MTR100481

MITRE TECHNICAL REPORT

Composable Operations Center

Naval Division
FY 10 Technical Report

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Abstract

Composable Operations Center (COC) is a MITRE-wide initiative that brings together the MITRE Innovation Program (MIP) and MITRE work programs to develop and demonstrate a common approach for hosting and rapidly composing operations center capabilities within a secure virtual computing environment. The initiative began in January 2010 and is expected to continue through September 2012. This document provides an overview of the MITRE Naval Division's engagement through November 2010.

The COC concept is developed to afford the capability to rapidly consume and produce essential information while operating in rapidly changing environments. As a generalized information-centric approach defined by unanticipated partners and events, the desired outcome for our sponsors is to be able to compose a scalable, tailored operations center within minutes vice days, weeks, or months that meets the current mission's objectives.

The overall technical objectives are to develop and demonstrate to key MITRE customers and stakeholders a common approach for hosting and rapidly composing operations center capabilities within a secure virtual computing environment. The environment will: be based on a defined framework so that components can be defined, built, managed, and shared separately from the core technologies; leverage Web 2.0 and virtualization technologies to rapidly compose critical Command and Control (C2) capabilities on demand; maximize the use of shared content from authoritative and trusted sources in common formats; reduce the physical footprint of conventional operations centers (air, ground and maritime); and allow C2/battle management capabilities (plan, organize, direct and monitor execution) to be decentralized and distributed across the battlespace.

To realize the objectives, the COC initiative has the following goals: (1) develop generalized approaches for instantiating information flows with unanticipated participants, (2) develop solutions to rapidly constitute essential processing, communication, applications and information, (3) demonstrate how to compose an operations center in minutes and hours instead of days, weeks or months, and (4) engage potential early adopters with proofs of concept. This report focuses on the initial steps to realize these four goals.

Goal one of information flows with unanticipated users is illustrated through standards-based, simple message and data formats. The ubiquitous nature of the simple formats results in many data sources and tools that enable data fusion, and the rise of prosumers that both produce and consume data. The second goal of rapidly constituting essential computing resources focuses on virtualization as the foundation of a composable operations center. Virtualization provides configurable compute, memory, storage and network resources that can be dynamically adjusted in a matter of minutes. Several MITRE proof-of-concept tools are discussed that automate the creation and management of operations centers, provide web-based mashup environment to compose mission capabilities and an app store to share the composed capabilities. Leveraging the capabilities of the first two goals, goal three composes an operations center measured in minutes during an October mashup event at MITRE Quantico's Demo room. The COC initiative has begun to integrate the evolving Marine Corps Tactical Service Oriented Architecture (SOA) to support consuming data from C2 systems. The fourth goal of engagement with potential early adopters builds on goal three focusing on mobile operations with a COC fly-away kit. The report concludes with observations of virtualization performance, network configurations, limitations of web-based tools and Virtual Machine (VM) management.

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1 Introduction

Composable Operations Center (COC) is a MITRE-wide initiative that brings together the MITRE Innovation Program (MIP) and MITRE work programs to develop and demonstrate a common approach for hosting and rapidly composing operations center capabilities within a secure virtual computing environment. The initiative began in January 2010 and is expected to continue through September 2012. This document provides an overview of the MITRE Naval Division's engagement through November 2010.

1.1 Background

MITRE embarked upon the COC initiative to influence the systems engineering of Command and Control (C2) systems and overall architecture of operations centers (ops center) at the Tactical and Operational Levels of War. This initiative is part of a broader area of MITRE research known as Composable Capability on Demand (CCOD®), which is focused on a set of technical means and constructs that will enable Department of Defense (DoD) and civilian users to dynamically assemble and employ elements of the Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) enterprise to successfully accomplish missions. CCOD® will allow users to adapt that enterprise to the nature and scale of the mission and adversary.

1.2 Objective

The COC concept is developed to afford the capability to rapidly consume and produce essential information while operating in rapidly changing environments. As a generalized information-centric approach defined by unanticipated partners and events, the desired outcome for our sponsors is to be able to compose a scalable, tailored ops center within minutes vice days, weeks, or months that meets the current mission's objectives.

The MITRE COC initiative began in January 2010 and is expected to continue through September 2012. The overall technical objectives are to develop and demonstrate to key MITRE customers and stakeholders a common approach for hosting and rapidly composing operations center capabilities within a secure virtual computing environment. The environment will:

- Be based on a defined framework so that components can be defined, built, managed, and shared separately from the core technologies.
- Leverage Web 2.0 and virtualization technologies to rapidly compose critical C2 capabilities on demand.
- Maximize the use of shared content from authoritative and trusted sources in common formats.
- Reduce the physical footprint of conventional operations centers (air, ground and maritime).
- Allow C2/battle management capabilities (plan, organize, direct and monitor execution) to be decentralized and distributed across the battlespace.

During Fiscal Year (FY) 10, MITRE established the necessary resources to successfully execute the COC initiative, to include the core engineering team, computing infrastructure and research pipeline. Currently, three COCs are established at MITRE Bedford, Quantico and San Diego to provide a development and demonstration environment in support of Air Force, Marine Corps and Navy customers, respectively. During FY 11, MITRE expects to establish a COC environment at MITRE Aberdeen to support the Army customers.

The COC initiative's goals are to:

- Develop generalized approaches for instantiating information flows with unanticipated participants.
- Develop solutions to rapidly constitute essential processing, communication, applications and information.
- Demonstrate how to compose an ops center in minutes and hours instead of days, weeks or months.
- Engage potential early adopters with proofs of concept.

The following key outcomes are expected as part of the COC initiative:

- Warfighter advocacy for application of CCOD® concepts to meet their emerging information needs.
- Acquisition community and industry acceptance of CCOD® approaches.
- Engage MITRE in direct technical work to apply CCOD® concepts to their programs and initiatives.

2 Information Flows with Unanticipated Participants

Operations centers are developed to be hubs for sharing information. Traditionally, most watch standers and other operations centers' personnel function as consumers of information. They consume multiple feeds and sources of information, gain situational awareness, and produce minimal information streams. With COC, personnel are envisioned to be "prosumers[1]" - they not only consume large amounts of information, but also produce commander relevant information that is shared across their networks. The root process of a COC is to receive information, make it relevant to the commander, and then share it.

Prosumers exist because information is shared through widely adopted, simple to use formats. For COC, the key formats are the same formats used throughout the Internet.[2] For transmission of data, the Hypertext Transfer Protocol (HTTP) is used, the structure (syntax) of the data is provided by eXtensible Markup Language (XML) and the meaning (semantics) is through several formats; with the key formats being Geo Really Simple Syndication (GeoRSS) and Keyhole Markup Language (KML). Since the formats are simple to use, many data providers expose their data in these formats.

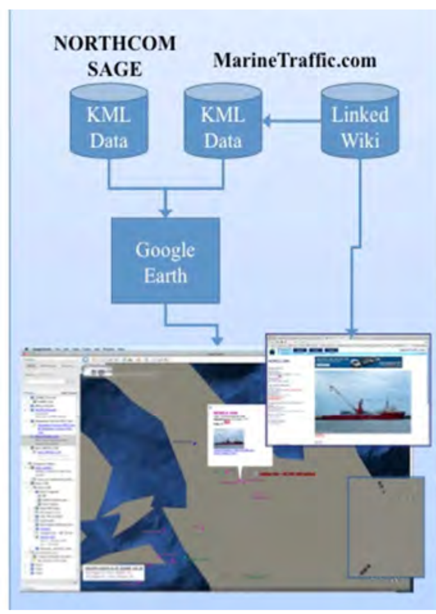


Figure 1 Loose-couplers enable data fusion

Figure 1 illustrates an example of data being shared using KML from two different sources and displayed via Google Earth. There are cases of duplicate data in this simple data fusion example; but, since the data is visualized based on latitude and longitude, the duplicates are fairly easily identified. MarineTraffic.com data is more accurate (more

[1] Tapscott, Don and Anthony Williams. Wikinomics: How Mass Collaboration Changes Everything. 2007. New York, NY: Penguin Group: 124-150.

[2] In COC, DoD formats are incorporated as well to include Cursor on Target and UCore.

recent updates) and much richer (track history, wiki of the vessels) with respect to the vessel track data. However, the SAGE[3] data provides other useful features, such as tracking the Gulf oil spill.[4] Because multiple data sources are available via the loose-coupler of KML, data can be easily fused.

3 Rapidly Constitute Essential Computing Resources

This section discusses the tools and techniques to quickly instantiate the computing resources. The key areas are virtualization and the MITRE CCOD® prototypes.

3.1 Virtualization

Virtualization provides the foundation for building the composable components of COC. Virtualization allows dynamic adjustment of computing resources to meet the operational demands. The computing resources are: compute (processing), memory, storage and network. Virtualization is made possible by software called a hypervisor that sits between a server's physical computing resources, referred to as the "host," and the operating systems (OSs) that use the computing resources, referred to as the "guests." The guest OSs run on top the hypervisor, which abstracts the hardware offering various configurations of computing resources to the guests.

The guests are unaware that the computing resources are not physical, which has some advantages for composability. Virtual resources means the mapping to computing resources is purely through file configurations. File configurations are easy to replicate, change and move between environments to provide fault tolerance and flexibility. For the COC initiative, VMware vSphere provides the virtualization infrastructure. Figure 2 shows the environment for MITRE Quantico and San Diego.

[3] Situational Awareness Geospatial Enterprise, https://sageearth.northcom.mil.
[4] Note the authoritativeness and correctness of the data feeds are still a concern.

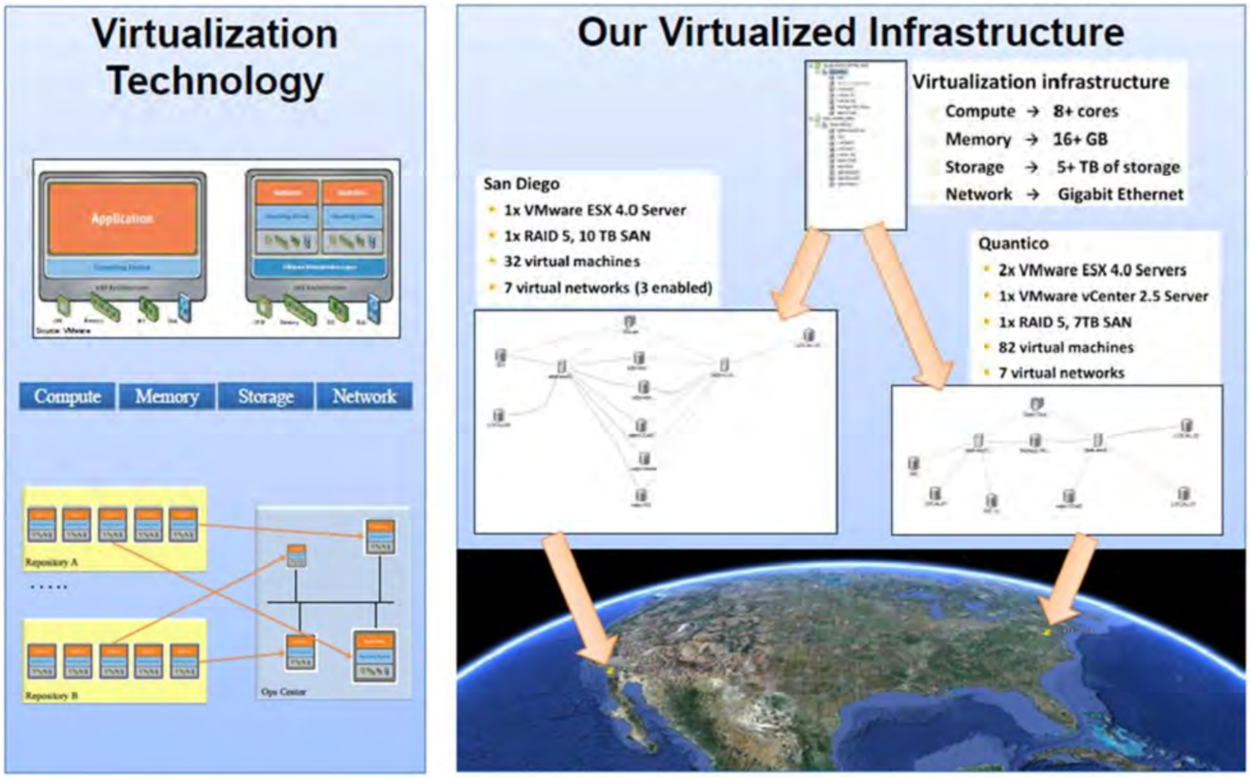


Figure 2 COC virtualization infrastructure

VMware vSphere consists of the following components:

- Computing resource management: vCenter Server provides centralized management of VMware vSphere servers (ESX and ESXi) to configure server clusters, permissions, and computing resources.
- Hypervisor: ESX is the hypervisor that abstracts the physical hardware's computing resources.
- User interface: vSphere Client, shown in Figure 3, is a Windows desktop application that allows users and administrators to access the management features of the vCenter Server or connect directly to an ESX server. The vSphere Client provides users with the ability to provision, start, and stop virtual machines as well as configure many properties of the virtualization server.

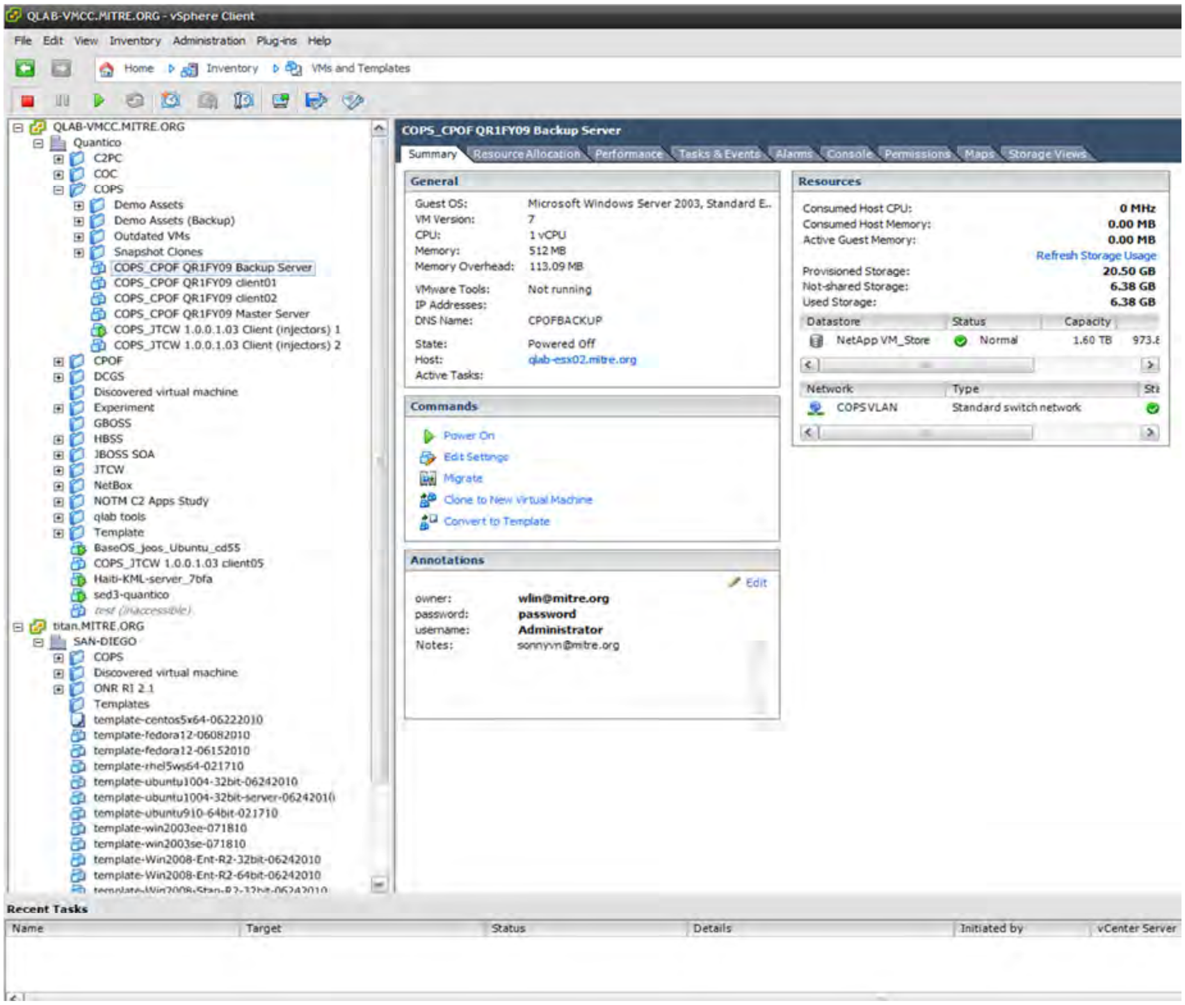


Figure 3 vSphere client interface

The COC initiative uses vSphere Application Programming Interfaces (APIs) to quickly configure Virtual Machines (VMs), including: moving VMs between networks, cloning VMs, changing memory and storage configurations, and sharing VMs with others within MITRE. Leveraging the VMware tools, it takes just a matter of minutes to clone a VM and power up for usage.

3.2 Virtualizing C2 Systems

Existing C2 systems provide critical mission processing and data sources that must be integrated into the COC architecture. As part of the FY 10 COC effort, Joint Tactical Common Operational Picture Workstation (JTCW) was virtualized to experiment with C2 system virtualization.

Because JTCW includes an OS as part of the install, it is best to locate the install media on the same Local Area Network (LAN) as the virtualization infrastructure. The team attempted remote installs from San Diego to Quantico to test the case of remote ops center installs. The installations would start but failed after a couple hours. Ideally, the install media should be directly connected to the ESX server via local disk or LAN, such as Storage Area Network (SAN) connected via Gigabit Ethernet (GbE).

Once installed, JTCW was cloned using vSphere and multiple JTCWs configured as described in Section 4. JTCW was accessed exclusively through the vSphere console, similar to other terminal services, such as Remote Desktop or VNC®. With any terminal services access, there was slight delay on updates during graphic intensive processing (e.g., moving tracks around the map). In future testing, a virtualization client (e.g., VM Workstation) will be used to test the perceived performance in a client-based instantiation.

Going forward, the COC effort will experiment with various C4ISR systems to evaluate where virtualization can improve composability of ops centers balanced with appropriate performance and usability to the end users. The MITRE COC tools discussed in the next section are focused on improved composabilty and usability.[5]

3.3 MITRE COC Tools

The COC initiative is leveraging MIP CCOD® research portfolio to provide:

- Ops Center on Demand: A virtualized Information Technology (IT) infrastructure coupled with a capability for deploying tailorable libraries of different IT configurations in minutes to support different mission sets on the fly. MITRE is prototyping the Ops Designer tool to demonstrate this capability.
- Tools for Composing C2 Applications: A web-based, drag-and-drop method for COC technical experts to build C2 apps on the fly for emergent requirements with different pre-existing information feeds and widgets. MITRE is prototyping the CCOD® Authoring Tool (CAT) to demonstrate this capability.
- Tools for Sharing Apps and Ops Center Designs: A service for distributing, rating, and sharing C2 apps among ops centers. MITRE is prototyping the SimpleC2 marketplace service to demonstrate this capability.

The COC technologies provide a foundation for quick, low cost innovations that capitalize on the technical knowledge of people in uniform. COC realigns the IT infrastructure so that it revolves around the mission, vice the mission around the IT. Composability enables operators to self-synchronize around relevant data sets and persist critical information, even in denied environments leveraging a properly distributed infrastructure. Figure 4 shows the mapping of the COC technologies to the CCOD® Reference Architecture.

[5] Performance analysis is expected as part of industry and sponsor engagement FY 11 through FY 12.

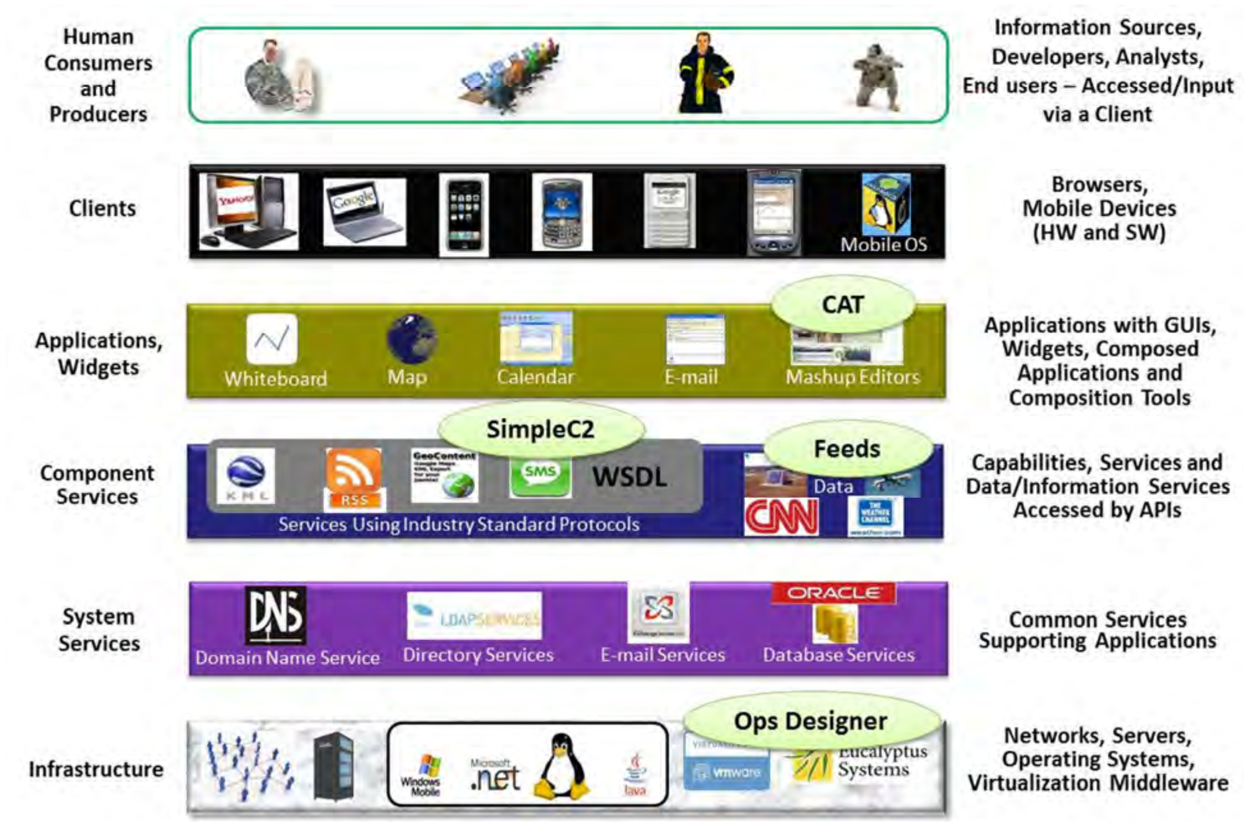


Figure 4 CCOD® reference architecture

Figure 5 shows how the COC tools support three distinct operator roles:[6]

- Combat Coder: Technically trained operator with background in software programming, adept with basic software development and Microsoft tools (e.g., web pages, Excel macros). Usually a self-selected role at the ops center focused on creating just-in-time capabilities to support the mission.
- Average Operator: Majority of operators, comfortable with technology, web-based and Microsoft tools. While less technical than combat coder, augments capabilities with simple modifications that get the job done.
- Commander: The ultimate consumer that defines the information requirements of the ops center. Leverages the capabilities developed by the combat coder and operators to make better informed decisions.

[6] Roles based on MITRE research: SimpleC2 Defining the Core Components of Command and Control, Todd Reily, Jan 2010; User Personas for Command-and-Control Environments, Todd Reily, Nov 2010.

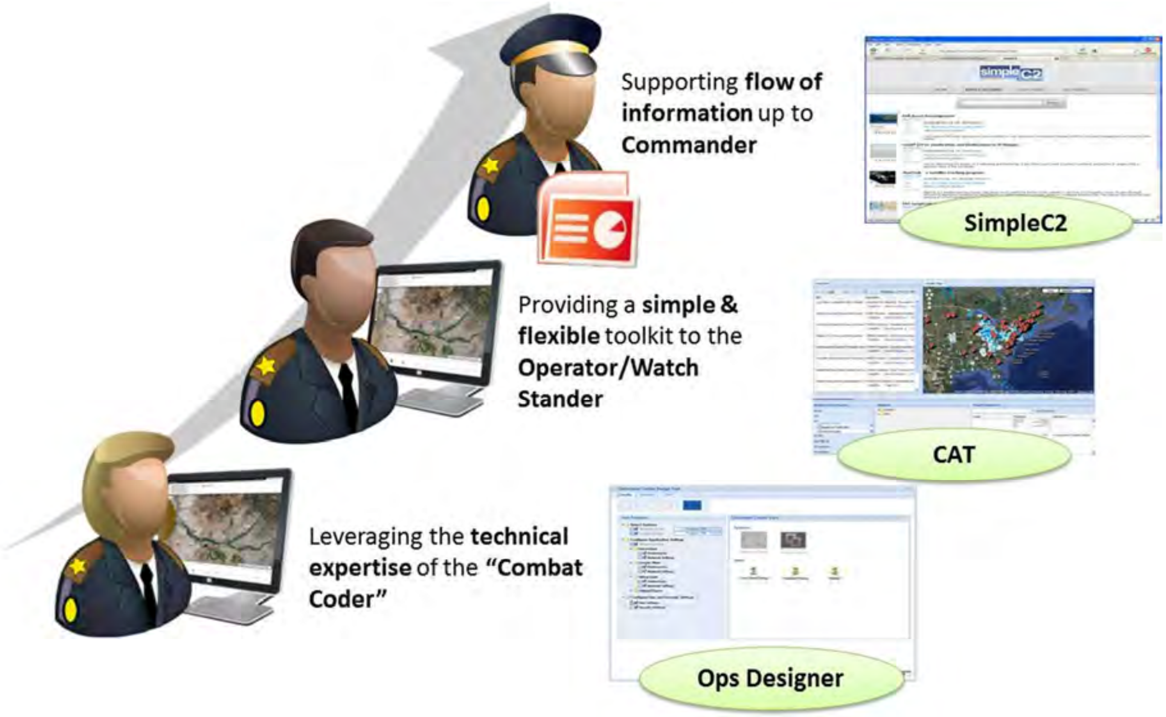


Figure 5 COC tools

3.3.1 Ops Designer

The Ops Designer tool provides a user-friendly, web-based interface to simplify the process of provisioning and configuring the virtual machines that comprise an ops center. The user is guided through the following steps: (1) create or modify an existing ops center, (2) select existing virtual machines from a repository to add to the ops center, (3) configure settings for individual virtual machines, (4) associate security permissions with the virtual machines, (5) build the ops center by instantiating the virtual machines on the ops center's virtualization infrastructure and (6) review the configured virtual machines once instantiated. Ops Designer manages the VM configurations using the Open Virtualization Format (OVF). OVF provides a standards-based XML format that is platform agnostic. Figure 6 shows an example of an OVF VM file.


```
<?xml version="1.0" encoding="UTF-8" ?>
<!-- Generated by VMware VirtualCenter Server, User: MITRE\wlin, UTC time: 2010-06-14T21:54:11.777212  -->
- <Envelope vmw:buildId="build-208111" xmlns="http://schemas.dmtf.org/ovf/envelope/1"
    xmlns:cim="http://schemas.dmtf.org/wbem/wscim/1/common"
    xmlns:ovf="http://schemas.dmtf.org/ovf/envelope/1" xmlns:rasd="http://schemas.dmtf.org/wbem/wscim/1/cim-
    schema/2/CIM_ResourceAllocationSettingData" xmlns:vmw="http://www.vmware.com/schema/ovf"
    xmlns:vssd="http://schemas.dmtf.org/wbem/wscim/1/cim-schema/2/CIM_VirtualSystemSettingData"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  - <References>
      <File ovf:href="COPS_LFOC-disk1.vmdk" ovf:id="file1" ovf:size="7454208512" />
    </References>
  - <DiskSection>
      <Info>Virtual disk information</Info>
      <Disk ovf:capacity="50" ovf:capacityAllocationUnits="byte * 2^30" ovf:diskId="vmdisk1" ovf:fileRef="file1"
        ovf:format="http://www.vmware.com/interfaces/specifications/vmdk.html#streamOptimized" />
    </DiskSection>
  - <NetworkSection>
      <Info>The list of logical networks</Info>
    - <Network ovf:name="COPS VLAN">
        <Description>The COPS VLAN network</Description>
      </Network>
    </NetworkSection>
  - <VirtualSystem ovf:id="COPS_LFOC">
      <Info>A virtual machine</Info>
      <Name>COPS_LFOC</Name>
    - <OperatingSystemSection ovf:id="67" vmw:osType="winXPProGuest">
        <Info>The kind of installed guest operating system</Info>
        <Description>Microsoft Windows XP Professional (32-bit)</Description>
      </OperatingSystemSection>
    - <VirtualHardwareSection>
        <Info>Virtual hardware requirements</Info>
      - <System>
          <vssd:ElementName>Virtual Hardware Family</vssd:ElementName>
          <vssd:InstanceID>0</vssd:InstanceID>
          <vssd:VirtualSystemIdentifier>COPS_LFOC</vssd:VirtualSystemIdentifier>
          <vssd:VirtualSystemType>vmx-07</vssd:VirtualSystemType>
        </System>
```


Figure 6 OVF VM file

By leveraging OVF, Ops Designer will be able to support multiple virtualization environments beyond the currently supported VMware. A screen shot of Ops Designer web interface is shown in Figure 7.

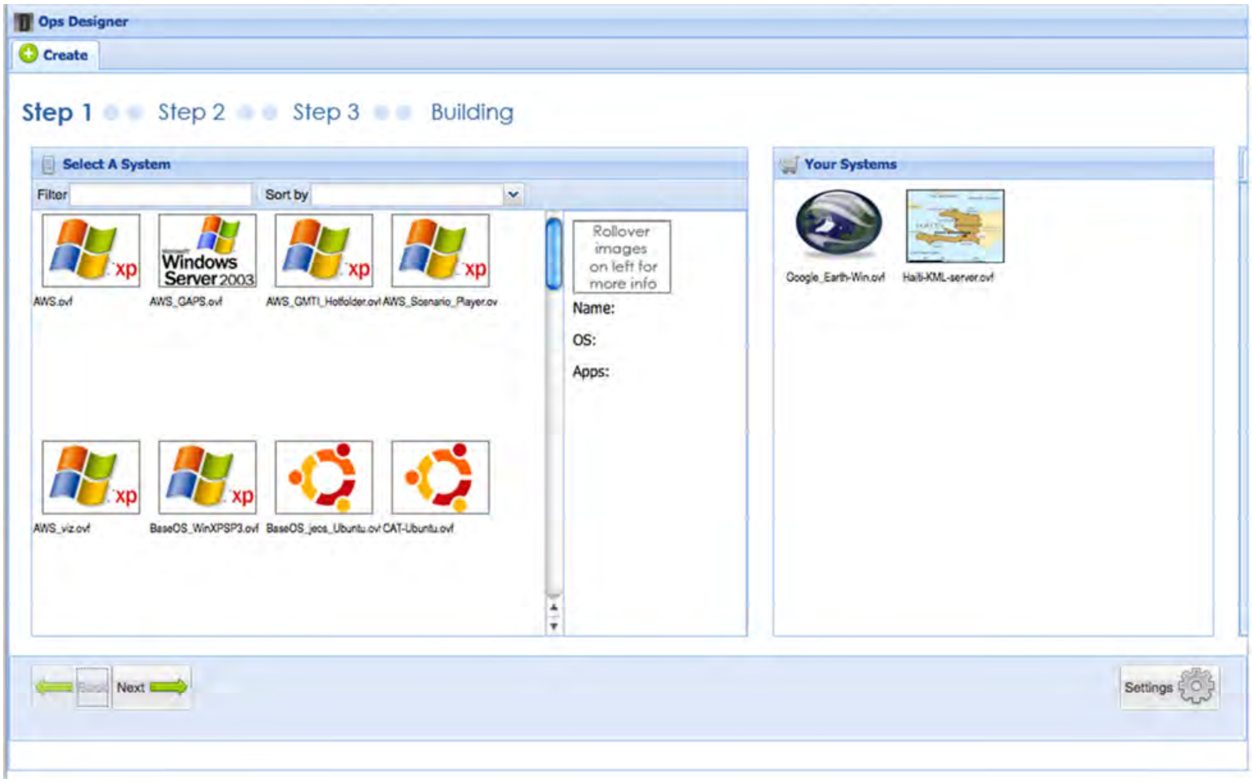


Figure 7 Ops Designer screenshot

The expectation is ops centers will be created (e.g., HADR-BN, STOM-REGT-LFOC) through Ops Designer then shared with others. All of the metadata and configuration pieces around a particular ops center are maintained in a back-end database. The FY 11 plan is to allow the configuration to be published as a single XML file or set of files which can easily be shared or re-instantiated. A user logs into Ops Designer and is presented with available mission-based ops centers as shown in Figure 8. If modifications are required for the ops center, a user can edit an existing configuration.

Figure 8 Operations centers based on mission sets

While Ops Designer abstracts much of the complexity to building ops centers, it is important to discuss some of the complexity to understand how the pieces fit together to automate the creation and management of sets of virtual machines. Figure 9 provides a high level view of the system components that make up the Ops Designer architecture. While core to the current design, in the future VMware ESX could be swapped out for other virtualization technology. The team purposefully designed Ops Designer to avoid vendor lock-in. The majority of the software is free open source software with proven track records in production environments and robust development and support communities.

Ops Designer is the hub of the VM provisioning, automating much of the process and acting as a bridge between the newly created VMs on a closed Virtual Local Area Network (VLAN) and an ops center network. Ops Designer uses tools for automating the system configuration during VM boot, Internet Protocol (IP) address assignment and name resolution, firewall software to isolate the newly created VM from the existing network, and remote access software to allow the user to log in to the VM via a web browser.

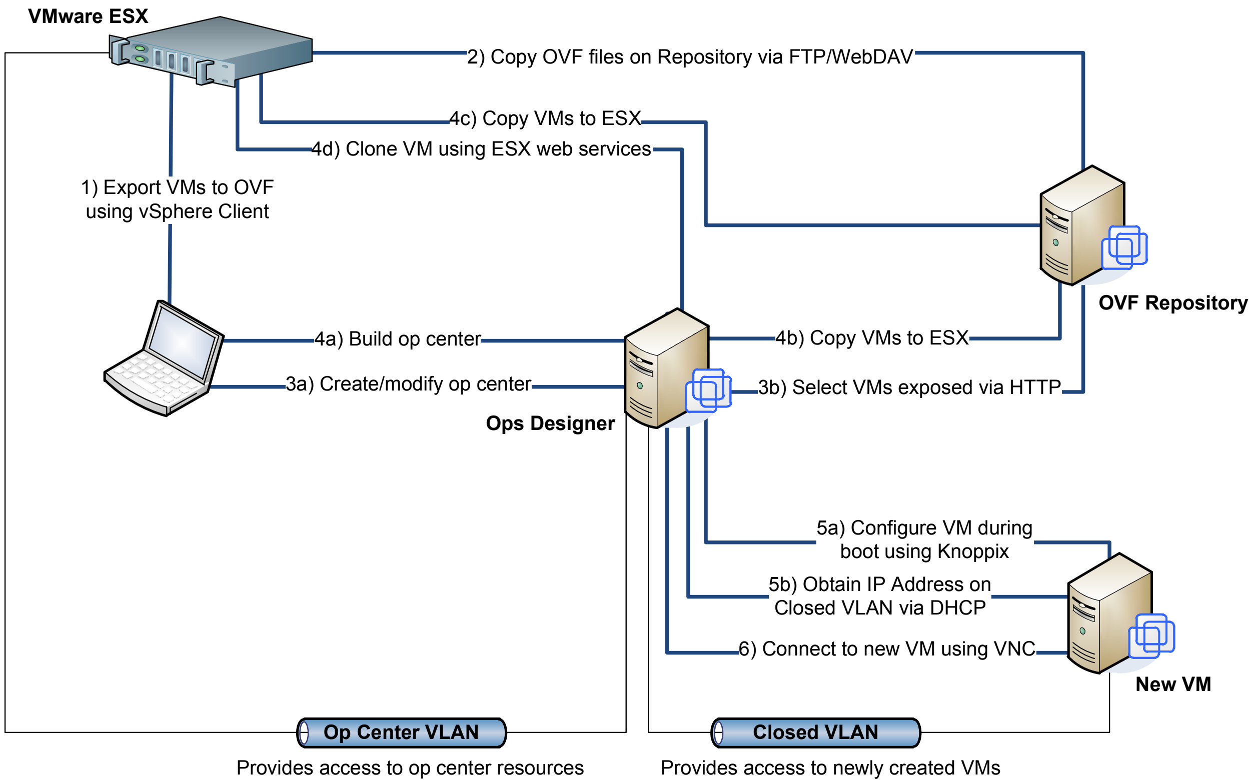


Figure 9 Ops Designer system components

The OVF Repository may be local as shown in the diagram above or remote. Multiple repositories may be configured to provide a large variety of VMs or to allow quick addition of new capabilities to the system. For example, if a coalition partner shows up with their own systems, these can be exposed as a new repository for inclusion in the overall set of capabilities. For the COC initiative, there are OVF repositories providing VMs from MITRE Marines and Air Force with Navy and Army to follow in FY 11.

The largest performance bottleneck when creating ops centers is copying the VM files from OVF repositories to ESX prior to cloning. In most cases, the VMs should be stored on the LAN and allocated sufficient network resources to efficiently move large files, numbering in the gigabytes, between the repository and virtualization server. Additionally, steps can be taken to reduce the amount of disk space taken up by a VM, such as using thin provisioning or reducing the unused storage bytes allocated to a disk.

Other approaches besides traditional file transfers protocols (i.e., FTP, HTTP) should be investigated for moving large files. For example, peer-to-peer networking technologies may be more appropriate to transfer large files between various ops center to increase performance and reliability. As more ops centers share VMs through OVF repositories, the number of peers available to download the VMs from increases. The increased peers provide more download sources to grab slices of a VM file using a protocol like BitTorrent. The COC effort plans to investigate various technologies to improve the sharing of VMs across the network.

From the user perspective, Ops Designer is a web page that provides simple to follow workflow for configuring the VMs that comprise an ops center. But under the covers, Ops Designer is part of a larger architecture which is providing many capabilities that are the foundation of a composable infrastructure.

3.3.2 CCOD® Authoring Tool

The CAT is a web-based mashup environment for a user to compose ops center mission capabilities. Through an intuitive drag-and-drop interface, multiple data feeds are added to core components (i.e., maps, data grids, detailed viewer). The core components are anchored to panes as shown in Figure 10. A data feed is linked between the components in the panes. For example, selecting a GeoRSS item on the map highlights the same item on the data grid.

Multiple feeds can be aggregated on a map similar to the KML, Google Earth example discussed in Section 2. Unlike Google Earth, CAT handles multiple formats (i.e., KML, GeoRSS, Cursor-on-Target, UCore). Since CAT processes the feeds in JavaScript, large and complex feeds can take a long time to load. The current prototype limits the number of items processed in the feed to reduce the load time.

Figure 10 CAT screenshot

CAT is not limited to processing data feeds; other web-based components can be leveraged, such as chat. CAT provides the ability to "dock" an eXtensible Messaging and Presence Protocol (XMPP) client (SparkWeb in the prototype) for chatting with other XMPP-based clients. As long as the component can be embedded in a webpage, CAT should be able to leverage it. One caveat to consider is that some web components require Internet access (e.g., Google Maps). In the case of disconnected operations, other components that provide the same functionality as the Internet-based component are being investigated (e.g., OpenLayers map).

A key feature of CAT is the ability to save the mashup application's configuration to share with others. A saved app is stored in the SimpleC2 Marketplace as an XML document as shown in Figure 11. The data feeds and location of components are saved to quickly be reconstituted using the "Create Component" button.

Another key feature of CAT is the ability of the tool to automatically connect the visual components that are using the same data feed. For instance, in the screenshot in Figure 10, if the user were to click a row in the spreadsheet widget, the map view would automatically zoom in and display information on the map marker which corresponds to the clicked item in the spreadsheet.


```
  - <restFeed id="Filtered Sample Marine Traffic">
    - <read remURI="%2FProxyServlet%3FxslURL%3Dhttp%3A%2F%2Flocalhost%3A8080%2FCAT%2Fdata%
        2Ftransforms%2FgeoFilter.xslt%26minLat%3D50%26maxLat%3D51%26url%3Dhttp%3A%2F%
        2Flocalhost%3A8080%2FCAT%2Fdata%2Fdoc.kml" polling_frequency="0" responseFormat="xml"
        format="kml" updateMode="1" method="GET">
        <elementsSubset />
      </read>
    </restFeed>
  </model>
- <view>
  - <centerPosition>
    - <widget id="org.mitre.ccod.GMapPanel3" remURL="" title="Google Map v3">
        <feed id="Reuters Top News" remURL="%2FProxyServlet%3Furl%3Dhttp%3A%2F%
          2Fws.geonames.org%2FrssToGeoRSS%3FfeedUrl%3Dhttp%3A%2F%2Ffeeds.reuters.com%
          2Freuters%2FworldNews" />
        <feed id="Army Front Page News" remURL="%2FProxyServlet%3Furl%3Dhttp%3A%2F%
          2Fws.geonames.org%2FrssToGeoRSS%3FfeedUrl%3Dhttp%3A%2F%2Fwww.army.mil%2Frss%
          2Ffeeds%2Ffrontpage.xml" />
        <feed id="US Doppler Radar" remURL="%2FProxyServlet%3Furl%3Dhttp%3A%2F%2Fearthnc.com%
          2Fkml%2FNexrad-nl.kmz" />
        <feed id="Sample Marine Traffic" remURL="%2FProxyServlet%3Furl%3Dhttp%3A%2F%2Flocalhost%
          3A8080%2FCAT%2Fdata%2Fdoc.kml" />
        <feed id="Live Buoy Conditions" remURL="%2FProxyServlet%3Furl%3Dhttp%3A%2F%
          2Fwww.ndbc.noaa.gov%2Fkml%2Fmarineobs_as_kml.php%3Fsort%3Downer" />
        <feed id="Filtered Sample Marine Traffic" remURL="%2FProxyServlet%3FxslURL%3Dhttp%3A%2F%
          2Flocalhost%3A8080%2FCAT%2Fdata%2Ftransforms%2FgeoFilter.xslt%26minLat%3D50%
          26maxLat%3D51%26url%3Dhttp%3A%2F%2Flocalhost%3A8080%2FCAT%2Fdata%2Fdoc.kml" />
      </widget>
    </centerPosition>
  - <eastPosition>
      <widget id="org.mitre.ccod.ChatPanel" remURL="" title="Chat" />
    </eastPosition>
  - <southPosition>
    - <widget id="org.mitre.ccod.GridPanel" remURL="" title="Data Grid">
        <feed id="Live Buoy Conditions" remURL="%2FProxyServlet%3Furl%3Dhttp%3A%2F%
          2Fwww.ndbc.noaa.gov%2Fkml%2Fmarineobs_as_kml.php%3Fsort%3Downer" />
      </widget>
    </southPosition>
  </view>
```


Figure 11 CAT app saved in XML

3.3.3 SimpleC2

SimpleC2 provides a web-based registry of resources: applications, data feeds and widgets. For COC, SimpleC2 is one place where CAT can save application configurations. The vision is that SimpleC2 provides the local app store at each ops center with SimpleC2 instances searchable across ops centers. Figure 12 provides a screenshot of SimpleC2.

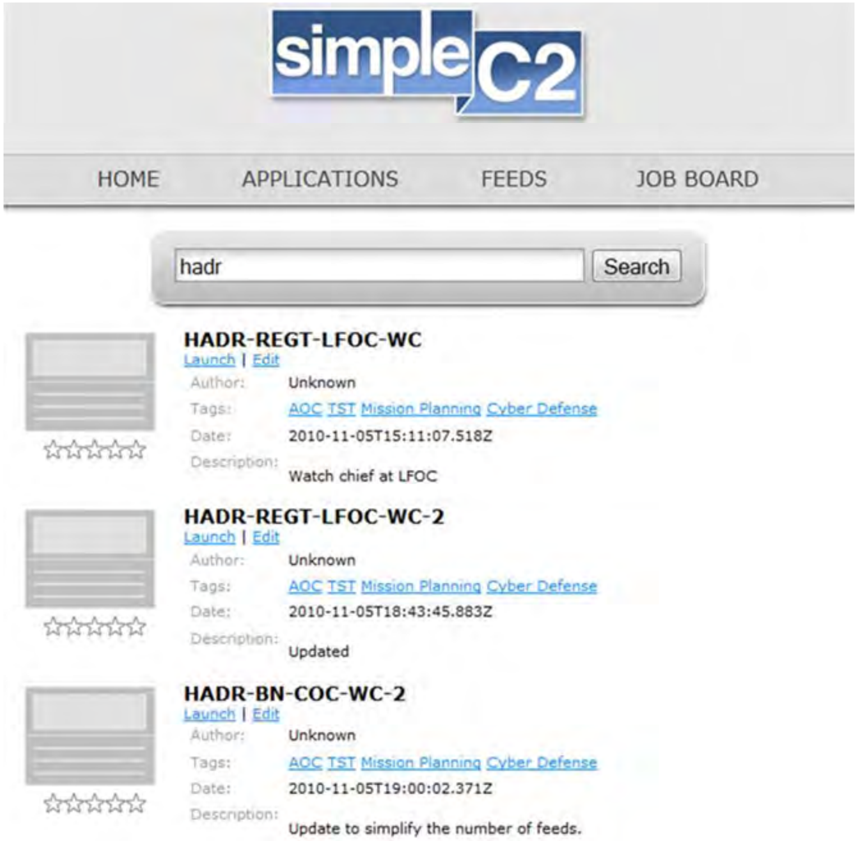


Figure 12 SimpleC2 screenshot

4 Compose an Operations Center in Minutes

Over the last year, COC has been demonstrated at MITRE Bedford, Quantico and San Diego. Most demonstrations leveraged the same Humanitarian Aid and Disaster Relief (HADR) scenario based loosely on the Haiti earthquake disaster of January 2010. The scenario serves as a backdrop to provide operational relevance for the demonstrations. The expectation is the same tools and information flows would be part of other scenario demonstrations.

In support of the HADR scenario mission, an Expeditionary Strike Group (ESG) is dispatched to the vicinity of the disaster with elements of a Marine Corps Light Armored Recon (LAR) Battalion (BN) afloat. The LAR BN's mission is to conduct security and reconnaissance operations ashore in support of the ESG as needed. This context demonstrates the traditional command structure with a Numbered Fleet Headquarters (HQ) directing ESG operations from a Maritime Operations Center (MOC) located home station in the Continental United States (CONUS), a Landing Force Operations Center (LFOC) afloat, and a LAR BN Combat Operations Center ashore. COC capabilities are demonstrated at the LFOC as the thread shows in Figure 13.

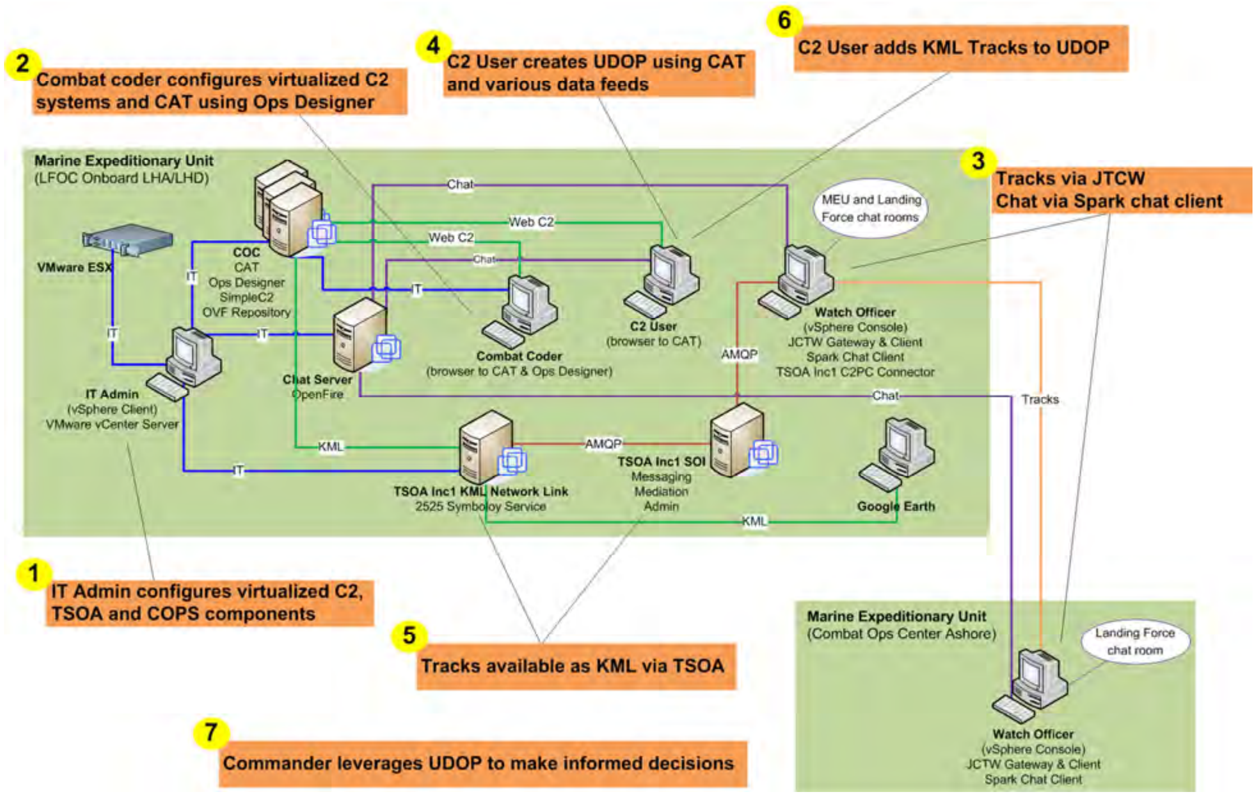


Figure 13 Demonstration thread

The demonstration thread illustrates the use of traditional C2 information sources (JTCW and chat), a Tactical Service Oriented Architecture (TSOA)[7], augmented by non-traditional information sources (data feeds). Depending on the operations, the data feeds consumed by CAT varies.

It is important to note that step #1, the IT administrator's configuration of the virtualized C2, TSOA and COC components, is a precursor to a composable ops center. While the initial establishment of the virtualization infrastructure and converting C2 systems to VMs takes hours to days, once the virtualization infrastructures is established and the VMs created and initially configured; these VMs can be cloned and reconfigured in minutes.

During a mashup event at MITRE Quantico on 14 October 2010, the MITRE team was able to establish a simple ops center as shown in the demonstration thread in about 45 minutes.[8] The following seven VMs were powered up, configured and ready for use:

- MAGTF Command and Control System Applications (MC2SA) Increment 1 (Inc1) TSOA running on Red Hat Linux leveraging JBoss community edition components.
- TSOA Inc1 KML Network Link to share JTCW tracks via KML.
- Two JTCW Gateway and Client with Spark chat client and TSOA Inc1 Command and Control Personal Computer (C2PC) Connector (enable publishing tracks to TSOA) to represent Regiment and Battalion level C2 capability.
- OpenFire chat server running on Windows XP.

[7] TSOA Increment 1 (Inc1) software suite is from Marine Corps Systems Command Product Group 11 Marine Corps Air Ground Task Force C2 Systems Applications (MC2SA) program.
[8] KML Network Link consumption by CAT is still a work in progress (steps #6 and #7) as Google Maps has issues consuming complex KML feeds.

- CAT and Ops Designer running on Kubuntu Linux.
- SimpleC2 running on Ubuntu Linux.
- OVF Repository running on Ubuntu Linux.

5 Engage Potential Early Adopters

As illustrated by the demonstration thread in the previous section, the Marine Corps is considered a potential early adopter of COC. The expected deployment environment is the Combat Operations Center which shares more than just the COC abbreviation. The Marines Combat Ops Center uses the same VMware infrastructure as COC. Also, the MITRE Quantico engineers that participate in the COC initiative are actively engaged in the software architecture, design and prototyping of the TSOA. The TSOA is expected to integrate into the Combat Ops Center in late 2011. Demonstrations have been ongoing at MITRE Quantico since September 2010 of both COC and TSOA.

To test the feasibility of COC in a deployed environment, a fly-away kit is being configured at MITRE Quantico as shown to the right in Figure 14.

The fly-away kit provides insight into the size, weight and power aspects of a mobile COC. The fly-away kit consists of the components shown in Table 1 housed in a hardened 11U transit case.

Figure 14 COC fly-away kit

Table 1 COC fly-away kit

Component	Description	Size	Power
KVM	TRIPP-LITE 8-port console	1U	100 VA
Network	Dell PowerConnect 5424 24 port GbE switch	1U	180 VA
Virtualization server	Dell PowerEdge R715 2x8 core AMD Opteron 6136 2.4 GHz (38400 MHz), 32 GB RAM, 8 GbE NICs	2U	800 VA
Virtualization server	Dell PowerEdge R415 2x6 core AMD Opteron 4176 2.4 GHz (28800 MHz), 32 GB RAM, 6 GbE NICs	1U	700 VA
Storage	Aberdeen XDAS iS1002 12TB SATA iSCSI SAN	2U	600 VA
Power supply[9]	Liebert GTX 1500 x2 (1500 VA capacity)	4U	
Total	**Compute=70320 MHz, Memory=64 GB, Storage=12 TB, Network=14000 Mbps**	**11U**	**2380 VA**

By engaging in detailed, hands-on research and prototyping, MITRE is in a position to provide objective and informed advice to our sponsors regarding the technology transition of COC.

[9] If the fly-away kit operated at full load, the 1500 VA Liebert power supply would not be sufficient. The plan is to replace with 2 2U power supplies capable of supporting 3000 VA.

6 Observations

This section provides observations gained during the execution of the FY 10 COC initiative.

6.1 Virtualization Performance

For COC work at MITRE Quantico, the ESX 4.0 server is run on a Dell PowerEdge R710 2x4 core Intel Xeon X5570 2.93 GHz with 48 GB of Random Access Memory (RAM) and 4 GbE network cards as shown in Figure 15.

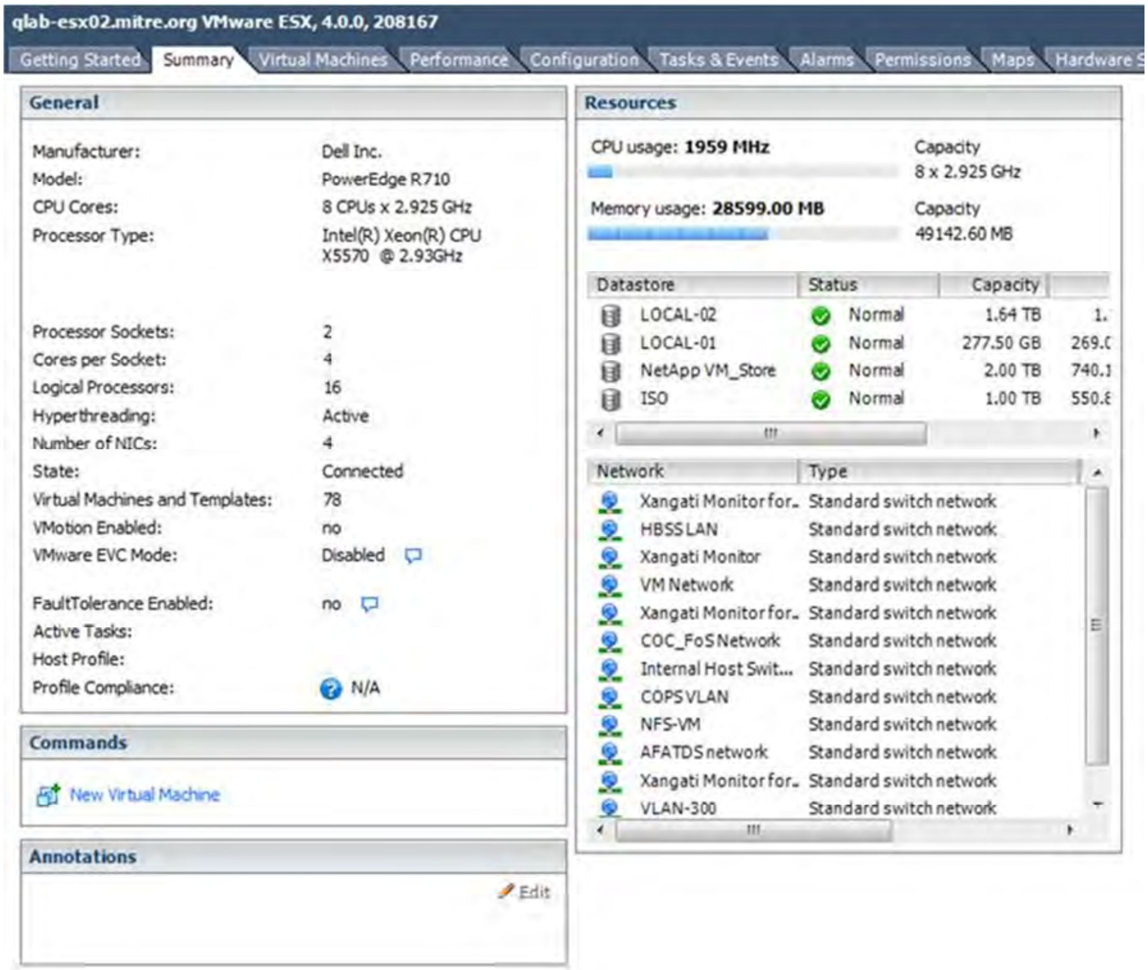


Figure 15 COC virtualization server at MITRE Quantico

The COC team fluctuated between 1-4 simultaneous users, with various periods of activity. The server was shared with other MITRE projects which increased the simultaneous user load up to 10 users. The number of simultaneous VMs running was from 10 to 30. Figure 16 shows the compute, memory and network performance over a 30 day period (5 October to 4 November 2010). Note the big spike in usage in mid-October as the team integrated with TSOA and had multiple demonstration events. Compute performance peaked around 20 October 2010 at 8,000 MHz, which is ~35% of the servers total Central Processing Unit (CPU).[10] Memory also peaked during the same period reaching close to 90% of the available RAM.

[10] 8 cores x 2.925 GHz = 23,400 MHz; 8,000/23,400 = 0.342.

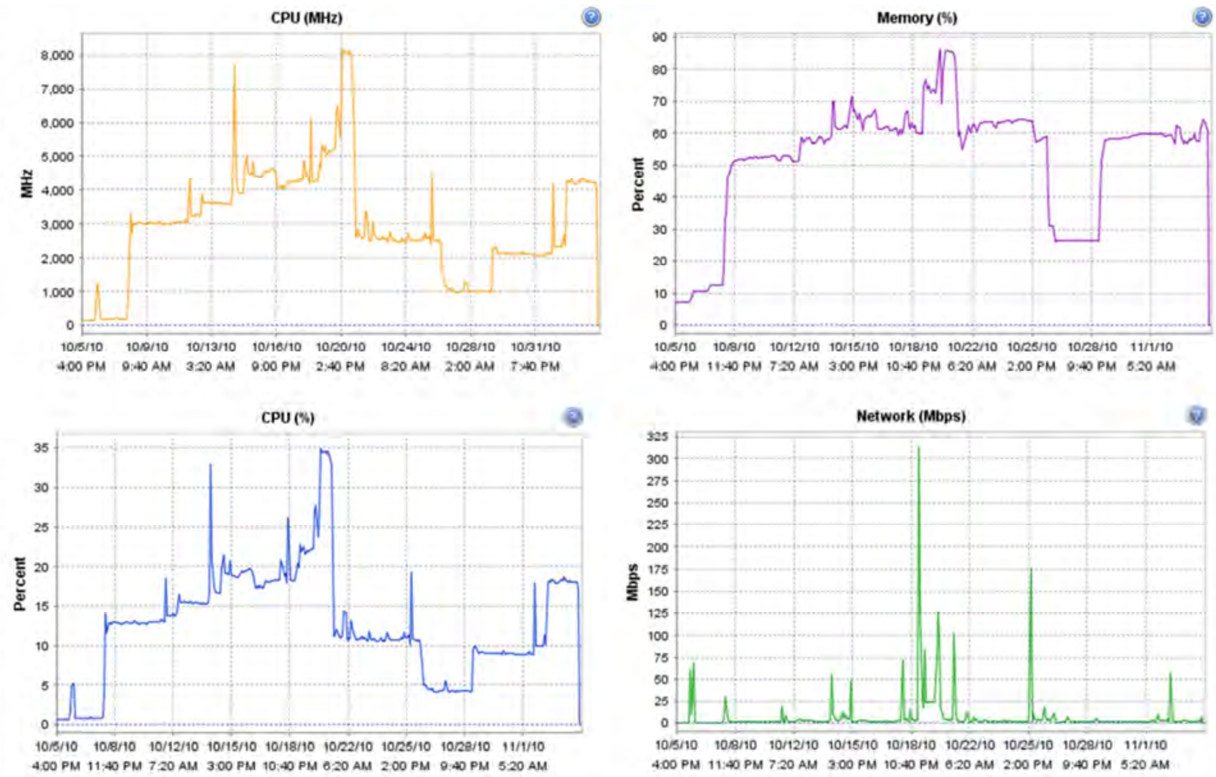
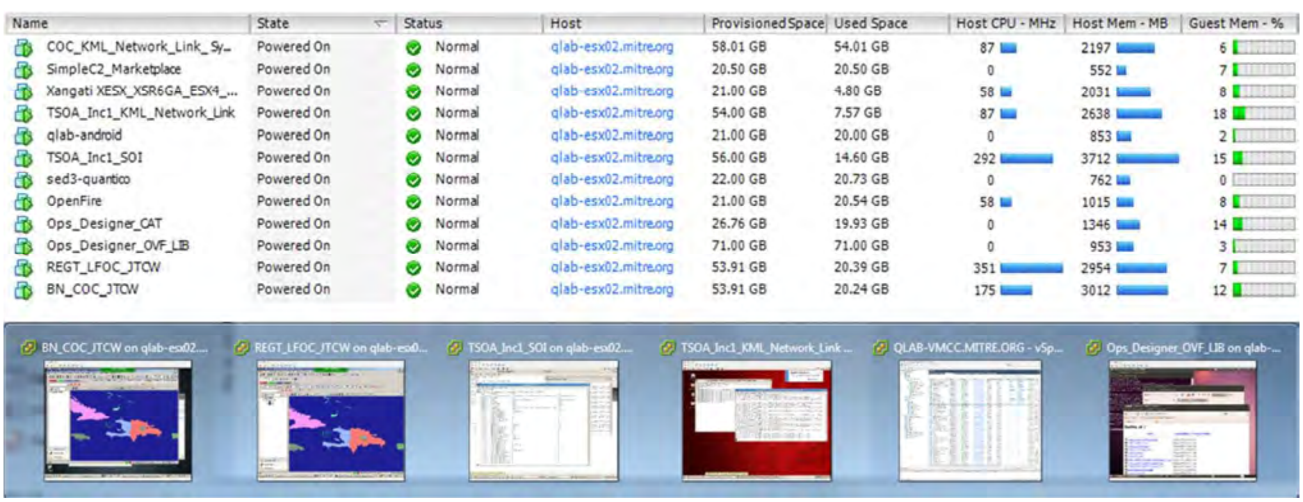


Figure 16 COC virtualization performance

Figure 17 provides more fidelity of compute, memory and storage usage during COC demonstration preparation. Eight of the twelve powered on VMs are COC related. These are the same VMs as the demonstration thread discussed previously. The total storage used by the COC VMs is 194.77 GB, which is much less than the 357.08 GB provisioned for the VMs. Based on how the storage for the specific VM is configured during the VM creation, all the storage may be allocated or only a portion allocated. Thick provisioning allocates (uses) all the memory that is provisioned to the VM. Thin provisioning dynamically adjusts the storage based on the needs of the VM.



Name	State	Status	Host	Provisioned Space	Used Space	Host CPU - MHz	Host Mem - MB	Guest Mem - %
COC_KML_Network_Link_Sy...	Powered On	Normal	qlab-esx02.mitre.org	58.01 GB	54.01 GB	87	2197	6
SimpleC2_Marketplace	Powered On	Normal	qlab-esx02.mitre.org	20.50 GB	20.50 GB	0	552	7
Xangati XESX_XSR6GA_ESX4_...	Powered On	Normal	qlab-esx02.mitre.org	21.00 GB	4.80 GB	58	2031	8
TSOA_Inc1_KML_Network_Link	Powered On	Normal	qlab-esx02.mitre.org	54.00 GB	7.57 GB	87	2638	18
qlab-android	Powered On	Normal	qlab-esx02.mitre.org	21.00 GB	20.00 GB	0	853	2
TSOA_Inc1_SOI	Powered On	Normal	qlab-esx02.mitre.org	56.00 GB	14.60 GB	292	3712	15
sed3-quantico	Powered On	Normal	qlab-esx02.mitre.org	22.00 GB	20.73 GB	0	762	0
OpenFire	Powered On	Normal	qlab-esx02.mitre.org	21.00 GB	20.54 GB	58	1015	8
Ops_Designer_CAT	Powered On	Normal	qlab-esx02.mitre.org	26.76 GB	19.93 GB	0	1346	14
Ops_Designer_OVF_LIB	Powered On	Normal	qlab-esx02.mitre.org	71.00 GB	71.00 GB	0	953	3
REGT_LFOC_JTCW	Powered On	Normal	qlab-esx02.mitre.org	53.91 GB	20.39 GB	351	2954	7
BN_COC_JTCW	Powered On	Normal	qlab-esx02.mitre.org	53.91 GB	20.24 GB	175	3012	12

Figure 17 Powered on guests

The total storage available to the virtualization environment is shown in Figure 18. While MITRE Quantico has a 12 Terabyte (TB) NetApp device, only 2 TB are currently allocated for use by VMware. Also, depending on the type of Redundant Array of Independent Disks (RAID) employed, the total available storage can quickly be reduced. Since MITRE Quantico is using RAID-5 and creating snapshots for backups on the NetApp device, about 6 TB is actually available for use. The other storage sources are local disks physically installed in the ESX servers ("LOCAL" listed in the figure below).

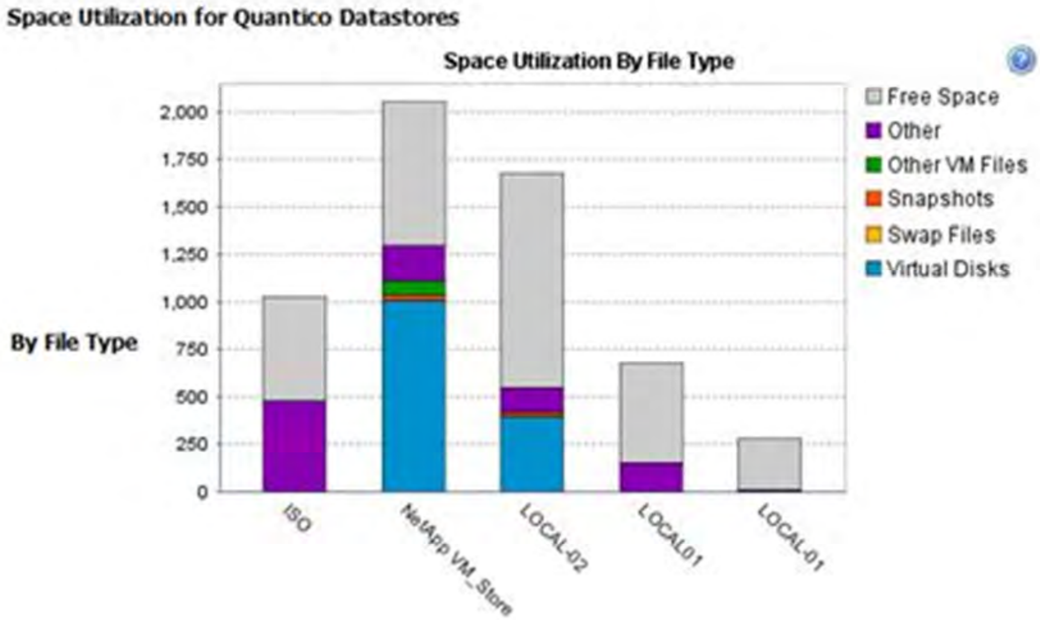


Figure 18 COC storage

Most virtualization environments employ clusters of multiple servers. The MITRE Quantico lab currently has two virtualization servers similar to the servers listed in the fly-away kit table. While a specific VM cannot be split across the multiple servers, the capacity is available to share among the VMs. For example, if one ESX server is near full utilization, the other ESX server would host new VMs. VMware advertises the ability to move live VMs between servers with no perceived performance impact to live users using vMotion. MITRE plans to investigate vMotion's capabilities in future analyses. vMotion would greatly increase the network utilization which is why multiple dedicated physical network cards and a sound storage approach is crucial. Also, as discussed in the Ops Designer section, locating VM files on the same LAN is important as copying large VM files across a Wide Area Network (WAN) is a performance bottleneck during VM cloning.

The MITRE Quantico cluster's compute and memory performance for the month of October is shown in Figure 19. The first row of charts shows the usage compared to the aggregate capacity. Notice that the CPU upper limit is 35,000 MHz and the memory 60 GB. The increased capacity is due to the server qlab-esx01.mitre.org (Dell PowerEdge R410). The second row of charts shows the usage of each server. As can be seen, most the activity is due to COC VMs on qlab-esx02.mitre.org (Dell PowerEdge R710).

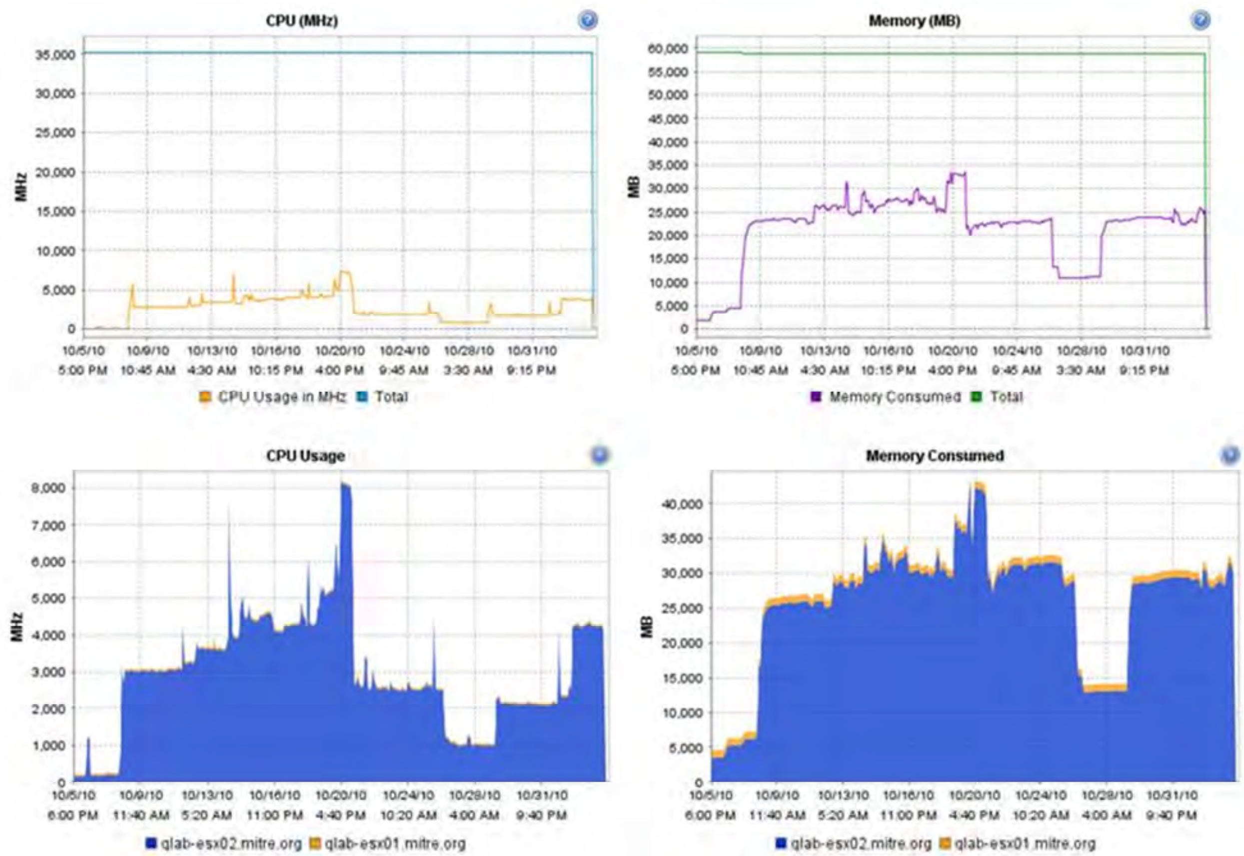


Figure 19 Virtualization cluster

The main observation from this high level performance analysis is resources are quickly consumed, especially memory. As virtualization is pursued, clustering should be considered along with appropriate redundancy measures. Clustering and redundancy increase complexity which virtualization environments, such as VMware, abstract to some extent. It is important to consider compute, memory, storage and networking as resources that will be aggregated in various ways in the operational environment and plan accordingly.

6.2 IP Address and Host Name

The Quantico lab and demo room are under the umbrella of the MITRE corporate network domain. As virtual machines were cloned, the machine names had to be changed to avoid conflicts with MAC addresses registered in the MITRE network to support IP address assignment (DHCP) and host name resolution (DNS). While cloning of VMs seems simple, the network configurations still require forethought to avoid network domain issues.

6.3 Web-based Tools

Using Google Earth as the benchmark for rendering KML, the web-based CAT tool using Google Maps had difficulty rendering large and complex KML feeds. CAT uses JavaScript for the rendering which can cause the browser to hang. For example, CAT had difficulty rendering KML from MarineTraffic.com. Also, the CAT tool currently lacks authentication functionality, thus restricting it from accessing feeds that require credentials for access. Google Maps and Earth plug-in require authentication with Google over the Internet. Therefore, a network that is disconnected from the Internet poses problems. The web-based tools simplify the user's experience but come with limitations that need to be considered. In many cases, the web-based tools will complement the client/server infrastructure tools.

6.4 Virtual Machine Management

VMware's vCenter Server is essential for managing groups of users accessing the same vSphere cluster. The convenience of creating a computer with a few clicks of a button creates the problem of VM sprawl. Because it's so easy to create virtual machines, users frequently create them without consideration for the management life cycle. To prevent VM sprawl, or, at a minimum, deal with the inevitable resource constraints, the COC team employed the following management techniques.

(1) Virtual machines should be explicitly labeled with an owner and contact information. Using the annotations block under the VM summary helps keep others informed. Attributes (e.g., username, password, email address) should be created for the annotations to provide consistent information across VMs.

(2) User groups (Windows or Active Directory) should be created and specific permissions assigned to the group in vCenter as shown in Figure 20. In the figure, the "COPS" group is a Windows group that contains the users associated with the COC work.[11] There are several specific users in the list as well, which are the overall administrators of vCenter. In the future, MITRE Quantico may remove the individual users and leverage groups for all permissions.

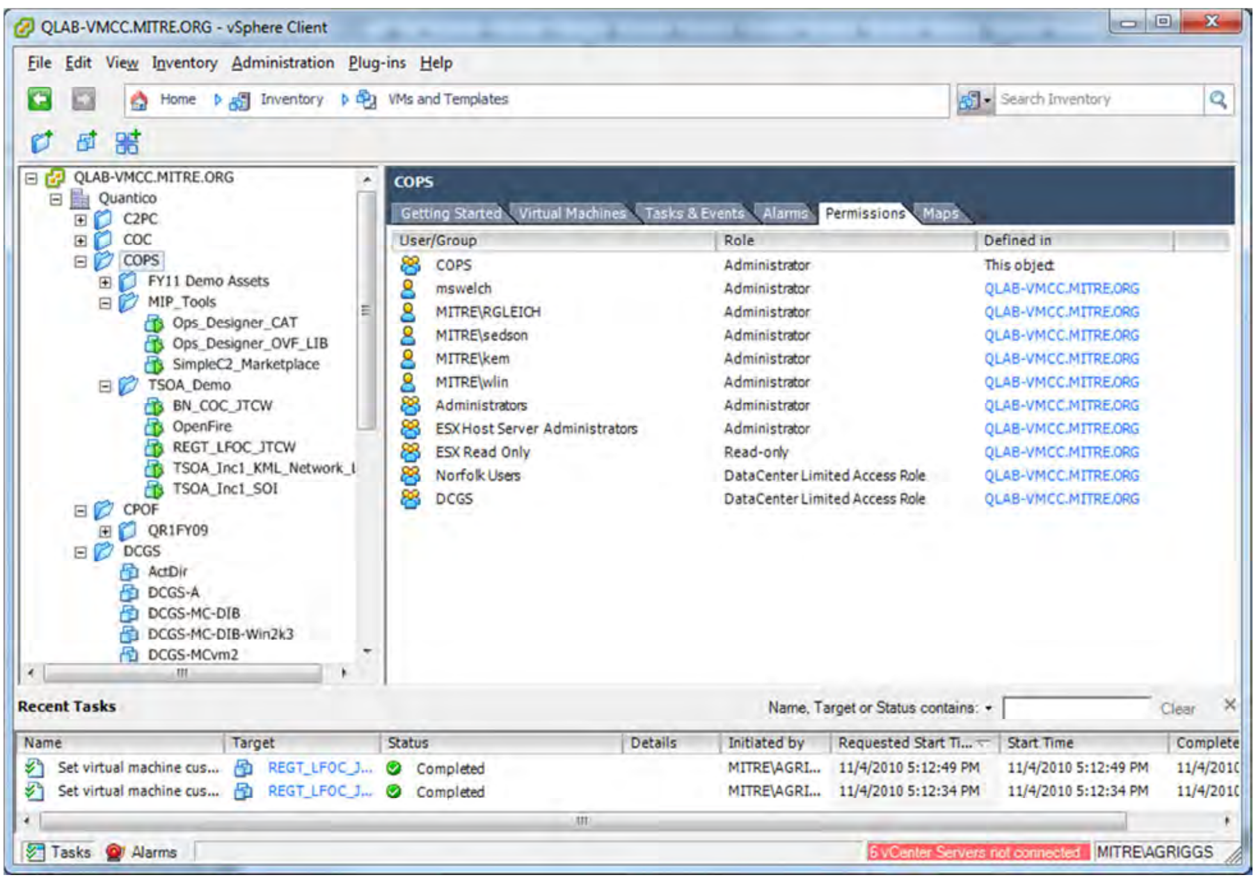


Figure 20 COC users are admins of COC VMs

[11] COPS used to be the acronym for Composable Ops Center.

(3) vCenter's folders feature should be used to separate assets for different groups. For COC, the folder structure provides a convenient way to group the VMs associated with the COC work. From the previous figure, the COPS group is "Administrator" of the COPS folder. Note the COPS group in Figure 21 is not assigned the Administrator role for the Quantico cluster. Folders are a good way to segment the user communities.

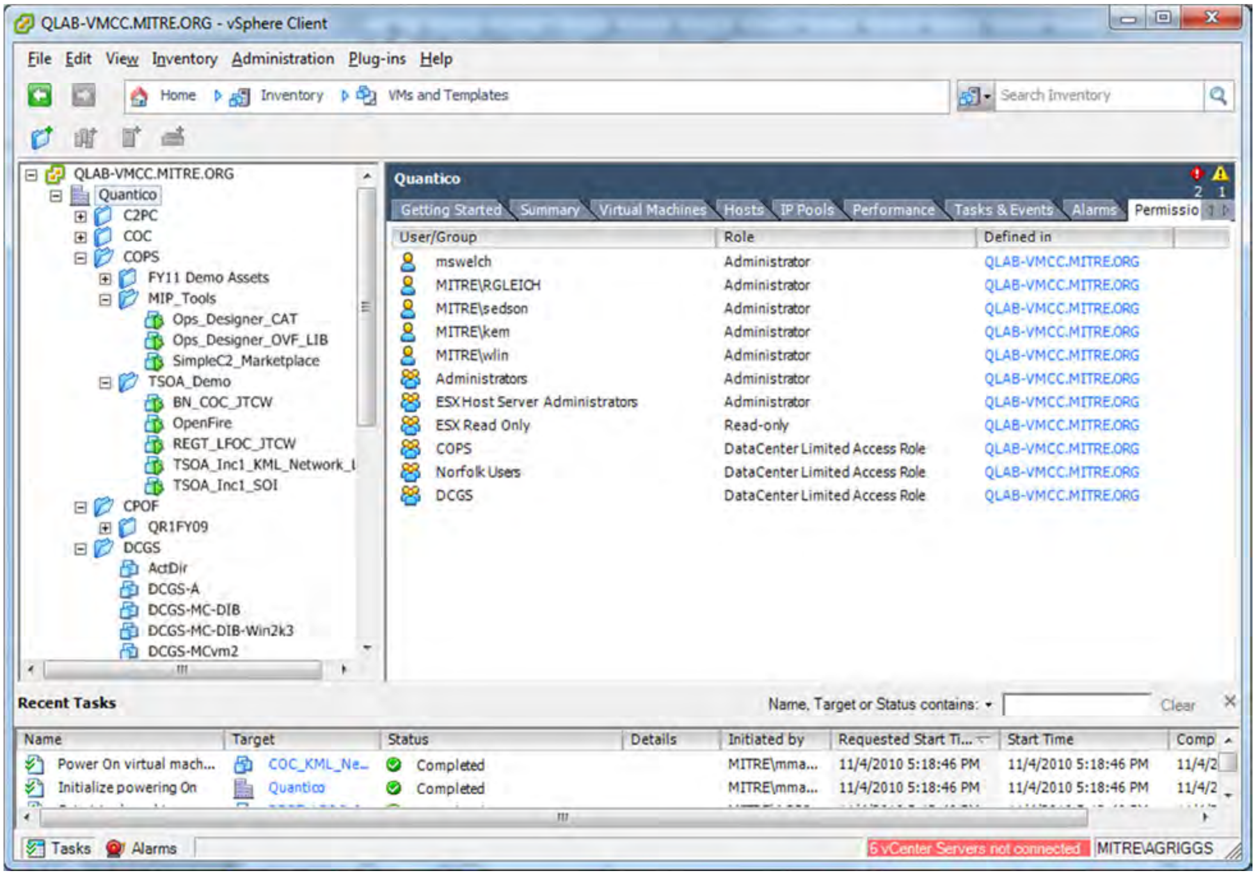


Figure 21 COC users are not admins of the cluster

7 Conclusion

During FY 10, MITRE established the COC initiative to promote common approaches for hosting and rapidly composing operations centers. FY 10 established the MITRE-wide team, multiple virtualized infrastructures, composable capabilities prototypes and initial integration with C2 systems. This report discussed MITRE Naval Division's exploration and observations through November 2010 into the COC's four goals.

Goal one of information flows with unanticipated participants illustrated the use of standards-based, simple message and data formats. The ubiquitous nature of the simple to use formats has resulted in many tools that enable data fusion and the rise of prosumers that both produce and consume data. The second goal of rapidly constituting essential computing resources focused on virtualization as the foundation of a composable ops center. Virtualization provides configurable compute, memory, storage and network resources that can be dynamically adjusted in a matter of minutes, thus adapting to the mission's needs. Several MITRE proof-of-concept tools were discussed that automate the creation and management of ops centers, provide web-based mashup environment to compose mission capabilities and an app store to share the composed capabilities. Leveraging the capabilities of the first two goals, goal three composed an ops center measured in minutes during an October mashup event integrating the evolving Marine Corps TSOA to support consuming data from C2 systems. The fourth goal of engagement with potential early adopters built on goal three focused on mobile ops with a COC fly-away kit. The report concluded with observations of virtualization performance, network configurations, limitation of web-based tools and VM management.

The first year of the COC effort focused mainly on the technologies that enable composability. Going forward, MITRE plans to continue investigation into the technologies and expand to additional sponsor communities. Over the next two years, the COC initiative will define a framework so that components of the ops center can be defined, built, managed, and shared separately from the core technologies. The framework should help in the acquisition of capabilities that can adapt to the mission needs and support on-demand data fusion.

Appendix A Acronym List

API	Application Programming Interface
BN	Battalion
C2	Command and Control
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CAT	CCOD® Authoring Tool
CCOD®	Composable Capability on Demand
COC	Composable Operations Center
CONUS	Continental United States
CPU	Central Processing Unit
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name System
DoD	Department of Defense
ESG	Expeditionary Strike Group
FY	Fiscal Year
GB	GigaByte
GbE	Gigabit Ethernet
GeoRSS	Geo Really Simple Syndication
GUI	Graphical User Interface
HADR	Humanitarian Aid and Disaster Relief
HQ	Headquarters
HTTP	Hypertext Transfer Protocol
HW	Hardware
IP	Internet Protocol
IT	Information Technology
JTCW	Joint Tactical Common Operational Picture Workstation
KML	Keyhole Markup Language
LAN	Local Area Network
LAR	Light Armored Recon
LFOC	Landing Force Operations Center
MAGTF	Marine Air Ground Task Force
MB	MegaByte
MC2SA	MAGTF Command and Control System Applications

MHz	MegaHertz
MIP	MITRE Innovation Program
MOC	Maritime Operations Center
OS	Operating System
OVF	Open Virtualization Format
RAID	Redundant Array of Independent Disks
RAM	Random Access Memory
REGT	Regiment
SAGE	Situational Awareness Geospatial Enterprise
SAN	Storage Area Network
SOA	Service Oriented Architecture
STOM	Ship-to-Objective Maneuver
SW	Software
TB	TeraByte
TSOA	Tactical Service Oriented Architecture
VLAN	Virtual Local Area Network
VM	Virtual Machine
WAN	Wide Area Network
XML	eXtensible Markup Language
XMPP	eXtensible Messaging and Presence Protocol

