovative Options for Developing Earth Science Capabilities

Abstract Title: Autonomous Satellite Operations via Secure Virtual Mission Operations Center

Authors: Eric Miller, General Dynamics Advanced Information Systems, Vandenberg AFB
Phillip E. Paulsen, NASA Glenn Research Center, Cleveland, OH
Michael P. Pasciuto, NASA Goddard Space Flight Center, Greenbelt, MD

Problem: NASA is interested in improving their ability to respond to rapidly evolving, transient phenomena via autonomous rapid reconfiguration, which derives from the ability to assemble separate but collaborating sensors and data forecasting systems to meet a broad range of research and application needs. Current satellite systems require human intervention to respond to triggers from dissimilar sensor systems. Additionally, satellite ground services often need to be coordinated days or weeks in advance. Finally, the boundaries between the various sensor systems that make up such a SensorWeb are defined by such things as link delay & connectivity, data & error rate asymmetry, data reliability, quality of service provisions, and trust, complicating autonomous operations.

Methodology Used: Over the past ten years, researchers from NASA's Glenn Research Center, General Dynamics, Surrey Satellite Technology Limited (SSTL), Cisco, Universal Space Networks (USN), the US Geological Survey (USGS), the Naval Research Laboratory, the Office of Operationally Responsive Space, and others have worked collaboratively to develop a "virtual" mission operations capability. Called "VMOC", this new capability allows cross-system queuing of dissimilar mission unique systems through the use of a common security scheme and published application programming interfaces (APIs). Existing world-wide, ground-based earthquake sensor systems, fed to a threshold monitoring system, were used to trigger VMOC to begin the process of selecting appropriate satellite sensor systems (based on sensor type and orbital mechanics). Once the sensors were selected, VMOC autonomously negotiated machine-to-machine with their ground operations systems to determine sensor availability and resource limitations (satellite power, etc…). With satellite system negotiations successfully completed, VMOC then began the process of determining which commercial ground stations would be appropriate for up linking commands, and, later, down linking resulting data. Once selections were completed, VMOC then autonomously negotiated machine-to-machine with ground service provider systems to obtain the services necessary, and to configure their antennas and equipment to track and communicate with the sensor systems. Finally, to minimize the impact of link delays and disruptions (common with satellite systems in low Earth orbit), new, "delay tolerant network" (DTN) protocols were utilized. These protocols autonomously compensated for rate mismatches between the high rate space-to-ground links and the lower rate ground connections as well as intermittent losses between system nodes.

Central Conclusions: the VMOC represents a completely new approach to integrated mission operations. By utilizing open standards and published APIs, VMOC allows mission unique systems to readily adapt and perform cross-platform queuing. VMOC also allows the use of a single network security solution and includes tools for things like the calculation and visualization of satellite orbital mechanics. Mission rules, codified within VMOC, prevent inadvertent or inappropriate operations (such as slewing a sensor across the sun) and provide prioritization at the user and command levels. VMOC can also provide standard telemetry displays (virtual strip charts, gas gauges, etc…) and annunciation. For purposes of this experiment, Earthquake sensors provided by the USGS (and located in Indonesia) were used to trigger VMOC negotiations with flight systems provided by SSTL (the UK-DMC satellite) and ground systems provided by USN (in Alaska, Hawaii, and Australia). DTN protocols, codified by NASA GRC and SSTL, were integrated into all systems. Using triggers from the Earthquake sensors in Indonesia (intentionally set at modest threshold values), satellite sensor collects and ground system operations were autonomously negotiated and implemented. All of the systems worked as predicted. In addition, the DTN protocols allowed both proactive and reactive fragmentation of large data files as well as reliable, sequential data drops over multiple ground stations.

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