The Jagged Joystick:
Game Technology for Net-Centric Training Simulations

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ABSTRACT: *By definition, network defenders must prepare for the latest attacks on the latest software running on the newest network topologies. Network product lifecycles shorten, and simulations are expected to incorporate the latest devices, protocols, and network management tools. This has been the authors' experience with SimBLEND, a 3D game-based framework for teaching computer network defense, currently under development. Other net-centric applications have similar demands. This report identifies how game-based technologies can be used for net-centric applications training, and lists features required of middleware architected to mitigate difficulties in integrating disparate technologies into a common training environment. Harnessing multiplayer game technologies for training is a widely shared goal. Anticipating broader adoption rates, some planners envision integrated portfolios that span traditional lectures and game-based simulations. Experiences cited by the SISO SCORM-SIM-SG group suggest game-based simulations could interoperate with other institutional learning management suites to quantify trainee improvements. Managers of net-centric applications have still loftier expectations, but when used for net-centric simulations, the 3D game environment can be unforgiving. To achieve composability and scalability, network objects and processes will need to be modified and/or replaced as technologies advance. Most games developed today feature costly investments in highly specialized 3D models. When change is feasible, it may be impossible without specialized talent. Skeptics worry that development of such simulations results in costly, inflexible designs that run counter to the need for nimble content. The middleware concepts presented are one element in improving this situation – the sandpaper needed to smooth the joystick.*

1. Introduction

For decades, the focus of the Modeling, Simulation and Training community has been in the "kinetic" domain. Whether it is aimed at the military arena, or operations other than war (OOTW), the common elements have been equipment, people, actions and events that have physical characteristics. This paper addresses an emerging new dimension – the cyber dimension – that is an integral part of net-centric warfare. Net-centric warfare requires that its underlying computing and communication resources maintain their confidentiality, availability, and integrity. In addition to the defense community, other government agencies, such as Veterans Affairs and the IRS, require a similar level of assurance to perform their missions. The critical infrastructures of the United States – including power, financial, and medical – are highly dependent upon secure and available computing and communications resources. To help ensure their integrity, all of these operational environments – military, civilian government, and industry – require a work force that is educated in and motivated to perform computer network defense (CND). A failure to supply that workforce jeopardizes the economic and physical security of our citizens.

2. The Need For CND Training

Unfortunately, there are not enough people trained in CND to defend the government and private sector’s critical networks. This problem is exacerbated when one filters the pool of potential network defenders to include only US citizens, which is generally a requirement of DoD facilities. Jack Johnson, Chief Security Officer at the Department of Homeland Security, [1] summed it up as: “There is an incredibly shrinking pool of IT security professionals in government.” Using a sports metaphor, he said: “The bench is not just thin; the bench is non-existent. We need to train the next generation.”

The government is also competing with industry for the same pool of network defense experts. A more recent report published by the Department of Management at the London School of Economics summarized the results of surveys conducted with IT executives, financial officers, and compliance specialists at large companies located around the world. InfoSec News [2] reports that: “While the lack of adequate help is currently most severe in the United States … the shortage of highly skilled security expertise will soon come to a head in other nations … and a *large number of companies rely on a very small pool of internal talent for handling compliance and security projects*, making it extremely difficult for those firms to replace their specialized workers when employees jump ship.”

New people need to be attracted to the network defense workforce. Studies – including a formal Cognitive Task Analysis of CND analysts performed by Secure Decisions for the intelligence community [3] – show that there is no single common career path into network defense; some of the most expert CND analysts do not have degrees in Computer Science.

The US government and industry need to capture the attention of young, motivated people and encourage them to enter and grow in the profession. Training is a critical element of this, but CND training can be a mundane, even boring, subject area; producing a training system that *thoroughly engages* trainees is the key to teaching those fundamentals of computer network defense that can improve their decision-making and related cognitive tasks in evaluating network configurations, packet flows, usage trends, connectivity patterns, and formulating remedial actions.

3. The SBIR Project

The need for CND training described was recognized by the Air Force Research Laboratory (AFRL) in Mesa, AZ which led to the development of Small Business Innovative Research (SBIR) topic AF071-038, “Integrated Simulations and Courseware for Network Defense Training”. Applied Visions’ Secure Decisions Division was awarded a Phase I contract for the topic in early 2007 and has recently been selected to continue into a Phase II effort.

The overall goal of the entire three-year project is to address the need for CND training through an innovative training system that provides entry-level CND analysts with the ability to learn fundamental concepts and practice their skills, within a single platform that offers both standard Computer Based Training (CBT) and innovative simulations for practical exercises. Because our envisioned training environment *blends* CBT with simulated scenarios, we refer to this future system as **SimBLEND** – the *Simulation-Based Learning Environment for Network Defense.* We also envision that the system will have a gaming look and feel to maximize the student’s motivation and level of engagement.

3.1 SimBLEND’s role in the ISD process

SimBLEND is targeted at the *Implementation Phase* of the Instructional System Design process, i.e. the method in which the instruction is delivered to the learners (see Figure 1). We also recognize that SimBLEND will be valuable for the *Evaluation* of the course’s effectiveness, but we expect to apply existing learning management technologies to assist us with this.

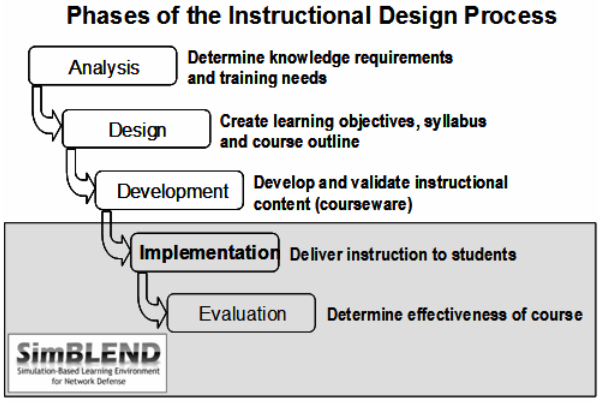

Phases of the Instructional Design Process
Analysis
Determine knowledge requirements and training needs
Design
Create learning objectives, syllabus and course outline
Development
Develop and validate instructional content (courseware)
Implementation
Deliver instruction to students
Evaluation
Determine effectiveness of course
SimBLEND
Simulation-Based Learning Environment for Network Defense

Figure 1 - SimBLEND is targeted at the Implementation Phase of ISD

Because SimBLEND is clearly focused on implementation, and not on designing or developing courseware, it relies on input from other training resources and interfaces to other training media. For example, someone external to SimBLEND will author the training content to be presented by the system and managed by the selected learning management system (LMS). Existing established network simulations such as NETWARS, NS2, and QualNet can be leveraged by SimBLEND alleviating the need of developing one “in house”.

3.2 Requirements Analysis

The most important step in designing and developing a new system is the accurate communication of operational requirements from those who need the system (the users) to those who will be building the system (the developers). In order to ensure the SimBLEND system is best aligned to meet the needs of the CND training community, an effort was made throughout the Phase I project to meet with potential users and obtain feedback on the SimBLEND concept and to gather system functional requirements.

Representative Operational Conditions - SimBLEND is being designed as a distance learning educational tool and as such has the goal to deliver education to students who are not physically "on site". Regardless of location, students only need a network connection and proper system credentials to be able to access SimBLEND content and take desired, available CND courses. Communication between instructors and students would largely be through integrated electronic means such as chat, email or videoconferencing.

SimBLEND can also be used for traditional, computer lab, classroom settings such as the Air Force Institute of Technology (AFIT) where student physical onsite presence is required and communication between students and instructor is for the most part, direct verbal exchanges.

Representative Training Content - SimBLEND's conceptual design allows for training of tasks where the quantity and task subjects are limited only by the CBT content provider's imagination and willingness to author SimBLEND vignette training practicums for each lesson. Although nothing about the design of SimBLEND precludes it from being used to train intermediate or advanced courses in CND, the initial emphasis of SimBLEND is directed at providing a training platform for entry-level CND students. A brief subset of material relevant to entry-level CND positions includes:

- Procedures and conformance
- How to configure a firewall
- TCP reset
- DDoS attack on routers
- Auditing logs for IA managers
- Peer to Peer (P2P)

Additionally, we view SimBLEND as a platform to offer vendor specific CND tool training such as the training material developed by SourceFire that teaches students how to configure and use Snort (an open source network intrusion prevention and detection system). Part of our Phase II commercialization plan includes targeting vendors of CND tools and offering the SimBLEND framework as a means to provide an innovative way to teach and train their customer base on desired tools and capabilities.

User Roles - At its core, SimBLEND supports two user roles - "Student" and "Instructor", but within the game-based training vignettes, the Student may take on any number of CND roles (such as data triage analysts, escalation analysts, correlation analysts, threat analysts, incident response analysts and forensic analysts) depending on the selected CND training module. It is also recognized that future versions of SimBLEND will allow multiple students to join forces to form new, overarching roles of "Red" (cyber attack) and "Blue" (cyber defense) teams.

Student Functional Requirements - From the SimBLEND system perspective, the main user is the student and as such, the student console will be our primary focus of the Phase II project. Satisfying the following student functional requirements will help ensure the SimBLEND system exposes the necessary functionality required for student's to learn and practice new concepts and skills.

- Log in
  - Student must log in and authenticate with the LMS
- View own course history
  - See what courses were taken
  - View performance metrics on past courses
  - Review material of past courses
- Select Course
  - Review course relevant CBT material at own pace
  - Course relevant material to be pushed to student console through LMS
  - Ability to pause, rewind and resume CBT material
- Take CBT comprehension assessment
  - Course relevant multiple choice questions are exposed
  - Scoring is recorded as hard metric back to the LMS
- Attend Mission Briefing
  - Instructions and objectives are laid out by Non Player Characters (NPCs).
  - Student has option to return to CBT for "re-training"
- Perform vignette training practicum
  - Training practicum content is based upon selected course and Student's selected role within the game.
  - Student has ability to request "hints" in order to complete mission

  - Capture “Soft” metrics (that are measurable but may not be direct indicators of performance) are collected such as elapsed time, order of steps performed, and whether or not standard protocol was followed
  - Capture “Hard” metrics (that are measurable and are considered direct indicators of performance) are collected such as number of objectives successfully met and the number of hints requested in order to complete the mission.
- Participate in After Action Review
  - Computer generated Non-player charaters (NPCs) debrief students on their performance and the impact of their performance on the overall mission
  - Student overall performance scores are provided and recorded back to the LMS
  - Student performance governs system recommended action for next course material to be covered. Good performance scores result in new material recommendations while poor performance scores result in recommended review of prior material.

Instructor Functional Requirements - Although we won’t build an Instructor Console until later in the program, we identified the primary requirements in Phase I, which consist of the following:

- Review student course history for any desired student
- Determine active student enrollment that identifies:
  - What students are actively taking a course
  - What course each student is working on
  - What part of the course each student is actively working on
  - Current automated assessment score
- Ability to intercede in any student’s lesson to:
  - End the training / course
  - Redirect the student by giving hints of what needs to be done
  - Force the student back to an earlier part of the lesson
- Receive automated alerts if student is taking longer than the lesson section’s expected completion time duration threshold
- Ability to connect to a given active student’s lesson/training session, drop in to the student’s virtual world as an avatar player and interact with the student

3.3 Top Level Architectural Design

Based on the Functional Requirements described above, we developed a high-level architectural design for SimBLEND, shown in Figure 2 below. The architecture is based on five main concepts (described in the ensuing paragraphs):

- A learning Management System (LMS)
- A scripting capability called “BLENDscript”
- A Network Middleware Abstraction Layer called “BLENDnet”
- A Scene Generator
- A Game Engine
- A Network Simulator

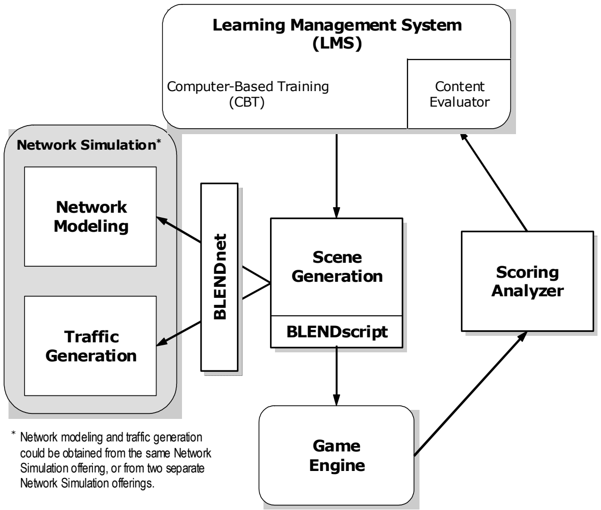

Learning Management System (LMS)
Computer-Based Training (CBT)
Content Evaluator
Network Simulation*
Network Modeling
Traffic Generation
BLENDnet
Scene Generation
BLENDscript
Scoring Analyzer
Game Engine
* Network modeling and traffic generation could be obtained from the same Network Simulation offering, or from two separate Network Simulation offerings.

Figure 2 SimBLEND High Level Architecture

3.3.1 Learning Management System (LMS)

The LMS is responsible for providing a means for instructors to:

- Author, maintain and deliver course material;
- Monitor student participation by tracking student progress through CBT material;
- Assess student performance with regard to CBT material.

In Phase II we will identify an off-the-shelf LMS that handles the kind of CBT we want to deliver in SimBLEND, and one that has the flexibility of being extended. Extensibility is desired since we would like the LMS to be able to take into account and manage performance measures that are calculated by the proposed *Scoring Analyzer* component. We envision adding a component to the selected LMS called the *Content Evaluator* that will be responsible for logging the student’s overall performance score (derived from the *Scoring Analyzer)* into the LMS, ensuring the student’s recorded performance during the training vignette will help drive the next set of CBT to be delivered.

Although not necessarily a requirement for the project, we would like to be able to select an LMS that is compliant with the 2004 Shareable Content Object Model (SCORM)[4] standard. Choosing an LMS based on standards (such as SCORM) will enable SimBLEND to better interoperate with training material from any organization (military or commercial) that has also followed the SCORM standard when producing content.

3.3.2 Scripting Capability (BLENDscript)

All commercial-quality game engines offer the ability to extend and customize games through the use of a scripting language. We plan on making extensive use of the selected game engine's scripting ability to push the requisite CBT and virtual vignette functionality into the game engine, coupled with the development of *BLENDscript* as the component that will be able to translate objects and desired actions from SimBLEND's internal representation to a script that tells the game engine what to display in the game environment along with what actions/moves are allowed.

3.3.3 Network Middleware Abstraction Layer (BLENDnet)

One aspect of SimBLEND that separates our approach to CND education and training from others is the ability to train on complex networks by leveraging an existing network simulation capability. In order to reduce the dependency on any particular network simulator offering, we will create a middleware abstraction layer – called *BLENDnet* – that will be responsible for the translation between the network simulator and SimBLEND's internal representation.

Abstracting the network simulation capability in this manner opens the opportunity to switch to different network simulation offerings, as the need arises, in a modular, unobtrusive manner. We have identified this capability to be on the critical path for the commercialization of SimBLEND: since we are relying on integrating third-party functionality to provide the actual network simulation, SimBLEND will be more viable if the choice of what network simulation package to use is left up to the customer. For instance, a military deployment of SimBLEND may prefer NETWARS, since it is free for government use, while a commercial deployment to an organization that is currently paying a license fee for a different network simulator may be more likely to use SimBLEND knowing that they can make use of technology that they already have in place.

3.4 Scene Generator

The purpose of the *Scene Generator* is to produce a script for the game engine to execute. The Scene Generator may also at times consult with the selected Network Simulator component, through BLENDnet, in order to represent a realistic network model to display within the training vignette section of the lesson.

The Scene Generator will gather all of the data it needs to either display the given CBT within the game environment for the learning section of the lesson, or to produce the virtual vignette for the training section of the lesson. Once the necessary data is gathered, the *Scene Generator* leverages BLENDscript to produce the gaming script that will be passed to the Game Engine component for execution.

3.5 Game Engine

Perhaps the most compelling aspect of SimBLEND from the student's perspective will be the simulation environment, where they will experience virtual vignettes to test their skills in a realistic setting. The key to achieving this capability is to enlist the services of a third-party game engine – a software package that creates a highly graphical, interactive, and engaging simulation that will keep the student involved in the training.

The vignettes can be as long or short as the content developers deem appropriate for the subject matter being taught. Each vignette will provide the student with a mission that may require the student to meet multiple objectives to complete the mission. Parts of that mission may be to analyze, react to and report findings on network traffic data that is supplied by the Network Generation part of the *Network Simulator* component. All the information required for vignette execution is gathered by the *Scene Generator* component and delivered to the game engine through *BLENDscript*. During execution of the vignette, mission specific hard and soft metrics will be collected and passed on to the *Scoring Analyzer* upon the completion or exit from the mission.

There are many game engines available in the industry, and most game engines support a variety of gaming styles. We believe that CND training can benefit from several gaming styles, and as such we will favor a game engine that offers a choice. One training scenario may best be presented by employing a real time strategy (RTS) game mode, placing the student in charge of procedures and conformance for a virtual Security Operations Center (SOC). In another scenario, a "first person shooter" (FPS) style of game might be more appropriate where the student is able to interact directly with firewalls or other equipment located in the virtual SOC.

Some of the capabilities that we look for in evaluating game engines include:

(1) Flexible, powerful and easy to use scripting language

(2) Game engine support tools capabilities and features

(3) Fast, efficient rendering capabilities

(4) Realistic physics engine

(5) Required level of effort to author and deploy a "simple" scene

(6) Good level of support, including active user forums

While we are currently using the open source Delta3D game engine on another project [5], as well having worked previously with commercial products such as the UnReal Engine [6], the rapid pace that fuels the gaming industry continues to provide new and better products each year. For our Phase II work we will evaluate new game engine technology, including Microsoft's XNA Game Studio, which offers a highly efficient environment for game development based on .NET and C#.

3.6 Network Simulator

The *Network Simulator* is responsible for realistically modeling real-life networks (military or otherwise) and for providing the capability to accurately simulate traffic scenarios on the network. For reasons detailed earlier, we will integrate an existing capability for this piece of SimBLEND. During our Phase I research we investigated several network simulation capabilities including NETWARS by OPNET and QualNet by Scalable Networks Technologies Inc.; as of this writing we have not yet made a definitive selection of a simulation vendor. Additional capabilities have recently come to our attention that we would like the opportunity to research further, such as the *Air Force Communications Agency Simulation Training and Exercise* (AFCA SIMTEX), developed by EADS North America Defense and Security and Systems Solutions Inc., and Architecture Technology Corporation's (ATC) CyDEST capability, developed under a recent AFRL Phase II SBIR.

Key capabilities of the Network Simulator include:

- Network Environment Modeling – Much like a fighter pilot who spends countless hours in an aircraft simulator prior to actually flying an aircraft, CND analysts should have the ability to practice their skills in an environment that will not affect "live" networks. They should have the freedom to explore the consequences of their actions, or inactions. Providing this kind of capability without costly (and complex) "simulator" hardware is essential to the mission of SimBLEND; we need a software capability to accurately represent arbitrary network environments including:
  - Network Topology – a view that shows how the various network assets such as hosts, servers, routers, switches etc. are connected
  - Device Templates – specifications and representative images of the devices on the network
  - Organizational Structures – identifying the organization, geographic location, building and floor plan.
- Traffic Generation – Two important aspects of simulating a network are: (1) the ability to simulate the actual traffic flowing across the network; and (2) to show how network traffic is affected when different actions are taken on the network, such as ports being closed or computers being taken offline. Different lessons that we present in SimBLEND will require different data. We will be looking to leverage a traffic generation capability to supply us with realistic network traffic that meets each lesson's objective. Additionally, we will be looking to have the gaming script generated by the Scene Generator's interaction with BLENDscript control how and when the network data is to be modified in response to user action.

4. Conceptual Prototype

During this Phase I effort, we developed "mock ups" of selected portions of SimBLEND functionality to graphically portray our concept which is a "learn and apply" game whereby the student first needs to acquire the requisite knowledge for a selected CND topic and then apply that knowledge while trying to complete topic specific mission objectives within a game setting. The sub-sections that follow give a brief glimpse of the main scenes and workflow we are planning to focus on for a Phase II working prototype.

4.1 Prequalification Room

The prequalification room allows the student to log into the LMS and select a CND course. The student is able to review the available course material browsing forward and backward as desired.

Depending on the course selection, the student will be presented with various qualification tests where a minimum score must be attained prior to the student being afforded the opportunity to practice what has been taught.

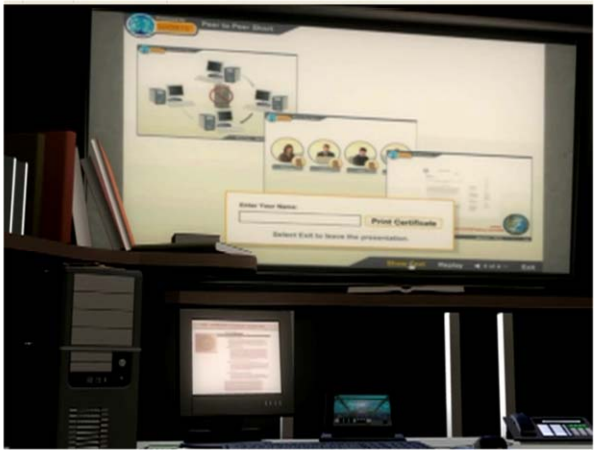


Figure 3 Prequalification Room

If minimal scores have not been met or excessive weakness has been detected in certain areas of the material, the student will be redirected to either review those same areas or be presented with new relevant material to help deliver the intended concepts.

Room Highlights:

- Course selection
- Delivery of off-the-shelf SCORM content
- Accessible to other digital learning materials
- Prequalification testing

4.2 Observation Room

The observation room is not a room the student will have access to, but rather is the central command location for the instructor and any distinguished guests.

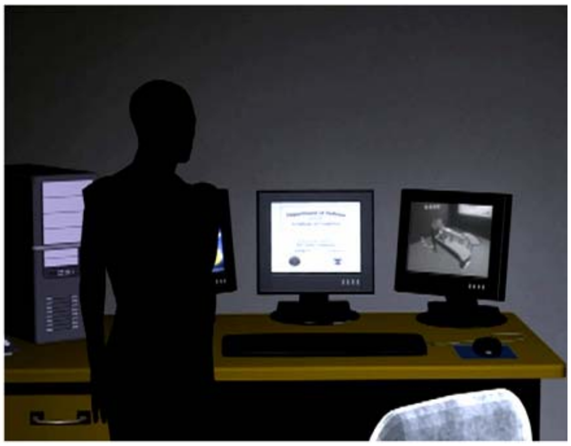


Figure 4 Observation Room

We envision the observation room having direct visibility over all of the rooms the student is able to access. This visibility may be direct through observation windows in the room or through bringing up desired rooms on a surveillance system to track particular students' progress through the course.

Room Highlights:

- Direct observation of learning and game play in real time.
- All rooms are visible from the observation room (either directly through observation windows or through surveillance camera video) giving the Instructor the overall view of what is taking place.
- Enables instructors to adjust attack plans or network characteristics while the game is in progress (idea for future version)

4.3 Network Operations Center Corridor

The Network Operations Center (NOC) corridor has offices for each CND job role. Each office door has a nameplate where the job role represented by that particular office is displayed.

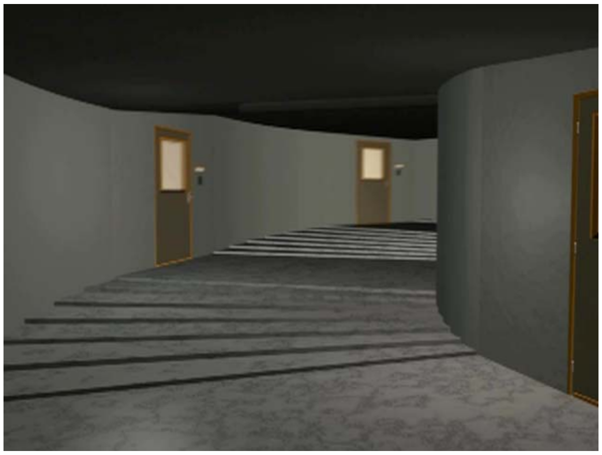


Figure 5 Network Operations Center Corridor

Student avatars walking through the corridor can stop at desired offices and learn the role and responsibilities of each job position. For those offices where the door is unlocked, the student avatar may enter the office and "take on" that particular job position for the currently selected CND topic.

Room Highlights:

- Learn about various CND job roles and responsibilities
- Select a user role from the NOC hallway by entering an office with desired job title

4,4 Mission Briefing Room

Once a student avatar selects a CND job role, SimBLEND determines appropriate mission objectives for the selected role and presents those objectives to the student in the mission briefing room.

The student will be given background context of the current situation and clearly defined objectives required to make the mission a success.

Room Highlights:

- Current state of affairs is conveyed to the student along with any necessary background political/historical context
- Based upon user role selection and CND topic, mission objectives are presented to the student.

4.5 Mission Vignette

The vignette part of the game is where each student gets to apply what they have learned. Upon completion of being briefed, the student will be directed to the NOC corridor to find the exit portal The vignette portal will bring the student into the game piece designed around the current CND topic. The student will be given the opportunity to face relevant CND challenges that are similar in nature to what the student can expect if fulfilling this job role in a real NOC. The student is scored based upon performance metrics of meeting objectives as well as protocol used, time taken, communications, etc.

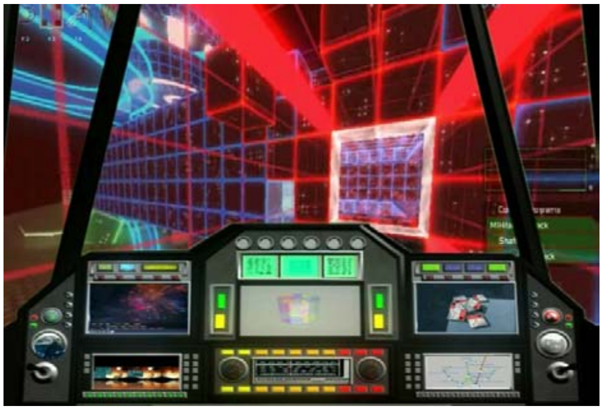
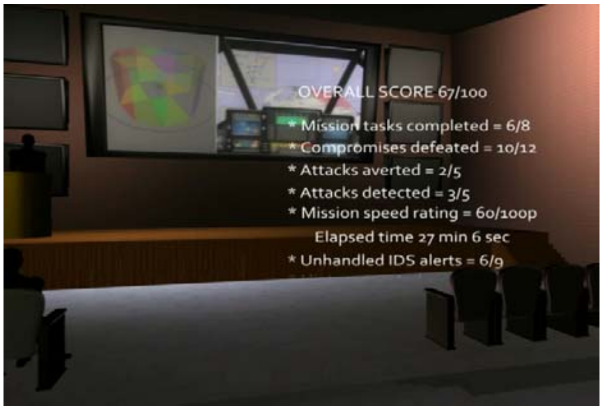


Figure 7 Scene from a Vignette

Upon vignette completion, the student is directed to be debriefed in an After Action Report room. Prior to actually being debriefed, the student will be subject to various evaluation assessments. A self assessment and additional subject content assessment including reverse questioning where the student needs to justify why wrong answers are in fact incorrect will be administered. The debrief will then take place covering how well the student met the objectives at hand, point out how performance can be improved and make recommendations for either next course selections or identify already reviewed course material that needs to be re-reviewed.

Room Highlights:

- Evaluation assessments
- Debrief of vignette performance.
- Recommendations for future CND topics or current topic remediation.



OVERALL SCORE 67/100

* Mission tasks completed = 6/8

* Compromises defeated = 10/12

* Attacks averted = 2/5

* Attacks detected = 3/5

* Mission speed rating = 60/100p

Elapsed time 27 min 6 sec

* Unhandled IDS alerts = 6/9

Figure 8 After Action Review Room

6. Summary

This paper describes progress on an SBIR project with the objective to develop an effective method of training for computer network defense. The project, now about to enter Phase II, has thus far defined requirements and an overall design framework for combining both computer-based training (CBT) with a model-based simulation environment. The system design includes the use of serious games technology to provide the student with a compelling learning experience, and connects with external learning management systems to provide a curriculum that takes the student through a complete set of courses to reach competency.

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Author Biographies

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ANITA D'AMICO is the Director of the Secure Decisions division of Applied Visions, Inc. Her research and publications are in the areas of information visualization, computer network defense, cognitive analysis, and technology transition into the operational environment. She received a B.A. from University of Pennsylvania, and an M.S. and Ph.D. in psychology from Adelphi University.

KEN DORIS is the Vice President of Engineering at Applied Visions. He has served as the Principal Investigator on previous SBIR projects at AVI that use gaming technology for battlefield analysis and visualization. One of the authors of IEEE 1278 (the original DIS specification), Ken has published numerous technical papers on subjects such as 3D visualization, realtime network traffic analysis and gaming technology. He received his Bachelor of Electrical Engineering degree from Rensselaer Polytechnic Institute.

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