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Utilization of a Multi-disciplinary Approach to Building Effective Command Centers: Process and Products

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ABSTRACT

Command centers have been a part of warfare throughout the ages for as long as nations have waged war against one another. The discipline of conceptualizing, designing, engineering and building command centers has evolved rapidly in recent years. Now, even with 'reachback' and 'virtual organizations,' warfighters still need to meet face-to-face and interact within a command center. There is an entire science of why this is so.

The business 'barriers to entry' to conceive and build a command center are minimal, thus, there are a wide array of organizations that do so - some well, some not so well. However, few organizations, even those who have done it right once or twice, have evolved building command centers into a robust, interdisciplinary process. The Space and Naval Warfare Center San Diego (SSC SD) has evolved a process and a number of disciplines over the course of the last decade-plus that believes is worth sharing as a process model for conceptualizing, designing, engineering and building command centers in the future.

In order to support operational commands with their mission and deal with a large volume of information, a multi-disciplinary approach must be taken in order to streamline business processes with support of information technology (IT) and information management technologies. Technology alone cannot solve problems, but must involve an array of disciplines (business processes, IT, and others) in order to fully resolve the information challenge.

The approach to building a command center must evolve from a blending of a number of disciplines, among them; work and process flow, cognitive task analysis, organizational information dissemination and interaction, systems engineering, collaboration and communications processes, decision-making processes, and data collection and organization. By blending these diverse disciplines command centers can be designed to support decision-making, cognitive analysis, information technology, and the human factors engineering aspects of Command and Control (C2).[1] This model can then be used as a baseline when dealing with work in areas of business processes, workflow engineering, information management, and IT.

We base our analysis on the 'best practices' of command center conceptualization, design and engineering as well as on the work multi-disciplinary teams at SSC SD that have built the following command centers or command center elements:

- Nimitz-MacArthur Pacific Command Center (NMPCC)
- Joint Intelligence Center Pacific Operational Intelligence Center (JICPAC OIC)

[1] George Galdorisi and Dr. Glenn Osga, "Human Factors Engineering: An Enabler for Military Transformation Through Effective Integration of Technology and Personnel", SSC SD Biennial Review 2003

- Joint Training, Analysis, and Simulation Center (JTASC) and Joint Forces Command (JFCOM) J9 Engineering Support for a large, high availability digital Library
- USPACOM Intelligence, Surveillance and Reconnaissance Battle Management Center
- Kunia Regional Security Operations Center
- Knowledge Wall/Knowledge Web (K-Web)
- Swamp Works Knowledge Management Tools
- Tomahawk Land Attack Human Computer Interface and User Centered Design
- HQ PACAF Command Center Support

This multi-disciplinary approach provides more effective and user-centered command centers as well as a process methodology that enables hardware, software and middleware to be refreshed faster, cheaper and more easily as new technologies evolve. This is especially important, given the rapid refresh rate of C4ISR technologies.

Ultimately, this paper will show that the way we have evolved the piece-parts of the KM discipline over the years, and the way we have brought those piece-parts together into a multi-disciplinary whole defines a process of building command centers that ultimately delivers the optimal product to the warfighter. Additionally, this process is based on the lessons learned from delivering a number of command centers to a wide array of customers.

Utilization of a Multi-Disciplinary Approach to Building Effective Command Centers

BACKGROUND

One of the most profound challenges for the technical community in building command centers for a wide array of warfighters is to develop these command centers by properly blending and balancing human interaction and information management.

This has been a challenge for a prolonged period of time, however, in the past decade, as technology development increased rapidly, the challenge has become even more daunting. While this may sound counter-intuitive, it is not. For while emerging technology has given the command center access to a proverbial "open playing field" of new and exciting technologies to pick from, selecting the right mix of technologies is now more challenging than it was even a few years ago.

Today, emerging technologies allow command centers to be designed to have full network connectivity and access rights to data across the commercial and military networks with more efficient hardware and software functionality. While information has been a basic building block of command centers in the past, information sources have proliferated through the years, making the process of selecting the "best of breed" even more challenging today than it was just a few years ago.

The Internet, NIPRNET, SIPRNET, and JWICS have provided a "worm-hole" for data packets and an opportunity for vast amounts of information for command centers to draw from. Once the large quantity of information is delivered, it is up to the commander and his staff manning the command center to use the data in support the command's mission(s). Thus, information management and fusion become key functional elements that imbue specific characteristics on a particular command center.

The command centers of the present provide a unique set of challenges, not only to the warfighters as command center operators, but also to the technical subject matter experts in design, development, and deployment of these command centers. Twenty-first century command centers are no longer "clunky" environments with slow machines, small displays and rough user interfaces that were the common features of their predecessors. Command centers today are technology driven, information source intensive, and workflow process dependent.

While a great deal of progress has been made in the design of command centers, the process can by no means be thought of as being "automatic" or even definable by use of a simple checklist. Rather, the design of command centers must entail an ongoing and iterative collaboration between multiple disciplines in order to develop an effective and functional center that meets warfighter requirements.

In order to support operational commands with their multiple missions and provide a large quantity of dynamic and useful information, a multi-dimensional and multi-disciplinary approach must be taken in order to address the challenges of enabling the warfighter to make better decisions faster with fewer people through the development of a functional, effective, and user-friendly command center.

INTRODUCTION

The design of command centers does not follow a generic template that can be utilized in a rote manner in order to develop successive command centers from ground up. This is due to the fact that command centers are developed based on the specific mission of the command and their missions, goals and objectives of each command typically vary dramatically. Therefore, command centers can vary dramatically based on the tactical and strategic operations of a specific command.

For example, Combatant Commanders (COCOM) have an enterprise level responsibility and therefore requires a larger scale of information gathering and decision support. Conversely, a Computer Network Operations (CNO) center where computer threats and the health of the Global Information Grid (GIG) enterprise are maintained would have a dramatically different form and function. A completely different type of command center, a Computer Threat Analysis Center where computer packets are analyzed, monitored, and correlated in near real time to determine if malicious activity is happening within the targeted network would be designed in a completely different manner. As another example, a different command center that provides a set of capabilities similar to any of those noted above, might have an additional capability of being able to deploy on demand. These are all examples where the mission of the command plays a crucial part in identifying the type of command center that must be designed.

There are numerous factors that are encountered universally in virtually every command center design. These factors typically include physical hardware that ensures operators have the necessary furniture, displays, communications, and computers. The commonality has provided a baseline in building command centers and plays an integral part of the initial development of a functional work environment. These common components within the command center allow shared information from one center developed to be shared with another. Conversely, as each command center shares overlapping design issues, there are complex and unique attributes that make the design and development of command centers one of the most challenging engineering efforts the technical community must undertake.

Building command centers can be a frustrating and ultimately unsuccessful effort if the command center design process is approached in a rigidly defined and narrow manner. Conversely, building a command center freely, without understanding the mission of the command, can also defeat the ability of the command to function efficiently and effectively.

Building effective command centers is not about building a futuristic and technologically state of the art room or rooms. The command center must contain functional rooms with "real-time" and accurate information that is presented in way that enables warfighters to absorb the most current processed information and make the optimal decision faster and with fewer people. Effective command centers are designed and developed by experts in

centralizing the coordination and management of information, personnel, and assets. These experts specialize in building command centers and developing efficient and effective ways for operators to successfully get information at or near "real-time."

The goal of command center design should be to provide the warfighter with a clear understanding of the maximum amount of "digestible" information at any given time to any individual in order for that individual to be able to decide upon a fast, accurate, and confident next course of action. The majority of the information should be organized and compiled in a manner that minimizes the gap between readiness and course of action. This can only be done successfully if the individual can enter a command center and immediately view and understand the information through displays, compiled reports, and some interaction with technology - all with a minimum amount of human interaction and with minimal investment in training.

APPROACH

The development of a command center follows the approach of the product lifecycle of software/hardware products. There are variations of this model that must be applied in order to successfully build a command center meeting specific warfighter requirements. These variations may include the waterfall method or incremental development and spiral development. The collective experience of SSC SD over the course of designing, fielding and supporting a number of command centers indicates that specific user requirements for a command center are typical for most of the command centers developed. The model that has been utilized as the starting point in building command centers follows a well-defined pattern containing the following elements.

- Requirements
- Design
- Specification
- Development
- Integration
- Testing
- Deployment
- Maintenance

This model is recognized as a good baseline for any product development process. However in Space and Naval Warfare Systems Center San Diego's examination of command center builds that have been unsuccessful, invariably, we have found that steps in this straightforward 'checklist' are skipped or the process is not followed at all. In every case, sub-optimized results have been the result.

However, despite the need for such a 'checklist,' the development of the command center is by no means a linear process from inception to deployment. There are various disciplines that must be carefully injected during all phases of the development cycle.

Therefore, in order to support operational commands and help them accomplish their mission, a multi-disciplinary approach must be taken in order to address the challenges of designing a functional and effective command center. The experience of SSC SD has shown that when engineers continually reference the elements listed above – from requirements definition to ongoing maintenance and support – the result is a command center that exceeds warfighter expectations.

One of the driving factors during the design and development of a command center is the influence of emerging technology. Available technology plays an integral, and often pivotal, role which molds the direction of the design of a product. Both command center designers and warfighers who will use these command centers typically try to harness the most up-to-date technology readily available in the market. Readily available technology allows architects to efficiently integrate technology to provide effective solutions. However, just choosing the best available technology and force-fitting this technology together in a massive integration effort rarely delivers optimal results. It is important to realize that insertion of the most technologically advanced software and hardware is merely one piece of the puzzle in developing a command center.

A number of factors contribute to a situation where the command center development approach has not been clearly defined. This makes capturing lessons learned and best practices often extraordinarily difficult. First, command center development has varying requirements based on the mission of the specific center. What may typically be a simple task can quickly become complex requiring many stakeholders' inputs and ideas. Second, technology insertion is a dynamically moving target. As mentioned earlier, technology insertion can create complex integration challenges. In addition, technology refresh is increasingly moving so rapidly that it poses engineering concerns that must be planned for future refresh upgrades. Third, information and knowledge management awareness is based upon customer needs and must be captured accordingly in order for producers and consumers to accurately utilize the information efficiently and effectively during the decision making process. Fourth, information overload and technology insertion must be dealt with as determining factors in successful command center design. Finally, building these command centers must be approached from various disciplines rather than focusing on a single expert.

The approach to building command centers must evolve from blending a number of disciplines, among them; work and process flow analysis, cognitive task analysis, organizational information dissemination and interaction, systems engineering, collaboration and communication processes, decision-making processes, ergonomic design, and data collection and organization. In support of these disciplines, "best practices" can be applied in order to fully support the understanding of the command center's mission and therefore develop an understanding of the problem sets of the stakeholders. The "best practices" in support of building command centers include:

- User-Centered Design
- Cognitive Task Analysis
- Visioneering

- Work Flow Analysis
- Systems Engineering
- Ergonomic Design

By blending these diverse disciplines, command centers can be designed that support decision-making, resource allocation, and the planning aspects of C2. In order to support the design and development of a command center, it is also important that lessons learned from the past are considered while contemporary disciplines and approaches are introduced.

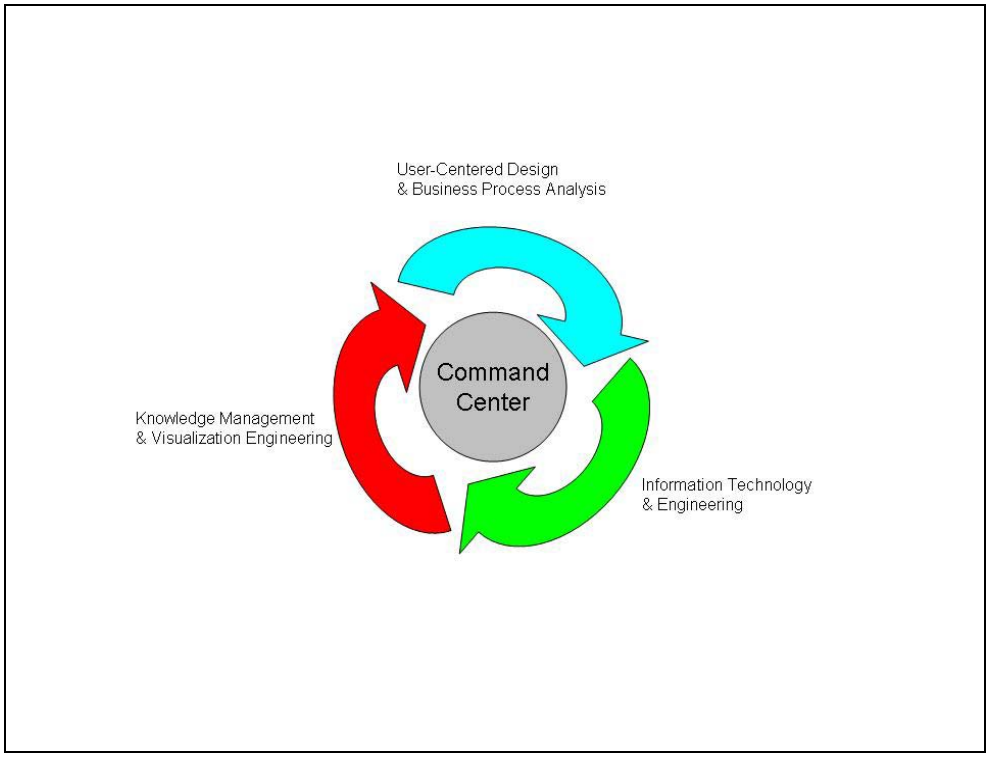


Figure 1-Multi-Disciplinary Approach to Build a Command Center

Developing command centers can generally be broken into four categories. These categories are:

- Physical Structure (includes ergonomics)
- User-Centered Designed and Business Process Analysis
- Information Technology Utilization and Engineering
- Knowledge Management and Visualization Engineering

Many command centers have been developed by beginning in a linear manner based on an already-determined structure or space. The command center's functions must then

include a series of compromises as the command center is 'force-fit' into the allocated real estate. Clearly this is a recipe for a dramatically sub-optimized command center.

In order to begin to arrive at the starting point of designing the physical structure, the command center design team must ask a number of questions. One of the most pertinent questions to be answered is whether the command center will be mobile. Another is; will the center be static and not change over time? Another question is; should the center be designed in such a way that when a crisis occurs, the command center can be dynamic enough to be able to handle any display change, furniture configuration, and/or have the ability to redirect the communications and other technological features that may be needed? If a conversion of an old facility is planned, then can the room be expanded or are there any physical constraints such as pillars or security facility issues such as non-standard walls that may affect the operations of the command center. These are just a few of the questions that an engineer must ask regarding the structure of the soon-to-be command center.

While some practitioners who build command centers embrace it, the philosophy, "we will build and they will come" does not reflect today's reality. While this may work for some, if the purpose of the command center is to provide accurate and actionable information and usable tools so warfighters can decide the next course of action, then we must look deeper and must understand the overarching purpose of each particular command center. Unfortunately, some centers have been built in a haphazard way and the command center's designers have not analyzed the other determining factors that must be accommodated in order to successfully bring a command center on line. Building command centers is not just structural with big screens and data on the wall, but involves analyzing the human factors, technology, and data representation in addition to the physical structure. An analysis of the function of the command center must be performed in order to properly match the need of the users.

Physical Structure

It is important to understand the limitations of the command center that will be developed. There will be three situations that may affect the other disciplines that will be integrated into this effort. The first situation is the development of the command center from the beginning. This type of situation is ideal, for it provides the flexibility of planning for the various factors that can affect the effectiveness of the command center. This situation enables the integration of the other disciplines into the initial process and helps influence the development of the physical structure required.

The second situation involves revamping of an existing facility. Regardless of the fact this has previously been done successfully, this typically requires some of the requirements to be modified in order to take into account some of the structural constraints the facility may have. For example, if the facility has a load bearing pillar in a location that may not be utilized as a watch floor due to the visual aspect, then this

would influence the location of the watch floor. If physical constraints exist, these may play some role in the use of the facility.

The third situation involves one of the key factors mentioned previously, that is, whether the command center will be mobile. This type of situation will require another aspect of engineering which will involve the ability to structurally develop a command center that is transportable and mobile on demand. Mobility may be a limiting factor due to the compactness of the resulting command center and whether or not the command center is even transportable may constrain the ultimate size of the command center.

Identifying the structural constraints and accommodations allows for the other disciplines to be implemented in an optimal fashion. This enables the other disciplines to plan for the constraints and allow for the engineers to be able to adjust to limitations that may affect the implementation direction. Even though it will restrict some development effort of the other disciplines, as long as it is identified early, then it can be easily integrated in a manner that represents, at a minimum, a thoughtful and acceptable compromise.

Assuming a command center can be developed from the ground up, what are some of the disciplines that will be utilized in order to successfully capture the user's needs while ensuring the surrounding environment is able to withstand the test of time to include technology refresh and data integration? The next sections will review the various disciplines that are considered to be critical factors in developing an effective command center.

User-Centered Design and Business Process Analysis

Warfighters are generally self-adapting individuals who are able to perform their jobs in a variety of demanding circumstances. These warfighters adapt during conditions ranging from deserts, to ships, to operational center settings across a wide-spectrum of physical environments and especially, dramatically different tool sets provided to them. If warfighters can control the environment, they will make necessary adjustments and adapt to their circumstances. In much the same fashion, warfighters in a command center will also learn to adapt to the various technological tools they have inherited. As time goes by, these individuals learn how to simplify and converge some of the steps to accomplish their work. Basically, they learn from experience and understand their work flow in order to optimize the steps necessary to accomplish their job even when a command center is sub-optimally designed. Customer Off-the-Shelf (COTS) and Government-Off-the-Shelf (GOTS) products typically provide users with a set of tools to do their job. In most cases, these tools were developed by first gathering requirements, then developing the tools, and then deploying them to the users without any user feedback until the users have to use the tools for the first time. This has often caused undesirable reactions by users and instead of users feeling the system was built for them, they feel it has been forced upon them at the completion of the product development cycle. This has been a recurring problem in developing command centers where software and hardware

ostensibly developed "for the users" tends to be non-user specified but rather technology driven designed by engineers for engineers.

As with every other tool developed, the tools utilized often drive the business process used to achieve the task for the users or warfighters. If tools are developed without first analyzing the process of the users task, then the tools will inevitably force users to perform steps that are either redundant or not optimized. This often makes the life of the user harder, not easier, as promised by the command center developers. Therefore, it is important to first analyze the business process of the users while ensuring the users are deeply involved in the development of their tools to ensure usefulness of the tools.

In order to accomplish this task, it is important to involve human factors engineers who are familiar with user-centered design early in the process. User-centered design is a discipline where users are thoroughly consulted and highly involved in a process ensuring that the product to be developed has the users in mind. This process initially involves identifying the product users or audience. Once the target audience has been identified, then the users inherently become part of the team establishing the requirements of the product. At this point, it involves having the users take part in workshops and meetings so that they can answer questions regarding product functionality, product and user environment, and priorities of software and hardware use. This is followed with various task analyses to understand the importance of each task as well as the work load involved during the processes the users take in each of their task models.

Additional steps in the task model then must be identified to understand the tasks being presently performed and the users' challenges and concerns in accomplishing required tasks. This is one example of information gathering performed by the user-centered design experts in understanding the needs of the users. After data gathering and task analysis, a preliminary prototype is delivered to test the information and the design the users had in mind and openly shared. This is a process where the users can actively participate in tests and validate the product and, for example, ensure the usability and usefulness of the software being developed. The prototype is merely used to validate the design of the product. While many think of prototypes as actually being, at a minimum, a working version of the software, it can really be as simple as a sheet of paper with proposed screen designs using a pencil as an application that has simple interactions representing a working model of the software to be developed.

Once the prototype has been developed, it is then tested by the users themselves in support of their task. This part of the process enables the human factors engineers to make the necessary changes to the design. This becomes an iterative cycle in which the users will provide feed back until the operational requirement is met in the prototype. While the prototype is being developed, it is not uncommon to simultaneously develop the actual product having functionality for the users to test and validate. This continues throughout the product development cycle until the software is released for use.

The major impact of the user-centered design process is that it iteratively builds the software for the users by the users. It helps validate the work up front and shortens the

gap between the requirements gathering and product delivery. The key to the user-centered design process is that users play a critical role in the design of the product during the whole development process.

User-centered design is one of the key disciplines used in developing an effective and usable command center. This enables warfighters to develop command center products that best meet their specific needs. This helps not only in the design and development of products, but also helps establish the business process involved in performing specific warfighter tasks. If this is done correctly, users will be able to function efficiently and effectively with the proper tools that have been developed for them. Thus, products are delivered to meet user's expectations with high level of usefulness.

Information Technology and Engineering

Information technology (IT) is another key area that plays an integral role in the design and development of a command center. As products are developed, there has to be an underlying architecture in order to support the functions desired by the users. Within the command center, there must be supporting command and control products that assist commanders in performing and coordinating personnel, communications, and physical resources in support of planning and controlling forces and operations to accomplish an operational mission. This means there must be various technologies embedded in the command center in order to support of the warfighter.

In developing a command center, there are quite a few technology issues that must be considered and resolved. This paper will discuss two major IT issues that must be addressed in the design of every command center. These issues have plagued engineers throughout the development cycle of virtually every command center. If command center designers consider these two issues during the course of every project, then they will effectively avoid most of the pitfalls that have befallen a wide array of sub-optimized command center designers.

The first issue is technology refresh and how it affects and influences the type of technology inserted into the command center. The advance of technologies of every kind has been extraordinarily rapid and often chaotic. Some technologists argue that these changes are coming too rapidly to ensure the best product is implemented to the overall design and development of a command center.

When considering technology insertion it is important to be able to determine which technology has the functionality to meet the warfighter's requirements. Will the technology be easily updated and will it be able handle growing requirements over time is a key question that should be foremost in the minds of command center designers. If the technology has been made effective and usable, whether it can be easily extracted from the command center in a way that it makes it relatively easy for engineers to integrate new technology? Another major factor in considering the refresh rate of technology is

the overarching costs of the refresh or upgrade. This is an example of the refresh problem taken from a Naval Research Advisory Committee Report.[2]

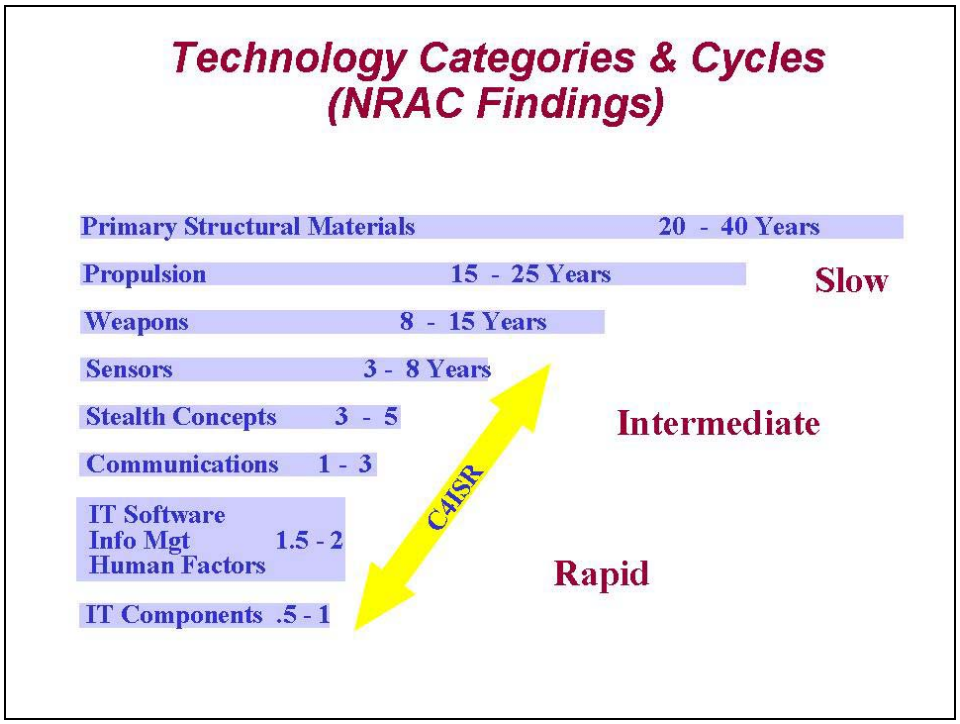


Figure 2-Technology Refresh Rate

The second issue that must be in the forefront of the minds of command center designers is the integration of technology. This can be a complex effort given the number of technologies needed as part of a command center. There are quite a few hardware/software technologies that can be installed. Examples of technologies that may be considered during the development include video walls, video teleconferencing (VTC), monitors, computers, and Voice over Internet Protocol (VoIP). Of particular note, any technology considered as a component in a command center typically raises the complexity of the overall architecture.

In order to design an effective and efficient command center, engineers must have an understanding of technology starting from the lowest level and must also have the ability to understand the requirements of the users. In addition, they must have the ability to assess technology in determining whether it meets user needs as well as integration requirements. Lastly, it is important that these engineers have the understanding of implementing the products from start to finish. This means that the engineers must have the ability to take the existing technology, integrate it, and successfully provide a solution to the users. Engineers involved with IT in command center development must have an

[2] Naval Research Advisory Committee, "Life Cycle Technology Insertion", Naval Research Advisory Committee Report July 2002

expert level of understanding the field of systems engineering, integration, and testing of technology.

Knowledge Management and Visualization Engineering

Arguably, in order to have an effective command center, it is important to be able to have access to the necessary information and data. Once data has been mediated, it is then important to have the access necessary to manipulate the information for use in the current system or integrate it in the user interface.

There are numerous data sources that can be exploited as a resource for a command center. The data sources are often easily accessible and if not, then some sort of active mediation is required to access the information deemed important for the command center. Four areas that comprise effective knowledge management and visualization engineering are: data management, data integration, data correlation, and information visualization.

Assuming data can be acquired, data management presents a challenge for a number of reasons, the first of which is storage. This can be deemed an information technology issue in having to deal with large storage devices or networks. In actuality, assuming the information technology application can hold the information, how do we decide which data needs to be stored? Therefore, it is important that we first understand what data we are retrieving in order to functionally use the information so it makes some sense to the users. It is not a matter of merely retrieving the data, but also understanding the quality of the data. In addition, there has to be some formatting and normalizing of the data in order to be able to provide common data storage, which can itself be challenging depending on the type of data format each source provides.

The next issue to be dealt with, which is really the continuation of data storage, is data integration. This problem is compounded in command centers designed specifically for the military where there are multiple security domains each data sources.[3] It would make sense to take the data sources and be able to combine them and integrate them into a single domain space for use. This is actually a complex problem that entails both information technology and security policies in order to allow the data to be viewed at one specific level. Assuming technology can produce a solution to this challenge, the integration concern then becomes an underlying issue of how information is categorized and made accessible by the various applications used in a command center.

Once the data has been managed and integrated it must be correlated. Data correlation is another aspect of data integration in where data is related to other data in so that it can provide additional conclusions or pictures. This act or process is typically done at another layer above the data storage layer where logic is applied to make sense of the

[3] Penney Myer and Sue Patterson, "Providing a Multilevel Secure Solution for the Rapidly Expanding World of C4I" SSC SD Biennial Review 2003

data in some manner. This will not eliminate the need for users to analyze the data and make sense of information, but it will allow the users to greatly reduce their workload and will also provide them with tools that will help them make higher level decisions.

Once the data has been retrieved, integrated, and correlated, then the next step is determining how to visualize the information so that it will help users determine the next step in a course of action. This will allow users to ultimately review the various data presented to them and give the users the ability to make sense of the data and utilize the information to make decisions at or near "real time." This allows information to be dynamic and the information may change over time which makes it especially difficult to address incoming information at any given time. Therefore, it is important that information be visualized in some static manner while capturing the information into the visualization applications. The information is not limited to raw data view, but rather is integrated information to applications in support of command and control components. It is important that the warfighters reviewing the data make quick and concise decisions based on the situational awareness within the command centers.

This is a discipline where knowledge management and visualization experts are needed to assess the value of the information and knowledge being retrieved and propose a strategy to represent the data in some meaningful view or concept. If information or knowledge is managed, it can be used for more than static encoding of sets of facts. It can be utilized much more effectively by representing disparate raw data in a view where users can easily interact with and provide information in order for users to make decisions.[4]

Experience with basic command center design has shown that if knowledge is not represented in words, then there has to be some form of representation users will be able to understand. The views may be from a simple snapshot of data to the level of complexity in which relationships of data are presented in some semantic network consisting of nodes and directional arrows. It is important to understand that raw data will require engineering so it will make sense at some level for the users depending on it. If data is not presented correctly or if command center designers make it too difficult for users to be able to view it in some understandable format, than the command center will not be used effectively by warfighters.

Integrating Areas of Expertise

At this point, the understanding of developing a command center entails not only structural changes, but a host of other factors. These changes involve other areas that are interwoven with the structural changes and therefore must not focus on a single discipline in order to accomplish a goal such as development of a command center. It is important to bring in and integrate other disciplines such as User-Centered Design and Business Process Analysis, information technology and engineering, and knowledge

[4] Douglas S. Lange, "Knowledge Base Formation Using Integrated Complex Information," SSC SD Biennial Review 2001

management and visualization. These are just some examples of the various types of disciplines that must be integrated in order to effectively develop a command center.

The questions, "where would you initially begin" and "which process must be followed in order to achieve the development of the command center," often arise. Some may argue that starting with the physical structure is the key and this may be the case. But, this is usually the starting point for some efforts since the structural area is typically the first area identified. At this point, it may pose some constraints in developing a command center especially if the requirements have not been specified in detail. But, these constraints can be managed and do not affect the integration of the other disciplines described. In addition, it is important to note that any time a discipline is introduced into the development cycle it can be introduced in some iterative fashion.

In using the multiple-discipline approach, the most important part is the utilization of the discipline through the process. This allows for the designer of the command center to approach problem sets from different directions and not just a single model approach. This will ensure that a command center is developed with the users in mind considering areas of ergonomics, user interface, information technology, and knowledge management.

During the development cycle, it is important to utilize the various disciplines in some iterative manner. This will ensure that requirements are fulfilled and validated accordingly throughout the process and ensure that the products being produced meet the needs of the users. An iterative approach involves a sequence of incremental steps. Each of these iterations has a well-defined set of objectives which produce a partial construct of the command center. In addition, the approach builds from previous iterations and evolves until the final product is complete.

Success Stories

There are a number of success stories where specific subsets of disciplines were utilized in order to build command centers or information centers for mission related functions. These centers were designed utilizing the subject-matter experts and "best practices" to provide guidance in the concept development, design, engineering, final development, and deployment based on the work done by multi-disciplinary teams at SSC SD. Some of the key successes using the multi-disciplinary approach include:

- **Nimitz-MacArthur Pacific Command Center (NMPCC)** – The SSC SD team provided planning and management, as well as much of the engineering design. The new headquarters of the U.S. Pacific Command was completed in 2004. The network-centric design of the C4I infrastructure allowed a single network backbone to support the multitude of command and control networks and applications.
- **Joint Intelligence Center Pacific Operational Intelligence Center (JICPAC OIC)** - SSC SD was recently selected to provide project management expertise

for the JICPAC Renovation Project that will repair/rehabilitate the JICPAC facilities in Hawaii and provide updated information technology (IT) capabilities to a reorganized JICPAC. SSC SD will provide project management and engineering oversight of the project. In addition, it is anticipated that SSC SD will be selected to design and install a significant part of the IT capabilities, including knowledge walls for four Operational Intelligence Centers (OIC). A variety of technical activities are envisioned; including human factors engineering, large display integration, IT system engineering, high-capacity data network design, and video teleconference/video distribution system engineering.

- **Joint Training, Analysis, and Simulation Center (JTASC) and Joint Forces Command (JFCOM) J9 Engineering Support** - SSC SD has provided significant command and control engineering support for JTASC and JFCOM. The SSC SD team has provided a method of managing large amounts of written documentation in an easily managed system in support of a large, high availability digital library.
- **USPACOM Intelligence, Surveillance and Reconnaissance Battle Management Center** - SSC SD completed initial development of the USPACOM J2's Intelligence, Surveillance and Reconnaissance Battle Management Center (USPACOM ISR BMC). The USPACOM ISR BMC will provide the Director of Intelligence (J2) with the capability for real-time ISR collection management and ability to share ISR situational awareness with other intelligence centers. A visualization display, five feet high by thirteen feet wide, will provide on-demand views of the Common Operating Picture (COP), collection management status, and multi-discipline intelligence screens.
- **Kunia Regional Security Operations Center** - The KRSOC Project goal was to "transform" information management at the Kunia Regional Security Operations Center (KRSOC) from a primarily manual-based operation to a network-centric operation utilizing web services. This project included diverse tasking ranging from cognitive task analysis to security management, from software engineering to usability testing and web design. The effort went from paper prototype to operational capability in a seven month time period. The project team applied net-centric concepts and a user-centered design approach to transform and advance the KRSOC Watch Floor.
- **Knowledge Wall/Knowledge Web (K-Web)** – The SSC SD team developed a concept of operations (CONOPS) for web-enabled knowledge sharing that effectively created a dynamic status board. The CONOPS was married to innovative hardware configured to create a Knowledge Wall and Knowledge Desks. The technology allows critical command status to be shared across a battle group, task force and operational theater. The project required the development and application of innovative knowledge engineering and cognitive task analysis techniques, as well as the fusing of knowledge management and systems engineering to develop a concept of operations that made the technologies viable.
- **Swamp Works Knowledge Management Tools** - The operational objective of the Swamp Works Knowledge Management Tools (Swamp Works KMT) effort was to help the COMSECONDFLEET and COMTHIRDFLEET warfighting

staffs deal with information overload currently delivered by today's sensors and networks. The approach taken by the Swamp Works team was to build intelligent agents to move information optimally from raw material to the creation of a decision-able product. The Swamp Works KMT included creation of a web-based point-of-presence for intelligent agents that watch standers could access to utilize the agents.

- **Tomahawk Land Attack Human Computer Interface and User Centered Design** - SSC SD was funded by Office of Naval Research (ONR) to apply their task-based (a.k.a. mission-based) user-centered design process to support Land Attack systems, especially the Tactical Tomahawk Weapon Control System (TTWCS). This effort started in FY02 with initial product transitions to TTWCS builds starting in FY03. The initial phase of the effort involved information and workflow analysis of TTWCS operators' mission and associated tasks. The goal of this analysis was to identify what decisions the human operator had to make, when he had to make them, what information was required, and what tasks could be off-loaded to automation to support the human. Follow-on phases of the project took the products of the information/workflow analysis and generated HCI designs. These designs were prototyped and underwent iterative user evaluations. The proven designs were then modeled for software development (using Unified Modeling Language [UML]).
- **HQ PACAF Command Center Support** - SSC SD was tasked the responsibility of supporting the HQ PACAF Directorate of Air & Space Operations (DO) and its division/squadron elements in maintaining and improving the command, control, and communications (C3) systems at HQ PACAF, Hickam AFB, Hawaii. This task has been expanded to support the Pacific Operations Support Center, the Air Mobility Operations Control Center, and the 17th Operational Weather Squadron as well as other operational elements in the 502nd Air Operations Group.

These successful installations conducted by SSC SD have had significant impact on the operations of the organizations involved. Most implementations utilized some variation of the multi-discipline approach utilizing a mix of disciplines to accomplish the work. The multi-disciplinary approach provides more effective, user-centered command centers, as well as a process methodology that enables hardware, software and middleware to be refreshed faster, cheaper and more easily as new technologies evolve. This is especially important, given the rapid refresh rate of C4ISR technologies.

SUMMARY

Over the past several decades, there have been a number of organizations that have designed and deployed a command center to support a particular operational or strategic mission. Each of these organizations created processes that were followed from inception to deployment and demonstrated that development of a command center is complex and requires some level of design and a specific thought process to ensure warfighters are provided with products to help them perform their job and perform it well.

Development of command centers has involved an ongoing learning process and one of the primary lessons of this learning process is that technology is not the single solution to building an effective command center. Command center development provides an opportunity to modify existing processes and utilize various disciplines to build an effective command center. In every case, the true test for having built an effective command center is whether the warfighters are able to make better decisions faster with fewer people. Command Center design engineers who keep this uppermost in their minds have the greatest chance of developing world-class command centers.

BIOGRAPHIES

George Galdorisi is Director of the Decision Support Group at Space and Naval Warfare Systems Center San Diego where he supports in the Center's efforts in strategic planning and corporate communications. Prior to joining SSC SD, he completed a 30-year career as a naval aviator, culminating in 14 years of consecutive experience as executive officer, commanding officer, commodore, and chief of staff. He is a 1970 graduate of the United States Naval Academy and holds a Masters Degree in Oceanography from the Naval Postgraduate School and a Masters Degree in International Relations from the University of San Diego. He graduated from both the Naval War College's College of Command and Staff and the College of Naval Warfare, and in 1994 he received the Naval War College's Admiral John Hayward Award for Academic Achievement. Additionally, he is a graduate of MIT Sloan School's Program for Senior Executives.

Glenn Tolentino is a Senior Systems Engineer for the Command and Control Department at Space and Naval Warfare Systems Center San Diego. He holds a Bachelor of Science Degree in Applied Mathematics and Computer Science from San Diego State University which he received in 1992. He also earned a Masters of Science Degree in Software Engineering from Southern Methodist University in 2002. He has worked in various disciplines to include software engineering, systems engineering, and systems integration for SSC SD. He has also toured with the Joint Task Force Global Network Operations Applied Technology Unit as the Deputy Director in 2002-2003 which gave him the opportunity to contribute his technical expertise and experience in the area of computer network operations and information assurance. He is currently a Systems Architect for various advanced C4I projects.

A Multi-Disciplinary Approach in Building Effective Command Centers

Tenth ICCRTS Symposium 2005
June 13–16, 2005

George Galdorisi and Glenn Tolentino

SPAWAR Systems Center
San Diego

Background

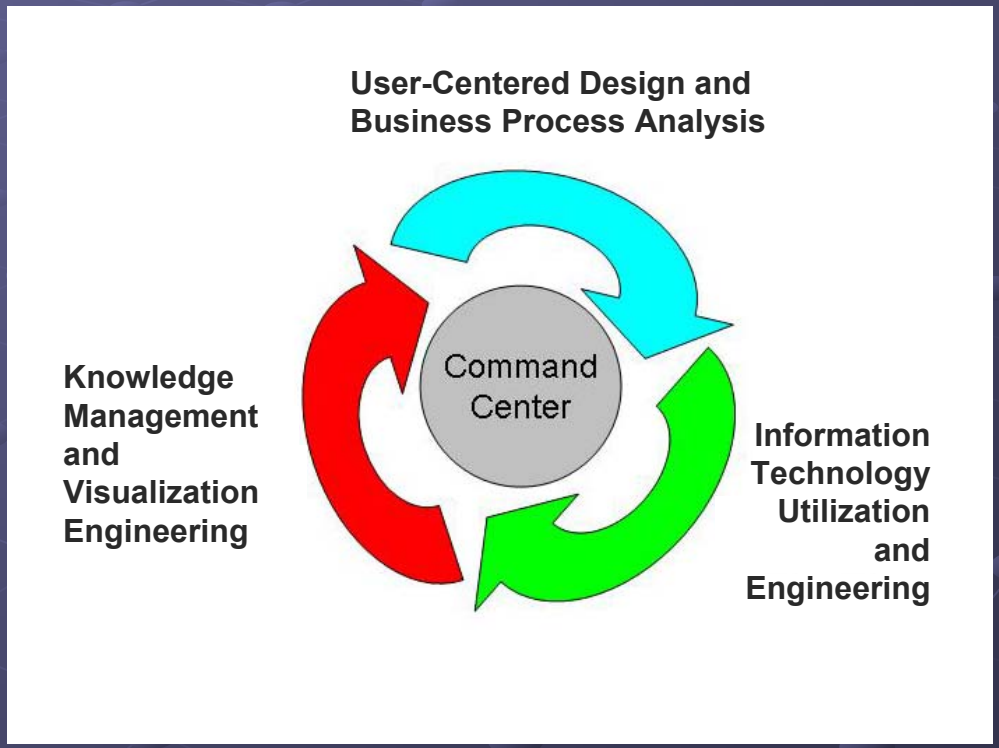
- Command Centers
  - Have been integral part of warfare throughout the ages
  - Have evolved in recent years in conceptualizing, designing, engineering, and deployment
  - Pose unique set of challenges from human interaction to information technology
- Command Centers are technology driven, information source intensive, and workflow process dependent
- Effective design must entail ongoing and iterative collaboration among multiple disciplines
- Multi-disciplinary approach to address the ongoing challenges

Approach

- Model that has been followed entails
  - Requirements, Design, Specification, Development, Integration, Testing, Deployment, and Maintenance
  - Variations to this known model may include the waterfall, incremental, and spiral development
- Not a linear process or “checklist”
  - Various disciplines must be carefully introduced during all phases
  - Blending a number of best practices in support of a multi-disciplinary approach

Development Categories

- Command Center Development Approach
  - Physical Structure
  - User-Centered Design and Business Process Analysis
  - Information Technology Utilization and Engineering
  - Knowledge Management and Visualization Engineering



Physical Structure

- Three primary situations identified
  - Develop from the beginning
    - Provides flexibility for planning and specification
    - Enables integration of other disciplines into initial process
  - Rehab an existing facility
    - Possibly successful but with constraints and boundaries
    - Modify requirements to successfully integrate into existing facility
    - May limit full optimization of key disciplines
  - Design a command center that is mobile
    - Limit of functionality due to mobility requirements
    - Complex information technology challenges
- Physical Structure is an important first step in bounding the problem for other disciplines

User-Centered Design (UCD) and Business Process Analysis

- Users must be involved in the development of the Command Centers
- User-Centered Design
  - Perform cognitive task analysis to understand requirements of users
    - Users take part in workshops/meetings answering questions regarding product functionality; major tasks are identified
    - User information is then used to develop a prototype (paper, drawings, software shell)
    - Prototype is then tested by users in support of their task and UCD engineers will make the necessary changes
    - Iterative process with engineers and warfighters to develop command centers
  - Validate work iteratively and minimize the gap between requirements gathering and product delivery

UCD enables warfighters to develop command center products that best meet their needs

Human Factors Engineering

Improve Work Flow, Collaboration and Group Dynamics

Provide operational evaluation of innovative concepts

- Collaboration, coordination, and connectivity
- Common operational pictures
- Time-sensitive decision-making
- Cross-echelon, consistent situation understanding

Information Technology and Engineering

- Information technology products must facilitate
  - Coordination of personnel, communications, planning
  - Controlling forces to accomplish an operational mission
- Most challenging information technology issues that must be addressed
  - Technology refresh
    - Rapid changes to fielded technology
  - Technology integration
    - Software and hardware
- Designers must understand both available technology and specific user requirements

Knowledge Management and Visualization Engineering

- Warfighters must have access to the necessary information
- Four areas for effective knowledge management (KM) and visualization engineering
  - Data management
  - Data integration
  - Data correlation
  - Information visualization
- Retrieval of data important but quality of data is key
  - Accessing data at multi-level security levels
  - Effective sorting of key information
- Data correlation to build decision trees
- Visualization of information to determine the next course of action (COA) by the decision makers

Knowledge Management and Visualization

Improve Situational Awareness, Understanding, and Decision Making

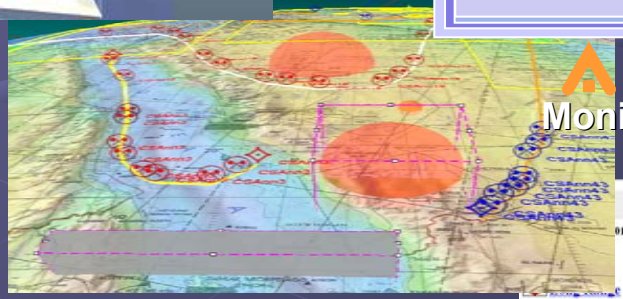
State of the Environment

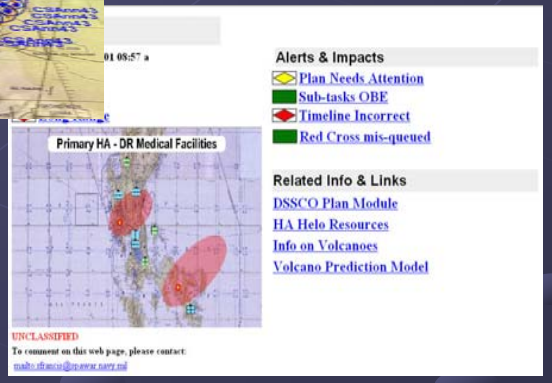
Goals | Experience

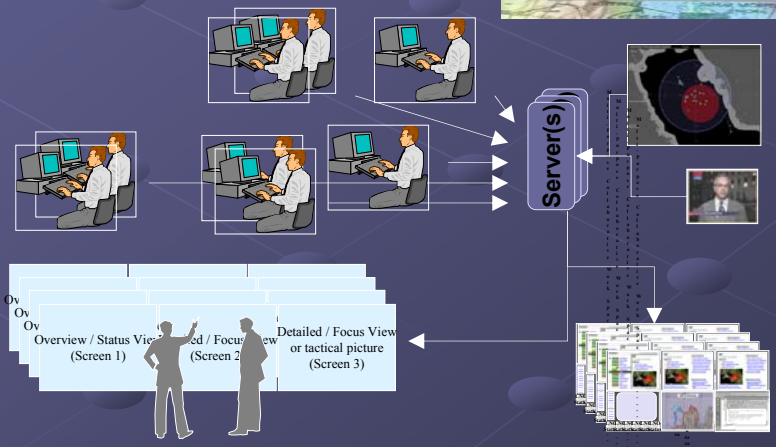
SITUATION AWARENESS

LEVEL 1	LEVEL 2	LEVEL 3
Perception	Comprehension	Projection

Monitor | Integrate | Predict







Integration of Disciplines

- Command center development entails various factors and disciplines
  - Physical Structure
  - User-Centered Design and Business Process Analysis
  - Information Technology Utilization and Engineering
  - Knowledge Management and Visualization Engineering
- Starting point is typically structural
- Structural compromises must be made
- Utilization of disciplines throughout the process
  - Introduce all disciplines early in the process
  - Not just physical structure or information technology
  - Iterative process using every applicable discipline

Success Stories

Command Center Development

CENTCOM Deployable HQ

- Very rapid development for CENTCOM
- Currently deployed in Qatar
- 25 shelters: size of football field
- 230 watch positions
- SCI, Secret, Unclass, and Coalition nets
- Provided overall technical direction, expertise (>100-work months)

Nimitz–MacArthur Pacific Command Center

- System engineering for C4I systems
- Design and implementation
- Crisis and day-to-day operations
- Advanced displays
- Multi-level network services
- Flexible connectivity to all work positions
- Onsite operational support

Nimitz–MacArthur Pacific Command Center

HQ21 C4I Functional Areas

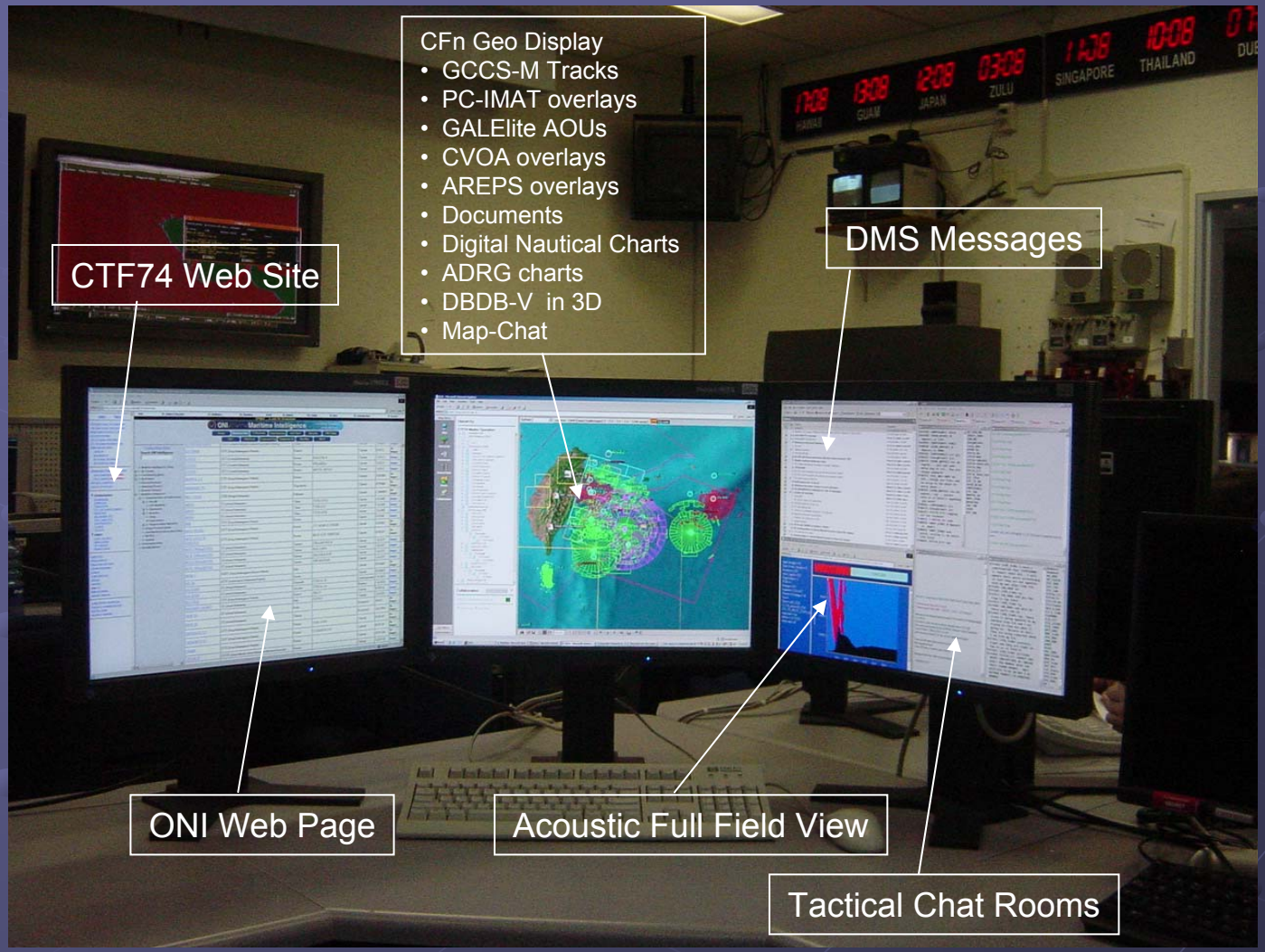
- **Tech Control—GENSER circuit management, includes ATC**
- **J2 ITSO (not pictured)—Intel circuit and network management**
- **RF/SATCOM—satellite connectivity**
- **Backhaul Cabling (not pictured)—cable plant to connect to other bldgs**
- **Telecoms—admin telephone, DRSN, and terrestrial (WAN) connectivity**

Nimitz–MacArthur Pacific Command Center

HQ21 Functional Areas (cont)

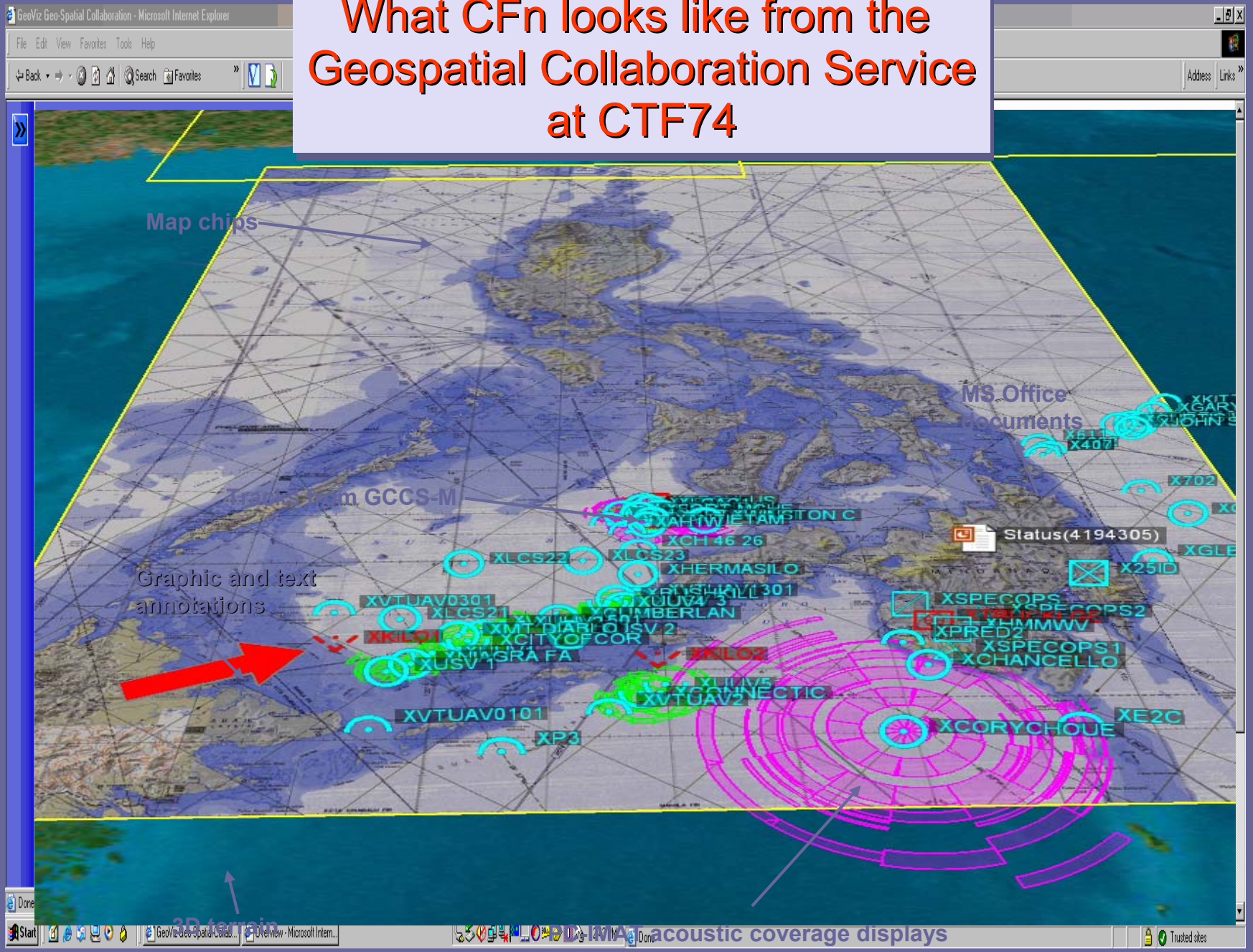
- **JOC: Crisis management; provides Battle Staff decision-making info; uses all C4I assets including national C2 systems**

TASW CFn Battle Watch Captain Display at CTF 74



CFn Web based C2 provides improved understanding

What CFn looks like from the Geospatial Collaboration Service at CTF74



Conclusion

- Command center development can be challenging
  - Command centers are technology driven, information source intensive, and workflow process dependent
  - Effective design must entail ongoing and iterative collaboration among multiple disciplines
- Apply various disciplines into the development process
- Command Center development approach
  - Physical Structure
  - User-Centered Design and Business Process Analysis
  - Information Technology Utilization and Engineering
  - Knowledge Management and Visualization Engineering
- Integrate disciplines iteratively with warfighters and engineers

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