

JSpOC Cognitive Task Analysis

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ABSTRACT

This paper overviews a Cognitive Task Analysis (CTA) of the tasks accomplished by space operators in the Combat Operations Division of the Joint Space Operations Center (JSpOC). The methodology used to collect data will be presented. The work was performed in support of the Air Force Research Laboratory's (AFRL) Space Situation Awareness Fusion Intelligent Research Environment (SAFIRE) effort. SAFIRE is a multi-directorate program led by Air Force Research Laboratory (AFRL), Space Vehicles Directorate (AFRL/RV). It is designed to address research areas identified from completion of a rapid response effort for the JSpOC. The report is intended to be a resource for those developing capability in support of SAFIRE, the Joint Functional Component Command (JFCC) Space Integrated Prototype (JSIP) User-Defined Operating Picture (UDOP), and other related projects. The report is under distribution restriction; our purpose here is to expose its existence to a wider audience so that qualified individuals may access it.

The report contains descriptions of the organization, its most salient products, tools, and cognitive tasks. Tasks reported are derived from the data collected and presented at multiple levels of abstraction. Recommendations for leveraging the findings of the report are presented. The report contains appendices that amplify the methodology, provide background or context support, and includes references in support of cognitive task methodology. In a broad sense, the CTA is intended to be the foundation for relevant, usable capability in support of space warfighters. It presents, at an unclassified level, introductory material to familiarize inquirers with the work of the Combat Operations Division; this is embedded in a description of the broader context of the other divisions of the JSpOC. It does not provide guidance for the development of Tactics, Techniques, and Procedures (TT&Ps) in the development of JSpOC processes. However, the TT&Ps are a part of the structure of work, and are, therefore, a factor in developing future capability.

1. INTRODUCTION

The purpose of this document is to report the availability of findings of a CTA of JSpOC operators accomplished by Air Force Research Laboratory's 711 Human Performance Wing with the cooperation of the JSpOC Capabilities Integration Office (JCIO). The purpose was to acquire information to support the design of task-centered visualizations integrated into a work support system. As such, it describes the work done by various units that make up the JSpOC, the tools they currently use, the information they need, and how they collaborate with others as they prosecute their mission.

This CTA will provide guidance to the development of the JSIP UDOP as well as future SAFIRE efforts. Understanding the type of flexibility needed to adapt the UDOP to evolving tools, TT&Ps, and doctrine is an important goal of this work. Providing guidance to the development of individual tools such as space environment visualization, collaboration, and decision support is another goal of the CTA. A final goal, emerging from our initial visit, is to support the JCIO by providing them with a document that can be distributed to government agencies and contractors, providing background or read-ahead material to visitors, perhaps decreasing the flow of visitors through the JSpOC.

2. BACKGROUND

The 614 Air Operations Center (AOC) at Vandenberg Air Force Base, California, is the United States Air Force's only space-focused AOC. The 614th AOC functions as the Joint Functional Component Command for Space (JFCC SPACE) JSpOC. The JSpOC provides Space Situational Awareness (SSA) and Command and Control (C2) for 29

joint space systems to deliver global and theater space effects. The JSpOC provides intelligence, strategizes, plans and executes combat operations and Global Space Coordinating Authority. In addition, it provides Defensive Space Control support for National, Department of Defense (DoD), civil and other space assets. The JSpOC was activated 18 May 05 in the 14th Air Force Headquarters building according to an article from Space and Missile Times. The JSpOC integrates various joint space capabilities and focuses them for end users to improve warfighting capabilities. Members of the JSpOC provide shared situational awareness to commanders as well as troops on the ground. The JSpOC is responsible for directing, planning and responding to theater commander and user needs and requirements.

The JSpOC integrates SSA and C2 to effectively task defensive space control and offensive space control activities to maintain space superiority.

An Air Force AOC under the command of JFCC Space, the 614th operates day to day as the JSpOC, where JFCC Space exercises C2 of all 29 joint space weapon systems. The JSpOC provides support to Joint Force Air Component Commanders (JFACCs) worldwide responding to simultaneous theater requirements. They provide direct support to the Central Command (CENTCOM) JFACC. In addition, they provide exercise support to European Command (EUCOM) and receive Northern command (NORTHCOM) tasking to support missile defense and Pacific Command (PACOM) tasking in support of special operations.

DoD Space assets are susceptible to numerous anomalous conditions. Austin (2008)¹ discusses some of the unique hazards that can quickly and permanently disable a spacecraft. These include the extreme natural radiation environment in space and collisions with other satellites or the ever-increasing amount of space debris. There is the potential for either intentional or unintentional disruption of space services as the result of radio frequency interference. As the interfering signal can originate from almost anywhere on the portion of the Earth visible to the satellite, quickly determining the problem and locating the source of the interference is challenging. Other threats include laser dazzling and anti-satellite weapons. Near real-time intelligent methods are needed to detect and distinguish between environmental, man-made, and unintentional acts. Figure 1 depicts just some of the complexities of the space environment.

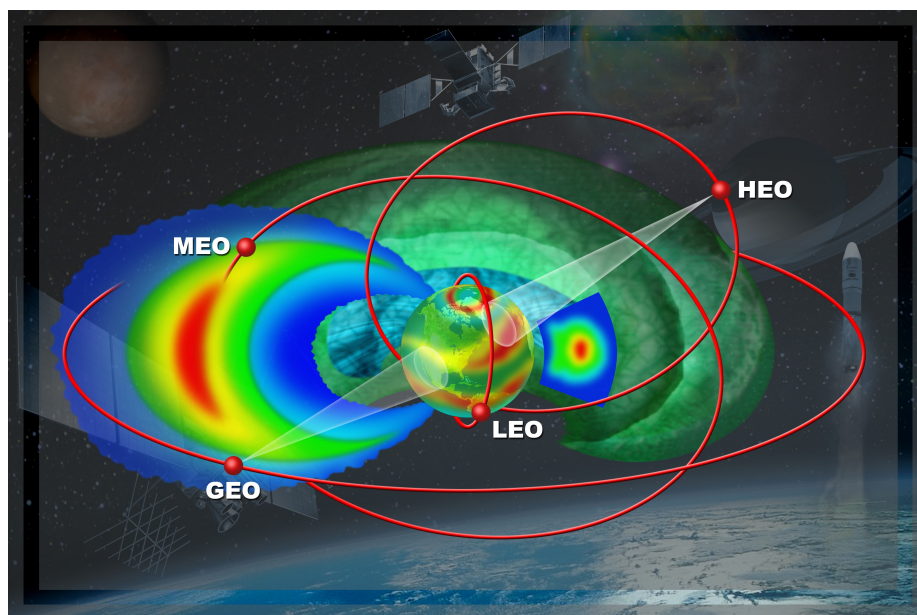


Figure 1. The complex space environment.

The SAFIRE program is designed to address several research areas in support of the JSpOC. These areas include Threat Characterization and Assessment, Intelligence for SSA, Data Fusion Performance Metrics, Dynamic Sensor Tasking, and Optimal Cognitive Environments. The above Science and Technology areas align with JSpOC, Space and Missile Systems Center (SMC) and Electronic Systems Center (ESC) requirements. AFRL's Battlespace Visualization Branch is uniquely suited to address the requirement for Optimal Cognitive Environments.

The Satellite Threat Evaluation Environment for Defensive Counterspace (STEED), developed by The Design Knowledge Company (TDKC), was baseline for development of the work-centered support system (WCSS) and visualization environment for the AFRL rapid response task. STEED is now the WCSS and visualization environment for the SAFIRE effort. As such, it already incorporates some decision tools developed by Space Vehicles (RV), Directed Energy (RD), Sensors (RY), Information (RI) and Human Effectiveness (RH) directorates.

The goal of this research was to determine the optimal distributed collaborative environment for operator effectiveness in space situation awareness and integrate into STEED, JSIP UDOP, SAFIRE, and other related efforts. In order to accomplish this goal, we needed to understand in detail the tasks, and therefore, decision and information requirements of individual operators as well as their interaction and collaboration requirements.

3. METHOD

CTA considers people who interact with information "actors" involved in their work-related actions, rather than as "users" of systems. The goal is to understand and describe the work actors do, their information behavior, the context in which they work, and the reasons for their actions. The CTA for the JSpOC surveyed, identified, and documented the structure of work for selected positions within the JSpOC. Of particular interest were those jobs which involved extensive interaction with other entities such as the Satellite Operations Squadrons (SOPS), 50th Space Wing (which operates the Air Force Satellite Control Network (AFSCN) sites), Strategic Command (STRATCOM), and the National Air and Space Intelligence Center (NASIC). The CTA captured the structure of work, including cognitive, perceptual, temporal, strategic, environmental/contextual, and collaborative elements. The methods and protocols developed for the CTA were based on the dissertation work of Dr. McCracken, adapted specifically for the present task, and were done in partnership with AFRL's 711 Human Performance Wing, Battlespace Visualization Branch personnel. The results of the analysis will be used to develop additional operator interface concepts to support the work of the US military space enterprise.

Many methods exist to do CTA. The method selected is dependent upon the context in which the CTA is to be executed. Because of the constraint relating to doing the knowledge acquisition work in the natural work setting, and the lack of information revealed through the literature review, the general methodology most suited to the task was that growing out of the naturalistic paradigm. Guba and Lincoln (1985)² and Kirk & Miller (1986)³ have described an approach that generates reliability and validity tests for the naturalistic approach. Since the present research has the nature of an extended, augmented case study pursued in a naturalistic setting and it was desirable to be able to make the strongest statements possible with respect to the research, the investigator chose adherence to the paradigm which reflected the nature of the study most closely, and provided the best fit to the data collected and to the nature of the explanations generated. The combination of methods specifically targeted at performing cognitive task analyses for Work Centered Support System design coupled with current and previous experience with JSpOC users was adapted to the context as the investigators understood the nature of the work and attempted to minimize impact on the personnel.

Sequence of Steps

The first step was to travel to Vandenberg AFB in August 2008 to conduct a series of observations and informal discussions with JSpOC personnel. The purpose of this visit was to organize the follow-on data collection and validation process. The observers used field notebooks to record observations and ideas as opportunities presented themselves. All data captured related to the structure of work and not to specific data in the workplace (for the first visit). The physical layout of the overall environment was sketched, with estimates (or measurements) of dimensions. Look angles to shared displays were noted and recorded, as were the elements of shared displays, including design notes on specific display formats. Work aids, the general layout of work areas, notebooks and

corollary material were noted as well as computer-based tools. Preliminary subject profiles were created that described the general characteristics of JSpOC operators.

Interaction/collaboration between members of the JSpOC crew was noted, as were the method of interaction support. Any workarounds that occurred because of deficiencies in existing tools were noted, as were obvious constraints that presented themselves such as limited work space or screen size (the latter was inferred by excessive scrolling).

Task or activity triggers were noted. A “normal” daily rhythm of work was described that included temporal characteristics of the structure of the operation. Activities were described in terms of their cognitive structure. Input to a task, operations on the input and work products were noted. Tasks were described as stand-alone or sequential; if tasks were sequential, any branching was noted, along with the rationale for the selection of one branch over any other(s).

Data collection spanned watch changes twice, so that hand-off procedures could be observed and noted. Work specifically related to the watch change was marked as such. Following each day’s data collection, the observation team convened, compared notes, discussed the day’s observations, and planned for the next day’s activity. Missing data was identified and flagged for acquisition the next day. The first trip spanned an entire work week at the JSpOC.

Following the first trip to the JSpOC, a trip report was prepared and included a preliminary structural description of the observed work; this included single word descriptions of typical tasks conducted by JSpOC Combat Operations Division operators. The structural description and trip notes were reviewed to develop the strategy for the next visit to the JSpOC. This included developing interview schedules (specific content and sequence of interview questions), additional observations desired/needed, validation procedures for CTA artifacts, and targets for collection of documents such as situation report forms, after action reports, Space Tasking Order structure, etc. An organization chart was prepared and the individuals who were the focus of additional data collection were placed within the organizational structure, providing context for the observed work. Preliminary thoughts about modifications/additions to the STEED work-centered support system were developed and mockups and/or prototypes of screens prepared.

The second trip to the JSpOC (September 2008) included the activities described for the first trip, but were expanded by executing focused observations of selected individuals. These observations were augmented by use of the structured interviews developed following the first visit. The interview portions were accomplished on a non-interference basis, i.e., at a time when the mission would not be impaired in any fashion. All interviewees were assured anonymity – that the data they provide would not be connected with their name. A top-level framework was developed that described information regarding what problems each individual solves in order to accomplish their job, what orients them to the problem, and whether they are required to detect or notice anomalies in the systems they use, control, or observe. The original premise, that we would seek the problems, questions, and information chains in use by each operator was modified to a request for a description of “a day in the life.” The modification was made due to the difficulty operators had with defining problems; this was due, in part, to the nature of the work. Much of the operator’s time was occupied by monitoring status, updating briefing slides, and collating/correlating information gathered by fellow operators. The day in the life approach was used to collect vignettes describing the work in the JSpOC. This was refined by asking what tools were required in order to monitor status, what kind of information was gleaned from the tools, and how that information is obtained/accessed.

The third trip expanded the coverage of positions previously covered and included meetings with individuals whose activity impacts Combat Operations Division operators, such as those responsible for installation and integration of the new large screen displays, members of the Strategy and Plans Divisions, and individuals involved in developing a common operating picture for the JSpOC floor. Screen mockups and prototypes were shown to selected individuals including those familiar with the STEED/JSARS workstation and feedback elicited.

The fourth trip (January 2009) was made to do a final confirmation pass on materials already consolidated, share a copy of the draft final report with the JCIO office, get input regarding future direction of the JSpOC as it continues to evolve and to record changes that have occurred over the course of the CTA.

Following this final trip, the report was finalized. The authors have worked to make a report that has the widest possible distribution without sacrificing detail or security.

4. PRODUCTS AND APPLICATIONS OF THE CTA

Products

The results of the CTA were documented in an AFRL technical report shown in Figure 2. This report is available, upon request, to DoD personnel and their support contractors.

The report outlines the 614th Air AOC command/support relationships. These relationships are shown graphically in Figure 3. An Air Force AOC under the command of JFCC Space (dual-hatted as 14th AF Commander), the 614th operates day to day as the JSpOC, where JFCC Space exercises C2 of all 29 joint space weapon systems.

Like traditional AOCs, the JSpOC is organized into four divisions: (1) Strategy, (2) Combat Plans, (3) Intelligence, Surveillance and Reconnaissance (ISR) and (4) Combat Operations. In addition the JSpOC has a Unified Space Vault. The report outlines the responsibilities of each division and the products that they are responsible for producing.

The JSpOC Command and Control cycle is very much like that of the Falconer AOCs and many products are similar. The cycle and major activities of each division are documented in the report.

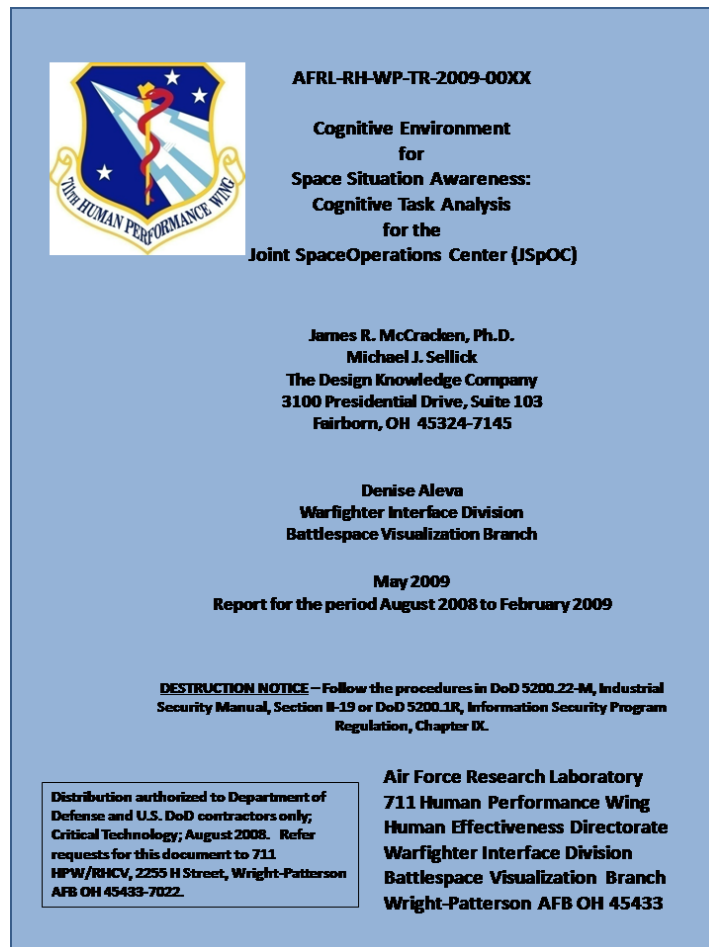


Figure 2. CTA report.

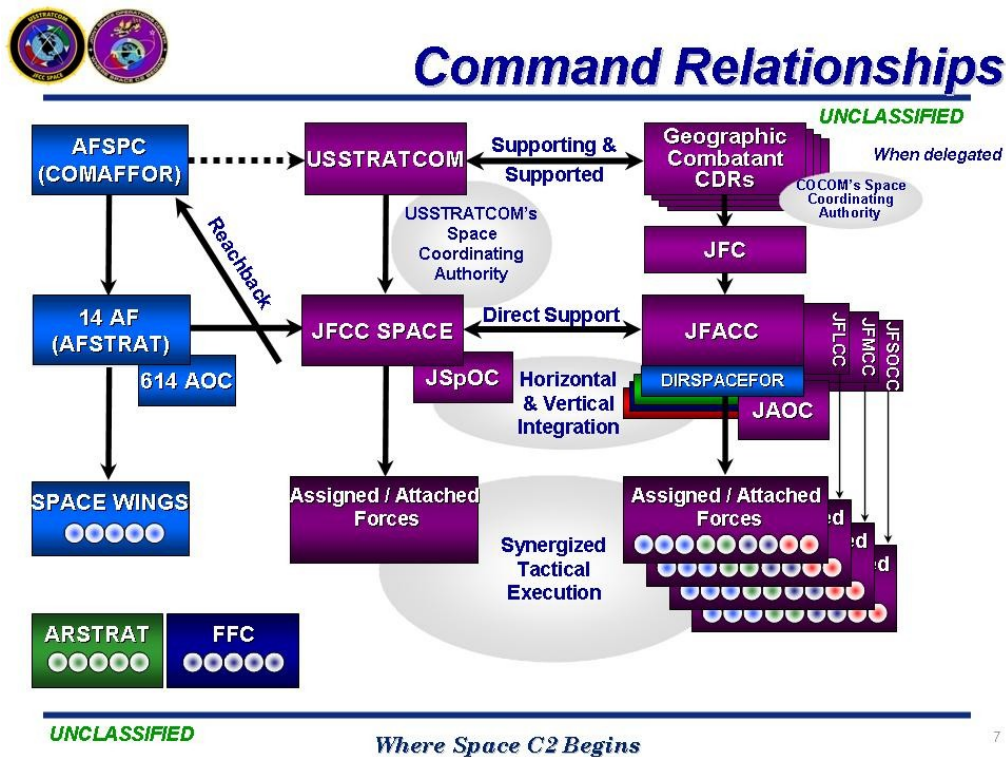


Figure 3. Command/Support Relations of the JSPOC. (From Joint Space Operations Center Mission Brief on JSPOC website.)

The report gives an in-depth focus on the day-to-day activities of Combat Operations Division. The physical layout of the Combat Operations Division floor is described along with the general operator workstation configuration and data wall configuration. More than 70 different tools were documented. An operator by tools matrix was developed. The Combat Operations Division team structure is described along with the responsibilities of the individual teams.

Each crew position in the Combat Operations Division is described in detail. This data was entered into a spreadsheet. The report describes the responsibilities of the particular crew position and the processes/functions required to carry out the responsibilities. This may include monitoring events or status of assets, collection and assimilation of data/information from various sources, using the information to perform tasks and relaying the results to others who may need it. We describe the data/information needed by the particular crew position to perform required tasks. It also tells where the information comes from and how it is accessed (i.e., received from a source outside JSPOC by telephone/ e-mail etc; accessed at a website or by using a tool; received from another JSPOC division (Strategy, Plans, ISR), another team within Combat Ops Division or other personnel within operator's own team. We then describe the products produced by a particular crew position.

In addition to inputs, processes and outputs associated with each crew position, the report documents the tools used by the particular crew position and where /how those tools are accessed. Tools may include but are not limited to NIPR (inbox, news-Fox & CNN, open source to provide information for JSPOC event message, SpaceFlightNow.com, commercial/civilian launches, SpaceX, Yahoo); SIPR (outlook; Merc chat to monitor PACOM, CENTCOM, SATCOM EMI, personnel recovery; SKIWEB (access RSS feeds and monitor joint events; also a way to report events - JFCC components under STRATCOM blog events, critical events pages), JSPOC website, Talon Namath, Single Integrated Space Picture (powerpoint slides updated twice a day)) JWICS (JAS blog - auto update from MCRS pushes log events, DEFSMAC - pending space activity, foreign launches), touch screen display for LSSD control. In order to understand the collaboration requirements, we documented all interactions of

each particular crew position, both within the JSpOC and outside, along with the purpose of the interactions and the type of information exchanged

Applications

The results of the CTA will be used to inform designs for several prototype screens for evaluation by JSpOC operators. Candidate designs identified early in our CTA work include: (1) Common Operating Picture (COP) design and use; workstation/COP integration; the Space Event and Re-Entry Tracking Software (SERTS) screen design; Processing and Display Subsystem Migration (PDS-M) screen design; Space Intelligence Preparation Of The Battlespace (SIPB), battlecab/floor interactions; and space weather (for theater integration team). The findings of the JSpOC CTA will influence Integrated Space Situation Awareness (ISSA), Space Threat Analysis and Characterization System (STACS), and other programs, including many ongoing Small Business Innovative Research (SBIR) projects. It can also be a report resource. There are also tool-level observations that may afford the opportunity to prototype integration of some existing tools to enhance information sharing between/among tools.

The JSpOC is a rapidly evolving C2 capability. Known enhancements currently under development include Space High Accuracy Catalog (SHAC) and Space Situational Awareness Foundational Enterprise (SSAFE); these were derived from the Space Defense Operations Center (SPADOC) and CAVENET capability. The ISSA and Rapid Attack Identification and Reporting System (RAIDRS) programs are developing prototype capability; the STACS Bloc 20 Increment prototype is installed on the JSpOC floor and is connected to SIPRNet. The JSIP UDOP will bring re-hosted ISSA 5.0 algorithms and capability (formerly part of the Space Common Operating Picture Exploitation System (SCOPES)). The goal of the UDOP is to provide a common work environment that can host a variety of tools, incrementally developing capability.

In addition to enhancements currently under development, the AFRL 711th Human Performance Wing has several ongoing research efforts aimed at future space situation awareness enhancements. These include Space Environment Visualization, Space Weather Visualization and Cognitive Environment for Space Situation Awareness. Figure 4 shows a conceptual design for a future SSA and C2 operations center integrating advanced visualization and interaction capabilities. In addition, we have several research efforts focused on integrated air, space and cyber operations and distributed collaborative cross-domain operations.

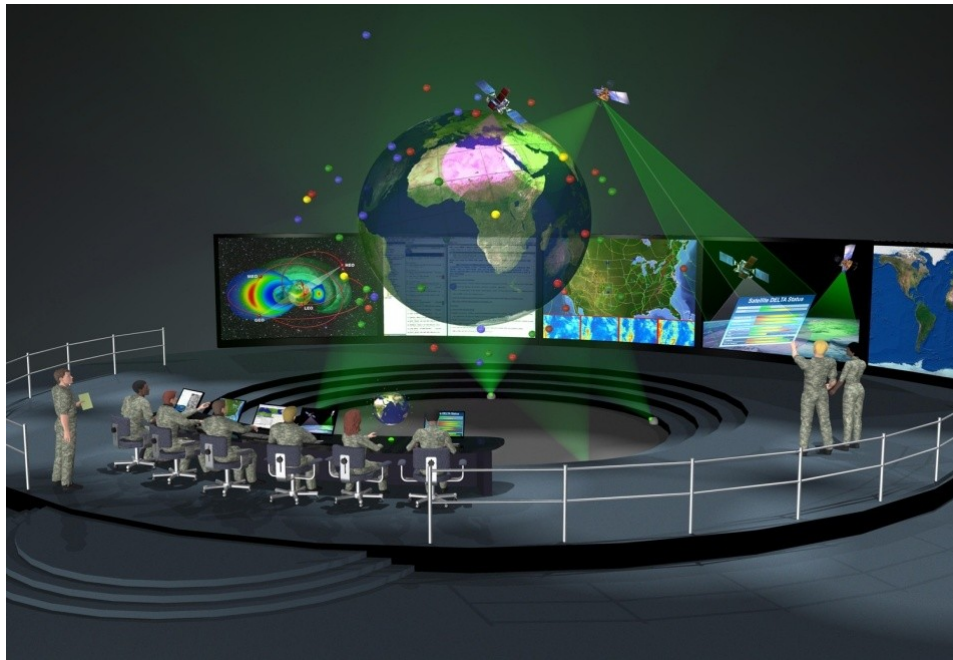


Figure 4. Conceptual future space operations center utilizing advanced display technologies.

5. DISCUSSION

As a unit, the Combat Operations Division maintains space situation awareness for the JFCC Space. Many of the tasks, therefore, involve monitoring, aggregating and reporting current status of various US space resources, as well as the relationship of US resources to various red and gray space objects and/or capabilities.

The types of tasks to be supported imply the need for certain types of tools and the requirement for information sharing or copying (between tools) and collaborating (between and among individuals and organizations). Particularly problematic is the moving of information across multi-level security systems. This entails transcribing data to compact disks, moving disks from machine to machine, copying data to the new machine and then destroying the disk. Information flow from low to high is possible; the reverse is not.

The higher levels of work structure imply how tools need to interoperate in order to combine the outputs of individual tools to develop a plan, accomplish problem detection, or make sense of a situation. Using the problem detection as an example, information might be aggregated from MCRS, phone calls to ground stations, input from space weather operators, and data from SISP in order to establish the status of a missile warning radar. That problem detection could either be a connect the dots or a rule-out strategy, depending on the context and available data.

A point of emphasis here is that stovepiped tools impart one impediment to work efficiency; multilevel security imparts another. Different strategies are required to resolve these issues; consideration should also be given to the interaction between issues arising from stovepipes and those caused by Multi-Level Security (MLS).

6. CONCLUSIONS

In addition to the development and integration of new tools, the JSpOC, including the Combat Operations Division, continue to evolve organizationally. Personnel are being added, new training programs are being prepared, and planning is underway to prepare for the support of taskable sensors. The command and control of dynamically taskable sensors will add another dimension of complexity to the JSpOC mission.

The CTA is a feed-forward mechanism to provide guidance and influence the structure of those developing capabilities. It identifies the structure of the work to be supported, defines the needs for process support, and records existing constraints on work (such as multi-level security, which currently requires operators to use multiple systems, including keyboards and mice). Under the UDOP concept, the user interface can evolve to adapt to increasing capability, changing TT&Ps, new collaborations, and changing cognitive strategies.

Good decision-making is dependent upon good information. Decision-makers need to create and maintain a comprehensive picture of the space situation in order to make actionable decisions. Brown (2008) emphasizes that space situation awareness is developed by integrating, fusing, exploiting, analyzing and displaying traditional and non-traditional space surveillance, reconnaissance, intelligence, and environmental sensor information and data sources along with system health and status information. As a follow-on to the JSpOC CTA, we will be examining intelligence products provided to the JSpOC; we'll document how these products are produced, in what form they are conveyed to the JSpOC personnel and how they are used in the protection of space assets.

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