SMALL SATELLITE MULTI MISSION C2 FOR MAXIMUM EFFECT

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ABSTRACT

This paper discusses US Air Force, US Army, US Navy, and NASA demonstrations based around the Virtual Mission Operations Center (VMOC) and its application in fielding a Multi Mission Satellite Operations Center (MMSOC) designed to integrate small satellites into the inherently tiered system environment of operations. The intent is to begin standardizing the spacecraft to ground interfaces needed to reduce costs, maximize space effects to the user, and allow the generation of Tactics, Techniques and Procedures (TTPs) that lead to Responsive Space employment. Combining the US Air Force/Army focus of theater command and control of payloads with the US Navy's robust user collaboration lays the groundwork for the fundamental change needed to maximize responsive space effects.

1. BACKGROUND

A great many advances have been made in small satellite technology in the past 10 years, but two associated elements continue to trouble the market: a ride to orbit and ground infrastructure to take advantage of the sensor platform. A great deal of effort has gone into the space lift side with the emergence of new launch vehicles, with common spacecraft interfaces, to reduce the cost of getting to orbit. Flight interfaces have been developed out of necessity to limit the number of variables and allow both sides to build to a common interface. The same has not been true for the ground operations infrastructure. With notably few exceptions, space platform architectures are paired with mission specific ground infrastructures designed to optimize the interface. These stovepipes ensure an efficient tie within a system, but don't allow for ready use outside of the stovepipe. In essence current ground infrastructures are not readily adaptable to a new mix of space based sensor platforms, and the small sat providers find themselves looking for a customer who is willing to invest in a ground station as well as the sensor platform.

Improvements are needed at both ends of the ground infrastructure: the spacecraft ground station operator and the deployed operational or tactical user. Current use of network interfaces for the Joint Space Tasking Order (JSTO) process is limited to email and text messaging to relay requirements to and from the field. Often the status of an on orbit asset is inferred by manually reviewing mission logs to identify why a specific task was not accomplished. Currently, the Joint Space Operations Center (JSpOC) manually derives detailed status of mission assets, such as constellation health, current tasking levels, ground station availability, and impacts due to future operations. These details are obtained from a variety of systems, in several formats, with no common way to access the required information.

Space Operations need robust tools that can track current conditions, receive real-time requests from the field, predict future mission capabilities, correct for limitations, and automate information flow that does not rely on hand entry or delving into mission logs for status. Often Joint Space Tasking Orders are generated without knowing the true status of the assets and whether or not the operations will deliver the required effects to the theater. In addition, the Joint Warfighting Space (JWS), Near Space, and Tactical Satellite (TacSat) programs are attempting to fly new sensor technologies that advance Operationally Responsive Space (ORS).

2. GLOBAL APPORTIONMENT

As the sensors and platforms are coming out of the research and development environment, the missions tend to have a multitude of agencies involved. When the sensor platform is delivered and placed into operation, the mission lacks a single operations manager needed to obtain the maximum benefit and to ensure that the new technology is being evaluated within the operational environment it is expected to support in the future.

On 19 July 2006, USSTRATCOM created a Joint Functional Component Command for Space (JFCCSPACE) at Vandenberg AFB in California. The Commander JFCCSPACE (CDRJFCCSPACE) is the primary USSTRATCOM interface for joint space effects to the supported commander. The CDRJFCCSPACE exercises operational control (OPCON) or tactical control (TACON) of designated space forces through the Joint Space Operations Center (JSpOC). This 24/7 node executes CDRJFCCSPACE missions for joint space command and control. CDRJFCCSPACE is the Global Space Coordinating Authority (GSCA); the single authority in USSTRATCOM to coordinate global space operations and integrate space capabilities CDRUSSTRATCOM does not control. The processes within the JSpOC are based on those used within an Air Operations Center (AOC).

The tasking of all US space assets OPCON or TACON to CDRJFCCSPACE begins with the JSpOC Strategy Division collecting the intent and needs of CDRUSSTRATCOM, CDRJFCCSPACE, all Theatre Space Coordinating Authorities (TSCA) and all Supported Commanders. These requirements are prioritized and a Space Operations Directive (SOD) is produced listing the effects required during a 24-hour period. These prioritized effects are then balanced against available resources in a Joint Master Space Plan that forms the basis for a Joint Space Tasking Order (JSTO). The JSTO is passed to subordinate units who then have 12 hours to plan how to deliver the effects required and 24 hours to deliver those effects.

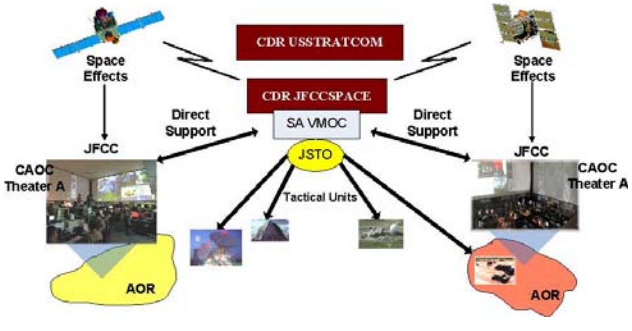

Figure 1: Balanced Space Effects

This process has a number of difficulties as it stands. Firstly, it can not easily be shortened to be more responsive to warfighters' needs. In the Air, Land and Maritime worlds, recent operations have driven home the recognition that some targets are Time Sensitive and require effects on target within the normal tasking cycles. Similarly, some space effects are needed within shorter time-scales than the normal process allows; currently these effects are directed by issuing changes to the JSTO. Secondly, the single JFCCSPACE can not synchronize its Battle Rhythm with each and every TSCA and Supported Commander. TSCA battle rhythms tend to be based on the local time in that theatre. If the JFCCSPACE battle rhythm happens to coincide with that of a particular TSCA, it will certainly not coincide with other TSCA's rhythms. Finally, existing processes can not direct effects in the timescale that Operationally Responsive Space sensor platforms such as TacSat and Joint Warfighting Space will require. A Theater Space Coordinating Authority that has been apportioned an ORS asset launched to support that specific theatre will demand effects in real time – not tomorrow.

It is clear, therefore, that it is necessary to develop a means to rapidly collate required effects worldwide, prioritize these effects and then deliver them. The JSpOC is the appropriate organization for managing the global apportionment of space assets for theater effect, but will require a new set of tools. By integrating key Network Centric elements of the Virtual Mission Operations Center, the JSpOC can begin to model and effectively apportion global platforms and sensors for maximum theater effect. With this in mind, the AF Space Battlelab and General Dynamics proposed the Space Apportionment For Effect (SAFE) demonstration that provides the JSpOC the relevant environment needed to frame the Network Centric, automated, end-to-end requirements flow needed to bound the JSTO Tactics, Techniques, and Procedures (TTPS) required to maximize theater space effects

3. SAFE DEMONSTRATION

The AF Space Battlelab's 2006 SAFE initiative will demonstrate Space Apportionment and Mission VMOCs in a "Systems of Systems" environment. SAFE will be accessed by the JSpOC, Combined Air Operations Center (CAOC), Satellite Operations Center (SOC), and field deployed users to begin developing the Concept of Operations (ConOp) that will support ORS deployment. The demonstration provides the CAOC direct access to sensor platforms and data that have been apportioned to them by the JSpOC. The VMOC tools will enable the JSpOC to model heritage and TacSat assets, fly the mission virtually in future time to refine the operations and iterate to obtain the optimum theater effect, generate an automated Joint Space Tasking Order, and issue the JSTO to the SOC for implementation—all through a standard secure web environment. As shown in

Figure 2.

In-theater operations support requests will be made via VMOC web pages in the test Combined Air Operations Centers representing multiple theaters. Langley's CAOCX will serve as the test CAOC for the demonstration. Within each theater, the Director of Space Forces will have access to the JSpOC and Mission VMOCs, and through them, will be able to allocate apportioned space effects to the warfighters within the theater.

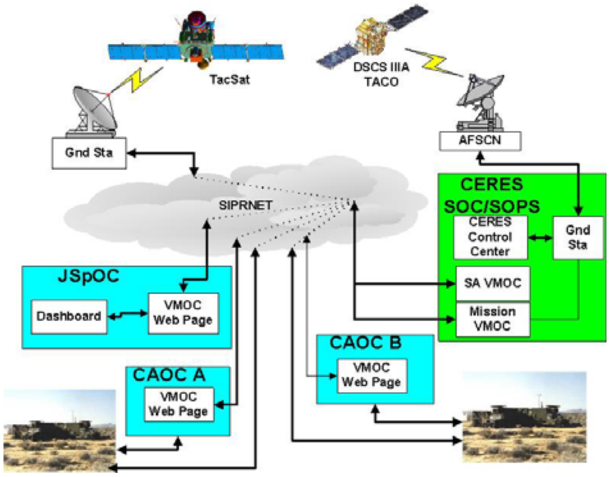

Figure 2: Space Apportionment For Effect (SAFE)

As an example, the JSpOC receives a request from Theater A for space-based imagery in support of an Army-deployed unit and a simultaneous request from the Theater B CAOC for space-based imagery and communications support for another deployed unit. The JSpOC will attempt to support operations in both theaters supporting conflicting requirements for limited resources. Once the JSTO is issued, the mission VMOC will be updated automatically to provide the theater warfighter direct access to the apportioned sensor platform and required data as directed by JSpOC policy. The JSpOC will use the SA VMOC tools to optimize the effects to both theaters. Upon review and approval by the JSpOC, the system will automatically generate and release the JSTO to the Mission VMOC and SMC Det 12/CERES as the Space Operations Squadron assigned to 14 AF. Real-time telemetry will be monitored by the VMOC and status will be displayed on the dashboard for the JSpOC and CAOC. Additionally, when the Joint Space Operations Center issues the JSTO, the user permissions are automatically updated in the mission VMOC to allow the CAOC to manage the direct support given to the Army deployed unit. The JSpOC provides management of the space assets for the mission by prioritizing the allocation of resources between the two theaters. Theater-level management is performed by the CAOC Director of Space Forces (DIRSPACEFOR) through appropriate VMOC user privileges. The DIRSPACEFOR apportions the access, allotted by the 14AF, as required to meet in-theater objectives.

The SAFE demonstration is designed to follow the standard C2 procedures in place today. The fundamental difference is that it is automated, reacting to changing environments, with situational awareness given via the dashboard that provides elements of a Single Integrated Space Picture. All members of the management chain will have insight into the resource allocation and apportionment, the health and status of the constellation, and the level of support being provided to the warfighters in the theater. Over the course of the demonstration, multiple scenarios will be tested, including sensor platform subsystem outages, ground station failures, and real-time reapportionment of assets.

While the SAFE demonstration focuses on the automated JSTO and interaction with the theater users, it does not address the need for a field deployed ground station that provides the theater direct down link needed to maximize space based effects. This aspect is covered by the Army Multi Use Ground Station (MUGS) demonstration.

4. MUGS DEMONSTRATION

The Army Space and Missile Defense Battle Lab's (ASMDBL) Multi Use Ground Station Spiral 2 provides the framework to demonstrate Network Centric Telemetry, Tracking, and Command (TT&C) and develop TTPs for command and control of tactical space assets. The MUGS experiment demonstrates the ability for anyone with secure Internet /Intranet access, and authority, to directly task a Low Earth Orbit (LEO) or near space sensor platform and payload from the theater, retrieve the data, and post the data on a net-centric server for retrieval by the requester. Net-centric tasking and apportionment by a theater commander's collection manager will be critical for theater operation of tactical satellites and near space assets of the future.

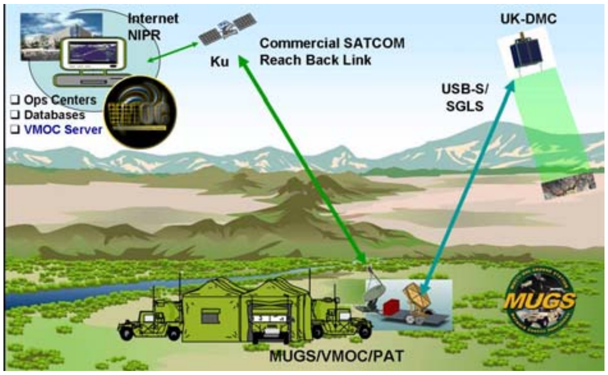

Figure 3: Multi Use Ground Station Overview

To best simulate the relevant tactical environment (Figure 3), MUGS combined the General Dynamics' Mission VMOC and the AF Space and Missile Systems Center (SMC) S-band Phased Array for Telemetry Tracking and Commanding (PAT) to provide theater direct up and down link with the Surrey Space Technologies Ltd (SSTL) United Kingdom- Disaster Monitoring Constellation (UK-DMC) satellite.

For the demonstration, the Mission VMOC is located at NASA Glenn Research Center (NASA GRC) in Cleveland, Ohio and is connected to the Army demonstration location in Colorado Springs, Colorado via the open Internet. In addition, the VMOC is connected to the SSTL ground station in Surrey, UK. The demo concept of operations takes advantage of having two ground stations to maximize connectivity with the space asset. When a field user requests an image, the VMOC determines the optimal configuration to return the image by the most effective path.

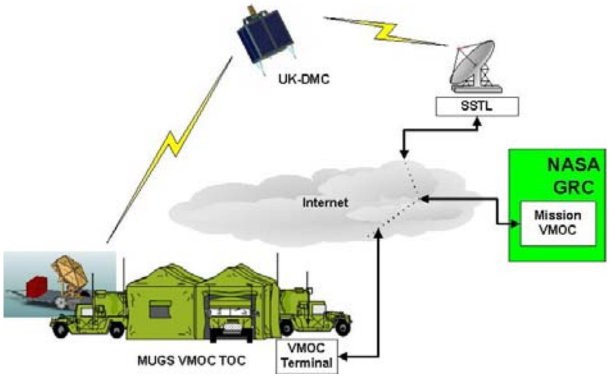

Figure 4: Net-Centric Connectivity

The prioritized SMDBL MUGS demonstration scenarios include:

1. Task the UK-DMC from MUGS and receive the image from MUGS
2. Task the UK-DMC from MUGS and receive the image from the SSTL ground station
3. Task the UK-DMC from the SSTL ground station and receive the image via MUGS
4. Task the UK-DMC from the SSTL ground station and receive the image from the same ground station

A point of concern with a demonstration that utilizes an operational resource, is scheduling. To ensure the demonstration does not disrupt the UK-DMC operations, a single scheduler will be used. In this case the VMOC will tie to the SSTL Mission Planning System for all user requests. Regardless of the path the request is filled by, all the imagery will be stored on both the VMOC and the SSTL databases.

The MUGS demonstration lays the foundation for a net-centric field deployed ground station required to support Operationally Responsive Space.

5. GENERAL DYNAMICS' VMOC

General Dynamics' Virtual Mission Operations Center is a web-based architecture designed for a Network Centric environment that:

- Adjudicates Networked Exchanges
- Centralizes Control Authority Policy
- Decentralizes Execution
- Uses thin and thick client web interfaces

The VMOC provides a framework to define, test, demonstrate, and field new technologies within the relevant environment capable of supporting secure distributed mission operations of heritage and IP-based platforms and sensors. The VMOC's Rules Based Authentication, Modeling, Multi Mission Planning, Scheduling, and Telemetry Tracking and Command gives command authorities, analysts, operators, and users unparalleled tools for controlling complex platforms to maximize mission effectiveness.

The SAFE and MUGS demonstrations are follow-ons to the successful 2004 VMOC demonstration that was a joint effort among the AF Space Battlelab, Army SMBDL, NASA GRC, Naval Research Lab (NRL), and General

Dynamics that validated the capability to use secure Internet protocols to perform telemetry, tracking and command as well as payload tasking of on-orbit assets.

VMOC development to date has focused on Asset Apportionment and Mission Operations. As shown in Figure 5, the Apportionment VMOC ensures the right person has access to the right asset as priorities and mission needs change by rapidly changing the mission rules sets that dictate access to the Mission VMOC. The Mission VMOC is the user's direct interface with the sensor platform. If a platform sensor has be apportioned to a set of users, all priority and scheduling is handled within the Mission VMOC to ensure access follows control authority policy. If a user requests an effect that is out of scope to the current apportionment, the control authority is notified of the new requirement. If the request is validated, a new mission rule set is sent to the Mission VMOC. Interaction between users and the VMOCs is by simple web browser. No mission specific software is required to reside on the user's computer.

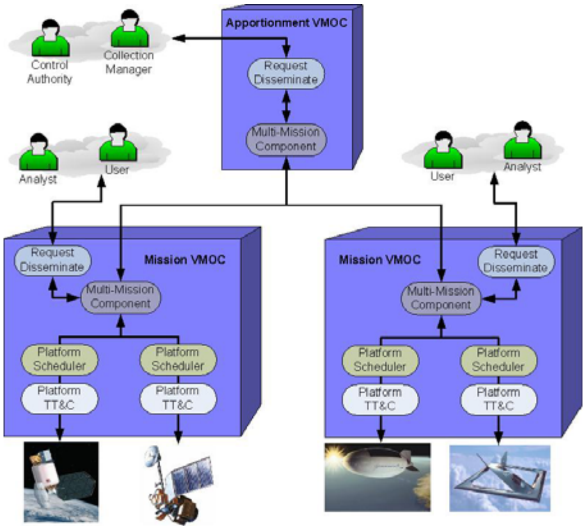

Figure 5: Global Apportionment, Theater Execution

Integration of key technologies and architectures like VMOC, are creating a decisive Warfighting advantage for tomorrow's battlefield!

6. US NAVAL RESEARCH LAB VMOCspydr

The NRL VMOC Spydr[1] is a net-centric test bed that explores advances in multi-tiered systems through continuous operational experimentation. Developed consistent with FORCEnet principles, it aims to pair and co-evolve the latest web technologies with the latest concepts of operations. The impetus for the VMOC Spydr began with the need to task and retrieve sensor data from TacSat-1. TacSat-1 is a low earth orbit (LEO) micro-satellite developed by the Naval Research Laboratory in response to a need for quick and inexpensive satellites that can serve as sensor gap fillers for operational military commands. VMOC *Spyd*r has matured and is now able to receive data from various sensors, making it a versatile and flexible net-centric information management system. Unlike massive databases, the VMOC *Spydr* does not host nor maintain large volumes of sensor data. Instead, sensor nodes (e.g. TacSat-1) collect and store data to local data servers called sensor concentrators (SC). The sensor concentrators perform such tasks as sensor scheduling, data processing, and data feed generation. The data feed generated by the SC is sent to the VMOC *Spydr* using existing XML standards ("Atom" feeds) via open web services. This data feed describes the data contents and its corresponding meta-data. The VMOC *Spydr* catalogues the various feeds it receives and alerts subscribers of new data. This scalable approach allows a broad user base to access, collaborate, and disseminate data collected from multiple sensors seamlessly. The overall intent is to create an environment that enables user collaboration in order to increase individual and shared situational awareness across organizational lines.

Figure 6 depicts the architecture.

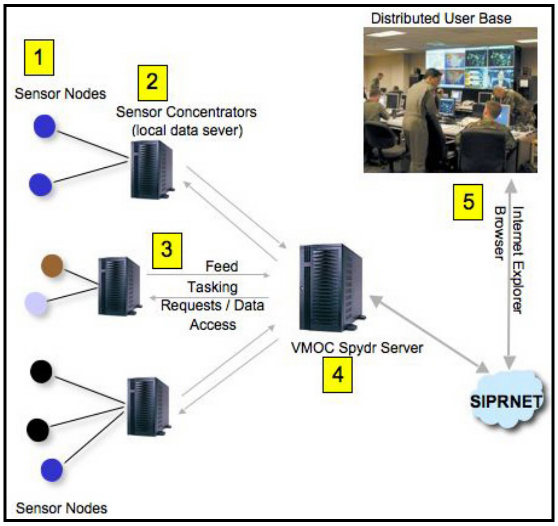

Figure 6: VMOC Spydr Multi-tiered System Architecture

The desired effect of this broad based collaboration via this architecture is to increase shared situational awareness (SA) amongst disparate and geographically dispersed groups.

Figure 7 depicts the process from data collection to action required to achieve this effect. The backbone of the architecture is based on Dr. Micah Endsley's work on situational awareness. The first level is awareness of the environment or battlespace. This is achieved through various tool sets that collect, process, validate, disseminate, alert, and grant users access to data. A good example is the General Dynamics' VMOC serving as the sensor concentrator for the VMOC Spydr. To the users, these systems create an individual mental model of the environment or battlespace. Without the proper tools in place to share individual mental models, errors in communication may lead to incorrect action. The second level of situational awareness, as depicted in Figure 7, aims to share mental models in order to create a common comprehension between players. Within the VMOC Spydr design there is a heavy emphasis on collaborative tools such as chat, forums and image annotation that help achieve this level of SA. The third level is projection and decision. After the environment is surveyed and evaluated, and a shared comprehension exists, members of a group can project cause and effect relationships with various courses of action. The last step is action based on decisions. In concept, the VMOC *Spydr* web site, not including the various sensor concentrators, is situated between data dissemination and broad scale comprehension.

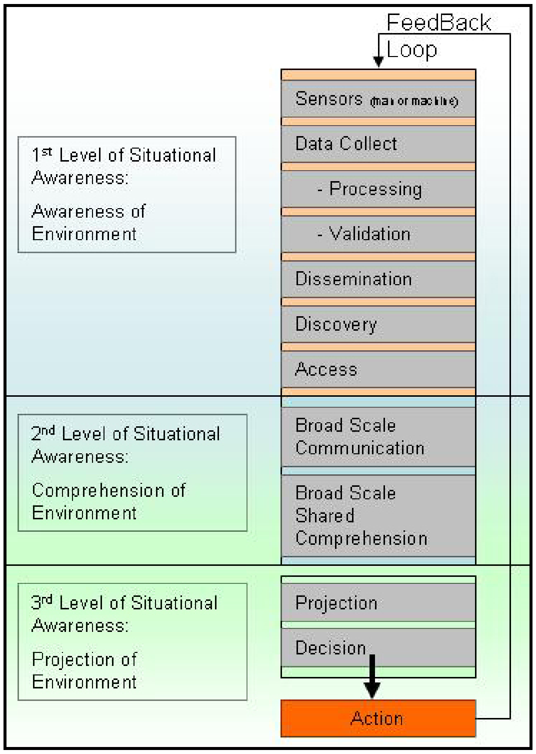

Figure 7 Processes for Achieving Action

VMOC *Spydr* is being developed by the NRL with support from the Office of the Secretary of Defense's, Office of Force Transformation (OFT) via a campaign of operational experiments. Operational experimentation aims to meet the immediate and emerging needs of warfighters by rapidly progressing through the design→build→test→deploy cycle. Through these cycles, the VMOC has emerged as a test bed to explore and validate the various interfaces that are required to create the architecture in Figure 6. It is also the platform with which to conduct operational experimentation in order to determine the changes in mission performance due to the framework in Figure 7. To date, OSD/OFT has integrated the VMOC *Spydr* in several exercises with DoD and non-DoD players. In these exercises, data from various sensors were used to evaluate the functionality and utility of the web site as well as to mature emerging concepts of operations. The VMOC *Spydr* architecture and design are continually being matured and through operational experiments and system improvements will new concepts of operations be enabled via the latest technologies.

7. NASA IPv6 DEMONSTRATION

In September of 2003, John Stenbit, Department of Defense (DoD) Chief Information Officer (CIO), signed a policy memorandum that outlines DoD's transition from Internet Protocol version 4 (IPv4) to Internet Protocol version 6 (IPv6) by 2008 as IPv4 is considered inadequate and incapable of meeting the long-term requirements of commercial entities and DoD. The achievement of net-centric operations, envisioned as a Global Information Grid of interconnected sensors and systems, depends on the effective implementation of IPv6. The DoD goal is to complete the transition to IPv6 for all inter and intra networking across the DoD by FY 2008. Recently, the U.S Government has mandated a similar transition for all U.S. Federal Government agencies including NASA. Budgetary realities have moved these dates out a few years. Nonetheless, the transition is taking place.

Some of the advantages that IPv6 has over IPv4 include:

- A sufficiently large address space to provide globally unique addressing
- Return of the end-to-end principles of the Internet (no need for Network Address Translation)
- Auto configuration
- Improved Security provided by
    - Scoped Addressing
    - IP Security capability as part of the protocol
    - No fragmentation
    - Multicasting instead of broadcasting

On 27 September 2003, a Cisco Systems router (Cisco in Low Earth Orbit (CLEO)), was launched onboard the UK-DMC disaster-monitoring satellite built by Surrey Satellite Technology Ltd (SSTL). The router was used to demonstrate net-centric operations in June 2004 using IPv4 normal and mobile routing [2]. The router firmware also included IPv6 routing although it does not poses IPv6 Internet Protocol Security (IPsec) capability or network mobility code as neither technology was available at the time of launch to orbit. For the next demonstration, the IPv6 capabilities will be enabled and the necessary ground networks will be configured to demonstrate IPv6 connectivity to a space-based asset. Static IPv6 routing will be used as will IPv4/IPv6 transition mechanisms.

In the 2004 VMOC/CLEO demonstration, mobile networking to the satellite from a secure infrastructure was demonstrated using IPv4. A number of ground stations where used for that demonstration including an SSTL ground station in Guildford, England, an Alaska ground station owned and operated by Universal Space Networks (USN), and a receive-only ground station operated by the US Army Space and Missile Defense Battle Lab. The upcoming NASA IPv6 demonstration plans to use the SSTL and MUGS ground stations, the enhanced DMC interface developed by USN under a US Air Force contract, and an S-band ground station owned and operated by the Hiroshima Institute of Technology.

NASA will use most of the original network put in place for June 2004 VMOC/CLEO demonstration. Initially, the mobile network IPv4 'home-agent' router will serve as the anchor point or "anchor router" for all IPv6 communications. Static host routes will reside in the anchor router. The Cisco router in Low Earth Orbit will be enabled for IPv6 and multiple host addresses will be configured, with each host route corresponding to a different ground station. In this manner, one can implement a predictive routing mechanism such that a controller can intelligently predict which ground station will be in contact with CLEO and transmit data to CLEO via that particular, unique host address as shown in

Figure 8.

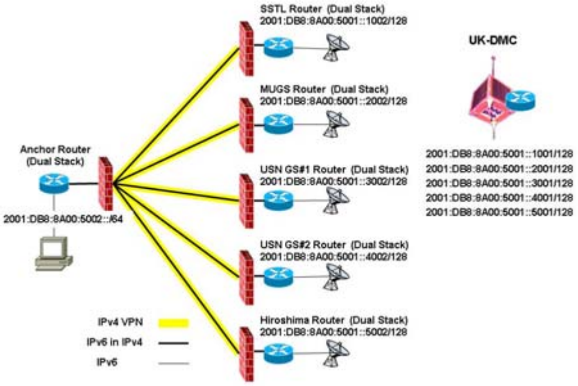

Figure 8: Predictive Ground Station Routing

Since SSTL's ground infrastructure is an operational system, the team plans the first deployment and test of IPv6 using the MUGS demonstration capability. Once configurations are proven with MUGS, they can be ported to the SSTL operational terminal as well as others.

Besides static IPv6 routing, NASA plans to encapsulate IPv6 packets inside an IPv4 IPsec tunnel thereby demonstrating network layer security from space to ground. In addition, NASA may attempt to run IPv6 over IPv4 mobile networks.

8. USGS DEMONSTRATION

The risk of natural and man-made disasters on a national and global basis are ever increasing. Thus, there becomes a growing need to not only maintain our existing capability but more importantly to expand and improve our coordination and infrastructure to support research, hazards monitoring risk assessment and management, and communication activities worldwide.

The USGS Center for Earth Resources Observation and Science (EROS) serves as a central coordination point for the acquisition and dissemination of remote sensing data in response to natural and man-made disasters in the U.S. and abroad. USGS EROS designation as the National Land Remote Sensing Data Archive for remotely sensed (satellite and aerial) data, enables the provision of historical and pre-event data for disaster response activities. Working with Federal agencies such as US Department of Homeland Security (DHS), US Federal Emergency Management Agency (FEMA), and US Northern Command (NorthCom), as well as State and local government agencies, EROS's Emergency Response team also coordinates the collection and scheduling of new acquisitions during disaster response operations.

The USGS is a partner agency in the International Charter on Space and Major Disasters, which represents a joint effort by global space agencies to put resources at the service of rescue authorities responding to major natural or man-made disasters.

The Charter is based on voluntary contributions, by all parties, of Earth observation satellite data. Each member agency has demonstrated its commitment to using space technology to serve humankind when it is most in need of assistance, in case of natural or technological disaster with data providing a basis for anticipating and managing potential or actual crisis. Announced at UNISPACE III conference held in Vienna, Austria in July 1999, the Charter was initiated by ESA and CNES with the Canadian Space Agency (CSA). Other partners include the Indian Space Research Organization (ISRO), the US National Oceanic and Atmospheric Administration (NOAA), US Geological Survey (USGS), the Argentine Space Agency (CONAE) and the Japan Aerospace Agency (JAXA), the British National Space Council on behalf of the Disaster Management Constellation (DMC), with the United Nations as a cooperating body.

Since November 2000, the Charter has been activated more than 100 times to assist in emergencies such as floods, fires, landslides, typhoons, volcanic eruptions, oil spills, tsunamis, hurricanes, earthquakes and civil accidents which occurred all around the globe. With a low response of 38 to 48 hours and by facilitating high reliability data, the Charter proved the effectiveness of space information for emergency management. The Charter and its partner agencies played a major role in supporting two of the largest disasters in recent times, the 2004 tsunami and Hurricane Katrina.

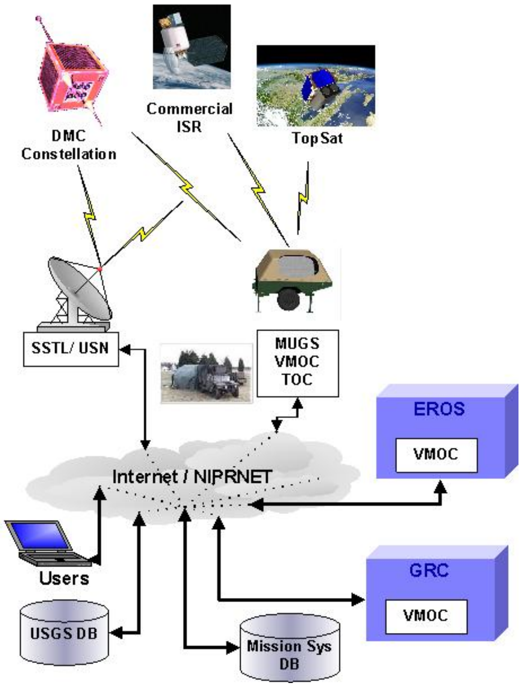

Figure 9: EROS Disaster Response

Teaming with the US Air Force and US Army, USGS EROS will demonstrate how the VMOC can provide space based assets in support of disaster response. The intent is to demonstrate how: 1) the aggregated access to additional archives and payloads, 2) the capability to task and schedule collections based on changing priorities, and 3) comprehensive views of asset capabilities will provide EROS emergency response personnel with significantly improved resources supporting their image acquisition missions both nationally and with the International Charter. The VMOC will be used to view all available assets for an event on a daily basis and will allow tasking and scheduling to proceed with maximum speed and minimum redundancy.

During disasters the loss of communications infrastructure can make data delivery very challenging. With the loss of internet capabilities, using media such as CD, DVD, and firewire becomes a necessity. The MUGS framework will be used to demonstrate how it will be possible to maintain communications with the field, assuring there is no loss of direct downlink from the space sensor platform. The MUGS will be used to maintain field user interfaces and provide for the delivery of any remotely sensed data acquired during the exercise.

The USGS EROS emergency response program plans to demonstrate that through the use of the VMOC and MUGS we will be able to provide disaster response remote sensing products in a timely and proactive fashion by making the data easily and rapidly accessible to the response community.

9. WAY AHEAD

The demonstrations and experiments discussed in this paper will allow operators to examine concept of operations and help determine their future system requirements. Current systems are working but the capabilities are limited and largely stovepiped. Future systems, such as responsive space assets (TacSats and Near Space), will dramatically stress current system capabilities and will require automated machine-to-machine tools for global apportionment, optimized for theater operations. Will the initiatives discussed in this paper fulfill 100% of the operator's needs? Most likely not - but what they can do is allow operators and warfighters to examine what works and what doesn't. Using common interfaces and net-centric software, these "systems of systems" can be more easily interfaced and adapted to provide the responsive space architecture notionally shown in
Figure 10.

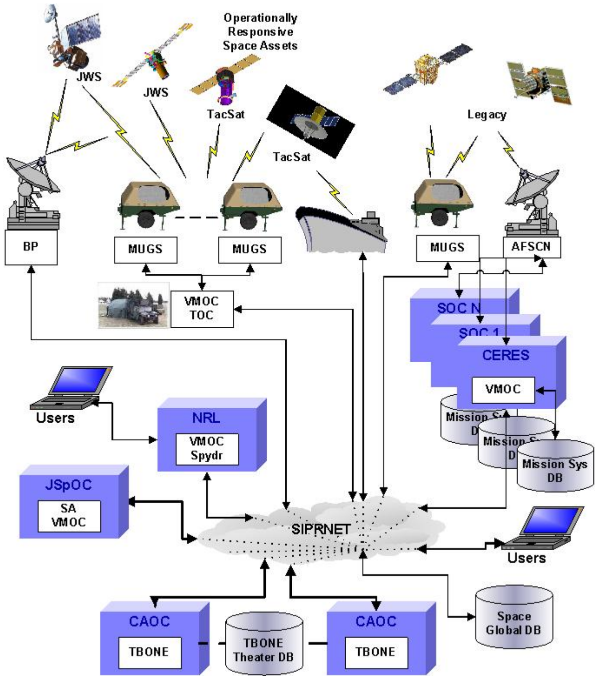

Figure 10: Responsive Space Operations

10. SUMMARY

The collaborative VMOC demonstrations create the relevant environment needed to frame the network centric, automated, end-to-end requirements flow that enhance space effects to the users. Small teams, working together for an optimum solution, can use a spiral development approach, adding capabilities to enhance operations. These initiatives are inherently easy to expand among government and commercial agencies. Programs, such as VMOC, SAFE, MUGS, IPv6, and Spydr, will undoubtedly lay the groundwork for the fundamental change needed to move toward net-centric satellite operations.

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[1] The term *Spydr* is a play on the word spider. It is intended to convey the ability to navigate like a spider across the web in order to pull data and users together and form communities of interest regardless of organizational boundaries

[2] W. Ivancic, P. Paulsen, D. Stewart, D. Shell, L. Wood, C. Jackson, D. Hodgson, J. Northam, N. Bean, E. Miller, M. Graves and L. Kurisaki, Secure, network-centric operations of a space-based asset: Cisco router in Low Earth Orbit (CLEO) and Virtual Mission Operations Center (VMOC), NASA Technical Memorandum TM-2005-213556, May 2005.