The Future of Watchstation Design: Evolution From Single Purpose to Intelligent Watchstations

TRACK THEME: Information Operations

Author: Linda O'Donnell

Address:
Mail Stop 4000-2E, Lockheed Martin
199 Borton Landing Road
Moorestown, NJ   08057

Email: linda.odonnell@lmco.com
Phone: 856 914 6708

Author: Leonard Wojton

Address:
Mail Stop 137-201, Lockheed Martin
199 Borton Landing Road
Moorestown, NJ   08057

Email: leonard.j.wojton@lmco.com
Phone: 856 914 6811

Abstract

The focus of this paper is to address the issues of watchstation design and the changes in the console design to support distributed mission task activities for joint operations of global command and control systems. Increased mission demands combined with smart weapons, automated functions and increased collaborative warfighter functions have increased the multi-tasking requirements to be accomplished. Humans in a warfighter role have shifted from a narrow task focus within a narrow job focus of a single purpose watchstation and a high human-in-the-loop interface workload, to becoming controllers of these distributed systems and collaborative activities. Current watchstation design requires the human to perform manual system operations in combination with numerous independent synchronous activities such as, communications and adjacent equipment operations. Future watchstations will need to be designed to support the work environment with; increased multi-tasking capabilities, dynamic monitoring of task processes, integrated system designs, and improved distributed team collaboration task capabilities. Advances in technology have enabled the design of an effective watchstation design that will allow for multi–modal user interfaces best suited to the task. Future watchstation designs will utilize self-adaptive interfaces, increased visual workspaces, agent technologies, integrated speech, and visual and direct touch methods to reduce the human-interface workload and streamline the tasks.

1.0 Analysis of the Multi-Modal Watchstation

In 1996 ONR sponsored the Multi-Modal Watchstation (MMWS) project to investigate design concepts that would support crew optimization in command centers. The design approach began with identifying the user requirements related to the total work environment and task workload drivers.

A task was defined as a job activity with the following attributes:

1. A goal-oriented work activity.
2. Varying in time from seconds to hours, or the entire watch period (six or more hours).
3. Supportable by computer-based aids.
4. Work supported by various levels of automation.
5. May be structured, rigid protocols to open-ended user-defined sequences.

The approach to the task-centered design in the MMWS project presents a method of explicitly representing mission tasks in the watchstation display formats (Osga, 2000). Assumptions made about the future task environment include the following:

1. Automation would be available.
2. Multi-tasking would be required for crew optimization across multiple threats and multiple warfare areas: land attack, air defense and area air defense.
3. Cross-training across multiple tasks would be possible.
4. System design would permit assignment of any task to any crewmember at a watchstation, limited only by authority and planned operating procedures.

The current release of the MMWS focused primarily on human computer interface (HCI) mechanisms that support multi-tasking and supervisory control. It is based on a task-centered design approach for situational awareness. For the MMWS prototype design, tasks were good candidates for automation support that were judged to be skill or rule based. The design of the watchstation explicitly embeds the tasks into the design as part of a user-interface protocol. The goal of this approach is to move the watchstation from a “passive” data delivery device to an “active” work assistant that can participate in the work process (Osga, 2000).

To develop an integrated set of candidate design solutions for the watchstation interface, research was conducted to develop workload assessment techniques to assess the interface methodologies. Van Orden developed a workload assessment system to examine operator state, operator activity, and environmental variables to derive an integrated workload measure in near real time for the prototype MMWS computer interaction modes. The task workload assessment system contains a total of five modules. The workload estimate module monitors estimated workload data from tasks appearing on the displays against tactical complexity and other factors (e.g., system failures). Two operator activity modules, a verbal activity module and a keypress/function usage module, measure operator-speaking variables (rate and pitch changes) and console interaction variables, respectively. Finally, information regarding operator state is obtained from separate eye activity modules dedicated to the assessment of drowsiness and high workload. These modules derive real-time moving mean estimates of pupil diameter; blink rate and duration, and fixation dwell times and frequencies. Workload assessment is determined by the integrator module, which receives input from each assessment module and is used for feedback as well as system management for self adaptation of workload distribution between the system and the operator (Van Orden, 2000).

Frequently overlooked, workload consequences on the human that are imposed by computer interface requirements are a significant factor in the effectiveness of computer supported interface design. System designers typically focus on “mission specific” requirements to derive the specifications of software functional design. They neglect workload derived from human-computer interface task activities such as GUI (graphical user interface manipulations) and work planning or time and resource management tasks (Osga, 2000). To effectively understand and interpret the interface methodologies, it is necessary to understand and develop the interface design solution taking into account the visual, auditory, cognitive and physical/haptic considerations (Wickens, 1992, Sanders and McCormick, 1993). Dynamically interactive computer systems that support mental models and naturalistic decision-making design solutions for complex systems must be carefully constructed to present to operators the right stratum (level of detail) in order to control the system without increasing workload or degrading performance (Rasmussen, 1986, Burns, 2000).

The advanced watchstation design of the MMWS attempts to enable operator's access and control of resources with far greater efficiency than in the past and to optimize the allocation of responsibilities and resources (Freeman, Campbell, Hildebrand, 2000). In addition, the approach lends itself to naturalistic decision-making processes, in that the interface to the system presents the operator with assimilated task information sets and provides natural-input multi-modal interactions, distributed collaborative operations rather than past console watchstation single function, single operator, human-in-the-loop unimodal control.

Key concepts that were evolved in support the MMWS design features are listed in below in Figure 1.

MMWS Design Concept Basis	**Design Requirements Should:**
Response Planner/Manager-individual threat response summary Task Manager Display-composite workload and tasks	Monitor concurrent loading and make schedules visible to user
Response Planner/Manager-range based, single threat summary. Task Manager Display – task summary display.	Monitor progress toward goals-offer assistance if needed-report progress toward goals-allow user to modify or create new goals.
Task Manager Display – Team Overview and workload indicators	Provide visual indication of task assignments and task "health"
Task Manager Display – task assignment summary. MMWS context and event monitoring to support task initiation.	Indicate who has task responsibility. Invoke and "offer" tasks when possible.
Multiple display surfaces-maximize visual workspace (within 5-95% reach envelope for touch).	Minimize workload to access info or controls.
Task Manager expand/contract task list and task filters. MMWS procedural list.	Provide full top-down task flow and status for mission tasks with consistent, short multi-modal procedures.
May involve varying levels of automation from full manual to partial to fully automated.	Provide visual indication of automation state with supervisory indicators.
Total Ship Information Management (TSIM) concept object database.	Agent based database queries automatically.
Information Sets assigned to each task.	Require user to know the tasks, not multiple applications-integrate information across the job vs. workload to shift between tasks focus.
Multiple displays, task locator "tabs", drag and drop task assignment to display, intelligent task sorting and priority visual cues.	Provide attention management and minimize workload to shift between task focus.
Static CACP estimates for tasks with assignment by threat" object" to qualified	Use task estimates for workload distribution and monitoring among crew members.

MMWS Design Concept Basis	Design Requirements Should:
crewmember.	
Highlight changed information when task is "dormant".	Provide assistance to re-orient progress and resources to minimize working memory load.
Top-down task descriptions carried through in display design as well as training curriculum.	Provide consistent terms, content, goals throughout.
3D auditory support to spatialize multiple voice circuits, audio icons and visual/auditory linking of events (audio spatialized to match visual location.	Support close proximity and distant collaboration via visual and auditory tools.

Figure 1. MMWS Key Design Concepts

The TADMUS project and related research work provided conceptual decision support display designs that were subsequently refined and further developed during the MMWS program. St. John and Osga (1999) developed and tested a Task Manager display to aid a supervisor in monitoring a developing situation. The display graphed the on-going tasks in a dynamic Gantt chart that allowed the supervisor a quick look summary of the key information related to task deadlines, duration, automation level, and task priority. The research findings concluded that users benefit from and were able to develop a conditional trust in the automation and the supervision and management of tasks based on this paradigm. In general, those who trusted did better, and as consistent with literature, there is a great deal of individual differences and strategies in deciding when and how to use automation to support a task (Kirlik, 1993, Lee and Moray, 1994, Riley, 1996, Parasuraman and Riley, 1996, Osga, 1999).

Figure 2. MMWS Task Manager Display

A key feature of the MMWS display interface is the "information set" that contains the "default" or typical information needed to support a task goal. In addition support information is automated as much as possible to reduce user workload in completing information seeking task goals. This design feature is intended to shift workload from the human to the system through automation.

2.0 Current Trends and Advantages of Intelligent Watchstations

The trends and advantages of the use of intelligent watchstations that utilize self-adaptation, agent technology, and multi-modal user interfaces are rapidly being developed throughout the military. Research and prototyping has shown that overall there is a significant improvement in performance and a reduction in error rate and fatigue with the use of intelligent systems (Maybury, 2000).

Future architectural definitions to support the intelligent adaptive systems are a significant factor in distributed knowledge-base watchstation design. This is exemplified in the intelligent submarine systems developed by the Undersea Defense Technology (Soulard, Raimondo, 1992). The architecture was composed of three main modules:

- Media Management Module: It is in charge of the formatting of the events arriving from the different media or devices.
- Multi-modal request understanding module: It is charge of the understanding of the multi-modal request from the operator. Based on a linguistic and semantic analysis of the formatted events fro the media manager, this module provides requests that are syntactically and semantically correct to the upper module.
- Dialog Understanding Module: This module aims at controlling the dialog consistency, i.e., when the operator makes a multi-modal request:
    - At finding the performing/current task of the operator,
    - At proposing an adapted answer or feedback to the request,
    - At updating dynamically the task model, the operator model and the interactions history by analyzing the interactions,
    - At managing the strategy of the system and at anticipating the further task.

An important component and major contributor to the core capabilities of advanced intelligent watchstation systems is the use and application of intelligent software agent technologies. They provide a tremendous advantage for developing intelligent, flexible, scalable, integrated, robust systems. Agents have the following capabilities: cooperation, proactively, and adaptability (Case, Azarmi, Thint, and Ohtami, 2001). As further discussed and shown in Figure 3, a combination of all the general agent capabilities provides the greatest benefits to ensure cooperation, proactivity, and adaptability. The circles correspond to general agent capabilities. Smart agents exhibit a combination of all capabilities. Cooperative agents communicate with other agents and act according to the results of that communication. Proactive agents initiate action without user prompting. Adaptive agents learn from past experience and change how they behave in given situations. Personal agents are proactive and serve individual users and collaborative agents are proactive and cooperate with other agents (Case, Azarmi, Thint, and Ohtami, 2001).

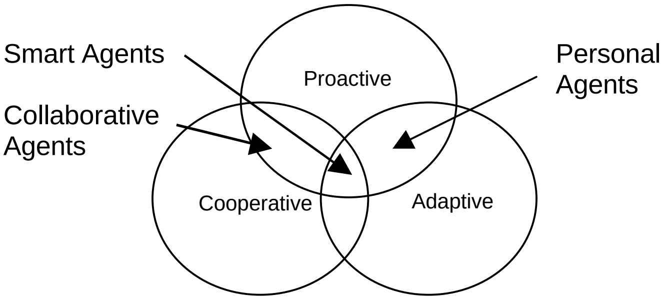

Figure 3. Agent Taxonomy

The use of agent technologies and advanced open agent architecture can provide the capability to construct flexible, dynamic, scalable, and robust distributed systems over system networks as multiple agent systems (Case, Azarmi, Thint, and Ohtami, 2001). Specifically agents can provide the following:

- Adaptive personal agents are ideal for finding a user’s personalized information. They can initiate tasks without explicit user prompting, and can undertake tasks in the background, such as searching for information. In addition, they learn from past experience and adapt to user’s behavior and responses.
- Personal agents both produce and consume information. They assist with transactions between members of the distributed e-community. By sharing their

domain’s knowledge with other agents, they contribute further to the community knowledge.

- Collaborative filtering agents specialize in promoting interaction among community members or in this instance across the force. These agents benefit from both senders and recipients because users can broadcast information to those who are interested in it without annoying other members. For example, contact-finding agents can locate experts in a given domain for possible collaboration tasks. In addition, agents can also work on behalf of users to shield them from excessive information or information requests.
- Multiple distributed agents can collaborate to service requests or mediate to metainformation databases to select resources that satisfy the request. They can also summarize responses from resources.
- Application agents profile information to generate responses that are relevant to the user’s personal interests.
- Reflective adaptation is based on the agent serves the function of dynamically updating interfaces and protocols for new interactions and collaborations.

The use of an advanced agent-based information management system combined with multi-modal interfaces provides the core components for intelligent watchstations of the future. Agents within complex distributed systems will enhance computer operations for the user through reducing the cognitive loads on the human and thereby support memory and task performance. Further advancements and trends will continue to support the development of ever increasing complex system requirements.

Another trend and a key aspect of distributed situational awareness and collaboration is that of awareness and developing tools to support virtual collaborative environments. Research by MITRE on a Collaborative Virtual Workspace (CVW) that uses Expert Finder and XpertNet, is being developed that is a place-based collaboration environment to enable team members to find one another and work together. Expert Finder is an expert skill finder that exploits the intellectual products created within an organization to support automated expertise identification. Both Expert Finder and XpertNet combine to detect and track experts and expert communities within a complex work environment. The goal, similar to but beyond Computer Aided Virtual Environments (CAVEs), is to support place-based collaborative environments where teams can communicate, collaborate, and share information (Maybury, Amore, and House, 2000). For future workstation environments real-time collaborative teams will need to be supported through extended sensor "expert" locators as well as to gain access to, and track the location of personnel to support specific mission tasks. In addition, there is a significant need for future research to determine the key considerations and aspects related to awareness, e.g. people, information, and tools that will be necessary to conduct effective distributed collaborative mission operations.

The use of Embedded Training Systems (ETS) is another design requirement that must be met for the user interface of the watchstation. End-user training is critical if these new applications are to be adopted and used effectively in the field, especially in the use of distributed collaborative operations. Experience and research has shown that software-operation skills are learned best when trainees are given extensive "hands-on" interactive coached practice in the mission application to be used on the job (Cannon-Bowers and Salas, 1998, Cheikes and Gertner, 2001).

The military has mandated the use of embedded training techniques for all new system designs and acquisition programs (Sherman, 2000). Research completed by Cannon-Bowers during the TADMUS program identified the advantages of well-designed intuitive ETSs for both individual and team performance. In addition, research conducted by MITRE focuses on developing ETSs that are intended to approximate the effectiveness of one-to-one expert human tutoring through the use of intelligent computer-assisted instruction (ICAI) techniques.

The current direction for open distributed systems will require Distributed Mission Training (DMT) (Ramesh and Andrews, 1999). DMT is mandated by the DoD and has its roots in the creation of an immersive, fully integrated, seamless, information system that connects independent simulation-based training environments that operate together (Carroll, 1999). The end-user will have access and be expected to access and control remote systems and train either individually or collectively as a team. DMT represents a quantum leap in the complexity of simulation-based training. Indeed it involves a shift from direct control of an individual learning psychomotor and procedural skills to indirect control of large numbers of individuals executing complex hierarchically nested sequences of psychomotor, procedural, cognitive and team skills in fluid, rapidly changing environments (Bell, 1999). This new paradigm for distributed collaborative operations and training must allow users to collaboratively train. The use of DMT and ICAIs has many advantages in that training is available to the users continuously, is tailored and adaptive to the users skillset level at all times, lower cost in that it does not to disrupt personnel with planned “school house” classroom instruction, and is more engaging than conventional training achieving desired levels of competency in less time (Cheikes and Gertner, 2001).

Finally, there are emerging requirements for multi-modal tools and interface techniques for the next generation watchstation. Specific factors that effect the interface methodologies include: time to learn, speed of performance, rate of errors by users, retention over time, and subjective satisfaction. Furthermore, data presentation and data interaction are user interface aspects that should be investigated in tandem, as each has a significant effect on the other during task performance (Bigbee, Loehr, Harper, 2001).

3.0 Issues Associated with Multi-Modal Watchstation Design

There are several issues associated with the current advancements in watchstation design and specifically with the multi-modal prototype.

The current multi-modal capabilities are far from mature and will require significant research and development to incorporate multi-modal interface techniques combined with intelligent agents, self-adaptation and a robust architecture to support future system requirements (Bigbee, Loehr, Harper, 2001).

In addition, several technologies are key to enabling an intelligent watchstation and must be evaluated. These technologies include self-adaptive input/output devices, multilingual speech recognition and generation, multimedia presentation planning, natural language dialogue management, database management technologies, information summarization, and virtual displays (Maybury, 1995). Advanced research associated with modalities will need to be conducted and include developing a naturalistic task-approach to support devices such as; mouse, keyboard, touch screen, track ball, stylus, speech recognition or synthesis, gesture recognition, eye tracking, collaborative virtual workspaces, and CAVEs (Osga, 2000).

Another key issue associated with increased multi-tasking requirements is the identification of the performance measures, workload, and associated task management strategies to fulfill this extended operational environment. At the present time future operational capabilities are unknown and will evolve over time. Therefore, the watchstation design solution must be flexible to adapt to these future changes and implementation strategies to support human-human, human-system, and system-system (Osga, 2000, Osga and Van Orden, 2000).

Finally, the increase of multi-tasking requirements requires additional vigilance to monitor situational awareness. Assuming the future watchstation design will support increased multi-tasking, vigilance, and awareness there still exists a concern for change blindness, due to over-tasking. Change blindness refers to the phenomena that humans are often unable to detect major changes in objects from one scene to the next (DiVita and Nugent, 1997). Human capabilities and limitations vary from user to user, especially as related to perception and short-term memory (Sanders, and McCormick, 1993). Therefore, a concern of the MMWS prototype and future watchstation designs that require increased visual display surfaces and multi-tasking requirements will impact operators rendering them unable to detect changes in high-tempo tactical events.

4.0 Further Research Recommendations for Intelligent Watchstations

Mandated by DoD, global, economic, and military operational requirements the future of watchstation design and its supporting elements including the architectural infrastructure is undergoing an evolution from individual systems to the development of a distributed, collaborative, knowledge-based joint force mission operations. As discussed by Maybury (1995), theater level mission planning for joint force operations will require an intelligent and intuitive mission planning interface for joint and multinational use, a set of collaborative knowledge based mission planning tools, and an information infrastructure that will enable the above.

As a result humans in a warfighter role are increasingly becoming controllers of smart weapons and unmanned air vehicles with longer delivery ranges using increased automation (Osga, 2000). This growth in weapons capability and control requirements is simultaneous with a significant increase of tactical information from network-centric technologies. Automation, including intelligent adaptive interfaces, and database management technologies, including the use of human factors in the design of watchstation design must be exploited to ensure warfighters are capable of fulfilling mission requirements in the face of growing tactical system complexity (Osga and Van Orden, 2001).

As described by Maybury (2001), Intelligent User Interfaces (IUI) are human-machine interfaces that aim to improve the efficiency, effectiveness, and naturalness of human-machine interaction by representing, reasoning, and acting on models of the user, domain, task, discourse, and media (e.g., graphics, natural language, gesture). IUIs are multifaceted, in purpose and nature, and include capabilities for multimedia input analysis, multimedia presentation generation, model-based interfaces, agent-based interfaces, and the use of user, discourse and task models to personalize and enhance interaction.

The following is a list of recommended future work that should continue to support the evolution of watchstation design.

- Continue to investigate and define network-centric warfare capabilities. Specifically, evaluate the impact of advanced technologies on human-human, human-computer, and system-system performance and communication requirements.
- Investigate additional usability and performance issues that still need to be addressed in support of a task manager implementation methodology and its implementation strategy for full multi-modal operations.
- Investigate advancements in display and system component miniaturization, resolution improvements and possible operational implementation for mobile computing of C4I operations.
- Continue to develop agent-based implementation strategies.
- Continue to develop multi-modal interface devices and implementation strategies e.g., mouse, keyboard, touch screen, track ball, stylus,

linguistics, speech recognition and synthesis, gesture recognition, eye tracking, collaborative virtual workspaces, and CAVEs (Soulard, 1992).

- Continue to research multi-modal interface techniques optimized Collaborative Virtual Workspaces that facilitate the combined use of visual and auditory inputs in a naturalistic manner.
- Continue to develop task-network models to extend the power of task analytic methods to develop executable computer models that can be predictive of human performance. In addition, task-network modeling tools as well as additional usability and performance issues will need to be developed and addressed in model-based analysis to support the task manager usability studies and full scenario task-network models.
- Continue research to determine the key considerations and aspects related to awareness, e.g. people, information, and tools that will be necessary to conduct effective distributed collaborative mission operations.
- Continue to evaluate factors that effect interface and task performance for individuals and distributed teams e.g., cognitive, perceptual, auditory, haptic, response times, change blindness, naturalistic decision-making, and differences in task requirements for force and multi-national coalition operations.
- Continue to develop and refine measures of performance as well as measures of effectiveness as adjustments to the interface methodologies and mission tasking requirements evolve.
- Continue refinement and development of distributed mission embedded training techniques.

5.0 References

Bell, Herbert H., “The Effectiveness of Distributed Mission Training”, AMC, Communications, September 1999, Vol 42, No. 9

Bigbee, Tony, Loehr, Dan, Harper, Lisa, “Emerging Requirements for Multi-Modal Annotation and Analysis Tools”, The MITRE Corporation, 2001.

Brannick, Michael, Team Performance Assessment and Measurement, Lawrence Erlabaum Associates, Mahwah, NJ, 1997.

Burns, Kevin, "Mental Models and Normal Errors in Naturalistic Decision Making", *5th Conference on Naturalistic Decision Making*, March 2000, Tammsvik, Sweden.

Cannon-Bowers, Janis, "Making Decisions Under Stress, EPS Group Inc," Easton, MD, 1998.

Carolan, Tom, Scott-Nash, Shelly, Corker, Kevin, Kellmeyer, David, "An Application of Human Performance Modeling to the Evaluation of Advanced User Interface Features".

Carr, Francis H., Hieb, Michael R., "M&S Interoperability with the DII COE: Building a Technical Requirements Specification", The MITRE Corporation, 2001, Simulation Interoperability Workshop, Orlando, FL.

Carroll, Lynn A., "Multi-modal Integrated Team Training", AMC, Communications, September 1999, Vol 42, No. 9

Cheikes, Brant A., Gertner, Abigail S., " Software Instrumentation for Intelligent Embedded Training", The MITRE Corporation, Bedford Massachusetts, 2001 <http://www.mitre.org/support/papers/tech_papers_01/cheikes_software/index.shtml>.

Damianos, Laurie E., Drury, Jill, Fandreclai, Tari, Hirschman, Lynette, Kurtz, Jeff, Oshika, Beatrice, "Evaluating Multi-party Multi-Modal Systems", The MITRE Corporation, 2000, Bedford, MA.

DiVita, Joseph C. and Nugent, William, " Managing Critical Events in a Multi-Modal Watchstation", SPAWAR Systems Center, San Diego, CA

Department of the Army, "Army Vision 2010", Washington, DC

Department of the Army, "TRADOC Pam 525-5", Force XXI Operations,

Freeman, Jared T., Campbell, Gwendolyn E., Hildebrand, Greg, "Measuring the Inpact of Advanced Technologies and Reorganization of Human Performance in a Combat Information Center," Office of Naval Research, *Proceedings of the 44th Human Factors and Ergonomics Society Annual Meeting,* August 2000, San Diego.

Freeman, Jared T., Cohen, Marvin, "A Critical Decision Analysis of Aspects of Naval Anti-Air Warfare", 1998

Gersh, John R., and Waltrip, Charles F., “Task Support Through Total Ship Information Management,” Technical Report Naval Sea Systems Command and the Office of Naval Research, John Hopkins University Appiled Physics Laboratory, Laurel, Maryland.

Guzzo, Richard, Salas, Eduardo, Team Effectiveness and Decision Making In Organizations, Jossey-Bass Publishers, Sand Francisco, CA.

Kellmeyer, David, Osga, Glenn A. “Usability Testing & Analysis of Advanced Multimodal Watchstation Functions”, *Proceedings of the Human Factors and Ergonomics Society 44th Annual Meeting,* August 2000, San Deigo, CA, pp 1-5.

Kelly, R.T., Morrison, J.G., and Hitchins, S.G., “Impact of Naturalistic Decision Support on Tactical Situation Awareness,” *Proceedings of the 40th Human Factors and Ergonomics Society Annual Meeting,”* September 1996, Philadelphia, PA.

Madaio, J. Hillers, B.J. and Vasilakos, J., “ Open Systems Architecture C4I Template”, Naval Engineers Journal, Winter 2001, Vol. 113, No. 1

Maybury, Mark T., “Distributed, Collaborative, Knowledge Based Air Campaign Planning”, *Nato/AGARD Lecture Series 200 on Knowledge-Based Functions in Aerospace Mission Systems,* November 1995.

Maybury, Mark, “Collaborative Virtual Environments for Analysis and Decision Support”, The MITRE Corporation, 2000, Bedford, MA.

Mayhew, Deborah, J. Principles and Guidelines in Software User Interface Design, Prentice Hall, Englewood Cliffs, NJ.

Miller, R., “Response Time in Man-Computer Conversational Transactions”, AFIPS Conference Proceedings, 1968, 33: pp.267-277

Neerincx, M.A., “ Optimizing Cognitive Task Load in Naval Ship Control Centres,” *Proceedings of the Twelfth Ship Control Systems Symposium,* October 1999, pp. 9-21.

Oonk, Heather M., St. John, Mark, Osga, Glenn A. “Designing Displays for Command and Control Supervision: Conceptualizing Alerts and “Trust-But-Verify” Automation”, *Proceedings of the Human Factors and Ergonomics Society44th Annual Meeting,* San Monica, CA. pp. 1-5

Osga, Glenn A., “21st Century Workstations- Active Partners in Accomplishing Task Goals”, *Proceeding of the Human Factors and Ergonomics Society 44th Annual Meeting*, San Diego, CA, 2000

Osga, Glenn A. “Task Managed Watchstanding - Concepts for 21st Century Naval Operations”, *Proceedings of the Human Factors and Ergonomics Society 44th Annual Meeting*, August 2000, San Diego, CA. pp. 1-4

Osga, Glenn A., Van Orden, Karl, Kellmeyer, David, “Task-Managed” Watchstanding: Providing Decision Support for Multi-Task Naval Operations”, Simulation and Human-Systems Technologies, pp.176-184

Osga, Glenn A., “The Task-Centric Multi-Modal Watchstation: A Key to Crew Optimization for Future Ships,” Naval Command, Control and Ocean Surveillance Center, RDT&E Division, San Diego, CA.

Osga, Glenn A & Van Orden, Karl F., “Key User Support Technologies to Optimize Future Command Crew Efficiency,” Naval Command, Control and Ocean Surveillance Center, RDT&E Division, August 2000, San Diego, CA.

Pharmer, James A., “Distributed Team Performance: An Executive Summary”, Naval Air Warfare Center Training Systems Division, May 2001, pp 1-5.

Preece, Jenny, Human-Computer Interaction, Addison-Wesley Publishing Company, Workingham, England, 1994

Neilson, Jakob, Usability Engineering, AP Professional, Boston, MA, 1993

Ramesh, R., Andrews, Dee H. “Distributed Mission Training, Teams, Virtual Reality, and Real-Time Netwroking, AMC, Communications, September 1999, Vol 42, No. 9

Rasmussen, J, Information Processing and Human-Machine Interaction: AN Approach to Cognitive Engineering, Elsevier, Amsterdam 1986.

Sanders, Mark & McCormick, Ernest, Human Factors In Engineering and Design, Seventh Edition, McGraw-Hill, Inc., New York, NY, 1993

Saunders, Thomas F., A Vision of the Future for the Air Force (and perhaps the whole DoD)”, The MITRE Corporation, 2000. <http://www.mitre.org/support/papers/tech_papers99_00/saunders_vision_af/index.shtml

Sheniderman, Ben, Designing the User Interface Strategies for Effective Human-Computer Interaction, Third Edition, Addison-Wesley, Reading, MA, 1998

Tang, John C., Leifer, Larry J., “A Framework of Understanding the Workspace Activity of Design Teams”, ACM, 1988, pp. 244-249.

Shneiderman, Ben, “Response Time and Display Rate in Human Performance with Computers”, AMC, Computing Surveys, Vol. 16, No. 3, September 1984.

Shieber, Stuart M. “A Call for Collaborative Interfaces”, AMC Computing Surveys, 28(4es), December 1996, <http://www.acm.org/pubs/citations/journals/surveys/1996-28-4es/a143-shieber>.

Soulard, Pascale, Raimondo, A. “Self Adaptive Interfaces and Multi-Modal Human Interaction for Combat Systems”, Undersea Defence Technology, London 1992. <http://www.artis-facta.com/PUB/92UDT/92UDT.HTML>

St. John, M. and G. Osga, “Supervision of Concurrent Tasks Using a Dynamic Task Status Display”, *Proceedings of the 43rd Human Factors and Ergonomics Society Annual Meeting,* October 1999, pp. 168-172.

St. John, M., Harris, W., & Osga, G., “Designing for multitasking environments: Multiple monitors versus multiple windows,” *Proceedings of the Human Factors and Ergonomics Society 41st Annual Meeting*, 1999, Santa Monica, CA:

St. John, M., Manes, D.I., Oonk, H.M., & Ko, H., “Evaluation of multi-monitor workspace designs: Multiple monitors vs. desktop diagram controls,” *Proceedings of the 43rd Annual Meeting of the Human Factors and Ergonomics Society Annual Meeting,* Santa Monica, CA., 1999

Van Orden, Karl F., ”Workload Assessment and Management for the Multimodal Watchstation”, *Proceedings of the 44th Annual Meeting of the Human Factors and Ergonomics Society Annual Meeting,* Santa Monica, CA., 2000.

Wickens, Christopher D., Engineering Psychology and Human Performance, Second Edition, HarperCollins Publishers Inc., New York, NY, 1992

Wickens, Christopher D., Gordon, Sallie, Liu, Yili, An Introduction to Human Factors Engineering, Addison-Wesley Educational Publishers Inc., New York,NY, 1998

Woodson, Wesley E., Human Factors Design Handbook, McGraw-Hill Book Company, New York, NY

www.army.mil/2010 Army Vision 2010

www.dtic.mil/jv2020/ Future Warefare

http://diicoe.disa.mil/coe Defense Information Infrastructure Common Operating Environment Home Page

ww.acq.osd.mil/bmdo/bmdolink/html/tmd.html Theater Missile Defense Programs

www.,manningaffordability.com/s&Tweb/T2MMWS SC-21/ONR S&T Manning Affordability Initiative

http://www.manningaffordability.com/S&tweb/Thrust_2.htm Multi – Modal Workstation: Background and Description

www.navy.mil U. S. NAVY

www.dtic.mil/jv2010/jvpub.htm Joint Vision 2010

www.dtic.mil/jv2020 Joint Vision 2020