VIRTUAL MISSION OPERATIONS CENTER
EXPLICIT ACCESS TO SMALL SATELLITES BY A NET ENABLED USER BASE

Eric Miller [(1)], Omar Medina [(2)], Phil Paulsen [(3)], Lt Col Jay Hopkins [(4)], Chris Long [(5)], Kimberly Holloman [(6)]

[(1)] General Dynamics-Advanced Information Systems, 1515 Iceland Suite 215, Vandenberg AFB, CA 93437, USA
Email: eric.miller@gd-ais.com
[(2)] US Naval Research Lab, 4555 Overlook Ave SW Washington, D.C. 20375, USA
[(3)] NASA Glenn Research Center, Cleveland, OH 44135, USA
Email: phillip.e.paulsen@grc.nasa.gov
[(4)] 614 Air Operations Center, Bldg 8401, Vandenberg AFB, CA 93437, USA
Email: jay.hopkins@vandenberg.af.mil
[(5)] General Dynamics-Advanced Information Systems, address, USA
Email: christopher.long@gd-ais.com
[(6)] Science Applications International Corporation, 100 Carpenter Drive, Sterling VA 20164, USA
Email: *kimberly.a.holloman@saic.com*

ABSTRACT

The Office of Naval Research (ONR), The Office of the Secretary of Defense (OSD), The Operationally Responsive Space Office (ORS), and the National Aeronautics and Space Administration (NASA) are funding the development and integration of key technologies and new processes that will allow users across the breadth of operations the ability to access, task, retrieve, and collaborate with data from various sensors including small satellites via the Internet and the SIPRnet. The Virtual Mission Operations Center (VMOC) facilitates the dynamic apportionment of space assets, allows scalable mission management of multiple types of sensors, and provides access for non-space savvy users through an intuitive collaborative web site. These key technologies are being used as experimentation pathfinders for the DoD's Operationally Responsive Space (ORS) initiative and NASA's Sensor Web. The ORS initiative seeks to provide space assets that can be rapidly tailored to meet a commander's intelligence or communication needs. For the DoD and NASA the VMOC provides ready and scalable access to space based assets. To the commercial space sector the VMOC may provide an analog to the innovative fractional ownership approach represented by FlexJet. This paper delves into the technology, integration, and applicability of the VMOC to the DoD, NASA, and commercial sectors.

1. BACKGROUND

The US Department of Defense (DoD) and the National Aeronautics and Space Administration (NASA) share a common goal of direct user sensor tasking, which represents a new approach to accessing space based platforms. With notably few exceptions, space platform architectures are paired with mission specific ground infrastructures designed to optimize the interface. While these stovepipes are efficient they are geared for a small specialized community and therefore lack common user access, prioritization, multi-mission management, and cross platform connectivity.

Internet Protocol (IP) based tasking of sensors is a revolutionary step in space operations [i]. It allows smoother interoperability with the Internet and the Global Information Grid (GIG), greater redundancy and survivability, and the ability for users and operators to access the information they need, when they need it [ii]. As IP compliant architectures mature and additional systems employ the technology, intangible benefits will evolve into tangible results. This is particularly relevant with dynamically taskable sensor platforms operating in the air, near space, and space environments. The fusion of multiple missions will provide collaborative space effects that have never been available through the current stovepipe architectures.

Elements of the Virtual Mission Operations Center (VMOC) have been funded over the last six years by ONR, OSD, ORS, and NASA and development plans are scheduled well into the future. While the paths were separate, they all share the common goal of supporting dynamically taskable assets in a tiered sensor environment. Both approaches exposed selected technologies in a relevant environment that served to educate and involve the community in the maturity of the VMOC initiative. The data collected from the ongoing development will allow an integration of concepts of operation and net centric technologies beginning in 2009.

2. VMOC SYSTEM

Responsive space requires all system segments to work together effectively to support operational users. The intent is to begin standardizing the spacecraft to ground interfaces needed to reduce costs, maximize space

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effects to the user, and allow the generation of tactics, techniques, and procedures (TTPs) that lead to responsive space employment. The VMOC system comprises three main components designated as tactical, mission, and apportionment and is represented in figure 1. Each component provides specific capabilities and is tailored to a specific user base. The tactical component is designed to support multi-sensor access and collaboration among a diverse user community. The mission component provides support for platform management, sensor access, data storage, processing, and sharing, while the apportionment component provides automated support, with man in the loop for user prioritization of ORS assets.

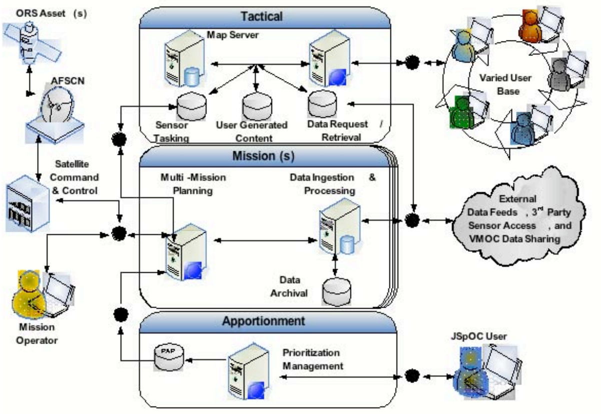

Figure 1 VMOC System of Systems

Specifics of each component are as follows:

2.1. Tactical VMOC: Enable the Users

Dynamically taskable assets are expected to be smaller and less expensive than their traditional counterparts. This reduction in cost and time to market will allow for an increase in the number of satellites which leads to an increase in the number of improvement cycles, facilitating more rapid development and deployment of capabilities. With more sensors available to a networked community of users, capabilities will emerge that challenge traditional approaches to managing the assets. This tiering of a wide variety of sensors and people will result in synergies that do not exist in small user communities or monolithic systems. In addition, this architecture will spur the development and maturity of more complex operations that accentuate and prioritize the strengths and uniqueness of dynamically taskable assets and its diverse user base. The Tactical VMOC was developed to lower the barriers of entry for access to space based capabilities and to explore, develop, and mature new methods of employment within a multi-sensor framework. The tactical server allows non-space savvy users the ability to:

- Task, track, and receive data from multiple sources
- Manage user accounts and assign privileges
- Subscribe to data feeds from a variety of sources
- Use collaboration, workgroups, and virtual teams

2.2. Mission VMOC: Manage the Sensors

Scalability, reduction of non-recurring costs, and responsive access to dedicated capabilities are the main principles that will allow for successful operation of dynamically taskable assets. Specifically, the addition of new satellites into the community of sensors and users must not come at an unreasonable cost in time, money, or manpower. These new sensors must “plug and play” within an architecture that exposes capabilities to a rich set of systems and users. To do this, the system must include the tenets of service oriented architectures, automation, standard processing, and standard interfaces. To that end, the mission VMOC provides for tasking sensors, ingesting data feeds from third party providers, and processing, sharing, and archiving data. A key element of the Mission VMOC is its ability to spread the tasking across collaborative systems allowing for the tasking, data collection, and processing of multiple assets through common web services that include:

- Mission rules generation
- Multi mission planning
- Interface to multiple command generation systems
- Data ingestion and archiving
- Data processing and data feed generation

2.3. Apportionment VMOC: Establish the Rules

Currently, command and control of DoD space assets is the responsibility of US Strategic Command (USSTRATCOM) which established a joint functional component command for space (JFCC SPACE) in 2006 and designated it as the global space coordinating authority. It is the single authority in USSTRATCOM to coordinate global space operations and integrate space capabilities. The tasking of all U.S. space assets assigned to JFCC SPACE is managed by the Joint Space Operations Center (JSpOC), which gathers requirements detailing desired effects from the commanders of USSTRATCOM and JFCC SPACE, all theater space coordinating authorities (TSCA), as well as from all supported commands. These requirements are first prioritized and then analyzed in terms of the availability of space resources to achieve the desired effects. The result of this process is the Joint Space Tasking Order (JSTO) which is passed to subordinate units who plan how to deliver those effects. The process is highly centralized, concentrating the command and control of U.S. space assets into a single organization. The current process, while highly effective for controlling and managing large space systems, needs to be modified for Operationally Responsive Space (ORS), which aims to reduce the requirements-tasking-effects cycle from 24 hours to hours or even minutes. With that in mind, the Apportionment VMOC provides the JSpOC a new tool needed to automate the prioritization and allocation process of dynamically taskable assets. In the case of ORS, the output is the Prioritized Allocation Plan (PAP). The PAP serves as the mission rule set for the Tactical and Mission VMOCs, identifying prioritized organizational access to the platforms. The Apportionment VMOC services allow dynamic apportionment and prioritization by providing:

- Asset apportionment
- Tasking priority based on authority guidance
- Standing apportionment requests
- Management of system outages
- Multiple assets for effects based operations

3. VMOC APPLICABILITY

The current VMOC system is an outgrowth of a variety of concepts put in motion by the US Air Force, US Navy, US Army, and NASA. Each addressed specific aspects of the tasking, collection, production, exploitation, and dissemination (TCPED) process. In 2008, the DoD elements, under the Naval Research Laboratory, began integration focused specifically on support to the Operationally Responsive Space initiative. Current discussions are taking place to begin integrating DoD and NASA elements in 2009 which will be focused on tying net-centric and sensor web initiatives to allow for operations across agencies. A good example would be integrating the effects from DoD and NASA Earth Science platforms in support of disaster response.

Another key element of VMOC development is commercial space. A series of VMOC demonstrations in 2004-2006 integrated the AF Space Battle Lab, Army Space and Missile Defense Battle Lab, NASA Glenn Research Center, and the Surrey Satellite Technology Ltd (SSTL) United Kingdom Disaster Monitoring Constellation (UK-DMC) spacecraft with the embedded Cisco in Low Earth Orbit (CLEO) router to validate the concepts of IP based command and control and direct theater level tasking [iii]. While all these organizations continue to develop mission unique capabilities, the VMOC provides the relevant environment needed to integrate the various new components in ways that can increase the benefit of space effects while reducing cost and increasing mission success.

An interesting concept that has been discussed recently is using the VMOC in support of fractional spacecraft ownership. To date, the VMOC systems have been integrating platforms already owned by organizations to provide integrated space effects. Each organization gets more capability by integrating systems without increasing cost to each organization. Fractional ownership, on the other hand, would allow organizations that do not have space assets the ability to get dedicated access to space assets as a part owner.

3.1. ORS Experimentation

ORS, in general, and the TacSat experiments, in particular, are geared to develop disruptive technologies and practices. Disruptive technologies seek to engage markets that have not been served by other means. This approach of engaging markets of "non-consumption" is represented by new methods of employment, new definitions of value and utility, new margins for return on investment, and new types of users [iv]. The particulars of these attributes only surface after a technology is matched along with a concept of operations and both are allowed to mature via experimentation. This concept/technology pairing is key to properly understanding and representing an emerging and disruptive technology like ORS.

The VMOC is creating a relevant environment where users, sensors, concepts of operations, and authorities are allowed to operate for the express purpose of experimenting with new and relevant capabilities [v], [vi]. An ORS space centric view is given in figure 2 and specifically shows the configuration that is being brought to bear in 2008 / 2009 demonstrations focused on the integration of the US Air Force, US Navy, and US Army requirements with the US Naval Research Laboratory serving as the program manager [vii].

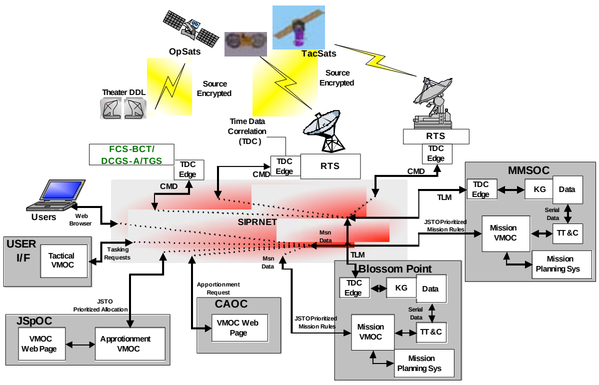

Figure 2 VMOC Operational Experimentation

3.2. NASA Sensor Web

Currently, the NASA Earth Science community 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. These collaborative systems improve overall data accuracy through their ability to calibrate and compare multiple, distinct sensor results for the same event. In response to this need, investments are being made in the “Sensor Web”, a coordinated observation infrastructure composed of a distributed collection of resources that can behave as a single, autonomous, taskable, dynamically adaptive, and reconfigurable observing system with a set of standards-based, service-oriented interfaces shown in figure 3.

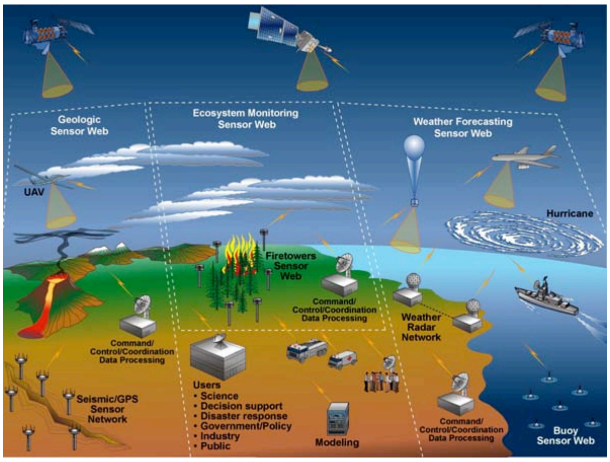

Figure 3 ESTO Sensor Web

These resources will be located wherever the data collection need is, either on the ground, in the air, at sea, or in space. Given the cost of some of these assets and the potential complexity of the integrated “system of systems” being proposed, asset adjudication will need to be performed to ensure that the right person gets access to the right system to obtain the right data at the right time. At present, most NASA missions are designed, built, tested, and operated as independent agents. Emerging concepts of operations involving systems such as the “A” train (six satellites flying in relatively close proximity with coordinated operations) are able to obtain synergistic observations of Earth phenomena. Future coordinated operations of multiple independent NASA satellite systems would likely benefit from a global coordinating authority similar in concept to that being used by the US military. The addition of the Apportionment VMOC to the existing NASA VMOC architecture would provide standardization of coordinated sensor web flight operations. The new process would be rules-based and autonomous to ensure the fair and timely allocation of resources. Additionally, a core VMOC system design philosophy is to provide common data system interface standards, allowing missions to interoperate and coordinate operations while sharing, and minimizing, infrastructure costs.

3.3. Commercial FlexSat Model

There are many examples of fractional ownership that range from time share condominiums to owning scheduled access of a corporate jet. The fundamental reason for all of them is to provide low cost to entry, shared burdening of maintenance costs, and priority service based on the level of ownership. In the space business there are several examples of partial ownership that include venture capitalists owning a share of the profits earned by a sensor platform as well as organizations sharing resources and data like the Disaster Monitoring Constellation (DMC). The DMC remote sensing satellites were constructed by Surrey Satellite Technology Ltd, but owned and controlled by separate nations, who have agreed to provide 5% of capacity free in support of disaster relief [viii]. For non-space faring nations, placing a sensor on orbit necessitates new international cooperative agreements serving political, economic, and national security objectives. Fractional ownership in their case puts the burden of agreements, insurance, manufacturing, launch, and operating costs on the system broker. This could be very attractive and allow a reduce cost and risk to a nation that would not otherwise be able to take advantage of a space based platform.

In 2005 Vice Admiral Arthur Cebrowski laid out the way ahead for ORS with the fundamental premise that “small satellites can provide great advantages in operational control, integration, responsiveness, costs, risk, and information-sharing among coalition partners” and that the new business model rests on reducing cost as a strategy [ix]. In 2007 Col Tim Doyne began addressing the concept of Coalition ORS (C-ORS) that uses the DMC model focused on NATO, where each member could agree to buy and operate a single small satellite. In this case, 26 small satellites would be available for use in NATO operations. The price tag would be in the low tens of millions of dollars each which is more attractive than purchasing an entire constellation or a single monolithic satellite. Individual NATO members would get the benefits of a constellation for the price of a single satellite. An extra benefit of the C-ORS model is that it would provide opportunities for larger block buys of small satellites than would be the case with heritage systems. These block buys would stimulate the space industries while providing economies of scale, resulting in lower mission costs [x]. In addition to fractional ownership, there are concepts being funded that deal with fractional spacecraft at the component level. The US Defense Advanced Research Projects Agency (DARPA) F6 (derived from: future, fast, flexible, fractionated, free flying) program is evaluating the fractionation of the spacecraft itself where the small satellites create a "self-forming network of spacecraft nodes" [xi]. While the cluster of vehicles operate as if they were a single spacecraft, the cost can be carried by many organizations. Since each small satellite serves as a subsystem of the whole, a failure in, or modernization of, one component does not terminally impact the group since each component can be replaced independent of the whole.

While fractionated ownership of space based sensors is being approached from several directions, the effect is expected to lower the cost to entry, share the burden of operations, and allow for priority service based on the level of ownership. To be successful, the business model will require a scalable ground architecture that allows for dynamic prioritization, multi-mission management, and common user access through the web. The VMOC is poised to support this emerging business model by providing the net-enabled framework required to manage the dynamic nature of fractional ownership. However, it is envisioned that as the concept and the technology matures the VMOC will need to incorporate additional services to handle international policies, quality of service, and billing.

4. Summary

The Virtual Mission Operations Center has come a long way from a variety of paths focused on collaboratively enabled space effects from dynamically taskable platforms. The past four years had many organizations focusing on specific pieces of the larger net-centric space environment. The next two years will be focused on the combination of the parts that lead to integrated space effects. As the new concepts of operations and tactics, techniques, and procedures are tested and refined, the DoD and NASA will be ready to take advantage of them. In addition, new commercial capabilities like fractional platform ownership will allow new and existing organizations to take advantage of the new markets that will certainly come as sensor and platform technologies advance.

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