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Composeable FORCEnet Command and Control: The Key to Energizing the Global Information Grid to Enable Superior Decision Making

Topical Areas:

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Abstract

This paper will examine one of the most critical aspects of transforming information age concepts and technologies – how do we "think about the problem" of Joint command and control. Our research has shown that warfighters operating in a Global Information Grid (GIG) and FORCEnet-enabled environment must be able to *compose* the command and control elements at their disposal to ensure superior decision-making to enable the Joint Force Commander to achieve the *Joint Vision 2020* goal of Full Spectrum Dominance.

The key word in this construct it *composeable* and our thesis is that commanders must have the ability to *compose* a command and control architecture that meets their warfighting requirements from a broad array of multi-tiered networked sensors, dynamic bandwidth capabilities and tailorable visualization. This paper will show that in the naval context, this requires that we engineer FORCEnet, from the keel up, *not* as a set-piece bundle of fixed capabilities, but as a fungible toolbox of capabilities that the commander selects based on the operational mission he must accomplish – as well as a set of capabilities that fits seamlessly into the GIG. Composeable FORCEnet enables warfighters to make the superior decisions necessary to win in battle.

We will describe how Composeable FORCEnet unlocks the power of the GIG to fundamentally alter the way in which military decision makers view, manage and understand the information environment in a Joint *and* combined warfighting context. We will show how Composeable FORCEnet supports shared situational awareness across strategic, operational and tactical levels to enable superior decision-making.

We assert that Composeable FORCEnet has two primary goals. One goal is to deliver a "composeable" framework that enables the discovery and utilization of web-based services as well as to "plug-and-play" new hardware and software. Composing hardware, software and services, including sensors and weapons, communications, computing, applications, collaboration and human-computer interaction components, permits the creation of new functional capabilities that meet emergent warfighting requirements. With Composeable FORCEnet, because the framework is based on open, publicly distributed web services, specifications and standards, these new functional capabilities lead to the inherent ability to create new organizational structures and even permit the development of new and innovative tactics and doctrine without re-engineering the supporting systems.

The second Composeable FORCEnet goal is to provide mechanisms to transform information into knowledge in a manner that directly supports decision making at all levels of command in a Joint and combined warfighting environment. This is accomplished by providing customizable (composeable) geospatial, functional, and temporal views of an operational situation so that the full spectrum of warfighting plans,

issues, concerns, and status can be tailored, assimilated, and understood by the commanders and their battle watch staffs.

Composeable FORCEnet provides an information representation interface to the composeable framework that is based on a geo-spatial (i.e. map) metaphor and which can be collaboratively viewed and manipulated over a network. Composeable FORCEnet will permit a user to migrate seamlessly across geo-spatial, functional and temporal dimensions. To facilitate and guarantee web based military Command and Control, Composeable FORCEnet also includes a variety of tools and mechanisms to allow a commander to compose his communications and computing environment and fully exploit the power of the GIG.

Technically, Composeable FORCEnet represents a transformation away from building turnkey systems that require large investments in integration toward providing seamless, open, object-based architectures that permit "*composeable*" services, hardware, and applications. Composeable FORCEnet is technically aligned with the Network Centric Warfare (NCW) initiatives being undertaken by the Navy for SEAPOWER 21 - FORCEnet and Task Force Web - that will provide a new conceptual framework for distributing and sharing information, and eliminating information stovepipes. The design of Composable FORCEnet ensures compatibility with the emerging Global Information Grid.

Our research to date has shown that Composeable FORCEnet dramatically changes C4ISR operations by providing the means to achieve shared awareness through an intuitive, map-based operational picture where information from any source may be geo-referenced, and where all users can participate in collaborative sessions. Composeable FORCEnet provides tailorable human-centric interfaces as the FORCEnet construct and the GIG demands. The goal of Composeable FORCEnet is to make possible command and control constructs that are limited only by the operational and tactical imagination of the military commander.

Composeable FORCEnet Command and Control: The Key to Energizing the Global Information Grid to Enable Superior Decision Making

The major institutions of American National Security were designed in a different era to meet different requirements. All of them must be transformed.

President George W. Bush
National Security Strategy of the United States
September 20, 2002

When asked what single event was most helpful in developing the theory of relativity, Albert Einstein is reported to have answered, "Figuring out how to think about the problem."

Men, Women, Messages and Media:
Understanding Human Communication

Introduction:

One of the most critical aspects of transforming information age concepts and technologies is Joint C4ISR. For engineers, one of the greatest challenges is providing tools to the warfighter that meet their needs across the complex and demanding spectrum from warfighting to peacemaking. If engineers can provide a tool to the warfighter that enables that warfighter to compose the C4ISR capabilities needed at a particular place, at a particular time, to deal with a particular operational challenge, then the technical community will have demonstrated its ability to meet known and anticipated operational needs with effective technical solutions.

In the naval context, one of the key challenges for warfighters is networking the elements of Sea Power 21 and answering the question – how do warfighters operating in a FORCEnet-enabled environment *compose* the C4ISR elements at their disposal to ensure superior decision-making and enable the Joint Force Commander to achieve the *Joint Vision 2020* goal of Full Spectrum Dominance? In the naval context, this requires that FORCEnet is engineered from the keel up, *not* as a set-piece bundle of fixed systems, but as a fungible toolbox of capabilities that the commander selects based on the operational mission he must accomplish.

The lessons of Operation Enduring Freedom and Operation Iraqi Freedom indicate that United States military forces must operate jointly – and must operate in a combined manner with coalition partners – in order to achieve success. To achieve this, FORCEnet must be implemented within the Global Information Grid framework to ensure "Jointness" with the other military services. (England 2003) Beyond that, just how FORCEnet capabilities will be utilized in a concept of operations, how they will transform naval, joint and even coalition warfighting, and how they will impact the thinking, planning and operating of the warfighters themselves has not yet been examined to the degree necessary to instantiate a "final engineering architecture" for a robust, survivable system. Therefore, we believe that demonstrating an early instantiation of Composeable FORCEnet is important to enable DoD and DoN decision makers to fully appreciate "the art of the possible" regarding what Composeable FORCEnet can deliver to the operational commander.

The intent of Composeable FORCEnet is to fundamentally alter the way in which military decision makers view, manage, and understand the information environment. We will show how Composeable FORCEnet supports shared situational awareness across strategic, operational and tactical levels to enable superior decision-making. We will demonstrate how Composeable FORCEnet tools enable the warfighter to compose warfighting C4ISR constructs "on the fly" to build the right bundle of capabilities to deal with the current tactical and operational situation.

Composeable FORCEnet has two primary goals. One goal is to deliver a "composeable" framework that enables the discovery and utilization of web-based services and sources of web-enabled data (or information) as well as to "plug-and-play" new hardware and software. Composing data sources, hardware, software and services, including sensors and weapons, communications, computing, applications, collaboration and human-computer interaction components, permits the creation of new functional capabilities that meet emergent warfighting requirements. The framework for Composeable FORCEnet is based on open, public, distributed web services, specifications and standards. Thus, these new functional capabilities lead to the inherent ability to create new organizational structures and even permit the development of new and innovative tactics and doctrine without re-engineering supporting systems.

The second Composeable FORCEnet goal is to provide mechanisms to transform fused data of known pedigree into information and then into knowledge in a manner that directly supports decision making at all levels of command. This is accomplished through a customizable (composeable) geo-spatial, functional, and temporal views of an operational situation where the full spectrum of warfighting plans, issues, concerns, and status can be tailored, assimilated, and understood by commanders and their battle staffs.

If we succeed, FORCEnet will enable command and control constructs that are limited only by the operational and tactical imagination of the commander. Functionally, Composeable FORCEnet will provide a representation interface to the information framework that is centralized on a geo-spatial (i.e. map) metaphor and which can be collaboratively viewed and manipulated over a network. However, Composeable FORCEnet will permit a user to migrate seamlessly across the geo-spatial, functional and temporal dimensions. To facilitate web-based military C4ISR, Composeable FORCEnet also includes a variety of tools and mechanisms to allow a commander to compose his communications and computing environment.

Technically, Composeable FORCEnet represents a transformation away from building turnkey systems that require large investments in integration toward providing seamless, open, object-based architectures that permit "*composeable*" information services, hardware, and applications. Composeable FORCEnet is technically aligned with the Network Centric Warfare (NCW) initiatives being undertaken by the Navy for SEAPOWER 21 - FORCEnet and Task Force Web - that will provide a new conceptual framework for distributing and sharing information, and eliminating information stovepipes. (Clark 2002) It is also consistent with the standards, specifications and policies being developed to support the Task, Post, Process and Use (TPPU) paradigm articulated by ASD NII and DISA.

Our research to date has shown that Composeable FORCEnet has the potential to dramatically change C4ISR operations by providing the means to achieve shared situational awareness through a tailorable and intuitive human-computer interface. Composeable FORCEnet supports shared situational awareness across strategic, operational and tactical levels to enable decision-making that *vastly exceeds* that of any potential adversary.

Background:

This paper describes a concept for implementing the Navy's vision for FORCEnet. The concept has actually been taken to the level of a technical demonstration, based on a simulated scenario, which illustrates the capabilities that evolving web technologies provide when applied to naval warfighting. During the demonstration, the underlying conceptual framework is described, the functionality provided by web-based services and tools are shown, and this functionality is then applied to several operational missions in order to demonstrate the warfighting implications of the concepts.

There are two key concepts that are emphasized with Composeable FORCEnet. One is the concept of "composeability" by which we mean the ability to compose warfighting capabilities out of web-enabled information, web service and web tool components. Composing information, hardware, software and services, including sensing and weapons, communications, computing, applications, collaboration and human-computer interaction components based on the utilization of open, public distributed web services, specifications, and standards, lead to the inherent ability to rapidly create new military functionality on the fly as the operational and tactical situation dictates.

But we have a broader vision than composing simple military functionality at the task or application level. We believe that the ability to compose functionality at that level, if applied across the services, will permit an inherent interoperability that would allow organizational components to be "composed" in new ways and which could be accomplished far more quickly than ever before and far more quickly than is envisioned in even the most optimistic scenarios.

Taken to the next level, if functionality and organizations can be composed, then new tactics and doctrine can be composed to create new warfighting strategies more quickly than ever before. Composing functionality, organizations and tactics based upon inherently interoperable components further suggests that the paradigm has implications for the way in which capabilities can be acquired in the future. We believe that the drive towards increasing the speed with which new capability is delivered may be achieved through this approach.

The second concept derived from Composeable FORCEnet is an approach to translate information from many disparate sources into actionable knowledge at all tiers of command. This is accomplished by providing customizable (composeable) geo-spatial, functional, and temporal views of an operational situation so that the full spectrum of warfighting plans, issues, concerns, and status can be tailored, assimilated, and understood by the battle watch staffs and the commanders. The extent to which the concept can be migrated down to the individual unit or warfighter remains to be explored.

While we do not make any claims whatsoever with respect to advancing scientific rigor or theory in this area, we do attempt to employ technological advances to help warfighters manage their information, search for and store it, and tailor the interface to information to make the interaction with information more intuitive than ever before. Through these means, and the evolution of decision support techniques, we are moving towards providing users with the means to integrate and make sense of much more information much more easily and quickly.

The evolution of FORCEnet capabilities will create a substantial infrastructure to produce, share and consume information. Within such an environment where so much information will be created, the integration of information into useful knowledge will be more challenging than ever and more valuable than ever. Knowledge about where and when to apply power will be moved away from the center and more truly "to the edge" following the information age transformation precepts of the Department of Defense. (Alberts and Hayes 2003)

Current Composeable FORCEnet Capabilities:

Composeable FORCEnet can dramatically change C4ISR operations by providing the means to achieve shared awareness through an intuitive, map-based operational picture where information from any source may be geo-referenced, and all can participate in collaborative sessions. Composeable FORCEnet provides tailorable human-centric interfaces (in a task-oriented context) as the FORCEnet concept demands. It is, in fact, so flexible that additional research will be necessary to determine how best to balance tailorability versus standardization of the interface. Optimum flexibility and intuitiveness have the potential to substantially reduce training requirements while making more of its functionality knowable and readily accessible. The following are examples of the functionality currently being demonstrated.

1) Composeable FORCEnet supports the ability to represent multi-dimensional aspects of the operational picture using a geo-spatial reference or map environment – in other words, the map metaphor. This capability will provide decision-makers with an ability to interact with information in a familiar and intuitive map environment.

2) Beyond the standard geo-spatial information associated with maps and tracks in command and control applications, Composeable FORCEnet also includes representations of functional/warfare information, temporal information and readiness information essential to developing and maintaining complete situational awareness.

3) The geo-spatial representation in Composeable FORCEnet becomes the interface to all situation-related information. No longer will it be necessary to access data and information from stove-piped, disparate sources that must be displayed on unrelated and inconsistent visualizations.

4) With Composeable FORCEnet users can place any URL on a geographical location; overlay high-resolution maps and elevation data on locations of interest; and drag and drop data and documents (e.g. spreadsheets, MS Word, PowerPoint) onto the map. Warfighters can subscribe to both raw and fused data with geo-referenced information that will automatically be displayed on the map. If the data source automatically publishes updates (e.g. live track data or sensor reports), these will be updated on the map.

5) Composeable FORCEnet integrates searches of web content that can be linked to the map, or objects on the map, by the user and subsequently shared with other users.

6) Composeable FORCEnet provides a unique capability to support shared situational awareness through its ability to enable collaboration sessions via the net. Users share maps, geo-referenced objects and hyperlinks while Composeable FORCEnet provides them a comprehensive drawing capability. Collaborative warfighting and support teams can share and update information using the same, interactive and intuitive picture. Real-time interaction about the map, the overlays, and the objects coupled with the ability to annotate the map supports shared situational awareness the ability to execute with synchrony and precision.

7) Composeable FORCEnet permits any representation to be tailored by the users. Its intuitive and interactive interface, based on well-known metaphors such as web browsers, search tools and graphic user interfaces such as windows-icons-menus-pointers (WIMP), dramatically reduces training requirements.

8) Composeable FORCEnet provides operational users the capability to compose their communities of interest for specific warfighting functions and allocate assured bandwidth to the information needed by that community to perform their

function. It provides not only the ability to perform information management, but also the ability to maintain situational awareness on how the nets and circuits are being utilized and are performing.

9) Composeable FORCEnet provides operational users the capability to prioritize their information flows to ensure that higher priority traffic is sent before lower priority traffic thus ensuring that information latency issues are addressed in accordance with the Commander's intentions for information movement.

10) Composeable FORCEnet provides mechanisms to support automatic network switching in the event of communications degradations or failures of any FORCEnet communications links. This implies the ability to sense performance of the network and provide connectivity situational awareness to decision makers so that communications assets can be automatically or manually reallocated (recomposed) to meet mission needs.

Composeable FORCEnet Operational Concept

The technologies and techniques instantiated in a Composeable FORCEnet architecture are designed to enhance the dominance of U.S., Joint *and* coalition warfighting capabilities well into the 21st Century. Those capabilities that are generally recognized to be among the greatest force multipliers for Joint and combined forces are those capabilities that enable operators to:

1) Exploit every relevant source of information gathered through organic and especially through inorganic means;

2) Establish shared situational awareness and clear understanding among everyone engaged in an operation no matter where they are;

3) Establish a speed of command which forces any opponent to react to our moves rather than the reverse;

4) Permit the execution of any operation to be accomplished with a precision that minimizes collateral damage while maximizing effects at minimum cost;

5) Permit operations to be carried out at least equally effectively whether done synchronously or asynchronously, and either by co-located or distributed forces;

6) Operate flexibly and with agility, where flexibility is meant to permit extant capabilities to be effective for any mission against any enemy, and where agility is meant to permit rapid changes in plans and resource requirements.

As one example of the expansion in thinking that Composeable FORCEnet enables, the exploitation of every source of information does not relate solely to information produced by the Navy, or the Department of Defense, or even by a pre-defined database. This means, for example, that a doctoral thesis, written in Tagalog by a doctoral candidate at the University of the Philippines, can be searched out, translated, understood, and brought into the information environment of a mission if it is found to be relevant to the successful completion of the mission. All of those functions can be done either manually or automatically or through a combination of the two techniques. The goal is to provide the operational commander with nearly limitless possibilities.

Providing these kinds of capabilities to the warfighter has been the domain of the Composeable FORCEnet effort at the Space and Naval Warfare Command (SPAWAR) and SPAWAR Systems Center (SSC) San Diego. Composeable FORCEnet provides the capability to demonstrate and evaluate the operational meaning of FORCEnet to the warfighter. In the conventional military sense, the operational construct of Composeable FORCEnet provides the ability to conduct and coordinate Naval FORCE operations efficiently and effectively. This means:

1) A warfighter, or organization, can collaborate with anyone, anywhere, anytime

2) Warfighters can allocate bandwidth and priorities for applications and individuals

3) Warfighters define their own quality of service standards

4) Warfighters can get sensor coverage when and where they need it

5) Warfighters can tailor their information requirements and presentations to support their missions

6) Warfighters can put the right weapon on the right target with speed and precision

If these are examples of what Composeable FORCEnet means, then it suggests a beginning set of operational metrics on which the warfighting value of Composeable FORCEnet implementations can be measured. At this level of definition, it therefore begins to be possible to develop experiments around capabilities and CONOPS in order to measure how well Composeable FORCEnet meets warfighting requirements.

Several early instantiations of the Composeable FORCEnet concept have been tested during the FORCEnet Limited Objective Experiment (LOE) – and the FORCEnet Initial Prototype Demonstration (IPD) in the ESSEX Expeditionary Strike Group (Trident Warrior 03). Earlier initiatives in the CARL VINSON Battle Group validated other composeability concepts and were used extensively during Operation Enduring Freedom to coordinate naval and Joint operations. (Majeranowski 2003) Further experimentation and demonstrations in operational environments are planned. Additionally, experiments that examine the assertions about speed to capability, automation, fusion and changes in the acquisition process must be conducted at the earliest possible opportunity.

The examples above are only a few of the required capabilities identified by warfighting organizations and which Composeable FORCEnet will provide. There are other domains of naval needs beyond warfighting that Composeable FORCEnet can also support, each with their own set of issues and constraints that are part of the everyday life of FORCEnet in the United States Navy. Composeable FORCEnet can provide the backbone for, among other things; quality of life improvements, medical treatment, logistics management, training and education, innovation and experimentation and navigation.

These support areas, like those revolving around warfighting, also require experimentation and demonstration to define transformational approaches. If the assertions that Composeable FORCEnet can provide "fully interoperable composed organizations more quickly" is validated, it proffers a potential to transfer a significant number of personnel needed to perform these functions from frontline units. The idea is that through composeability, organizations can interoperate across the FORCEnet enabling them to support the front-line units who themselves are focused on conducting naval warfighting.

Delivering FORCEnet Warfighting Capabilities:

Development of modern warfighting systems has, by and large, built upon layers of technologies as shown in Figure 1. Most systems developments include every layer (although clearly there are some that do not incorporate a computer, some without a human-computer interface, and a number without collaboration capabilities). The building blocks shown in the figure have been relatively stable over many years, even though the technologies at each layer change, sometimes rapidly.

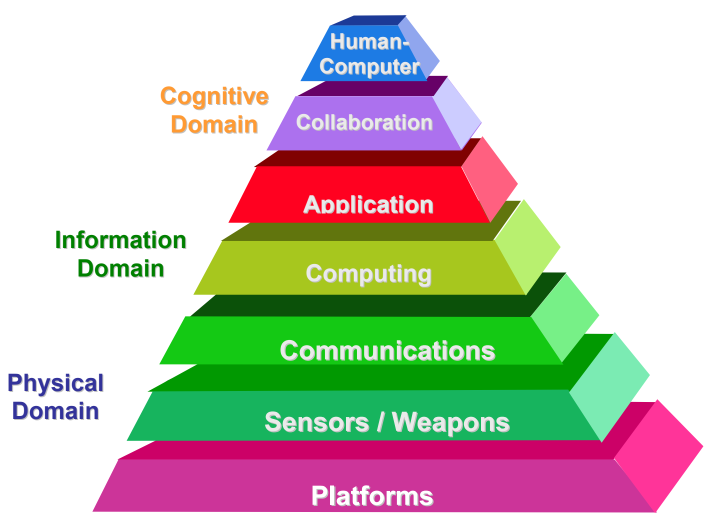

Figure 1 – The Technological Building Blocks of Modern Warfighting Systems.

As shown in Figure 1, warfighting systems generally rest on the foundation of a platform that provides mobility to move to, as well as within, the theater of operations. Platform technologies include submarine hull plating, stealth systems, naval architecture, propulsion systems, crew systems and many others.

Platforms carry a variety of sensors for developing a picture of the battlespace, often to create safe separation from it, to provide accurate targeting information, or to gain intelligence information, among other reasons. Sensor technologies have developed to increase standoff distances, to "map" the battlespace in different spectra, to increase the resolution of the "map" and to increase the sampling rate. Sensor technologies include the development of advanced sensors themselves, but even include advanced signal processing techniques and other related technology areas. Platforms also carry weapons for a variety of purposes, which themselves often carry sensors and which are integral to the warfighting operation and therefore need to interoperate in the same way as a weapon or sensor. Weapon technologies, apart from the warhead, need the same technology solutions as platforms and sensors.

Data from the platforms, sensors and weapons are shared over communications systems. The technologies that make this possible include antennas, waveform engineering, networking components and protocols, and multiplexing among others. In the naval context, this communication layer typically involves tactical data links.

Data that are shared over communication systems, whether long or short distances, or even internally to a system are now quite often mediated by a computer, which stores and remembers and performs programmed functions on them. We are reminded of how computer technologies have evolved over the past 40 years in terms of memory, storage capacity, chip speed, I/O, and architectures, etc. In addition, operating systems, and even the development of the browser could be included among the computing technologies.

Making use of data – ideally data whose pedigree is known - by translating it into information that's understandable to a user (in other words, that *informs*) requires the use of software applications. Technologies that have changed the nature of applications, besides the explosion in functionality and the move towards seamless interfaces between application segments, include such diverse areas as the programming languages, object oriented designs, agents, agent architectures and artificial intelligence methods, and even virtual machines.

Sharing information among users and between systems is made possible through the use of collaboration technologies. Collaboration is recognized as fundamental to distributed operations in that it permits people to maintain a shared awareness of relevant aspects of a situation and to develop common plans. These are relatively new and are just beginning to experience widespread use. They include technologies such as e-mail, video teleconferencing, groupware and chat, among others. Nevertheless, this is an area where an understanding of the principles of collaboration, let alone the application of those principles to system design and engineering, is still maturing.

Finally, the ability for users to interact with information that percolates up through the layers is provided by the human-computer interface. This layer provides both the mechanism for presentation of the massive amount of information that can be provided by the system, as well as the means to manage the information and to operate on it through the applications, and to manipulate the systems themselves, i.e. the communication components, sensors and weapons, and platforms.

Warfighting capabilities are composed of an engineered system that integrates technologies at each of these layers. Managing this process is the job of a program manager who is responsible for selecting technological solutions to meet the specified requirements. Figure 2 illustrates this situation. A program manager delivering a system in 1995 used the best that technology had to offer by 1995. A program manager in 2004 looks to 2004 technologies to meet his newer requirements. These vertical cuts through the layers can produce what are often referred to as "stovepiped" systems that do not share information and cannot interact in any usable or effective way. Information sharing is done manually. When it's necessary for two systems to interact, an integration effort is created which is generally done on a case-by-case basis, is expensive due to forced re-engineering often requiring the most expensive engineering experts available, and, most unfortunately, is not always completely successful. Integrating systems into larger capabilities, to create a system of systems, is becoming increasingly impractical due to the cost and complexity of the large re-engineering efforts required as a result of the constant evolution of technology and exponential rise in the number of component systems that must be integrated.

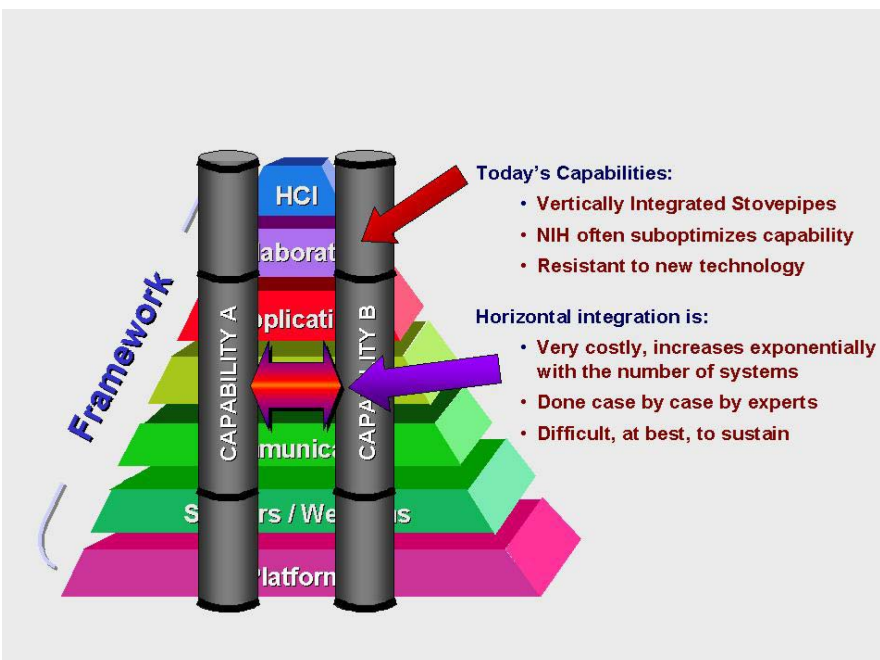

Figure 2 – Stovepipes.

It appears, however, that the marketplace, responding to similar pressures for interoperability in the public sector, has caused the development of new information technologies that hold promise for changing the capability acquisition paradigm. At each of the layers of the pyramid, technologies are evolving which have some promise for making future capabilities/systems inherently interoperable.

A small set of the technologies that are evolving as cross-platform standards are shown in Figure 3. For example, at the sensor layer, markup languages make it possible for systems to operate on data from any compatible system's database. At the communications layer, Internet protocols make it possible for networks to pass information between them. At the computer layer, virtual machines make it possible for applications to process information developed under different operating systems. At the application layer, the semantic web promises to make the boundaries between applications more seamless. At the collaboration layer, technologies such as email, groupware and chat rooms make it possible to track multiple conversations in parallel and apply the information from one to the others. At the human-computer interface layer, common metaphors like the desktop metaphor in use by Unix and MS Windows and the Mac OS, make it possible to transfer training between systems and to interact seamlessly with different systems' functions.

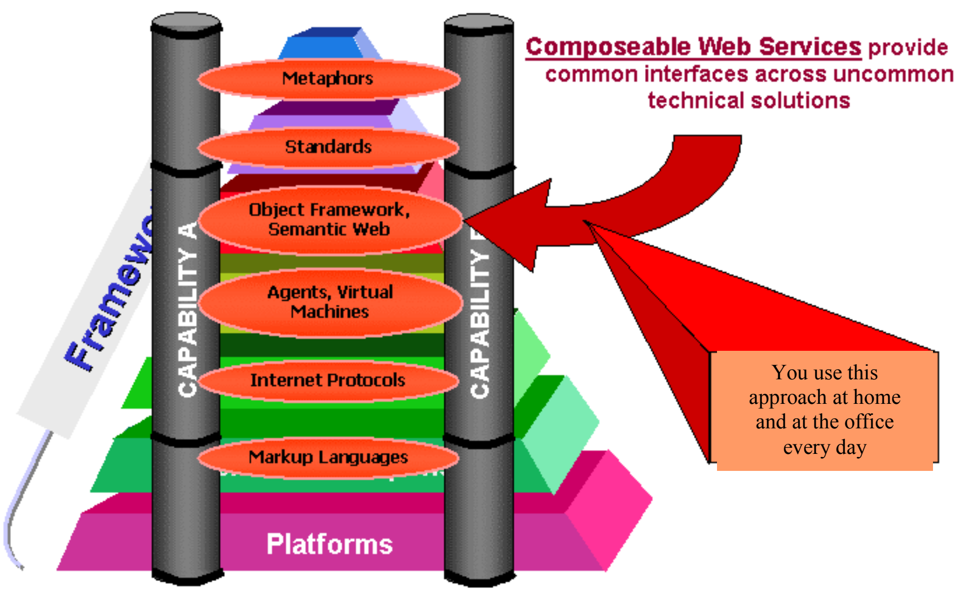

Figure 3 – Composeable FORCEnet View

These are only a few examples of how technologies, many designed to operate within the framework of the web, begin to make it possible to "compose" capabilities from technologies based on common standards, specifications, and interfaces. As this paper is being written, an effort to produce a roadmap for future warfighting technology needs in each of the layers is underway. This will help in understanding much more fully the extent to which the appropriate standards exist, where there are inconsistencies between the applications of standards or specifications, and where technology investments need to be made.

Analogies to this approach are common in the commercial sector. One consumer-based example of composeability, as it applies to a capability, might be of an individual who wishes to produce a home movie. Today, he/she might visit a local computer store and shop for a computer. There will probably be shelves of computers to choose from producers such as Sony, Fujitsu, Compaq, Toshiba, Mac or a custom built PC. The selection depends on factors such as cost, memory, speed and included peripherals. A movie editing application would be selected from among several available from different software developers based on cost and features and that software would be installed, usually via an installation wizard, into the computer. Then, a digital camera, perhaps from Canon or Olympus or Kodak, or other manufacturer would be selected, again based on cost, resolution, size, zoom, and other features important to the user. As the scenes are shot, they can be loaded into the editing program using Firewire or USB connections, or perhaps via a disk. When a draft video has been completed, the producer might want to get some assistance from a colleague, so he/she can select an internet provider based on cost and availability and, using a browser of choice, the movie can be sent to them for their input using their own system, which may include quite different components. What was accomplished in this process was to compose a capability by buying the components that met each of the user's requirements. Moreover, as newer products with improved features become available, this person can replace one component at a time to achieve improved capability, leaving the others in place to operate as before. This was possible because commercial standards now permit these components to work together seamlessly.

We are advocating that similar approaches to developing the components and achieving capability be adopted in the naval warfighting domain where it is practical, feasible, safe and effective. While it is likely that there are some numbers of environments where this approach may not meet those requirements, a composeable systems approach is likely to be able to co-exist with systems that are designed to special purpose levels of specifications.

Technically, Composeable FORCEnet represents a transformation away from building turnkey systems that require large investments in integration toward providing seamless, open, object-based architectures that permit "*composeable*" services, hardware, and applications. It can also radically change the acquisition paradigm by creating a truly evolutionary development process that evolves through plug and play components, and subscription based services, which are compliant with open standards. This acquisition paradigm will permit a steeply accelerated speed-to-capability together with a sharply reduced cost since it permits web-based, distributed services to be accessed through inexpensive servers (and can potentially adapt to peer-to-peer architectures), which can quickly participate in Sea Trials or other experiments.

Composeable FORCEnet provides the potential to transform our acquisition process from focusing on delivery of pre-composed capabilities to ships, to one in which the user self-composes the capabilities he needs…much like our example with home movie making. Sailors will be able to link into served capabilities or subscribe to information sources that provide them new operational capabilities…capabilities well beyond which their pre-composed mission suite of capabilities provides them now.

It will also be possible to install new capabilities alongside existing systems for evaluation during normal Carrier Strike Group and Expeditionary Strike Group deployments, instead of scheduling expensive, difficult-to-coordinate special test events and exercises. In doing so, the maturity of the capabilities being demonstrated can be incrementally improved (spiraled) during a deployment as the services will be upgraded and delivered across the net to the units involved in the "test." This process supports rapid inclusion of military value feedback into the next spiral of development and provides a mechanism to co-develop and refine the tactics, techniques and procedures to be used operationally.

The first proof of concept, in the demonstration of Composeable FORCEnet, is built upon the emerging technology of the objectified information framework being developed under the PEO C4I & Space PMW-157 WebCOP Project within the Space and Naval Warfare Systems Command using the Extensible Information System (XIS). This framework, known as the Geo-Spatial Replication Service (GRS), is built upon the Open GIS Consortium's (OGC) standards for Web Map Services and Web Feature Services and provides a web-enabled, service-oriented environment for Composeable FORCEnet to access and display heterogeneous sources of data. Because XIS has transitioned to become a core component of DISA's Common Operational Environment, and the initial WebCOP framework has already been adopted by PEO C4I & Space, the transition of initial Composeable FORCEnet capabilities to a Program of Record (GCCS-M) is already underway. In addition, the GRS architecture is compatible with the new technology being developed for DISA's Network Centric Enterprise Services (NCES).

Composeable FORCEnet will, in the near future, utilize the Extensible Tactical C2 Framework (XTCF) being developed under the Knowledge Superiority and Assurance Future Naval Capability program of the Office of Naval Research to apply web services to multiple data sources.

The Composeable FORCEnet proof of concept was originally developed and demonstrated at SSC San Diego in a command center environment and with simulated data based on a Humanitarian Assistance/Disaster Relief scenario. Further development of the concept has taken place in increasingly realistic and operational environments, including the FORCEnet Limited Objective Experiment 3-1 and the FORCEnet Initial Prototype Demonstration.

Composeable FORCEnet has also been demonstrated as a solution to difficult C2 legacy data integration issues for FORCEnet. This is accomplished through the development of simple legacy system interfaces (LSI) that web-i-fy information now enclosed within existing systems. When LSIs are developed, they instantiate a publish/subscribe port into the legacy system information storage that enables its information to be shared on FORCEnet with other Composeable FORCEnet enabled users.

Instantiating the FORCEnet Technical Concept:

The Composeable FORCEnet technical concept is based on a fundamental departure from the legacy notion of system-centric application development and deployment. Decades of naval operational and technical experience have shown that interoperability cannot be achieved through the development of stovepipe applications and systems. But neither can it be achieved solely through systems integration, or even a system-of-systems concept – a set of systems that has been integrated via a layer of blanketing middleware code, another, larger stovepipe. Interoperability is likely to require the adoption of a Service-Oriented approach rather than a System-Oriented one. Composeable FORCEnet adopts such an approach. A Service-Oriented Architecture delineates the roles of service provider and service consumer in network-centric operations, and emphasizes the benefits of this modular approach. Focusing component definition on providing or consuming a defined service simplifies design and greatly eases the burden of integration, deployment, and maintenance.

Composeable FORCEnet provides the ability to represent and collaboratively share information from any data source on an n-dimensional geo-spatial map. Composeable FORCEnet's ability to create geo-referenced map objects is based on the continuing development of the Geo-spatial Replication Service (GRS), which provides a web-enabled, Service-Oriented environment for access to heterogeneous sources of data. Composeable FORCEnet's use of this architecture permits the map information, track information, and all new and legacy sources to be objectified and to be geo-referenced.

Embracing the design patterns and developer's guidance of the Navy's Task Force Web initiative, Composeable FORCEnet rests solidly on the foundations of open industry standards for interoperability and the ideas of modular Web Services. Moreover, Composeable FORCEnet couples a powerful information representation, and knowledge management methodology with these emerging standards to provide for information exchange and understanding

Composeable FORCEnet provides an ability to relate information as objects that are derived from dispersed data sources so that views can be created, presented, and shared among all users. In the near term, Composeable FORCEnet uses and extends the GRS architecture. GRS was an early development of the CINC 21 ACTD and is now an integral part of the PMW-157 WebCOP. GRS also takes advantage of the Task Force Web standards and the Expeditionary Persistent Sensors (EPS) grid architecture (based on DARPA's CoABS program), among others.

Composeable FORCEnet Architecture

XIS™, the framework and foundation of this architecture, is an information management library and set of modular information-oriented software components designed specifically to enable diverse, disparate data to be fully modeled, complete with all desired and relevant semantics, for use by any kind of visualization, tactical decision aid, or analysis processing application. Begun as a DARPA research project, and used by dozens of DoD development projects, XIS™ has transitioned to become a core component of DISA's Common Operational Environment (COE) and will be fielded as part of GCCS 4.X.

Using XIS™ inherent ability to objectify data, Composeable FORCEnet achieves a layered dynamic multi-dimensional (logical, functional, physical, temporal, geo-spatial) model representing all available information. All entities, their attributes, and their capabilities are objectified and thus available to any display system, interactive visualization, dynamic decision aid, or command and control application on the network. Thus, objects in a geo-spatial map can be related and linked into temporal (e.g., MS Project) or functional (e.g., Tabular) representations.

Composeable FORCEnet leverages the ease with which new data sources can be integrated into an XIS-enabled web environment, and builds on the plugable infrastructure that XIS provides for testing, incorporating, and exploiting new information fusion engines, correlators, or automated decision aids (Figure 4).

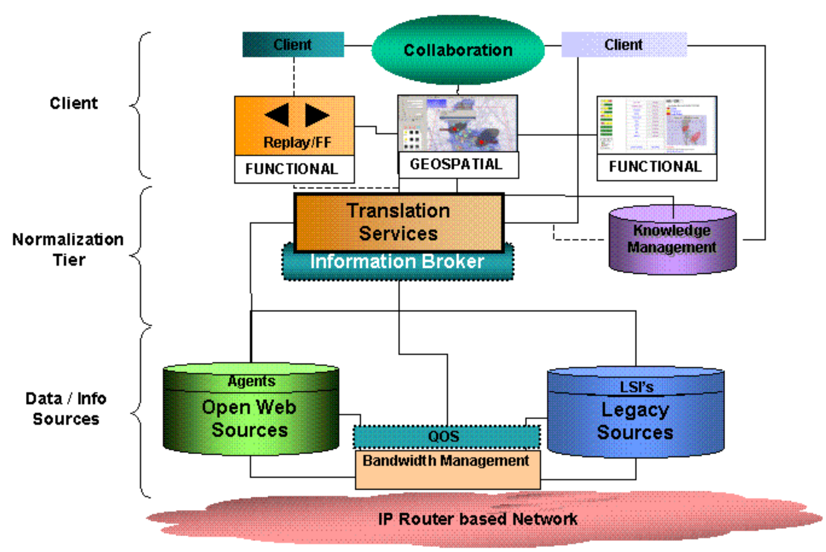

Figure 4 - Elements of a Composeable FORCEnet Architecture

Coupled with this semantically rich objectified view of the relevant data, Composeable FORCEnet adds a powerful, open set of standards for sharing this information with literally any kind of information processing application or service via an integrated suite of information exchange APIs (these APIs will be extended and/or replaced by those from XTCF). Composeable FORCEnet leverages published and adopted industry standards and emerging Web Service specifications for information exchange, including Task Force Web-compliant modules, to enable a true Service-Oriented information framework based on the OpenGIS® Consortium's (OGC) OpenGIS Web Services architecture. Building on the OGC's core Web Map Service (WMS) and Web Feature Service (WFS) specifications, Composeable FORCEnet's underlying transformational architecture is completed via these vetted standards for information transfer, exchange, and processing. These open standards complete the GRS, providing the public interfaces by which diverse client applications can dynamically interact with a wealth of available data.

The WMS specification governs the behavior of a Web Service that produces geo-referenced maps. The specification supports operations that describe for any client the kind of maps offered by that service, such as descriptions of the kinds of features available for rendering, the varieties of projections supported, and the kinds of image formats than can be returned. Any web-enabled client application can thus receive exactly the map images it requires by submitting the appropriately constructed URL to any WMS advertising the desired capabilities. This URL encodes within it the size of the desired image, the image format (.jpg, .png, .bmp, etc), the geo-spatial bounds of the map requested, and the requested sets of feature data to be rendered onto the generated map. Similarly the WFS specification defines the interactions between arbitrary web-enabled clients and a Web Service that produces XML data.

The key to interoperability provided by the core specifications, as well as a host of other related OpenGIS Web Services specifications, will provide the complete independence of the application or module invoking these Web Service operations from the server implementations themselves. No longer does a client application have to bind to the legacy APIs of some stovepiped system, or tap into a legacy message queue and parse this format or that. Now there is an industry standard set of well-defined Web Services that enable programs and DoD service organizations to build mission-specific applications that can seamlessly consume and share geo-spatial data with the entire network.

It's About Composeability, Not the Components

The Composeable FORCEnet concept is based on the understanding that there is still much to be done in the area of standards, and that these standards may always be in flux. These are among the issues still needing significant research and development. Nevertheless, the proof of concept has been able to move forward by selecting particular components that are now in compliance with Open GIS standards (or which are easily brought into compliance). These selections have been meant to prove the concept of composeability, and to show the warfighting implications of the concept of FORCEnet, not to promote the particular choices for components themselves. As more choices of components become available, the ability to "plug and fight" will become even more compelling.

The implications of this approach is that the components described in the preceding section, the GRS and XTCF, and those described in the following section, GeoViz and Kweb were among those selected to prove the concept because they complied with open, public standards for service-oriented architectures. In the Composeable FORCEnet demonstration, other components that are compliant are also demonstrated (for example PMW 157's WebCOP, which is supported by the acquisition command and which has actually been deployed), but there is not adequate space to discuss all of them here. These and other features may well be replaced in future demonstrations by components that are equally compliant, but with more desirable features.

The principle point of Composeable FORCEnet is that the framework, based on service-oriented standards, permits any combination of compliant services that support publication of any source of data which can be subscribed to by any visualization client and which can be understood through an intuitive interface described below.

Visualizing Complex Information

At the top layer of this framework, Composeable FORCEnet provides for the representation of information. Implementing a newer generation of shared situational awareness, the representation layer provides both access to, and the ability to manage, information through three key human-computer interface metaphors. The further development of these metaphors is a very important part of the Composeable FORCEnet development effort. The central metaphor is based on the recognition that warfighters historically have planned and executed operations by way of a map, which of course is a metaphor for actual geo-space. The use of electronic-based maps, together with web tools and web services, opens up new opportunities for expanding the map metaphor into an extensible, adaptable, pluggable new Human-Computer Interface for FORCEnet and the Global Information Grid (GIG).

One of Composeable FORCEnet's current core geo-spatial representation component is GeoViz, a COTS state-of-the-art multi-dimensional geo-spatial rendering engine, capable of efficiently rendering large quantities of geo-spatial and amplifying data (Figure 5). This is critical in today's C4ISR environment where bandwidth between the visualization and the operator is at a premium and must be used economically. The GeoViz environment provides a plug-in component to Internet Explorer, simplifying the deployment among all component forces by downloading the plug-in.

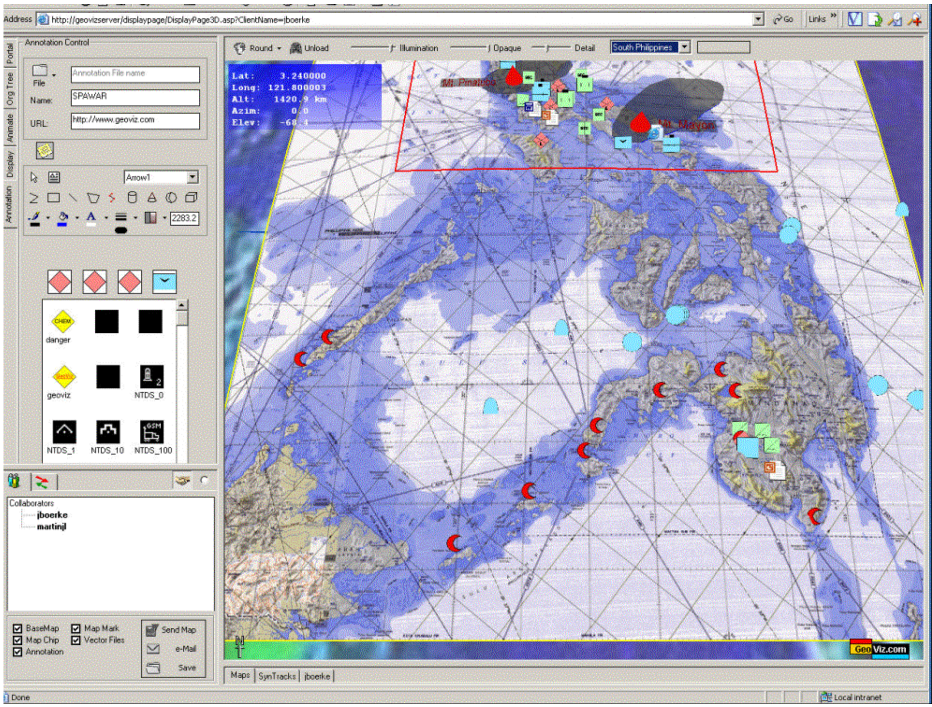

Figure 5 – GeoViz Geo-spatial Display

GeoViz provides peer-to-peer collaboration capabilities through a web portal, including conventional chat (see Figures 5-8 for sample screen shots). Users may also manipulate content on the geo-spatial display, and then share these annotations with other users. Web-streamable and highly compressed content are composed of four layers: Multi-dimensional terrain, maps/imagery, vector/track, intelligence and other information.

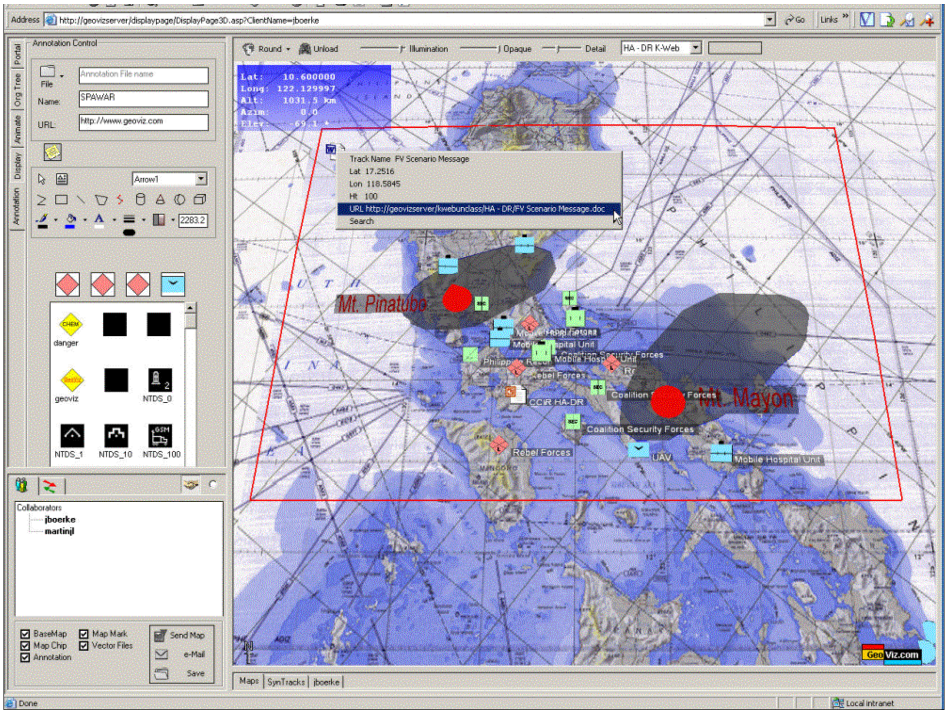

Figure 6 – GeoViz COP

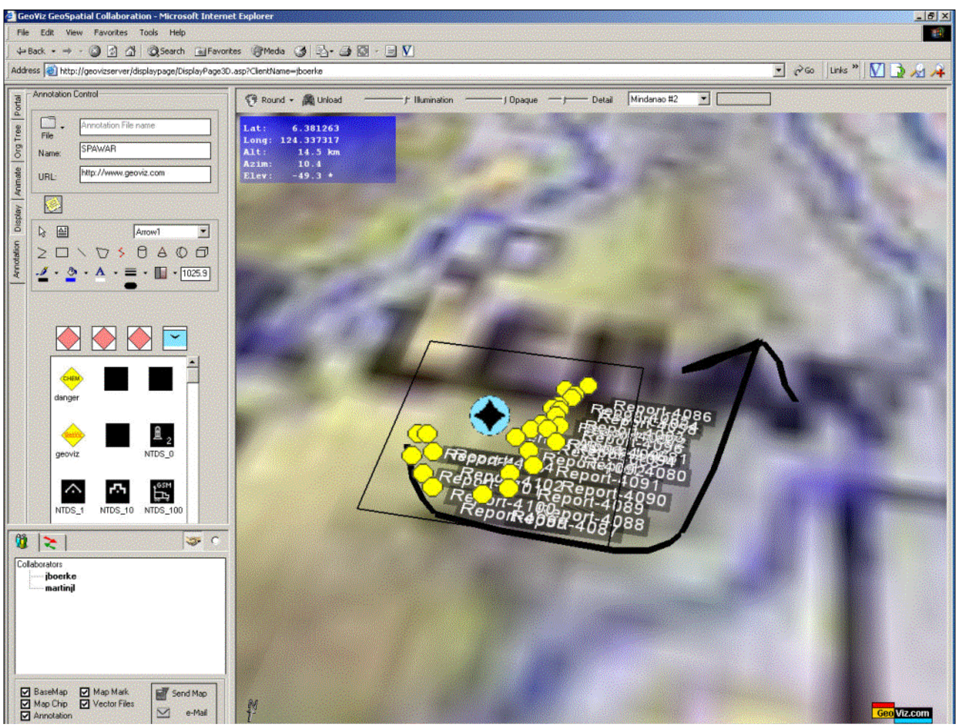

Figure 7 – GeoViz Map Chat About Agent Discovered Sensor Contacts

Any web-enabled data producer can independently serve these layered data sets regardless of their original source. Similarly, data consumers can request customized map/image based information in any configuration.

Underlying GeoViz is a web-based strategy relying on the Extensible Mark-up Language (XML). XML allows all information to be represented as sets of name-value pairs. XML schemas are provided to the GeoViz data server that then encodes their data according to this schema in XML. This type of organization, which was previously a barrier to systems interoperability, is now resolved dynamically at run-time, allowing all components of a C4ISR architecture to evolve independently.

A second human-computer interface metaphor used in Composeable FORCEnet is the browser. Over the past several years, the concept of hyperlinked information that is available through "point and click" manipulation has become commonplace. One of the current browser interfaces used in the Composeable FORCEnet demonstration was adapted from a project known as the Knowledge Web (or KWeb) sponsored by the ONR. KWeb (Morrison 2001) is based on a client-server architecture and provides an organization, notably a military command staff, with the capability to make decisions more quickly through the ability to post information to a server which is available to authorized individuals constantly, rather than at specified briefing times. Significantly more information is more widely available and more quickly than ever before. More importantly, analysis producers do not have to be "web masters" due to a simple template-based publication scheme, which enables the producer to write text, create and add graphics and link other information. Moreover, consumers, including the top-level commanders, need minimal, or even no training beyond familiarity with the browser interface, because of the simplicity of the design of the KWeb information displays.

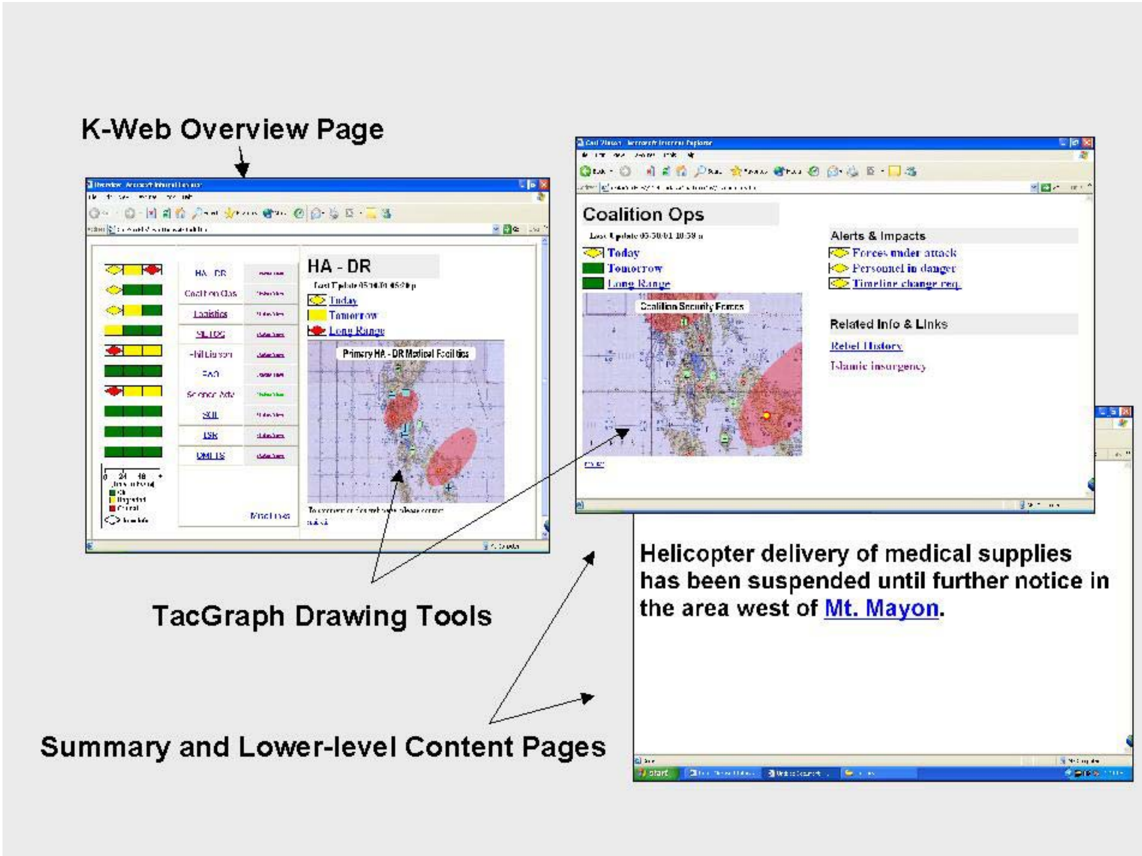

Figure 8 – KWeb Pages

An example of a KWeb display is shown in Figure 8. Three levels of the KWeb are shown, for consumers at different levels of the command staff. At the lowest level of information production, an intelligence report showing a current event is posted to the web. At that level, amplifying information is linked as appropriate. The report is summarized up to the next level as an alert that new information of importance has been posted, and which is hyperlinked to the original report. That page is summarized as part of an overview page which can be consumed at the highest level of the staff and which summarizes all components or functions of the organization using icons to denote currency and importance.

KWeb was implemented on board the USS Carl Vinson during her deployment to Operation Enduring Freedom and was found to be of such utility that it was subsequently transitioned under the ONR KSA FNC program to fleet use. (MacKrell 2003) During the deployment in Carl Vinson, it was shown to assist information producers and users with the transformation of data into information and of information into knowledge. One example of this transformation from the Carl Vinson is shown in Figure 9, where an original weather report has been transformed, using the TACGRAPH template of KWeb, into a graphic that provided useable and understandable knowledge by planners and pilots.

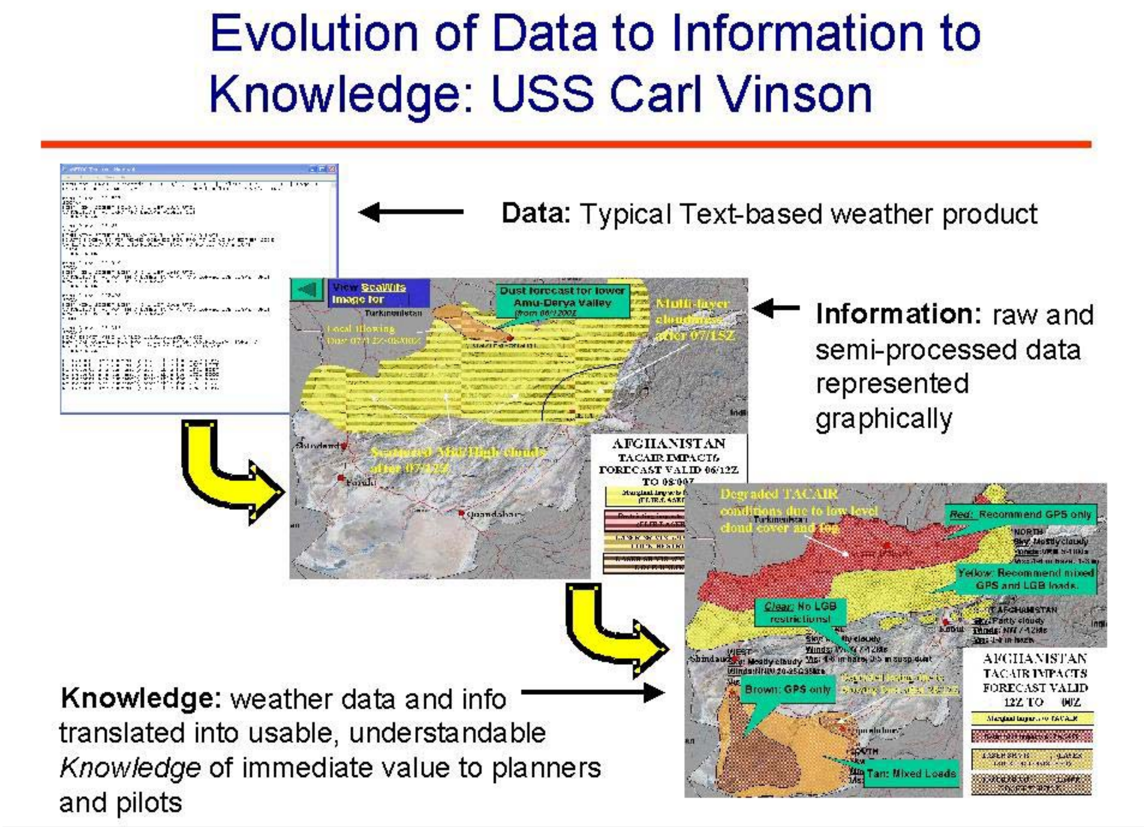

Figure 9 – Value-Added METOC Reports

More Than Just Technical Services

As defined at the start, and as presented in Figure 10, Composeability in the sense that it is used in the context of FORCEnet has a broader definition than merely the web services, the data sources, and the applications. Composeable FORCEnet is meant to convey the idea that by virtue of the ability to compose these components, it should become possible to compose organizations because they are inherently interoperable through composeable services.

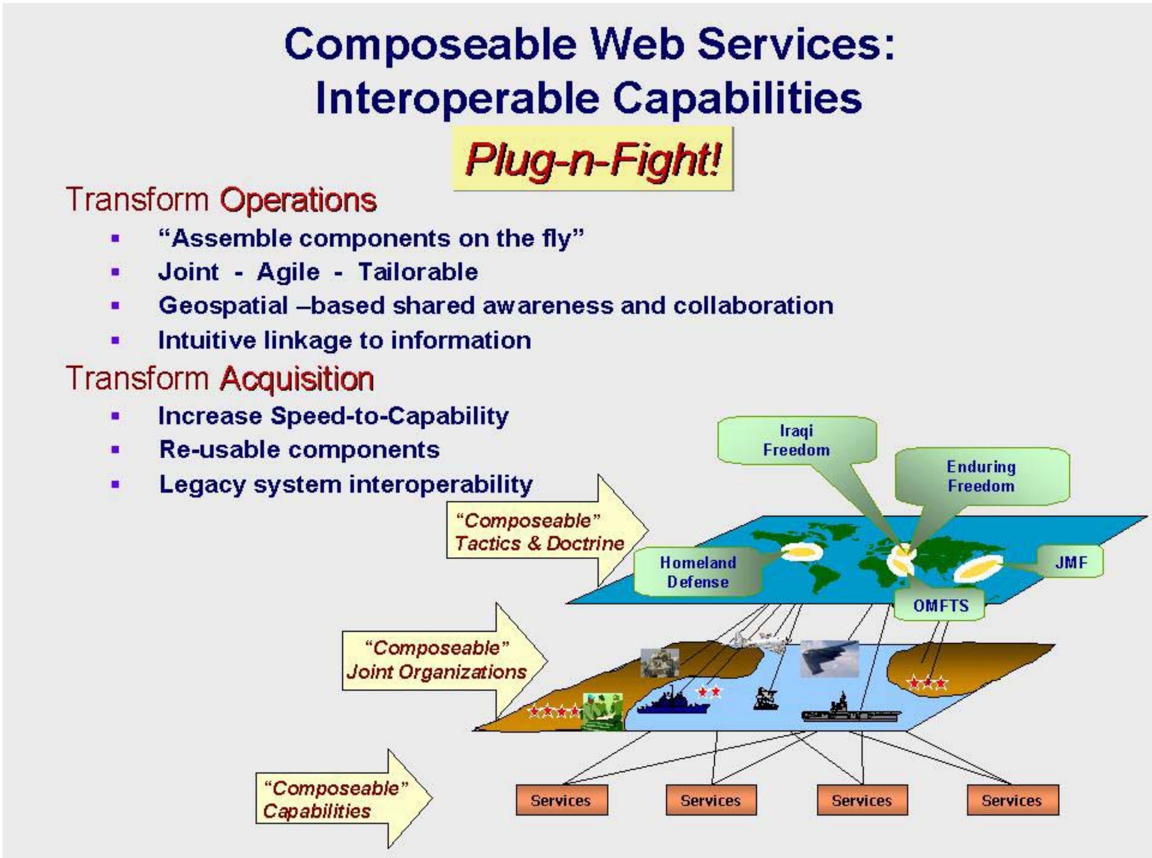

Figure 10 – Composeable FORCEnet’s Concept of Plug and Fight

Moreover, Composeable FORCEnet suggests that this methodology should enable warfighters to compose new tactics and new doctrine through the use of new services and innovative organizational structures. This needs to be followed by additional work with assertions that should lead to testable hypotheses and further experimentation. These experiments should be conducted to understand the full implications of Composeable FORCEnet. Implications with respect to training, security, and interoperability with coalition forces are among the many experiments that remain to be conducted.

Composing and Visualizing Capabilities:

Ultimately, it is the naval and Joint warfighter – and not the engineers - who will use the capabilities needed for the immediate operational and tactical problem. Our research suggests that warfighters operating in a Composeable FORCEnet-enabled environment will soon be able to *compose* the C4ISR components developed by the engineering community at their discretion to ensure superior decision-making. This capability has the potential to enable the Joint Force Commander to achieve the maximum degree of operational effectiveness across the entire spectrum from warfighting to peacemaking, and to do it faster than ever before.

Joint Commanders must have the ability to *compose* a command and control architecture that meets their warfighting requirements from a broad array of capabilities, including multi-tiered networked sensors, dynamic bandwidth capabilities and tailorable visualizations. When FORCEnet is engineered from the keel up, *not* as a set- piece bundle of fixed systems, but as a fungible toolbox of capabilities that the commander selects based on the operational mission he must accomplish, the result is a system composed of precisely the attributes the commander needs. (Office of the Chief Engineer, SPAWAR 2003)

As operational commanders of naval forces build their own, *personalized,* warfighting systems it will likely drive these same operational commanders to put more specific demands on the engineering community for future instantiations of FORCEnet, enabling operators and engineers to better communicate on what is, arguably, one of naval warfighting's most important issues – how to deliver the right information, at the right time, to the right people while preventing an adversary from gaining access to this information.

Conclusions

This paper has examined a concept for implementation of FORCEnet as a key component of Sea Power 21. Under this concept, information, C4ISR systems, organizations and tactics can be composed virtually "on the fly" to provide optimized capabilities when needed. Initial instantiations of FORCEnet capabilities have achieved success operationally. Future instantiations of Composeable FORCEnet are underway as this paper is written.

As with any new capability delivered to the Fleet and to the field, the future utility of Composeable FORCEnet is unknown. However, based on the demonstrated operational success of initial FORCEnet capabilities, and based on the enthusiastic response to demonstrated Composeable FORCEnet capabilities by a wide array of the Department of Defense and Department of the Navy senior leadership, we anticipate that the ultimate utility of Composeable FORCEnet will be limited only by the imagination of the operational commander.

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