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DEVELOPING A LARGE-SCALE DISTRIBUTED INTERACTIVE SIMULATION SYSTEM

Thomas Mastaglio

LORAL Federal Systems
CCTT Integrated Development Team
12461 Research Parkway, Suite 400
Orlando, FL 32817, U.S.A.

ABSTRACT

The Close Combat Tactical Trainer (CCTT) is a simulation-based training system being developed using a concurrent engineering approach. Industry and government engineers together with prototypical system users comprise the concurrent engineering teams. User representatives are located, along with industry, in an integrated development facility where they interact on a daily basis with the rest of the engineering team. CCTT is a large-scale complex simulation, its primary purpose is to improve human performance through its use in training. Focusing on human performance improvement as a simulation system product mandates a development effort based on usability engineering. Because CCTT has complex Human-Computer Interaction requirements, field users have been integrated throughout the design, development, and evaluation phases of the program.

1 INTRODUCTION

The United States Army requires training environments in which to practice combined arms close combat in order to provide collective training for combat arms units and their supporting elements when organized into a combined arms team (Loral 1993). SIMNET (Thorpe 1987, Alluisi 1991) was an advanced technology demonstration that the synthetic environments provided using Distributed Interactive Simulation or networks of simulators (Beaver, O'Brien, and Riecken 1992) can accommodate this requirement. The success of that research and development effort motivated the Army to embrace simulation technology as a fundamental basis for their future training systems and establish a requirement for the Close Combat Tactical Trainer (CCTT).

In CCTT, fully interactive collective task training is conducted on a virtual battlefield based on a database of computer generated terrain (Johnson, Mastaglio and Peterson 1993). The CCTT system will support Army ground force commanders in planning, conducting, and reviewing unit training on a computer-generated synthetic battlefield. CCTT is a system of networked simulators and computer workstations which as a whole provides a simulation. That simulation must support Army units in training to perform their collective tasks. An effective simulation will result not only if each component works properly, but if the synergism of their collection into a holistic system is demonstrated to be adequate for those purposes.

Normal good engineering practices by themselves will assure that components are properly designed and implemented. To insure the overall simulation meets the end users need we found it important to incorporate their perspective early in the development phase of the program. The approach chosen to achieve that goal was to integrate user into our development organization and processes.

CCTT is being developed using a concurrent engineering approach (IEEE 1991). The CCTT integrated development team (IDT) incorporates prototypical system users into the concurrent engineering process (Mastaglio and Thompson 1993). The user representatives which participate in concurrent engineering activities are known collectively as a User Optimization Team, specifically for CCTT, the Army Optimization Team. That team is comprised of both on-site users and a supporting cast of Subject Matters Experts (SME) working at Army schools and centers.

This paper describes how users are being integrated into the CCTT development. Its purpose is to share with other simulation system developers what we believe is an innovative approach to achieving the goals of participatory design (Schuler and Namioka 1993). This is crucial for a complex simulation system. The approach can be applied to other large scale simulation development efforts.

2 WHY A USER-FOCUS

CCTT is a complex human-computer interaction system. It includes over 50 different interfaces of varying types. Included in the system are:

- workstation interfaces to the computational system,
- simulators that interface with the synthetic environment via the computational system and
- computer interface devices and techniques that do not necessarily replicate a real world piece of equipment but which must provide realistic access to the synthetic environment.

We want to insure that this system functional complexity does not carryover to the manner in which the system interfaces with users or to the manner in which the system is operated. Therefore, a participatory approach to system development that includes a strong user-centered focus was selected.

The primary purpose of CCTT is to train soldiers to better perform as a team. It is not unique, but rather is the first of an entire class of simulation systems which will be developed over the next several decades to support a trend in military training which is to augment operational exercises with simulator/simulation-based training. This class of simulations present a unique problem in that their primary product is neither simply system efficiency nor representational fidelity for analytic studies, but rather training or simulation system level effectiveness. The success or failure of these training simulation systems will be determined by their:

- user acceptance.
- ability to replicate real world task performance conditions, and
- efficacy in changing human behavior (i.e., improving task performance proficiency in both the replicated and actual environments).

2.1 User Acceptance

Development activities need to include the participation of actual users of these training systems to guide design activities toward meeting the above three objectives. User acceptance is enhanced by garnering the consultation of prototypical users who work within the training/combat development communities throughout the design and development process.

There is, of course, a direct impact, an improved system design resulting from user participation. There is also an indirect impact involving user acceptance that results when the community the users represent learn that a system development will take into account what that community thinks and wants.

2.2 Replicating Task Conditions

Simulating the environment in which training occurs is difficult, especially insuring that we include as part of a selective fidelity (Miller 1991) analysis those system features which are critical to performing the collective tasks. We are specifically concerned with two types of fidelity. The terrain that represents the virtual world must be of sufficient fidelity to adequately achieve a sense of immersion. The simulators must have sufficient fidelity to adequately support task performance. Users need to be frequently consulted to review the virtual environment used in a training simulation. An up front analysis is used to determine the required fidelity of each simulator based on the collective tasks the system is designed to train. Users review that analysis and resulting design decisions.

Exposing the simulation system's design and prototypes of each type simulator and workstation to users early in the development process insures their features properly support learning of the training tasks. Selective Fidelity is a key concept for designing simulation systems: the "selection" process has to be user-supported as well as analytically based on support for the training tasks. These processes require user support.

2.3 Improving Task Performance Proficiency

Effectively modifying human behavior is both the most crucial of these three criteria and the most difficult one to evaluate during design and development. The expert judgment of users who are current in their combat discipline needs to be brought to bear in evaluating design decisions. Similarly, this type of user needs to be called on to assess system effectiveness incrementally during development and early production runs.

A training system, more so than even men-in-the-loop combat systems, must be developed with a user focus. Training effectiveness will be achieved only if user needs and expectations are understood and incorporated early in the development process. Our approach to CCTT was established with that in mind. We are using an integrated development methodology which includes users representatives as part of an industry/government team.

3 THE USER OPTIMIZATION TEAM

We call our approach to integrating users into the CCTT development a User Optimization Team, specifically the Army Optimization Team (Mastaglio and Thompson 1993) because the Army is our customer and the user of CCTT. The Army Optimization Team is comprised of on-site soldier-experts and a matrix of outside expertise, other active duty soldiers available for off- and on-site consultation. The industry team designated an engineering staff member whose primary role is overall responsibility for integrating users, the program's Training Effectiveness Advocate.

3.1 On-Site Users

The on-site team is comprised of soldiers who represent the primary training audience for CCTT. An Officer with recent experience in the types of units which will train using the system heads up the team. He provides expertise on collective training and supporting battle staff operations. Two senior Non-Commissioned Officers (NCO), one from the Armor Center, the other from the Infantry Center, provide expertise at the simulator and task performance level. The NCO's are master gunners and experienced training developers. All are members of Concurrent Engineering (CE) Teams; they attend weekly meetings, review design documentation, and advise system and software engineers on decisions regarding the system design.

3.2 Subject Matter Experts

The on-site team is also responsible for interfaces between the CE Teams and outside subject matter experts (SMEs). They accomplish this using an electronic mail network established to link SMEs at remote locations with simulation engineers.

A network for SMEs was established by the Army. There are twenty-five SMEs at 11 proponency centers whose jobs' are training and combat development. They teach, develop, or evaluate tactics, techniques and procedures for the Army. Their areas of expertise include combat operations within their branch, the use of specific pieces of equipment on the battlefield, combat service support operations and etc.

SMEs are a resource for answering specific questions and are also called on to support on-site user reviews. They answer questions using electronic mail. Queries regarding system design issues are forwarded through the on-site members of the optimization team via that system. When user review panels are convened to assess analytic efforts, preliminary designs, and prototypes, these same personnel travel to the development facility.

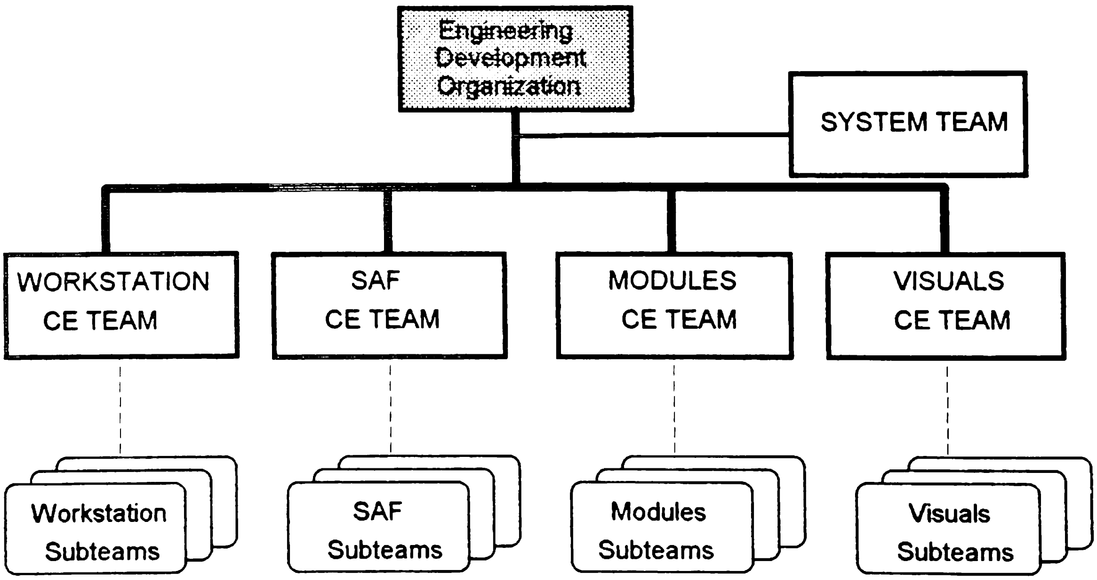

FIGURE 1 CE Team Organization for CCTT Integrated Development

4 CONCURRENT ENGINEERING

The CE Teams developing CCTT are product focused. The customer's program office engineering staff and industry's development engineers are key members of and jointly lead these teams. The teams include expertise from a variety of domains that are also often represented by joint working groups. Users also participate on the CE Teams. They work, as needed, with those sub teams developing individual system components or which are organized to focus on special programmatic or technical issues.

4.1 Concurrent Engineering Teams

The CCTT Integrated Development approach organizes all of the engineering effort and personnel into the CE Teams shown in Figure 1. A Module Team is responsible for the design, prototyping and production of all simulator modules in CCTT. A Semi-Automated Forces (SAF) Team is responsible for designing and implementing the SAF software.

A Workstation Team is responsible for software development and hardware integration of all workstations in CCTT. This includes both those used by the training audience (e.g., the workstation replicating the Fire Support Element) and those used to support system operations (e.g., the Master Control Console). The Visuals CE Team produces the visual databases and renderings of all entities in the synthetic environment.

The System Team is somewhat different than the CE teams, but is managed within the development organization as if it were. Rather than responsibility for specific components, the Systems Team is responsible for the overall system architecture, directing and enforcing compliance with DIS standards and interoperability issues. The System Team also has responsibility for integration of the CE Team-built components, support for user evaluations of incremental builds of the system, and system test near the end of development.

Sub teams are comprised of members of each CE Team. They work on a specific piece of hardware or software. These teams will meet as required and are less formal in that they are frequently those engineers who work together, perhaps even in the same office, on a daily basis on some part of the system. The four formal CE Teams meet weekly or bi-weekly at a regularly scheduled time.

The CE Teams have functional expertise support across a variety of domains. Some areas of expertise reside in one or two individuals (e.g., Safety) and therefore these same individuals are members on all CE Teams. Other areas have a larger staff of engineers working on the program and it is split between teams (e.g., Human Engineering). Teams are collectively responsible for addressing the requirements and concerns of each domain, they call on the assigned team member in that area to support them. Each team member is in part responsible for the team's solution. This is a departure from many development organizations where staff from some areas serve to oversee and critique the efforts of others rather than directly contribute to the solution.

4.2 Role of User Optimization Team in CE Process

The User Optimization Team plays a crucial role on each CE Team. Its members provide an interface to and represent the proponent and user community for CCTT. Their role includes both serving as a respondent to requests and inquiries that arise during CE team activities and being a catalyst for user-focused activities.

As an example of their role as a respondent, a question about the potential application of CCTT in training or how a piece of equipment being simulated is actually used gets referred to the User Optimization Team member on-site. He may answer the query directly if it falls within his area of expertise. If not, he will initiate an action to obtain an official answer using the SME-Net. He is responsible to the CE team for obtaining an adequate response. All such information is advisory only; the responsibility for what is implemented in the CCTT simulation still resides with the development engineers. Acceptability of the design and the system during reviews and testing remain the responsibility of the industry engineering staff.

The Army Optimization Team Members often find themselves serving as catalysts. They help the CE teams forecast when user reviews are appropriate. For example, coordinating user review of analytic results or prototypes scheduled for completion need to be projected far enough in advance that the Army can arrange for the appropriate support. The Optimization Team finds that their role is often more proactive, reminding their CE Teams to plan for and request needed support.

5 CONCLUSION

Based on initial experiences, the User Optimization Team is proving to be an effective technique for incorporating user desires and perspective when developing a training simulation. The approach is better than techniques such as user juries alone or more traditional periodic formal reviews for the user community or structured working groups. Our experiences and lessons-learned can be applied to the development of any complex simulation that will ultimately include men-in-the-loop whether it is used by trainees or analysts in the field.

The User Optimization Team approach is a key aspect of the CCTT Total Quality Management (TQM) approach. It insures that user/customers for CCTT are an integral part of the development process. Our goal is improving the quality of the simulation and enhancing user acceptance. The techniques described here are specific for a training simulation system and, as discussed above, the very nature of training devices make their development a prime candidate for this approach. However any complex simulation system development efforts could benefit from the integration of users into the engineering process following the user optimization team concept.

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AUTHOR BIOGRAPHY

THOMAS W. MASTAGLIO is a Senior Engineer with Loral Federal Systems Company. He is the Training Effectiveness Advocate for the CCTT Integrated Development Team in Orlando, Florida. Prior to assuming that position, he served 22 years in the U.S. Army and was a Simulation Systems Consultant for PAIDEIA in Virginia Beach, Virginia. He has a PhD from the University of Colorado in Computer and Cognitive Science. His research interest focus on applying human-computer interaction technology and processes to large scale complex system developments, specifically in the domain of simulation applications.