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The Virtual Observer/Controller (VOC): Automated Intelligent Coaching in Dismounted Warrior Simulations

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This report describes the efforts and results of examining the feasibility of creating a Virtual Observer/Controller (VOC) to observe and critique Soldiers' performance as they are engaged in simulated small-unit, dismounted infantry training using the Soldier Visualization System (SVS) at Fort Benning, Georgia. The successful integration of these two technologies will mean that the training value of the simulation-based exercises will not be completely dependent on the military expertise of a human observer/controller. Investigating the development of the VOC required several major efforts: (a) identifying the Soldier behaviors that merit performance evaluations; (b) developing situation triggers in the context of a training scenario that stimulate the Soldier behaviors we wish to observe and to evaluate; (c) determining how to detect those behaviors in an automated fashion, and; (d) developing instructional strategies that can adequately respond to both individual actions and small-unit collective behaviors.

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INTRODUCTION

This report describes the work done in response to the following Phase I STTR topic:

> *Develop intelligent, automated coaching and feedback for training dismounted small-unit leaders and teams within a collective virtual simulation/computer gaming environment. The intent is to merge two training technologies – intelligent tutoring engines for individual skill training and virtual/gaming simulations for small-unit, dismounted operations. A synthetic, intelligent "virtual" observer/controller (VOC) shall be created within simulations to perform the real-time coaching and feedback functions similar to those functions executed by actual observer/controllers (O/C) or unit leaders during field exercises within a unit or at the Army's Combat Training Centers.*

This report is comprised of six major sections: Introduction, Methods, Findings, Discussion of problems and issues in automating observation and control, Discussion of some details of the virtual training system of interest, and a Summary of the entire report. This introduction section presents a statement of the problem and a narrative that illustrates what might occur during some future operational application of the Virtual Observer/Controller (VOC). The Methods section describes what the authors did to fulfill the requirements of the statement of work. The Findings section presents the results of the technical investigation, focusing on what the envisioned training system would do. The two Discussion sections delve deeper into how the system would provide the required capabilities.

Statement of the Problem

Training using simulated environments has progressed rapidly in recent years due in no small measure to the significant investment by the Department of Defense (DoD) in general and the Army in particular. Simulations for small-unit dismounted warrior operations have benefited from recent advances in technology. Some of these advances include increased graphical display resolution and detail in the physical terrain needed for dismounted operations and in modeling and displaying realistic human behavior. These simulation environments can provide immersive, realistic, and engaging experiences. However, in spite of the technological advances, simulation environments are still practice environments. Without the intervention of a knowledgeable human mentor and the use of sound instructional design of training scenarios, poor performance may be learned just as efficiently as good performance. Even with a human in the loop there will be variations in training effectiveness that are a function of the human trainer's knowledge of the subject matter and his instructional skills.

As simulation technologies have advanced there have been corresponding advances in the development of increasingly sophisticated simulated "mentors" or "coaches" in the intelligent tutoring community. These tools include advanced intelligent tutoring technology where Domain Experts (also known as Intelligent Agents) are created to monitor and assess student performance in particular domains within a training environment. The authors have previously developed and applied training tools to support decision-making training for the dismounted small-unit leader in the conventional environment. Of particular interest to this project are our

ExpertTrain applications that employ intelligent tutoring technologies to provide adaptive training within scenario-based environments (see Appendix A and McCarthy, Wayne, & Morris, 2001). The ongoing intelligent tutor developments have enhanced the tutoring capabilities of embedded "virtual coaches." Furthermore, there is an increasing body of evidence that these tutoring systems produce significant improvements in instructional effectiveness and efficiency (e.g., Wisher, McPherson, Thornton, & Dees, 2001).

This report describes the efforts and results of examining the feasibility of creating a VOC to observe and critique Soldiers' performance as they are engaged in simulated small-unit, dismounted Infantry training using the Soldier Visualization System (SVS) currently in use at Fort Benning, Georgia (see Appendix B). The successful integration of VOC and SVS technologies will mean that the training value of the simulation-based exercises will not be completely dependent on the military expertise of a human O/C. The next section illustrates a hypothetical application of the VOC training technology in some future training situation.

Narrative of a Future VOC Training Application

2LT Thomas is a new Platoon Leader (PL) in 2nd Platoon, A Company, 2nd Battalion, 502nd Infantry. 2LT Thomas has several new Squad Leaders (SL) in his platoon. 2LT Thomas decides to take advantage of a new training opportunity at his base. He decides to send one of his SL and two of his fire team leaders to a virtual training facility. 2LT Thomas suggests that the squad conduct an exercise. One SL and two fire team leaders prepare to practice maintaining their situational awareness during a simulated exercise. One of Soldiers puts on his virtual realty helmet and steps into the system, while the two other men sit down at personal computers. The Soldiers log in, and the VOC retrieves their individual learning profiles. The VOC selects the best scenario for the Soldiers. The scenario selected is a building-clearing scenario that focuses on situational awareness and that sharpens room clearing tactical skills. The VOC asks the Soldiers if they want to do this exercise with other Soldiers from others units or use computer-generated forces for their other team members. The Soldiers choose to work with the computer-generated forces first because they are just getting used to working together as a squad.

The squad receives a mission briefing stating that they are to conduct a dismounted patrol. The scenario places the squad on the streets of Baghdad in the early days after its capture. After reviewing their ROE, the men see that they are actually in a street in Baghdad. They are part of a platoon, but the only Soldiers that are visible right now are the nine members of this squad. The other squads consist of computer-generated forces.

The SL issues an order to use bounding overwatch and to proceed up both sides of the street. The VOC notes that the SL has used the correct formation and movement technique. After a few minutes, a shot rings out. While most of the men immediately move to cover, the VOC notes that the Alpha team leader took cover behind several 55-gallon drums. The voice of the PL plays in the team leader's headset telling him to seek real cover, not just concealment. Meanwhile, the SL is trying to determine if anyone knows where the sniper is, and verify that there were no casualties. One of the squad members says that he saw a sniper in the second floor window of a building in front of them. The SL reports to the PL and receives orders that the platoon is going to clear the suspected building. His squad is told to establish a base of fire. The SL directs his men to occupy positions to provide suppressive fire. The voice of the PL tells the SL that he should have taken a better look at the area and selected positions that allowed them to isolate the building and cover the window where the sniper was seen. The SL directs the Alpha team leader to a new position, and orders Bravo team to cover Alpha team's movement.

The squad hears on the platoon net that another squad is getting into position on the other side of the building. The Alpha team leader sees an enemy Soldier in a different building. He reports to his SL that he sees enemy movement, and the SL sends the PL a contact report. The VOC recognizes that an important piece of information was not in the SL's report. The SL did not give the direction of movement of the enemy. This is a crucial piece of information since the enemy was moving in the direction of the building the platoon is going to clear. The VOC decides to pause the simulation while each Soldier is given a situational awareness assessment. Each Soldier is shown a map of the area and is asked to indicate on the map where friendly units are, where enemy units are, where the most vulnerable and strongest positions are for both sides. After this brief individual situational awareness assessment the VOC sees that the SL did not realize that a given sector was vulnerable, whereas the Alpha team leader did. The VOC decides not to tell the squad about this discrepancy, but saves this information for the AAR. The VOC resumes the training exercise after everyone has finished the situational awareness assessment.

Next, the squad hears over the radio that that another squad has breached the building and has secured a foothold. The PL orders the 1st squad to enter the building to clear it. The SL reminds his team that they will be using the strong wall as opposed to the opposing corners method of placing men into position in rooms. Once they have cleared a room, the SL makes an error of not correctly marking all the exits, and the VOC reminds the SL to do this correctly. The fire team leaders are occasionally reminded to not to stop and shoot while they are standing in a doorway.

At the end of this 15-minute exercise, the VOC conducts an AAR. The VOC begins the AAR and focuses on the team's lack of shared situational awareness. All the Soldiers are asked to write a few sentences summarizing what they think happened. After everyone has written their own explanation the VOC shares what it thinks caused the problem (the fire team failing to report that enemy were moving towards the building.) The Soldiers are then able to discuss this problem. The Soldiers' explanations and conversations are recorded, but not analyzed by the VOC. The SL is asked by the VOC to explain why he chose the sequence of rooms to clear that he did. The SL is presented with a system of menus to help elicit the reasons for his choices. The SL is also told that he should swap out his lead teams more often. The Soldiers can decide to do another training exercise and the VOC will select another scenario for them.

METHOD

Focus was placed on squads and teams, as opposed to larger units such as platoons or companies. Furthermore, we focused on building-clearing scenarios in urban operations. We adapted Battle Drill 6 from FM 7-8 (1992) for our purposes.

We conducted a partial cognitive task analysis and a detailed scenario walk-through. We then examined the results of the scenario analysis and extracted situation triggers and behavioral details. The last step was to attempt to develop concrete practical methods for the detection and evaluation of the situations and behaviors that can be converted to software algorithms, rules, heuristics, and data.

We built a prototype that incorporated a very simple cognitive model for room clearing using the Unreal Tournament Engine (Unreal and Unreal Tournament are trademarks of Epic MegaGames, Inc). This effort was conducted to investigate some of the issues associated with employing the cognitive modeling technology we wished to use in constructing the VOC.

Preliminary Cognitive Task Analysis

We did not attempt a formal or exhaustive cognitive task analysis, nor a detailed training needs analysis. These tasks should be part of any subsequent efforts. Rather, we focused on a subset of the small-unit dismounted Infantry subject matter. Our goal was to pick a subset small enough to allow examination of a number of issues in depth, but broad enough to cover the major categories of actions and behaviors applicable to a small unit. We reviewed a number of reports that focused on urban operations (i.e., Phillips, McDermott, Thordsen, McCloskey, & Klein, 1998; Klein, Phillips, McKloskey, McDermott, Battaglia, 2001; Pleban, Eakin, Salter, & Matthews, 2001). We also examined the material prepared by the STRICOM-sponsored effort Dismounted Warrior Network (Singer, Grant, Commaford, Kring, & Zavod, 2001). After this document review we conducted a partial cognitive task analysis consisting primarily of information from interviews with a subject matter expert. This information was used to develop tactical scenarios involving a small dismounted Infantry unit approaching, securing, and clearing a building (see Appendix C). Focusing on a specific and limited tactical scenario such as this helped manage the scope of this effort.

Scenario Analysis

After the development team and the subject matter expert finished reviewing the technical documentation and the results of the cognitive task analysis, we created and dissected detailed actions required of the squads and fire teams in the building-clearing scenario. We developed a series of sketches showing the position of each squad and fire team throughout the scenario to force our conversations to be very concrete and specific. During these discussions we repeatedly asked ourselves a series of questions:

- Why was a certain action required?
- How is an action performed incorrectly?
- What would a human O/C be watching for, qualitatively and quantitatively?
- How might a triggering condition be modified to change the expected behavior or action?
- What level of granularity should be used to decompose behaviors into discrete actions?

Regarding the action granularity, there was considerable discussion regarding what level of behavioral detail was appropriate. We settled on two guiding principles. The first was that we were trying to teach Soldiers, who have some years of military experience, the knowledge and skills that are specific to urban operations and avoid training that was accounted for earlier in their military career. The second guiding principle was that we wanted to focus on those actions and behaviors that could be legitimately done wrong or "badly" in view of established doctrine, TTPs, established SOPs, and lessons learned materials. For example, we did not wish to examine the specific path a Soldier might take moving from one point to another. We did want to consider whether the Soldier moved from one covered and concealed place to another, and that the Soldier did not take a path that left him exposed to enemy fire for longer than was necessary.

The cognitive task and scenario analyses identified ***what*** we needed; investigating ***how*** to fulfill these information and modeling requirements would answer the feasibility question. We discovered that attempting to determine whether a Soldier had fulfilled expectations could get very complicated (see Appendix D). This issue is discussed at length later in this report.

Feasibility and Requirements Analysis

The central goal of this effort, investigating the feasibility of building a VOC, resolves into two broad questions: (a) Can we extract sufficient information from the simulation environment to know what is occurring, and (b) Can we model the instructionally interesting aspects of a human O/C? Once we completed the scenario analysis we had the basis for working out the following items that were a more detailed version of our two broad questions:

- Extract specific rules that governed the behaviors we identified
- Consider how we would be able to tell whether a Soldier was emitting the behavior
- Determine how we could initiate the situation triggers inside the simulated environment necessary for every behavior of interest
- Examine the qualitative and quantitative measures postulated for a human O/C and consider how these measures could be modeled in the VOC.

The two questions were transformed into rules, usually expressed as an "if-then" statement, although this is only a notional representation because the actual knowledge representation is more an implementation question than a design or feasibility question.

Each rule was examined to identify what information would be needed to evaluate the rule. For example, a situation assessment rule might include an "if" clause that contains the phrase, "The enemy engages your unit." In this case, the simulated environment would have to provide information about an enemy unit and whether it fired at a particular friendly unit. The analysis of the data and information needed by the rules included enough depth and detail to ensure that the simulation could extract the necessary data when it was needed. A sample of the rules may be found in Appendix E.

The second item, detecting whether a Soldier fulfilled an expectation of behavior, is closely related to the extraction of information from the simulated environment, only this time it is information about the Soldier's actions. The analysis here is focused on determining whether Soldiers' actions can be recognized and extracted when needed. In this analysis and in the rule analysis we just described, we were trying to specify the details of various kinds of messages that the simulated environment must trigger and send to the VOC. Trying to describe exactly when, where, how, and with what data a message is to be triggered, from a concrete system design perspective, uncovers all of the cases in which something is easy to say, but difficult to automate in software. As an example of this unexpected complexity, consider a rule that is trying to evaluate a Soldier's firing position. To do this, it must be possible to know when the Soldier has arrived at their intended destination. If the Soldier runs from one covered position to another in several short bursts, then how long should the system wait before deciding that the Soldier has arrived. Should the system wait until the Soldier actually fires his weapon? What if he is firing along the way to keep the enemy suppressed? Perhaps the system should wait a certain period of time after the Soldier's movement has ceased, but how long should that be? The details of this analysis produced very concrete data and message triggering requirements and allowed very specific examination of the feasibility of extracting the needed information.

The third item, situation trigger analysis, was heavily dependent on the preceding two analyses. However, this step was more about making sure that there was some tactically believable way, in the context of a training scenario, to create a situation that required each and every behavior we wished to train. The capabilities of the simulated environment were considered at this point. If the simulated environment could not support what was needed with its current capabilities, then the technical aspects of extending the simulated environment's capabilities were explored before we answered the feasibility question.

Our fourth item, identifying the qualitative and quantitative measures that the VOC should use provided the basis for a VOC that would function like an expert human O/C. Specifically, these measures included situation assessment capabilities, behavioral evaluation mechanisms, and instructional intervention strategies. However, these measures are only potential requirements for the VOC and were examined for feasibility by considering how easy or how hard it would be to model them. This effort amounted to developing the automated measures of effectiveness and measures of performance suitable for use in the VOC. We examined each of the situation assessment measures discussed above and identified those cases in which the effort required to automate them would be significant when compared to the value provided to the training system by that capability. This was an important part of the analysis because we were building a training system and wanted to focus effort and resources where we would get the best value from an instructional standpoint.

FINDINGS

This section of the report presents the results of our investigations. It is broken down into two subsections that include a description of the system and various components, and preliminary sets of requirements for the VOC and the SVS. The section concludes with a brief discussion of future steps that seem reasonable based on our findings.

System Description

In its simplest form, the model of the system is depicted in Figure 1. The simulation presents an interface to the Soldiers and is connected via a messaging protocol to the VOC. All communication between the VOC and the Soldier is handled by the simulation interface.

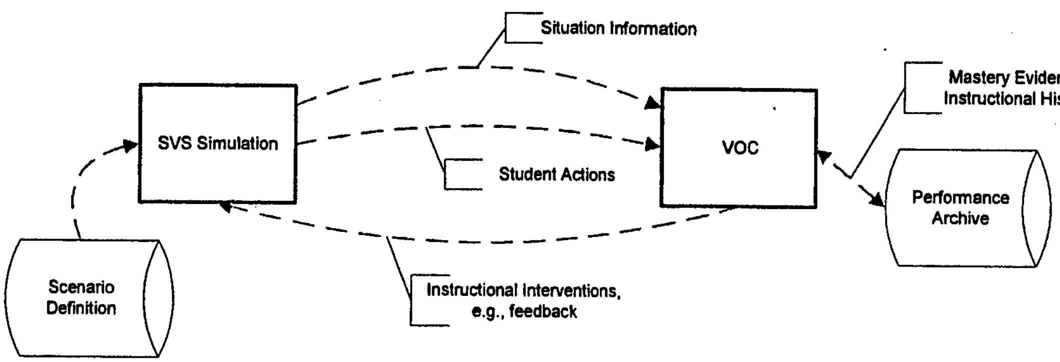


Figure 1. **High-level system diagram.**

The prototype system is focused on Soldier teams comprised of a SL and two fire team leaders from a dismounted Infantry platoon. A PL and platoon sergeant (PSG) will be simulated via scripted and triggered voice communications sent from the simulation environment to the squads. The SLs and fire team leaders will engage in a building-clearing exercise hosted by the SVS. The team members will be computer-generated forces (CGF).

The system will incorporate a VOC comprised of four separate modules: a module for each player, i.e., the SL, fire team leaders, and a team coach that will be focused on monitoring the performance of the fire team as a unit. The individual coaches will be closely monitoring each individual's behaviors and providing immediate feedback, when instructionally appropriate. In addition to providing feedback to the individual team member, these coaches will forward performance information to the team coach. The team coach will be focused more on diagnosing patterns of behavior based on the information received from the individual coaches and will provide feedback about the team to the SL.

SVS Simulation Description

The SVS™ Dismounted Infantry (DI) Immersive simulation system is a first-person human-in-the-loop tactical training system (also see Appendix B). The term "tactical" is used to intentionally differentiate SVS from other existing marksmanship-type trainers that do not support unrestricted user movement through the environment. Using United States Department of Defense standards for synthetic environments (databases) and networking protocols (Distributed Interactive Simulation (DIS) and High Level Architecture (HLA)), the SVS DI supports individual and collective level training. Figure 2 illustrates the SVS architecture.

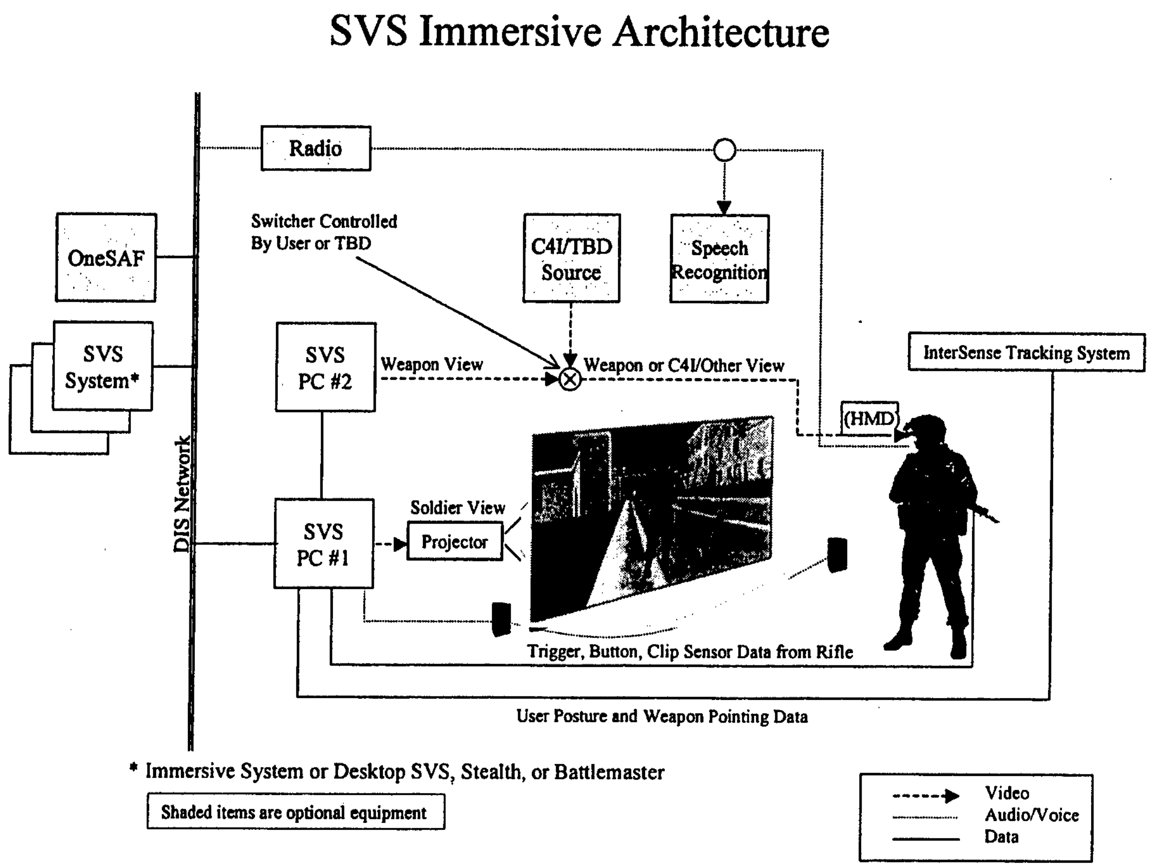


Figure 2. **SVS immersive architecture**

The SVS is configured so that the user stands in front of a 7.5 x 10 foot rear-projection screen. The computer generates an image of the synthetic environment and other objects and entities. The image is projected onto the screen. The Soldier controls his movement through the environment by means of a miniature joystick integrated into his weapon. The user can see and can be seen by other entities in the environment. He can engage these entities with his weapon, and can be engaged by them as well.

The InterSense tracking system provides weapon-pointing information used to project round impact information into the virtual environment upon weapon firing. This system also tracks the Soldier's position with a 10 x 10 foot play area, and is used to monitor posture (standing, kneeling, prone) that is reflected by the Soldier's animated character in the virtual environment.

In the Land Warrior version of the SVS, a second PC is used to generate an independent line-of-sight (LOS) into the virtual world, and can be used to simulate sensors such as binoculars or laser ranging devices, or as a weapon sighting display. This configuration has been integrated with a simulation command, control, communications, computers and intelligence (C4I) system, a digital radio system, and a helmet-mounted display (HMD). A speech recognition system has been proposed as an additional data source for the VOC. The latter is not a part of the basic system, but demonstrates the ability to augment the SVS to support additional training objectives.

The SVS software provides total system functionality that can be divided into the general categories of synthetic environment display, human capabilities simulation, weapon employment, and other supporting functions. Other products independent of the SVS provide additional system capabilities such as instructor system control, scenario generation, data logging, and replay.

VOC Concept Of Operations

This section of the report describes how the VOC processes instructional and trigger conditions. In the following major section (Automated Measures of performance and Effectiveness) we will discuss the situation assessment capabilities of the VOC.

The VOC's basic operations can be described as:

- Observe the situation
- Form expectations of behavior
- Monitor Soldier performance and compare to expectations
- Intervene instructionally when expectations are violated.

This description of the VOC concept of operations focuses on instruction and intervention.

Let us consider how the VOC will be triggered into action. Much as a human O/C may stand silently observing a training exercise for periods of time until some interesting event occurs and then take an action, the VOC needs similar triggering mechanisms. Because the simulation is sending a variety of messages to the VOC, these messages will be used to initiate instructional processing. In general, there are two kinds of messages being received by the VOC, and each trigger different processing. When a message about a change in the world is received (these are called Expectation Messages), the VOC updates its internal situation assessment information with the new data and then modifies expectations of behavior warranted by the change. Following that, it performs a review of all outstanding expectations to see if there are any with expired periods of performance. If there are, the VOC's instructional processing is initiated.

The second kind of messages that the VOC receives is those sent in response to an action taken by the human Soldier being trained (these are called Action Messages). These messages initiate the behavior evaluation processing where the VOC compares the Soldier's action, represented by the message just received, to established expectations. The match is successful if the expected and actual behaviors agree within appropriate tolerances (Target condition), or, if the actual behavior can correspond to an anticipated error condition (Bug). Regardless of whether the evaluation results in the declaration of a Target or a Bug, the evaluation processing concludes by initiating the instructional decision-making processing.

The instructional processing seeks to answer the following questions:

- Is an instructional intervention warranted?
- Which Target(s) or Bug(s) should be addressed?
- Which instructional intervention strategy should be employed?

- What should the specific content of the intervention be?

As we discuss these four questions, we will address the capabilities and interactions of the two classes of coaches. As we have noted, the instructional processing is initiated when the VOC's comparative processing reaches an evaluative conclusion. That conclusion provides the data needed to evaluate the first question, such as what subject matter item is involved (usually identified by learning objective) and either the class of problem (which bug type or category has been identified) or an indication that the result was a target condition. This information is used to classify the nature of the instructional opportunity. Ignoring the possibility of providing positive feedback, we will use the data from the evaluation to classify the problems identified by the coach's performance evaluation as a minor problem, a major problem, or a catastrophe. We have defined a minor problem as one that does not adversely affect the successful completion of the mission during the training exercise. A major problem is one that might interfere with the training goals of the scenario, thus jeopardizing completion of the tactical mission. This should be corrected with an immediate instructional intervention. A catastrophic problem is defined as something that requires restarting the exercise, such as the death of the SL.

Our second question dealt with choosing which instructional opportunity to pursue. A likely event in any real world training exercise is that several instructional opportunities may arise all at once. The following rules will be used to select among the possibilities:

- Polarity of Opportunity
  - If the opportunity is for positive feedback, then the instructional weight of the opportunity will be decreased. Otherwise, the instructional weight will be increased.
- Instructional Recency
  -If instruction of any sort has been delivered recently, then all instructional weights will be decreased.
  -If instruction on this topic has been delivered recently, then the instructional weight associated with that opportunity would be decreased a lot.
  -If no instruction has been delivered recently, then all instructional weights will be increased.
  -If no instruction on this topic has been delivered recently, then the instructional weight associated with that opportunity would be increased a lot.
- Learning Objective Priority
  -The instructional weight associated with a given instructional opportunity will be adjusted in proportion to the priority assigned to that objective for the current instructional evolution. Reportable objectives are higher priority than other objectives.
- Granularity Of Action
  -In the case of a negative opportunity, those closer to the smallest atomic actions for which coaching is possible will be weighted heavier than those farther away from atomic actions. Conversely, for positive opportunities, higher nodes are weighted heavier than lower nodes

Once we have selected an instructional opportunity, we can address the third question: What instructional intervention strategy should be used? There are six different types of instructional intervention strategies that the VOC will be able to provide:

- Immediate feedback (both negative and positive)
- Delayed feedback that is only given after some period of time
- Student Dialog, which is a computer-hosted dialog that focuses on why the Solder made the choice he did
- Situational awareness assessment for the SL and two fire team leaders
- After-action review (AAR) focused on team-level goals
- Introduce forced or natural consequences into the scenario, particularly in reaction to human error

The first three items listed will be generated from the individual coach, while the unit coach, focused on team goals, will generate the last three. A series of pedagogical rules will help determine the type of response employed. The instructional responses provided by the VOC for each class of problems were modeled after an experienced O/C. Minor problems are not dealt with immediately, but may be recorded for later use in an AAR. A major problem will be dealt with immediately, with an intrusive feedback aimed at the appropriate individual. A catastrophic problem would result in a pop-up message announcing the end of the problem and perhaps some reason for ending the training trial.

Immediate feedback is the most effective type of feedback in most tutoring situations. However, if a Soldier makes an error during a firefight, then feedback will be delayed until a later in the mission, or during the AAR. The immediacy of feedback will depend upon several factors:

- The severity of the action
- The number of humans that will be affected
- The ability for an intervention to have an overall positive impact on all Soldiers while not interfering with other salient activities
- Previous actions taken by the Soldier that warranted feedback

The most obvious feedback channel is to create an auditory feedback message using synthetic speech technology. If the Soldier's action is correct, the coach may supply some or all of the following information:

- A statement that the Soldier's action was correct
- A restatement of the Soldier's correct action
- A rationale for the correct action

If the Soldier's action is incorrect, then the coach might supply some or all of the following information:

- A statement that the Soldier's action was incorrect
- A restatement of the Soldier's incorrect action
- A statement of the consequences of the Soldier's incorrect action
- A statement of the correct action to take (determined during the Cognitive Task Analysis)
- A statement of the rationale for the correct action

Pleban and Salvetti (2001) described a method of online situational awareness assessment that allows the system to assess whether a Soldier knows where the enemy and friendly units are. We plan to pause the simulation for all the SLs and for two fire team leaders while their shared situational awareness is analyzed. Soldiers will be asked to drag-and-drop figures representing the squads, platoon leaders, and fire teams, as well as suspected enemies. Because the VOC knows the state of the world, it can provide feedback to the Soldiers, and can recognize when members of the squad have different assessments of the enemy than other members. The latter condition suggests weakness in the squad's ability to communicate their shared situational awareness.

The AAR will be focused on group level goals, but will benefit from the knowledge of who was making errors. The AAR is also the place to comment on patterns of behavior that do not generate a pedagogical response during the mission. For example, "You failed to switch your lead fire teams between clearing and security detail. While there are no set rules about swapping, you should have made a change to the lead team earlier."

A sixth type of instructional intervention strategy is to change the scenario. This is a type of cheating, in which the tutor plays an all knowing O/C and can make the players suffer consequences for mistakes that they may have not noticed. For instance, if a point man fails to continuously scan the environment, then the scenario will be able to make an enemy movement that can be used later as learning experience. Under some conditions, we may choose to give immediate feedback as a default. However, if the student is engaged in a fire fight, rules will determine if feedback is given either at the end of the fire fight, during the AAR, or not at all. For instance, suppose a Soldier charges into a room without first making sure his team is ready. We would give the feedback by stating, "*You rushed into the room before you heard from each member of the team that they were ready.*" However we cannot give this feedback immediately because it would violate our rules to give it only when there is a probability that the Soldier will attend to it.

We also need rules to give feedback depending on the context in which it is given. Each of these choices will change the nature of the feedback. For instance, feedback that is deployed a few minutes beyond the event will need to identify the context in which the error occurred. For instance, feedback might consist of the following statement: "*In the middle of that last fire fight, you rushed into the room before you heard from each member of the team that they were ready.*" The first part of this statement establishes the context in which the error occurred. If this error is left for the AAR, then it might be combined with other errors of the same type. It may also connect to a pattern of errors that occurred at the same time. The feedback statement will include contextual information so that the feedback is linked to the appropriate event and behavior.

It is possible that an error might not be addressed until the AAR. There are two reasons for this. After a sufficient amount of time has passed, the urgency to make a comment may decrease. In addition, some team errors may not be detected at particular points in time during the mission. Therefore, the opportunity to provide immediate feedback would not emerge. For instance, if one team moves to clear a building quickly, and the VOC detects that the squad took too long to the clear the building because of the second fire team's delay, then the VOC would address this during the AAR.

The number of humans affected by the feedback should be a factor in determining the content of the feedback and when it is offered. During a real mission, an O/C might intervene when errors would destroy the value of the training exercise. The VOC should do the same. As an extreme case, if a SL misunderstood his mission brief, and he set up his assault point in the wrong position, then the mission may prove to be a failure at the outset. This is an instance when the VOC should intervene immediately to reduce wasted training time.

Now we consider some specific differences between the individual coaches and unit coaches. The individual coaches will have their own set of instructional rules to decide among three broad instructional intervention options:

- Provide immediate feedback to the individual
- Record the error and contextual information for later use
- Inform the unit coach about the problem, potentially providing a feedback message

In the latter case, the unit coach can decide, using its own instructional rules, whether to execute an instructional intervention, or to discuss the issue during the AAR. While individual coaches will provide feedback on the specific errors individual Soldiers make, the unit coach will provide feedback on higher-level team goals, such as the percentage of the building cleared in a given time. The VOC will be able to point to specific errors committed to explain why a group failed to meet their team goals. At other times it will not be certain why a group failed to reach its goals. Under these conditions, the VOC may bring up an issue during the AAR, but might leave the final analysis to the Soldiers.

Automated Measures of Performance and Effectiveness

In this section of the report we will present examples of the specific knowledge that the VOC needs to operate, as well as the performance and effectiveness measures that it will implement. We will also present our approach to managing the challenges we encountered due to the inherent complexities of dismounted infantry operations.

In light of all the recent investigations into dismounted infantry operations in urban terrain, there is a large amount of information about how Soldiers should act in a variety of situations. Klein et al. (2001) captured a great deal of information relevant to our building-clearing scenario, and we have drawn heavily from it. Klein et al. (2001) focused on PLs. However, much of its content is relevant to SLs and fire team leaders. Klein et al. (2001) captured a number of factors that can affect situation assessment and decision-making, such as the intensity level of the conflict and the enemy's capabilities to engage. We will evaluate the situation in order to decide what the proper action might be for the small units we are considering. Furthermore, the values associated with these factors and their importance can change quickly. For example, maintaining stealth is less important while breeching a building than it is while approaching the building. All this must be accounted for in the design and implementation of any system that seeks to automate this processing. To do this with software requires not only the identification of the relevant factors, but ways to extract or derive their values and infer their importance to the simulated world.

We have already discussed the VOC's need to assess the unfolding situation and derive behavioral expectations. This represents one class of knowledge that must be developed. We refer to this as situation assessment knowledge. The VOC must also be able to observe the Soldier's behavior and compare it to predetermined expectations. This latter capability depends on the VOC's knowledge of what constitutes a match between an expected and an actual behavior. A match is declared when observed behavior resembles expected behavior within tolerances or performance qualifiers. We refer to this knowledge as "behavior evaluation knowledge." Together, the situation assessment and behavior evaluation knowledge comprise the knowledge base that the VOC needs to function effectively.

In examining the various aspects of situation assessment that are required to critique a building-clearing exercise, there is a wide range of technical complexity. The simple issues include determining whether a Soldier responded to a request for information in a timely fashion. The more complex issues include deciding whether the enemy's actions are sufficient for a particular fire team to engage them. Our investigation examined the range of issues and concluded that they are not insurmountable. In this section of the report we will discuss the automated measures of performance and effectiveness that the VOC will need. These measures will be represented, at least notionally, as a series of rules and heuristics.

As we began to assess the situation assessment challenges in this domain, we realized that the number and complexity of the rules that would be needed for intelligent, automated situation assessment were high. Our approach to managing the complexities we encountered, especially in automating situation assessment behavioral expectations, was based on a divide-and-conquer philosophy. We were looking for ways to attack this problem with a multi-phased approach: (a) prove feasibility, (b) build a small prototype, and (c) build and evaluate the prototype.

Our solution amounts to breaking up the logical processes needed by the VOC into a series of smaller steps. The VOC is always trying to answer two questions:

- What should the Soldiers be doing under the immediate conditions?
- What are the Soldiers actually doing?

The first question manifests itself in the VOC as the following generic situation assessment rule: If (some situation exists) then (take some action).

The "If" clause is an assessment of the simulated world, in the form of a conclusion that some specific, relevant situation exists. The "then" clause represents an action that is expected of the Soldier. We decided to handle the processing of these situation assessment rules in several steps. The process of evaluating the "If" clause conditions will be done separately from the processing of the "Then" clause. The processing of the "If" clause will be further broken down into three steps:

- What is the situation category (e.g., enemy action)?
- What is the specific situation event (e.g., enemy fired at friendly unit)?
- Who is affected (i.e., what friendly unit or Soldiers)?

The processing of the "Then" clause is also split into two steps. Initially, situation assessment rules will only have a description of "what" the expected action is supposed to be. "How" the expected action should be executed will be handled separately. Thus, the "Then" clauses, except in the simplest situation assessment rules, will be types or categories of actions (e.g., take immediate cover). The how-to details associated with a "Then" clause's expected action will be processed separately. In the example we have been using, where the "Then" clause is "take immediate cover," we would consider the rules regarding "taking cover" (e.g., seek cover that provides adequate protection).

The benefit of this multi-phased approach is that one rule serves as an activation trigger for other rules. This can serve to manage the growth of the problem space that must be represented in the knowledge base. We will return to this idea in a following section.

Using our three-step process, we consider a situation and then the rule set. A fire team on patrol has been engaged by an enemy element and has taken cover. While behind cover, the fire team leader can see an enemy combatant and has a good line of fire. The simulation has already informed the VOC about the engagement, the move to cover, and the fact that the enemy combatant is visible to the friendly Soldiers. All this information has been recorded in the VOC's internal situation assessment representation. This representation can be thought of as a blackboard on which all the aspects of the situation are captured for use by the rules that determine what a Soldier should be doing at any point in time. The blackboard is also where the specific elements of the rules of engagement will be stored. These items will also be used whenever rules are evaluated that are sensitive to ROE issues.

One of the features of the blackboard is to support triggering or activation of the rule or rules as the situation unfolds. This triggering process handles the first two questions in our three-part process. When the VOC is informed that the enemy engaged a fire team, the information allows the VOC to recognize that the category of action is an enemy action. This allows the rules associated with enemy actions to be activated. The second piece of information provided by the simulation lets the VOC know that the specific type of enemy action is an engagement. This further pares down the number of rules that must be examined in response to the situation. For this discussion the fire team has already taking cover after contacting an enemy element. This represents another piece of information sent from the simulation environment. Consider the following collection of rules that relate to enemy actions:

- If the fire team is taking fire and knows the location of the enemy, then return fire
- If the fire team has recently seen an enemy and the element of surprise has already been lost and the ROE allows it, then fire at the enemy's last known location
- If the enemy does not know the fire team's position and stealth is important
- If in a hostile environment and the ROE is non-restrictive, the enemy location is known, and the fire team has been fired upon, then return fire

Based on what the VOC knows so far, two of these rules can be evaluated. In the detailed design of these rules, there would be further qualifying information associated with every component of the "if" clause to deal with the uncertainty that may exist. Thus the rules will not necessarily resolve to an absolute certainty. For example, we may be confident, but not certain, that the enemy knows the location of a particular friendly unit. Let us assume that two of our rules evaluate so that their "If" clause is true, and that the "Then" clauses both say return fire. This creates the expectation that the friendly unit should fire at the enemy. If two rules evaluate to different but simultaneous conclusions, then a voting or weighting strategy must be employed to determine which conclusion is most important. Later in this report we will examine how a Soldier's actual behavior is evaluated in light of expectations. The details of how the Soldier should fulfill the expectation are left to subsequent processing. During that processing we will consider other factors, such as remaining ammunition, what weapon to use, and how many rounds to fire.

We have not yet dealt with the third question: Who is affected? In our example, the enemy engaged a friendly unit. The simulation provided information about the enemy engagement, such as where the rounds were impacting and what evidence was available to reveal the enemy location. Determining what friendly unit was involved requires figuring out if the rounds were impacting close enough to any particular unit so that they would consider themselves under attack. For a single engagement by an enemy, one friendly unit might be considered under attack while a more distant unit might only be expected to take cover and watch.

Situation Assessment

In this discussion we presented a series of specific situation assessment triggering events, situation factors, and examples of each. We then described how we detected all of these items in an automated fashion.

The first step of the situation evaluation process was to identify the situation category and the specifics of the situation. Table 1 contains examples of stimulus categories and specific instances of those categories.

Table 1
Stimulus Categories and Specific Instances of Those Categories in the VOC

Stimulus Category	Stimulus Examples
Enemy Actions	Engage friendly element, Movement, Surrender, Retreat
Orders from Higher	Assault, Retreat, Request for report, Move

Stimulus Category	Stimulus Examples
Friendly events	KIA, WIA, Element fatigue
Civilian actions	In line of fire, Mob forms, Assisting enemy forces, Overt acts against friendly forces
Equipment	Weapon malfunction, Radio malfunction, Out of range for communication with higher, Equipment missing or not operational

Table 2 presents a list of factors that can influence situation assessment and whose value must be determined whenever they are relevant.

Table 2

List of Factors That Can Influence Situation Assessment in the VOC

Factor	Possible values
Enemy's experience, training and morale.	Highly trained, high morale, Poor Training, low morale
Friendly's experience, training, and morale.	Highly trained, high morale, Poor training, low morale
Enemy Level of Resistance	Fanatic level of resistance, High level of resistance, Low level of resistance
Condition of friendly forces equipment.	Equipment operational and available, Equipment missing or non-operational
Quality of friendly forces equipment.	Current first-line equipment, Outdated equipment
Equipment available	Trucks, helicopters available, No support available
Friendly forces fatigue.	Well-rested, Exhausted
Light conditions, visibility.	Daylight, clear skies, Night, cloudy, fog, rain, smoke or other obscurants

Factor	Possible values
Weather conditions.	Temperate, Extreme hot or cold temperatures, Humidity, Wind speed, direction
Terrain from line of departure to Objective.	Rubbled urban terrain, Clean clear streets.
Distance from line of departure to Objective.	Less than 2km from LD to objective, Greater than 2km from LD to objective
Size of Building to be cleared.	Single story, single room building, Multi-story with multiple rooms
Proximity of other Friendly Forces.	Friendly forces within supporting range, No forces within supporting range
Rules of Engagement (ROE)	Complex ROE, Simple ROE
Attitude of Civilian Population	Friendly Civilian, Belligerent Civilians, Hostile Civilian
Urgency of mission	Mission Urgent, Mission Routine
Intelligence Available	Accurate Intelligence, No Intelligence Available, Poor Intelligence

Situation Assessment Rules

After considering what the information needed to process the "If" clause of situation assessment rules, we turn our attention to the "Then" clause. The "Then" clause in a situation assessment rule only determines the category of behavior or action that the Soldier needs to execute. We will consider the rules for determining the specific behaviors in the next section. Table 3 presents a simple mapping of stimulus conditions and events to expected behavior categories.

Table 3
Situation Assessment Rules used in the VOC.

Stimulus Conditions	Behavior
Engaged by enemy forces	Taking immediate cover

Stimulus Conditions	Behavior
Reports of enemy activity	Determining enemy location Changes movement technique
Known or suspected enemy location	Reporting enemy location
Returning fire or covering friendly move	Providing suppressing fires
Enemy fire or hostile intent per ROE	Firing in self-defense
Preparation for move or assault of objective	Establishing a Base of Fire
Screening movement, obscuring enemy observation, signaling	Use of smoke
Engagement by enemy forces WIA/KIA Call for Fire SITREP SALUTE Report ACE Report	Reporting to PL (for SLs)
When beginning a movement When Set following a move	Reporting to SL (for fire team leaders)
Ordered by superior	Movement Techniques
Squad ordered to new location Team assaulting a building	Correct orders to subordinates (voice, radio, and hand and arm signals)
Ordered by superior	Providing cover to other elements
Ordered by superior SOP/TTP	Building breaching
Entry point secured	Building entry
1st man enters room	Room clearing
Room determined clear by fire team leader/SL	Marking cleared rooms
SL determination based on mission posture	Requesting support from higher
TTP/SOP Elements fatigue	Rotating fire team responsibilities
Consolidation	Cross level ammunition, request resupply, evacuate WIA
Building Cleared	Report to higher
Ordered by superior	Move to pick-up point
Arrive at pick-up point	Report to higher

The following are samples of the situation assessment rules:

Whether a Fire Team/Squad should fire:

- If the fire team is taking fire and knows the location of the enemy, then return fire.
- If the fire team sees the enemy and the ROE permits it, then fire at the enemy's last known location.

- If the fire team has recently seen an enemy and the element of surprise has already been lost and the ROE allow it, then fire at the enemy's last known location.
- If the enemy does not know the fire team's position and stealth is important and the enemy is adequately suppressed, then do not fire.
- If in a hostile environment and the ROE are non-restrictive and the enemy location is known with confidence and the fire team has been fired upon, then return fire.

Whether a Fire Team/Squad should take cover:

- If the fire team has received fire, then they should take immediate cover.
- If the fire team is moving by bounding overwatch, then each move should be from one covered position to the next.
- If the threat of enemy artillery or mortars is imminent, then they should take cover.
- If the threat of enemy observation is high, then they should take cover.
- If the team receives an order from higher to take cover, then they should take cover.

A Fire Team/Squad should report to higher:

- If the team comes in contact with the enemy. (SALUTE Report)
- If the team is engaged by enemy forces. (Contact Report)
- If the team has a WIA/KIA. (Red Report)
- If there is a requirement for a Call for Fire.
- If there is a significant change in the situation. (SITREP)
- At consolidation. (ACE Report)
- When requested by higher.
- At certain times (0600, 1800, etc) as stated in the unit SOP.

A Fire Team/Squad should use smoke:

- If the team needs to obscure their movement from the enemy.
- If the team needs to mark their location.
- If the team needs to mark an enemy location.
- If the team receives an order from the SL to use smoke.

Fire Teams/Squad should not use smoke if:

- Wind speed and direction are not favorable.
- Smoke is not readily available, or is not available in the correct color.
- ROE prohibit use of smoke.

A Fire Team/Squad should call for mortars or artillery:

- If other weapon systems are not effective against the enemy.
- If the team/squad receives an order from higher to engage with mortars or artillery.

In order to request mortars or artillery the following conditions need to be met:

- There must be a supporting mortar or artillery unit able to range the target.
- The team must have communication with the Forward Observer or firing unit.
- ROE must allow use of mortars or artillery.

A Fire Team/Squad should request the heavy weapons squad:

- If organic squad weapons are not effective against the enemy.
- If the team/squad receives an order from higher to engage the enemy with the heavy weapons squad.
- If the heavy weapons squad is available and not assigned another mission.
- If the PL approves employment of the heavy weapons squad.

A Fire Team/Squad should move using bounding overwatch:

- If the fire team or squad comes under enemy fire.
- If enemy contact is expected.
- If directed to do so.

Action Execution

For the building-clearing scenario, the following high-level goals were identified from Klein et al. (2001):

- Secure the perimeter
- Approach the building
- Enter the building
- Clear the building
- Maintain and extend security

Much of the planning aspects and situation assessment knowledge that are necessary in clearing a building are more the purview of the PL than of the SLs or fire team leaders. We decomposed each of these goals into smaller steps that represent the reasonable responsibilities of SLs and fire team leaders. This resulted in the following list of expected Soldier behaviors:

- Taking immediate cover
- Reporting enemy location
- Providing suppressing fires
- Firing in self-defense
- Establishing a Base of Fire
- Using smoke
- Reporting to PL (SLs)
- Reporting to SL (fire team leaders)
- Movement Techniques
- Correct orders to subordinates (voice, radio, and hand and arm signals)
- Providing cover to other elements
- Building breaching
- Building entry
- Room clearing
- Marking cleared rooms
- Requesting support from higher
- Rotating fire team responsibilities

These behaviors have a mixture of situation dependent aspects and situation independent aspects. For example, reporting to higher must be done using the expected report format, regardless of the specific content of the report. The situation assessment rules all have uncomplicated "Then" clauses, such as "return fire." The "Then" clause constitutes an expected action on the part of the Soldier. However, these expected actions need further situation-based qualification before they can be applied. The additional qualifications associated with these expected actions are captured as a separate set of rules.

Table 4 presents a sample of action execution rules, whereas a more completed list is found in Appendix C. For each action there is an associated set of evaluation criteria related to those actions. The details of the automated detection mechanisms are discussed below.

Table 4
Action Execution Behavior and Evaluation Criteria Used in the VOC

Action or Behavior	Evaluation Criteria
Take Immediate Cover	
	Seeks first available cover, within 3-5 second move.
	Cover must provide adequate protection from small arms up to 12.7mm.
	Does not expose any portion of body to direct fire.
Reporting Enemy Location	
	Reports enemy location within 30 seconds of contact.
	Enemy location is accurate within 100 meters (6-digit grid coordinate).
	Reports to appropriate leader (SL or PL).
Provides Suppressive Fire	
	Provides accurate fires on enemy.
	Provides volume of fire to force enemy to cease or significantly reduce fire.
	Does not expend ammunition needlessly (ammo conservation).
	Uses all weapon systems available (AT-4, SAW, M-240).

Action Evaluation Details

There are two kinds of Soldier behavior evaluations: outcomes and processes. Using state information available from the simulation, we can recognize when the student has or has not achieved a desirable state (e.g., cleared the building in a reasonable time). That state is an outcome. For example, the coach might say, "You took too long to clear the second room." An outcome-based assessment will not attempt to determine if the student failed to establish the desired state or failed in his attempt to do so. On the other hand, a process assessment would recognize when the Soldier made an error in the process leading to that state. For example, the O/C might say, "You waited too long after receiving the order to breach the building." Both process and outcome assessments have their usefulness in this domain and both will be used where appropriate.

Table 5 presents a sample of the specific behaviors we have identified in the building-clearing scenario and how they might be evaluated by the VOC. For each behavior or action, there are a number of possible evaluations that can be made. Whenever the evaluation concludes that the behavior is as expected, a target is declared. However, when behavior does not meet expectations, there are specific aspects to the failure (e.g., an action was taken too late) that we can look for. These failures are called "Bug" conditions and are listed in Table 5. Following the table, we will discuss how each of these Target and Bug conditions will be detected.

Table 5
Behavior Descriptions and Evaluation Possibilities Used in the VOC

Behavior	**Evaluation Possibilities**
While Team A Moves: Team B Covers	**Target**: Team B provides the correct level of suppressive fires while team A moves **Bugs**: Shoots when not needed Does not shoot when needed Shoots when risk of fratricide is too high Does not look towards enemy location Does not look towards Team A
SL Reports to PL that Team A is in position	**Target**: SL reports to PL, in a timely fashion and using correct communications techniques, that Team A is in position **Bugs**: Reports before hearing from Team A Slow to forward report to PL Incorrect phraseology
3rd SL moves with lead team for C2	**Target**: SL "follows" Team A over to building entry point **Bugs**: Doesn't follow assault team Leads assault team Goes somewhere else
Team B moves to building entry location	**Target**: This movement action should be identical to the Team A move. Refer to that move for details **Bugs:** Moves before other squads can cover Does not go to correct location

Behavior	Evaluation Possibilities

Action Detection

Table 6 presents one of the action execution criteria samples shown in Table 4. In this presentation the automated detection mechanism is shown. The full tables of rules and action criteria are shown in Appendix C.

Table 6
Action or Behavior Detection Rules Used in the VOC

TAKE IMMEDIATE COVER	
Rule	**Automated detection mechanism**
Begin moving within 3-5 seconds after receiving enemy fire	Knowledge of when the enemy began shooting at unit and when they began moving
Seeks first available cover	There may be more than one object in the environment that can provide cover and the VOC will be able to determine that the element under fire has moved to the closest one that will provide adequate cover.
Cover must provide adequate protection from small arms up to 12.7mm.	Knowledge of simulated objects available for cover, including the object's location and which side of it provides cover from the enemy.
Does not expose any portion of body to direct fire.	Friendly unit does not move from behind cover until safe to do so.
Determines Enemy Location	
Rule	**Automated detection mechanism**
Uses visual cues such as smoke and movement to determine enemy location	Knowledge of enemy location, and whether the visible indications of the incoming fires were rendered in the display being viewed by the Soldier.
Uses audio cues such as gunfire, personnel, and vehicular movement to determine enemy location.	Sound cue location and direction information.

Dealing With Uncertainty

There are several sources of uncertainly with which the VOC will have to reason. First, there is the uncertainty associated with knowing when to deem that a solder has mastered a particular skill. Then, there is the uncertainty of interpreting a Soldier's actions. One way to deal with the former type of uncertainty is to employ Model-tracing Intelligent Tutoring Systems (e.g., Anderson & Pelletier, 1991). Because humans will never be perfect, and because humans sometimes take correct actions for the wrong reasons, we must use some method of dealing with the uncertainty about which skills a Soldier has mastered. One common way of dealing with this is Corbett and Anderson's (1995) Knowledge Tracing.

The second source of uncertainty causes the "credit-blame assignment problem." If you have a reasonably complicated task, then there will be situations when there are two plausible explanations for a Soldier's action. Which action do you assume they took? For instance, if you see a Soldier moving backwards, is it because he has decided to retreat, or is he trying to reposition to outflank an enemy? If retreating is appropriate at this point, do you credit the retreating action, or do you treat the action as a flanking maneuver? Martin and VanLehn (1995) offered an elegant method for making a principled guess as to an interpretation of each action that takes into account the prior probability that a student would take each action. According to Russell and Norvig (2003), Bayesian networks are now acknowledged to be the best way to model uncertainty, replacing a plethora of more ad hoc techniques used during the past 30 years. Martin and VanLehn (1995) have already shown how to use Bayesian Networks for this purpose in the tutoring context, and thus present a mathematically principled and computationally tractable method for the VOC to use in handling action uncertainty.

Simulation Modifications and Instrumentation

Receiving the Soldier's actions from the simulation amounts to a series of messages flowing into the VOC. The messages that provide this information are grouped into two broad categories: expectation messages and action messages. These mirror the two kinds of information that the VOC needs. The expected and actual information, and the supporting messages, will include the following: (a) a list of every discrete tactical situation that needs to be identified to the tutoring engine, the necessary expectation message, and the data that the message needs to provide to adequately characterize the context, (b) a list of every discrete action that the Soldier (or unit) can take, the necessary action message, and the data needed to help characterize the action, and (c) the specific details, rules, and data associated with both the student actions and the situation contexts in order to identify message trigger conditions. Table 7 provides a summary of the information needed from the simulation. A more complete list is found in the

Preliminary System Requirements section on the following page.

Table 7
Simulation Information Needed From SVS to Make Assessments

Category	Specific Items
User Action	Fires a weapon
	Throws a grenade
	Moves
	Orders subordinate

Category	Specific Items
	Reports to higher
	Takes cover
User Status	Location
	Ammunition
	WIA/KIA
	Fatigued
	Fired at
Enemy Action	Fires a weapon
	Throws a grenade
	Sees friendly unit
	Moves
	Reinforcements arrive
	Surrenders
Enemy Status	Location
	Becomes visible
	WIA/KIA
World Object Information	Objects suitable for cover
	Building location, size layout
	Terrain features
Equipment	Existence of vehicles
	Location of vehicles
	Weapon operational status

The following items represent more complicated types of information needed from the simulation. The technical details associated with how this information will be obtained can be found in the Discussion section of this report.

- Identification of objects suitable for cover for a specific friendly unit and from a specific enemy location
- Orders or reports that a human Soldier has issued, and both the type and content of the report
- Sound event localization information
- How much ammunition a Soldier has at any point in time (both CGF & human)
- How to detect an enemy shooting at but missing friendly
- Information about entities rendered on the visual display, how big they are, how long they were rendered in the trainees visual field
- Human readable names for all entities in the simulated world that might be referenced in instructional feedback
- Movement information about a human Soldier to determine if the movement path taken was reasonable
- The sweep extent and sweep speed of a human Soldier's visual gaze and information to determine if the sweep was enough to view an entire room during room clearing.

Preliminary System Requirements

This section contains a partial set of requirements for the VOC and for the simulation. The simulation requirements have been collected from various portions of this report.

The VOC shall be able to process the situation assessment and action execution rules contained in Appendix E. The VOC shall support the instructional strategies described in the VOC Concept of Operations section of this report. Table 8 shows the message type, the data needed, and the triggering conditions for the VOC.

Table 8

Simulation Message Descriptions, Data Needed, and Trigger Conditions for the VOC

Message Type	Data Needed	Trigger Conditions
Cover object information	Type of object, What cover it provides, Location, Size	Scenario initialization
World Object information	Type of object, Location of object	Scenario initialization, interesting objects only
Room interior objects	Location of object, Room region dimensions visually blocked by object	Whenever the user can see into the room and see the objects in the room
Friendly unit status	Unit designator, Unit size, Location, Fatigue status, Operational Status, Ammunition remaining	Scenario initialization and whenever any of the data change
Enemy disposition	Size of enemy unit, Status of enemy unit, Location, Posture	Whenever this information is told to user and only to the degree it is told to user via intelligence.
Enemy to friendly visibility	Friendly unit designator, Enemy unit designator, Line of sight indication, Other visibility	Sent whenever friendly unit gains information about what enemy could know about friendly, but only what friendly could know
Friendly to enemy visibility	Friendly unit designator, Enemy unit designator, Line of sight indication, Other visibility	Sent whenever friendly unit gains information on enemy unit

Message Type	Data Needed	Trigger Conditions
Message Sent	From, to, when sent, content, form, delivery mechanism	User sends a message
Unit movement	Which unit, Starting location, Movement formation and technique, When movement started	Unit begins moving
Unit arrival	Time of arrival, destination location	Unit stops moving
Sound cue	Spatial location, What made the sound, Distance qualifier	When a sound cue is delivered to the user
Visual Cue	Real world location, Rendered on display, Field of view location, Size information, Duration information, What was rendered	When a visual cue is presented to the user
Friendly fires	Firing rate, Firing direction, Round destination, Weapon fired	Whenever friendly fires
Hostile fires	Friendly unit that could know this information, Firing rate, Firing direction, Round destination, Weapon fired,	Whenever enemy fires and it could be detected by a unit or units
Base of Fire establishment	Time of establishment, Entity providing cover, Location	When established
Wall breech	Time of breech, Mechanism of breech, Size of breech	When a wall is breeched
Room entered	Friendly element designator, Room identifier	When element enters room

Other Simulation Requirements

The SVS Battlemaster shall generate scenario events in the same way that events are generated by other simulated entities so that the VOC sees all changes induced by the Battlemaster station. Events generated by the Battlemaster shall be identified by a host identification that defines all simulation hosts (computers). SVS shall provide a method for placing a wolf-tail or other similar marker on a wall outside a room to indicate the room has been cleared. SVS shall provide a method for placing a satchel charge on a wall to blow a hole in it.

Preliminary System Design

Figure 3 repeats the information shown earlier in Figure 1. It illustrates a training system that incorporates a VOC. In this diagram the simulation is represented as a single box, which includes all aspects of the simulation, the user interface devices, the displays, and the necessary computers. The information flowing between the simulation and the VOC is represented by three broken lines, and these lines indicate communication channels and protocols through which all the information necessary for the systems operation will pass. In the lower left of the diagram there is a box labeled Scenario Definition. For any training session, a scenario will be presented to the Soldiers. On the far right of the diagram is a box labeled Performance Archive, where the VOC stores all the performance information gathered during training sessions. These archives are organized along several dimensions, including Soldier identification, the time and date of training sessions, the scenario involved, and other pertinent information. The contents of the archive include instructional history (e.g., feedback delivered, scenarios experienced), and mastery evidence derived from the VOC's action evaluation decisions. There is no user interface provided to the VOC because all interactions with the Soldiers will be through the simulation interfaces. Any instructional interventions generated by the VOC will be forwarded to the simulation for display or presentation to the Soldiers.

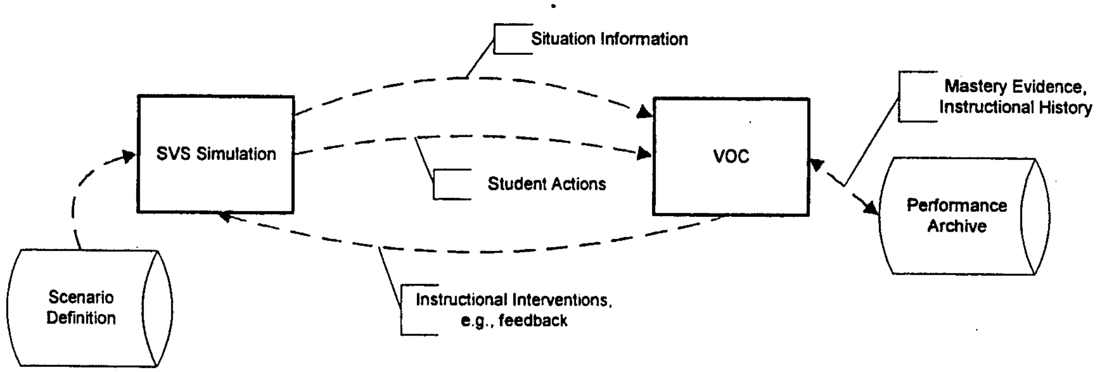


Figure 3. **Preliminary system design (from Figure 1)**

In Figure 4, the three lines connecting the simulation and the VOC represent a stream of messages being passed back and forth between them. From our discussions earlier in this report, you will recognize information regarding the situation, (indicated by the top line in the figure); information about what the Soldier is doing (the middle line), and instructional interventions such as immediate feedback (indicated on the lowest line of the figure). The specific content of all of this message traffic will be developed during a detailed design phase. The Preliminary Requirements section of this report provides a list of what the messages must include.

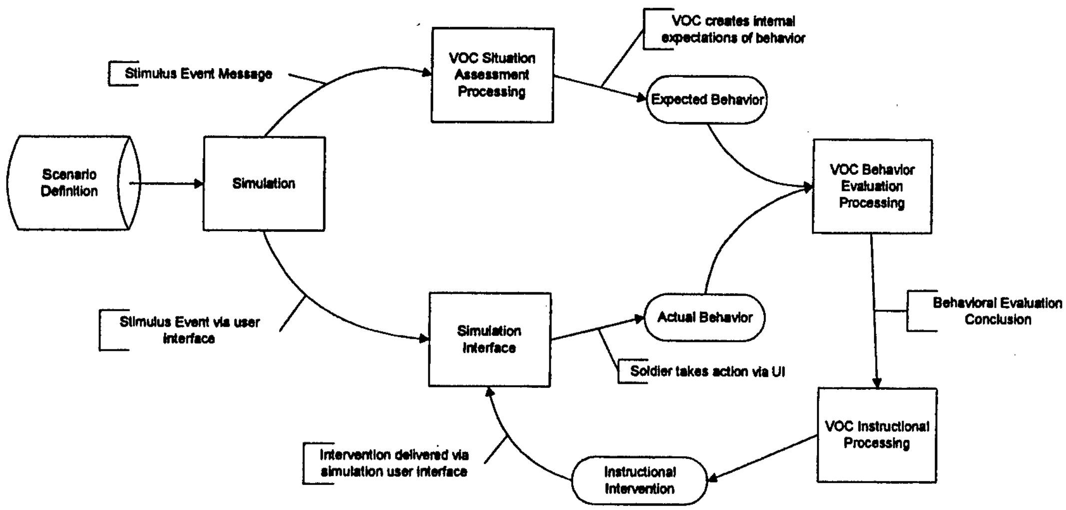


Figure 4. **VOC processing diagram**

Figure 4 focuses on the VOC's internal structures and processes. The same two kinds of information leaving the simulation remain: about situation information messages and Soldier Actions. In this diagram we split the various processes of the VOC and the data being used to support those processes. At the top of the figure we see a box labeled VOC Situation Assessment Processing. This is the component where the stimulus event messages are processed. The output of this processing will always be the expected behaviors. During a scenario, there may be a large number of expected behaviors in existence. On the right of the figure is a box labeled the VOC Behavior Evaluation Processing. The data coming into that segment of the VOC include the expected behaviors from situation assessment processing and the actual behaviors of the Soldiers. The VOC is constantly comparing the actual behaviors with the expected behaviors. When it reaches a conclusion about this comparison, it forwards that conclusion to the VOC's instructional processing. The instructional processing is where a decision is made on whether to intervene, on what subjects an intervention takes place, a decision about which type of instructional intervention, and the content of the intervention. If an instructional intervention is decided upon, then it is forwarded to the simulation for delivery to the Soldier.

Figure 5 indicates that the VOC itself is made up of several discrete modules. Each of the individual coaches will be managing their own performance archive as shown by the figure. Because we focused on a squad, and because there are two fire team leaders in each squad, there is a pair of fire team leader coaches indicated in the figure. The knowledge encoded in each of these coaches will be different. During a scenario, each of the Soldiers has unique responsibilities, and these differences must be reflected in the knowledge used by each of the coaches. There will be differences between the fire team leader coach and the SL coach, and both will have a different knowledge base than that of the unit coach. Because our architecture does not preclude having more than one team, there might be a family of VOCs watching multiple squads during an exercise. In order to function correctly, the appropriate situation information must be forwarded to the correct VOC. If one squad has been told to approach the building and another squad has been told to establish a base of fire for a support by fire mission, then those orders must be forwarded to the correct squads so that the expected behaviors can be established.

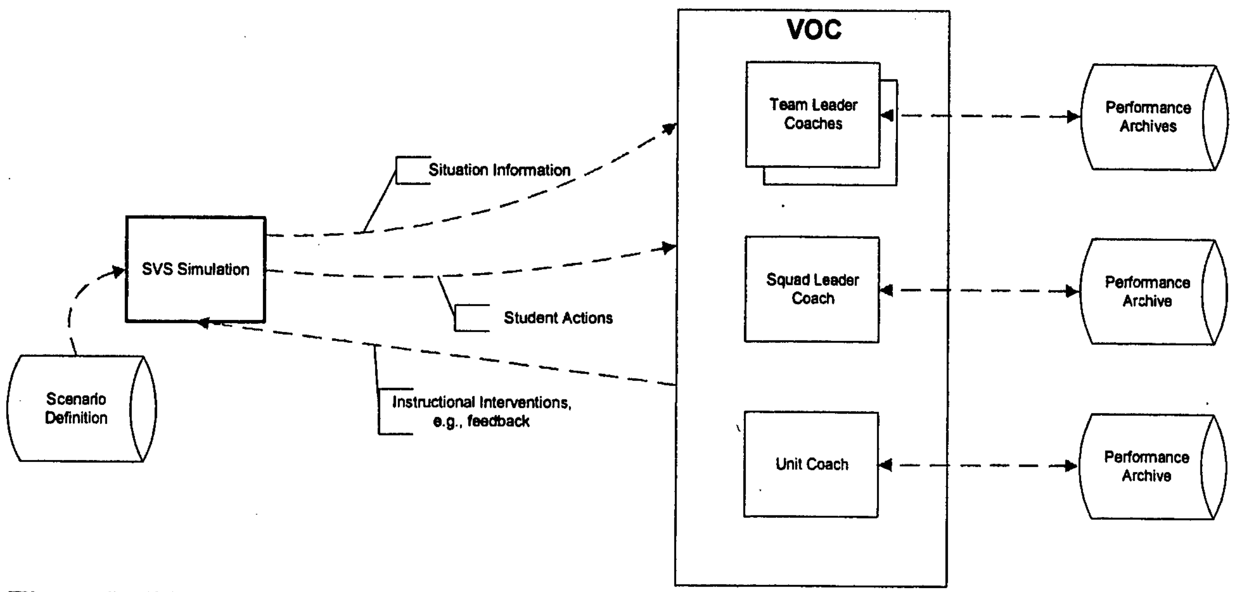


Figure 5. **VOC component diagram**

DISCUSSION OF AUTOMATING OBSERVATIONS AND CONTROL

In this section we will discuss the technical issues and challenges associated with developing the situation assessment rules, behavior detection strategies, and behavior evaluation approaches.

Automated Situation Assessment

Recall part of what a human O/C would do: observe the situation and form expectations of Soldier behavior. Thus, we must, as much as possible, encode into the intelligent tutoring system the human O/C's map between their understanding of the current situation and the correct behaviors that correspond to that situation. We call this knowledge map Situation Assessment (SA) knowledge, and we call the human O/C's conclusions about what the Soldier should be doing Expectations or Expected Actions. To build the VOC, this SA knowledge must be built into the system rules that trigger or activate Soldier expectation messages from the simulation. The SA knowledge forms the software version of the human O/C's observations of the situation, and the rules triggered or activated by this knowledge establish the expectations of the Soldier's behavior.

As an oversimplified example of the SA rule, we may state, "If a fire team is taking fires from a visible hostile unit, then the fire team may return fire IAW the ROE." In this case, an expectation message would be sent to the coach announcing that the enemy unit has fired on the friendly unit. The message is triggered by the enemy firing, which may be a scripted action designed into the scenario or a behavior of a semi-automated hostile force. In either case, the coach is notified of the enemy action at the same time the Soldier receives the fires. This, in turn, activates the SA rule in the coach and establishes an expectation that the friendly unit should shoot back. The VOC observes the Soldiers to see if their behavior matches the expected behavior.

The encoded SA knowledge must be able to adjust the dependent and independent aspects of the expectations. Automating this SA knowledge can be very challenging. One way is to hard-code SA knowledge into scenario definitions and into simulation processing. This technique can work for simple cause and effect SA knowledge, such as always requiring a specific response when the PL asks for a report. However, this approach can also be brittle when dealing with dynamic situations where both the actions of the Soldier and the actions of intelligent entities in the simulated world can change the situation.

Consider the following example of how hard coding SA knowledge could be counter-intuitive. A fire team might be required to provide cover to other elements. A more complete expression of this behavior using specific teams and the scenario we have been discussing is: "Bravo team provides the correct level of suppressive fires while Alpha team moves from one location to another." This statement seems easy to say and understand if you are a human subject matter expert in urban operations dismounted Infantry situations. However, it is a challenge to turn it into an automated computer-based algorithm or heuristic. A human O/C watching a training exercise would size up the tactical situation by considering the following:

- The locations of the supporting squads
- The enemy's location
- The enemy's recent or current behavior
- ROE
- The tactical experience of the teams
- The current stealth of the teams as they move and cover

Based on an analysis of the tactical situation, the human O/C and the VOC form an expectation of Soldier behavior that could be different than that cited above. For example, "ravo team should not shoot as Alpha team moves to its new location unless Alpha team is being engaged by an enemy element." What follows is a discussion of the rules that determine one possible action of a fire team, whether to fire on the enemy.

Should The Fire Team Shoot?

Consider the following series of notional rules, all of which can be in effect at the same time, with differing levels of importance, depending on the situation. They all help to determine if the fire team should fire:

- If the fire team is taking fire and knows the location of the enemy, then return fire
- If the fire team sees the enemy and the ROE permits it, then the fire team should fire at the enemy

- If the fire team has recently seen an enemy and the element of surprise has already been lost and the ROE allows it, then the fire team should fire at the last known location of the enemy
- If the enemy does not know the fire team's position and stealth is important and the enemy is adequately suppressed, then do not fire
- If in hostile environment and the ROE is non-restrictive and the enemy location is known with confidence and the fire team has been fired at, then fire at the last known enemy location

Notice that in these rules the "If" clause is the situation condition and the "Then" clause is the expected action that relates to the condition. Thus, the information we need out of the simulation environment is whatever will inform the coach that the "If" condition has occurred. In the list of rules above, the following "If" conditions must be identified:

- Fire team is being fired at
- The fire team has been fired at
- Fire team sees an enemy
- Fire team has recently seen an enemy
- ROE in effect
- The enemy does not know the fire team's position
- The element of surprise has been lost
- Stealth is important
- The enemy's location is known

We will now examine how the simulation environment can inform the coach in each of these situations.

What Does "Fired At" Mean?

The first item, Fire team is being fired at, requires that we resolve what being fired at means. There are two aspects to this information. The simulation environment has knowledge of what the enemy is doing because it is under the control of the simulation. However, in most cases, the simulation cannot inform the coach of ground truth unless the Soldiers can also perceive ground truth through their interface with the simulation environment. Thus, the coach can only be told what the Soldiers can know about the situation. In this case, the fire team will likely hear the sound of the gunfire and, if the rounds are being fired in their direction, will see some indications of where the rounds are hitting. They might also see muzzle flash or smoke, if they were looking in the right direction when the shots were fired and if the enemy's position made those visual indications possible. This suggests that the coach should be sent information regarding the following items:

- The fire team should have heard gunfire
- The fire team should have heard round impact audio cues
- The visual cues of the enemy's fires were visible
- Round impact visual cues were visible

We will examine each of these in turn.

The information regarding the sound associated with the enemy's fires must contain whatever directional information the Soldier received, such as the left-to-right panning location of the sound, a qualifier regarding what weapon system made the sound, and some indication of its proximity to the fire team. This message must also be directed to the correct Soldier, because if multiple squads are in the same scenario, the same sound can be to the right of one Soldier and to the left of another. The same information is required regarding the auditory cues of rounds impacting. Examples of the audio cues required to determine if the fire team is being fired at are shown in Table 9.

Table 9
Audio Cue Messages for the VOC

Types of Information	Specific Data
Sound cue event	Indicates what type of information is being provided: audio, visual,
Spatial location	3D coordinates
What made the sound	Small arms, round impact,
Distance qualifier	30m or "nearby"

The information regarding the visual cues is somewhat more complicated. While the simulation can inform the coach where the visual cues were located in the simulation environment, there is no way to know if a Soldier actually saw the visual cue. What we can know is that the visual cue was rendered on the display in the Soldier's field of view, along with some size and duration information, so that they could have seen it. We are making the assumptions that the Soldiers are looking for visual cues and that an impact dust cloud is visible. Examples of these visual cues are shown in Table 10.

Table 10
Visual Cue Messages for the VOC

Types of Information	Specific Data
Visual Cue event	What type of information is being provided: audio or visual?
Real world location information	3D coordinates
Rendered on display	Yes/no
Field of view location, if rendered	Horizontal and vertical angle from center of display
Size information, if rendered	In pixels
Duration Information, if rendered	How long was the image in the display
What was rendered	Smoke, flash, impact dust

The simulation's ability to provide these data is only part of the process. There are two more steps. The first step is to decide how sure we are that the Soldier could have perceived the visual cue events and the second is to decide whether the fire team is close enough to these visual and audible cues for it to mean they are being fired at. We will deal with the location question first. This involves comparing the location of the fire team and the visual and audio location information. There will be some situations when the fire team knows it is being fired upon, such as when the round impact locations are within a meter of the fire team. Conversely, there will be situations when the rounds are impacting a great distance from the fire team. However, we must be prepared to qualify those ambiguous situations where it is not clear who the enemy is firing at. One way to manage this problem is to define a sphere or zone around the fire team in question and declare that if rounds are impacting inside this zone, then the fire team is being fired at. This begs the question of how sharply defined the zone should be, because two rounds impacting one inch apart should be considered as very similarly placed, regardless of the fact that one was inside the zone and one was outside the zone. There are two ways to manage this kind of artificial discrimination. The first is to use fuzzy logic to decide whether a round's impact location belongs in the close-enough category. The second is to define the zone large enough so that the outer limit of the zone is close to the too-far-away limit. Ignoring rounds that lie just outside the zone is reasonable.

A sureness algorithm based on the image rendering data derived from the simulation environment will allow us to know if Soldiers were able to detect the cue messages. This sureness factor will also influence our instructional strategies. If we get a very high sureness factor, we can safely select an instructional intervention that corrects the Soldier for missing the cue, if indeed he missed it. However, if the sureness factor is lower than some threshold, and evidence suggests that the Soldier missed the visual cue, then the instructional intervention should not make the correction.

When a fire team has been fired upon, a timer can be started that indicates how long it has been since a particular fire team has taken fire. Once a threshold has been established regarding how long into the past you must go to ignore past engagements, it is a simple thing to evaluate the condition that the fire team has been fired upon.

Consider the following algorithmic approach to answering the question of being fired upon. We must characterize the firing rate and firing direction of the enemy in a quantifiable way. One way to do this is to consider the incoming rounds or bursts of automatic rounds passing through a spherical zone around a friendly element that defines what being fired upon means. Figure 6 below is an engagement detection algorithm flowchart.

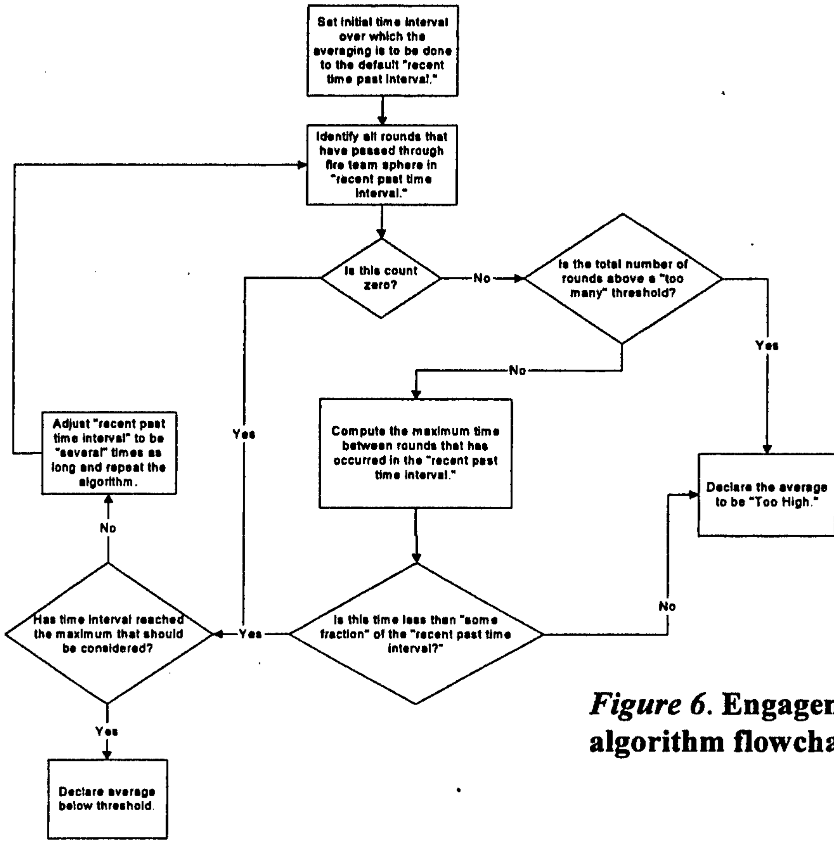


***Figure 6.* Engagement detection algorithm flowchart**

The first step in the algorithm is to establish the time interval over which we wish to compute the average firing rate. This time interval should be an adjustable parameter to allow the algorithm to be tuned based on how it performs in training exercises. Once this is done, the algorithm counts all the rounds that have passed through the Alpha team's sphere, using fuzzy logic to handle near misses. If this count is zero, then it may be appropriate to increase the time interval and count the rounds again. This "increase-interval-and-count-again" process could be repeated until the time interval has reached a maximum value. This maximum time interval could represent the point of time in the past before which we do not care if the enemy has fired at Alpha team's position. This point of time could be when Alpha team arrived at their current location. Assuming the rounds count is not zero, the algorithm would next determine if the total number of rounds fired is too high. This parameter simplifies the algorithm's behavior in the face of massive enemy fire, for example, if the enemy has poured automatic weapons' fire into Alpha team's position. If this simple test fails, then the algorithm can examine the average rate of fire over the time interval in use to see if the frequency of fires is high enough to justify returning fire.

Have We Seen the Enemy?

Deciding whether a Soldier has seen something in a simulation environment is problematic. As in the case of the visual cues associated with rounds impacting, the same collection of visual scene information is needed regarding the enemy. Was the enemy rendered on the screen? If so, then how large was the image, where in the Soldier's field of view was it, and how long was it visible? All the same issues described above are in effect, with one more complication. Was the Soldier supposed to focus his attention on the area where the enemy was last seen? If the tactical situation required the Soldier to pay particular attention to the enemy's last known location, then that objective must consider the sureness factor we described above. We would like to know whether the Soldier concentrated his visual attention on the area of interest.

Because we are in a simulation environment, the simulation always knows what part of the simulated world is being drawn on the output display. The Soldier has complete control over where he is looking. We can now consider extracting direction of gaze information from the simulation. As with the sureness factor, there is some amount of detailed information that can be extracted, such as how much time elapsed since the enemy's last known location was rendered on the display, how much of that time was not in the field of view, and some indication of where in the field of view it was rendered. All of this detail must be examined to derive a conclusion regarding the Soldier's attentiveness. An algorithm that uses these data to arrive at a conclusion must contain several parameters that can be adjusted based on experience with the algorithm in an operational system. Combining the visual cue sureness factor with the qualitative conclusion about the Soldier's attentiveness provides the opportunity for a number of instructional interventions.

The next item on our list is "Fire team has recently seen an enemy." Again, this is an instance where we need to mark the passage of time from one event to the next. However, in this case, we need to start the clock only after we have confirmed that a fire team has seen the enemy. This confirmation can be derived from indirect evidence such as the fire team firing at the enemy's location and/or reporting to higher that they have seen the enemy.

Rules of Engagement

The rules of engagement (ROE) will have the effect of changing the various weights and priorities associated with the rules used to evaluate the situation or the Soldier's behavior. As an example, the rules of engagement may prohibit firing until they have been fired upon. In such a case, a fire team that has not been engaged, but fires at a human who crosses in front of a window in a building reported to hold enemy forces, would be evaluated as incorrect. The rules of engagement must be reported both to the human Soldiers in the exercise and to the VOC. This can be handled by assigning specific ROE data to a scenario definition in two forms: (a) a human readable form, and (b) as data that the coaches can accept and process into the rule base. When a scenario is selected for an exercise the simulation will report to the human Soldier, through its interface, the readable form of the ROE. The data form of the ROE is then forwarded to the coach who adjusts the rules to match the ROE.

Does The Enemy Know Where We Are?

There are ways to answer this question that do not require sophisticated processing techniques. If the enemy is firing at friendly units, then the enemy knows the location of the units. A second approach could be the use of a scripted, triggered report, such as a human spy observing the enemy observing the friendly units and reporting it to the friendly unit. These two techniques do not solve the general question, but provide mechanisms that do not disturb the realism of the situation.

Has The Element Of Surprise Been Lost?

This is the same question we just considered: "Does the enemy know where a friendly unit is?" In this case, not knowing the answer to the question has different implications than the knowledge about what the enemy knows.

Is Stealth Important?

This issue is more about an operational parameter than it is about a specific behavior, although determining it can be handled several ways. There are doctrinal rules that specify stealth for certain actions or procedures. These can be encoded into the VOC's knowledge base. Additionally, there can be an order from higher to maintain stealth. The VOC would then know that stealth was important.

Is The Enemy's Location Known?

A report from another unit or source of intelligence can announce that the enemy is at a certain place. Such an announcement is plausible in the real world, can easily be scripted in a scenario without disrupting the sense of realism. The message can be sent as a simple piece of data to the coach, and the report establishes a certain knowledge that friendly Soldiers know where the enemy is. What follows is a discussion of several SA rules and how they can be encoded into a combination of triggering expectation messages that are sent from the simulation to the coach, along with the corresponding rules that create the correct situation dependent expectations of behavior.

DISCUSSION OF DETAILS OF THE SVS SIMULATION ENVIRONMENT

The SVS will be required to provide specific data to the VOC. While much of the data are contained in simulation packets transmitted among simulations on the network, some data are available only inside the SVS. This section begins with a brief discussion of the distinctions between these sources of data and the implications for the architecture of integrating the VOC into the SVS. Subsequent sections define these data and suggest ways in which the SVS will most effectively convey this information.

SVS Data Architecture

The SVS is a distributed (networked) virtual simulation system, utilizing either the Distributed Interactive Simulation (DIS) IEEE standard (v2.0.4) or the High Level Architecture (HLA) to communicate (over the computer network) entity and event information that occur in the virtual world (i.e., synthetic environment). Despite initial attempts by the Department of Defense to transition simulations from DIS to HLA, 99% of networked simulation users run in DIS mode. The DIS 2.0.4 consists of about 27 predefined network packets (called protocol data units or PDUs). The SVS uses only four of these packets that make up the majority of all packets in any typical simulation exercise. These four are Entity State, Fire, Detonation, and Collision PDUs. The SVS uses other PDUs for simulation control and transmission of nonstandard information.

The DIS PDUs are transmitted as UDP IP packets on a given network port. An exercise ID is used to associate a set of PDUs with a given simulation exercise. There are commercial toolkits that facilitate reading DIS PDUs.

EntityState (ES) PDUs are transmitted onto the network for each entity at a rate determined by the entity's rate of change (either angular or positional), or at some minimal time-based rate if they are not moving enough to exceed the rate thresholds. An ES PDU is also sent when a state change occurs (e.g., go from standing to kneeling, or alive to dead). Each EntityState defines the entity, its physical description, and rate of movement, location, status, and markings. Because each ES PDU contains everything there is to know about an entity, and because each entity has a minimum transmission rate for these ES PDUs, one can join a simulation exercise late and still learn of each entity in the simulation within a given time period (normally 10-12 seconds). Another important aspect of DIS (not specific to SVS) is the concept that each entity decides its own state, for example, if another simulator shoots at and hits "my" simulation entity, then "I" decide if I am wounded or killed.

Fire PDUs are sent when an entity fires a weapon. It contains the location from which the weapon was fired, direction of fire, what ammunition was fired, and if another entity is the target. Detonation PDUs are sent when ammunition detonates. For example, one can tell where a bullet hits from the Detonation PDUs. Collision PDUs are sent when an entity hits another entity or a structure.

All of the PDU structure and content is defined by an IEEE specification. Data from within the SVS simulation is collected and packaged for network transmission in accordance with the defined standards. However, PDUs do not contain all data available from a simulation. Within the SVS, information on weapon firing mode, ammunition stores, whether objects are associated with sounds or make sounds themselves, and user control inputs, are not transmitted over the network. Thus, the implication is that direct communication between the SVS and the VOC will be required to provide necessary information to the VOC. In this discussion, a definition of information source will be provided, as will an assessment of the difficulty of modifying the SVS to provide the required information.

SVS and VOC Information Requirements

Much of the required entity data are available on the network, (e.g., where it is, where it is headed, its path over time, whether it employs a weapon, is hit by ammunition or collides with another entity or object in the environment). Any information that is generated by the SVS for distribution over the network is also available internally and upstream of when this information would be available from the network. Obtaining data directly from the SVS would increase the timeliness of the information. What follows are specific information needs generated by the scenario to help define the VOC requirements. This section describes alternatives by which the SVS can provide this information.

Techniques for Identifying Objects Suitable for Cover

The issue here is operationally defining what affords cover in the virtual environment. These include environmental features such as trees and gullies, structural features such as buildings, light posts, and curbs, and entities such as vehicles, barrels, and furniture.

Options for identifying these within SVS include:

- Tagging structures in underlying database: Terrain development tools such as MultiGen can be used to tag polygonal (terrain) structures with comments identifying them as providing cover, along with a location and volume. The SVS would locate and maintain a list of these when loading the database, and a search process would be undertaken by the SVS to identify them at defined choice points. While straightforward, this would be labor intensive.
- Pre-identifying terrain features with SVS zones: The SVS uses the concept of zones to define volumetric regions that are used to identify chemical or radiological contamination areas, or areas in which specified sounds will be heard. These are rectangular, cylindrical, or spherical in shape. Zones could be overlain on defined cover areas and preprocessed and stored as a scenario file using the SVS authoring capability. Available as broadcast data and as non-standard persistent objects, this structure is also used for interoperability with ModSAF and OneSAF. This application is also labor intensive.
- Use broadcast objects (entities) as cover: This is only a subset of possible cover in addition to terrain features. It is available as broadcast data coming into SVS and is currently available.

Recognizing Soldier Orders and Reports

Options for identifying Soldier orders and reports within the SVS include:

- Menus - The user can select screen-presented menu options using a weapon-mounted two axis controller. While this is an artificial constraint and all options must be pre-defined, it is the easiest option to implement. The resulting selections will then be available as internal data available to be sent to the VOC if necessary.

- Speech recognition (SR) - Speech recognition technology continues to improve and is a likely source of recognizing the orders or reports of a Soldier. This approach requires the development of a relevant grammar and some field experience to determine its practicality in a potentially very noisy environment.
- A C4I system was developed at Fort Benning, Georgia, for use with the SVS. It enabled the user to send and receive reports and orders and to view a dynamic map display. A custom interface device enabled immersive users to control this system, while others used a conventional desktop version. This approach is more flexible than menus but less so than speech recognition.

Sound Cues

We must differentiate how sounds are associated with objects versus how they are presented to the user. The SVS will detect internally if sound is being generated and where the source of the sound is located relative to the user. This feeds the sound generation system. Currently, the SVS uses standard Microsoft DirectX sound generation capabilities with four speakers. There are higher fidelity options, (e.g., the 3D sound system developed by the Institute for Creative Technology (ICT) that is currently being integrated into the SVS).

Tracking Human Soldier and CGF Ammunition Levels

Ammunition is tracked internal to the SVS and is used to identify when a magazine is empty and when a Soldier is out of ammunition. At present, the SVS CGF ammunition is not tracked. This will be added.

Enemy Engages and Misses

All non-guided munitions are not represented in the virtual world as entities. Thus, fly out is a computation that only has an effect once it "hits" something and a detonation PDU is issued. Possible alternatives for assessing this and providing to the VOC include:

- Use entity identification information in the enemy's Fire PDU. Within SVS, (assuming SVS station or SVS CGF used for OPFOR), a 5-degree cone is generated at the fire event. Any entity within this cone is identified as the entity being shot at. If there are multiple entities, then the first encountered is identified. Thus, to determine if a team is being fired upon, either the SVS or the VOC should have a list of the members of each fire team (or whatever level is desired), and, if one member is being fired upon, then the team is under attack. These are existing data on the network.
- Look for detonations in the immediate vicinity on objects and in buildings. These are existing network data.

- Use vector information between user and friendly forces and enemy forces to provide a gross level of detailed information. This would not be difficult, but additional integration effort would be required.
- User can know he is being fired upon by the sound of shots and muzzle flashes. These data are not exact, but provide adequate information. This is independent of the VOC knowing that a friendly is being shot at.

World Object Names

All objects in the simulated world that might be referenced in instructional feedback (e.g., large concrete planters, hills, buildings, rooms, windows) need human readable names that must be accessible to the VOC, either by request or provided as data in any messages sent from the simulation to the coach that relate to the entity. Techniques for tagging non-entity structures or objects, similar to those described for identifying terrain or objects as capable of providing cover can be used for ascribing nominal identifiers to objects of interest. As noted previously, the tagging process would be laborious, but the SVS modifications could be accomplished.

Soldier Route Monitoring

Using pre-stored routes, currently used to control SAF, the SVS can watch an entity move and determine if the movement was reasonable (i.e., it more or less followed the path that was pre-stored), and then forward that information to the VOC.

The SVS currently provides a mechanism for laying down paths as part of the process of programming CGF travel routes. The CGF subsequently follow these paths when commanded to execute movement behaviors. Thus the line segments concatenated to form an overall path are converted to linear equations against which CGF position is compared over time to perform path corrections to keep it on route. This approach can be used to monitor user movement along a predefined path and assess how well he is keeping to the defined route. A defined error metric could be continuously passed to the VOC for assessment and correction if deemed necessary. This error data would be internal to the SVS only. Since the mechanism to generate the error measure is in place, modifying the SVS to perform this feature would be very simple. Detecting that a Soldier arrived someplace requires a definition of where the place is (coordinates) and a radius threshold for arrival at that point.

Identifying Where a Soldier Looked

The determination of line of sight and visual angle is straightforward in the SVS, but definition of a room is problematic. We have discussed the possibility of using an alternate representation of the environment, a compact terrain database (CTDB) format used by OneSAF for reasoning purposes. It has terrain feature data, plus knowledge of entities and of buildings by special representations called multiple elevation structures (MESs). This representation could be used for many of the terrain, cover, concealment, and building reasoning tasks described above.

One benefit to this approach is that CTDBs are frequently built for many of the 3D databases that the Government uses, and the MES structures also carry information about apertures, windows, and doors.

An alternative approach is to use the SVS zone feature to define rooms and hallways. This would be a laborious process, but tags could be applied for reporting.

The SVS could use a visual cone defined by the system field of view around the orientation axis of the user. In the SVS, the user's head is not tracked to determine field of view. Instead, the user's body orientation is rotated to look around. This cone can be tracked and its intersection with the room walls can be used to conceptually paint the room with the circular or oval intersection of the cone with the wall. The total area thus painted can be assessed, and when a specific percentage of the area has been painted, the room can be assessed as searched. This would be a moderately challenging task to program into the SVS and would be available as internal data only.

SUMMARY

Training using simulated environments has progressed rapidly in recent years as a result of increased investment by the Department of Defense in general and the Army in particular. Simulations for small-unit dismounted warrior operations have benefited from recent advances in technology. Some of these advances include increased graphical display resolution and detail in the physical terrain needed for dismounted operations and in modeling and displaying realistic human behavior. These simulation environments can provide immersive, realistic, and engaging experiences. However, in spite of the technological advances, simulation environments are still practice environments. Without the intervention of a knowledgeable human mentor and the use of sound instructional design of training scenarios, poor performance may be learned just as efficiently as good performance. Even with a human in the loop there will be variations in training effectiveness that are a function of the human trainer's knowledge of the subject matter and instructional skills.

As simulation technologies have advanced there have been corresponding advances in the development of increasingly sophisticated simulated mentors or coaches in the intelligent tutoring community. Intelligent tutoring systems have been fielded in areas ranging from the deployment of Field Artillery units (Wisher, McPherson, Thornton & Dees, 2001), to teaching students the details of solving Algebra problems (Anderson & Pelletier, 1991). These ongoing tutor development efforts have enhanced the tutoring capabilities of the embedded virtual coaches. Furthermore, there is an increasing body of evidence that these tutoring systems produce significant improvements in instructional effectiveness and efficiency (Wisher, McPherson, Thornton & Dees, 2001).

This report describes the efforts and results of examining the feasibility of creating a Virtual Observer/Controller (VOC) to observe and critique Soldiers' performance as they are engaged in simulated small-unit, dismounted infantry training using the Soldier Visualization System (SVS) currently in use at Fort Benning, Georgia. The successful integration of the VOC and SVS will mean that the training value of the simulation-based exercises will not be completely dependent on the military expertise of a human observer/controller (O/C).

Sonalysts, Inc, Worcester Polytechnic Institute, and Advanced Interactive Simulations collaborated to investigate the feasibility of producing a training system that supplies instructional interventions that are pedagogically sound and contextually relevant to Soldiers engaged in small-unit training with the SVS. The proposed prototype training system would support small unit, dismounted infantry Squad and Team Leaders. Based on our investigation, we believe it is feasible to integrate an intelligent tutor with the SVS and produce a VOC to provide sound instructional support to members of small dismounted infantry units engaged in simulated urban operations exercises. Furthermore, we believe there is reason for optimism that this approach can be extended to a variety of other first-person simulated contexts.

The intelligent tutoring technology capabilities of Sonalysts Inc. and Worcester Polytechnic Institute have been exploited to develop a design for the VOC that attempts to mimic the behavior of a human O/C. The VOC has to observe the situation, form expectations of Soldier behavior, observe the Soldier, compare the observed behavior with the expected behavior, draw a conclusion about the Soldier's behavior, and then make an instructionally sound assessment regarding if, when, and how to intervene. These instructional interventions can take the form of immediate feedback to an individual Soldier, critical information for an After Action Review (AAR), or other actions discussed later in this report.

Investigating the development of the VOC required the following major efforts: (a) identifying the Soldiers' behaviors that merit performance evaluations (e.g., reporting to higher, suppressing an enemy unit); (b) developing situation triggers in the context of a training scenario that stimulate the Soldiers' behaviors we wish to observe and to evaluate; (c) determining how to detect those behaviors in an automated fashion, and; (d) developing instructional strategies that can adequately respond to both individual actions and small-unit collective behaviors.

The process we used to accomplish these four objectives included a partial cognitive task analysis and a detailed analysis of a scenario in which a dismounted squad on patrol in urban terrain undertakes a building-clearing mission. The situation triggers and the detailed behaviors expected of the Soldiers were derived from these analyses. Following this, the triggers and behaviors were closely evaluated to determine exactly how to detect them with software and hardware. Finally, we derived specific situation assessment and behavioral evaluation rules and criteria. These rules and criteria form the knowledge base that must be incorporated into the VOC and also proscribe the information that must be extracted from the simulation environment to detect the situation triggers and Soldier behaviors.

The proposed training system is comprised of a simulated environment that has been instrumented to extract and feed the necessary situation data, information, and Soldier behavioral data to the VOC. The VOC has been broken down into two classes of coaching modules, one for monitoring individual Soldiers (i.e., Squad and Team Leaders) that is called the Individual Coach, and one to monitor the entire squad that is called the Unit Coach. There will be two kinds of Individual Coaches, one with the knowledge base for observing and evaluating Squad Leaders and one for Team Leaders. The various instructional strategies employed by the VOC will be apportioned differently to the two classes of coaches. The individual coaches will use real-time feedback as their dominant instructional interventions, while the unit coach will employ a wider range of strategies and will reserve for itself the ability to pause the scenario for an instructional intervention.

Building a training system incorporating SVS and a VOC appears feasible, but should be done in at least two phases: (a) construct a prototype with a carefully selected set of features to support an evaluation of the instructional effectiveness of the prototype, and (b) analyze the results of the evaluation and, based on lessons learned, decide what the next effort should be. The evaluation could suggest that modification of the prototype to support more evaluation is warranted, or that the concept has shown such instructional promise that it is reasonable to construct a more capable version that could be used for actual training.

References

Anderson, J. R., & Pelletier, R. (1991). *A developmental system for model tracing tutors.* In Birnbaum (Ed.), The International Conference on the Learning Sciences. Association for the Advancement of Computing in Education, Charlottesville, Virginia. New Jersey: Lawrence Erlbaum, Inc.

Corbett, A. T., & Anderson, J. R. (1995). Knowledge tracing: Modeling the acquisition of procedural knowledge. *User Modeling and User-Adapted Interaction, 4,* 253-278.

Klein, G., Phillips, J., McCloskey, M., McDermott, P., Wiggins, S., Battaglia, D. (2001). *Decision-Centered MOUT training for small unit leaders* (Research Report 1776). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (DTIC No. AD-A394 066)

Martin, J., & VanLehn, K. (1995) Student assessment using Bayesian nets. *International Journal of Human-Computer Studies, 42,* 13-17.

McCarthy, J. E., Wayne, J. L., & Morris, J. J. (2001, June). *Closed-loop adaptive education.* Paper presented at the 13th World Conference on Educational Multimedia, Hypermedia, & Telecommunications (Ed-Media 2001), Tampere, Finland.

Phillips, J., McDermott, P.L., Thordsen, M., Mckloskey, M.J., & Klein, G. (1998) *Cognitive requirements for small unit leaders in military operations in urbantTerrain.* (Research Report 1728) Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (DTIC No. AD-A355 505)

Pleban, R.J., Eakin, D., Salter, M, & Matthews, M. (2001). *Training and assessment of decision-making skills in virtual environments* (Research Report 1767). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (DTIC ADA389677)

Pleban, R. J., & Salvetti, J., (2003). *Using virtual environments for conducting small unit dismounted mission rehearsals* (Research Report 1806). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (DTIC No. AD-A415 298)

Russell, S., & Norvig, P. (2002). *Artificial intelligence: A modern approach.* New York: Prentice Hall.

Singer, M., Grant, S., Commaford, P., Kring, J., & Zavod, M. (2001) *Team performance in distributed virtual environments* (Technical Report 1118). U.S. Army Research Institute for the Behavioral and Social Sciences. (DTIC No. AD-A396 489)

Department of the Army, (1992, April), *Infantry Rifle Platoon and Squad* (FM 7-8). Washington, DC: Author.

Wisher, R. A., McPherson, D., Abramson, J., Thornton, D., & Dees, J. (2001) *The virtual sand table: Intelligent tutoring for field artillery training.* (Research Report 1768). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (DTIC ADA388158)

APPENDIX A

EXPERTTRAIN TECHNOLOGY

Sonalysts began development of ExpertTrain in 1992 as a way to provide real-time coaching in simulation-based, rapidly changing environments. The instructional metaphor we used in developing this technology was that of a master-apprentice relationship. Our goal was to put a synthetic tutor into the learning environment (*i.e.*, embed the tutoring engine into the simulation), provide the tutor with a detailed "memory" (*i.e.*, a learner or student model) of each individual student, and support the following high level requirements:

- Employ event-based scenarios designed to exercise student mastery of specific learning objectives,
- Monitor and assess student performance throughout a simulation-based exercise,
- Provide feedback to the student as required during and after an exercise, and
- Update the learner model with mastery and instructional history information.

ExpertTrain comprises the following:

- Domain Expert – A software module that represents the knowledge of an expert in the subject matter domain (dismounted infantry operations, in this case) and assesses the student's performance.
- Learner Model – A data repository that reflects the student's mastery with respect to course learning objectives and the coaching that the student has received (also known as instructional history).
- Instructional Expert – A software module that produces instructional decisions. Considering inputs from the learner model and the domain expert, the instructional expert determines whether to intervene in the student's activity, what issue to address if an intervention is warranted, which type of intervention to employ, and in the case of the VOC, to whom to direct the intervention. This module will be extended to deal with collective tasks, and some investigation will be conducted to determine what additional instructional strategies may be appropriate in the dismounted infantry simulation environment.
- Student-Device Interface – The medium of communication between the student and the intelligent tutor system, which is usually the simulation environment. As such, its interface creates the learning environment and provides the medium through which the Instructional Expert communicates its instructional interventions.

A description of how these components interact during a simulation-based education session is presented in Figure A-1.

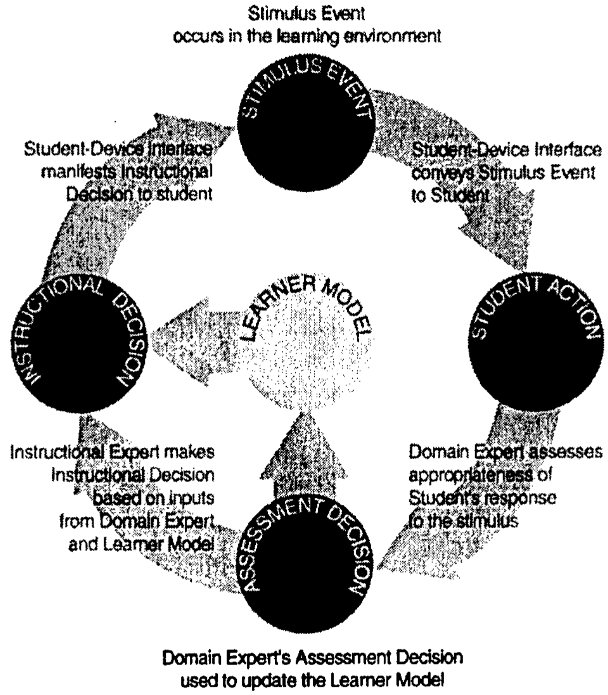


Figure A-1. **ExpertTrain cycle of operation**

Using the Domain Expert, Learner Model, Instructional Expert, and Student-Device Interface, the student is placed in a situated learning environment. This learning environment can be either a simple desktop computer simulation or a fully immersive environment. Scenario events within this environment are communicated (via messages from the instrumented simulation) to the domain expert that in turn invokes expectations of student behaviors. These expectations are derived from the domain specific knowledge embodied in the domain expert. The domain expert then monitors the student's response to these events (also via messages from the simulation) and assesses whether expectations were met or violated. These assessments are then passed to the instructional expert and used to update the learner model. The instructional expert, using the input from the domain expert and information from the learner model, determines the appropriate instructional feedback and provides it dynamically. The cycle of stimulus event, student action, assessment, and feedback continues throughout the exercise (see, for example, McCarthy et al., 1995; McCarthy et al., 1994).

Another way to consider the situation assessment capabilities of an ExpertTrain-based VOC is to recognize that it is attempting to answer the same question as the human O/C: "Given these observed conditions, what do I expect of the student?" The resulting VOC monitoring of student behavior allows the VOC to compare actual performance to these expectations, as mentioned earlier. However, ExpertTrain was also designed to provide feedback in response to specific errors identified a priori during the knowledge discovery and engineering efforts. During these knowledge engineering efforts (conducted during the Mission and Task Analysis phase of this effort) the "expectations" of behavior associated with any particular tactical situation can be both positive and negative; that is, in addition to specifying good performance (referred to as "target" behaviors or states), Sonalysts attempts to identify likely or prototypical errors (referred to as "bugs") in student performance. These "bugs" are often tied to more targeted coaching strategies. The expected actions (targets and bugs) are described in terms of observed student behaviors or effects (*e.g.*, explicit student actions or changes within the modeled world that indicate dismounted infantry actions).

Figure A-2 illustrates the processing within the ExpertTrain tutoring engine during a simulation-based exercise. Beginning at the bottom of the figure, certain aspects of world data are determined to be instructionally important; that is, they represent trigger conditions for some expected individual or unit behavior or performance. These "instructionally important world conditions" are then "instrumented" in the simulation by a set of data-driven "sensors" or "demons" that are sensitive to those conditions and transmit them to the domain expert from the simulation.

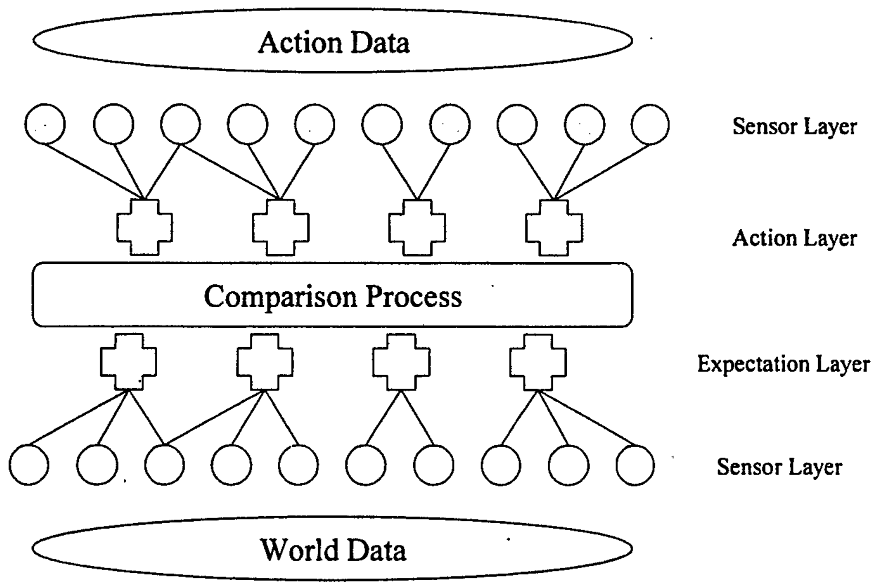


Figure A-2. **ExpertTrain assessment process**

Continuing up through the figure, these incoming messages from the simulation trigger domain-specific rules regarding certain combinations of world data that then form the basis for generating expectations of individual or unit behaviors. In a manner similar to a semantic network or a production system, ExpertTrain (as the Virtual O/C) recognizes certain combinations of events or states, links them to expectations, and prioritizes those expectations. For example, if the sensor layer recognizes conditions A, B, and C, then ExpertTrain might expect the student to perform actions 1, 2, and 3 with a priority of HIGH. However, if instead the world data reveals conditions A, B, and D, then ExpertTrain might expect the student to perform action 4 with a priority of LOW.

A similar process examines the student's performance. Beginning at the top of the figure, separate sensors (instrumented simulation elements) examine the states of world or individual and unit data. The sensor findings are combined to indicate the presence or absence of critical student activity or behavior.

Individual or unit behavior or performance assessment decisions are the result of the comparison process indicated in the center of the figure. Each action that is recognized in the top of the figure is "offered" to each of the expectations originating from the bottom. In turn, the expectations can "claim" an action as matching a target expectation or matching a known bug associated with that expectation. In practice, the matching process is sensitive to learner model mastery data. As an individual or unit gains mastery, additional performance precision is required to match a target expectation. As additional actions are recognized, expectations (targets or bugs) may become "completed." When an expectation has been completed, a positive (for targets) or negative (for bugs) assessment decision is rendered.

APPENDIX B

SOLDIER VISUALIZATION SYSTEM SIMULATION DESCRIPTION

The following sections summarize the general SVS system functional capabilities.

Synthetic Environment Display

The SVS system displays synthetic environments, or databases, that are in industry standard OpenFlight format. Additionally, SVS can import SEDRIS and TerraPage format databases. In databases that have been appropriately constructed and labeled, the SVS can support dynamic terrain features such as opening and closing doors, shooting out windows and doors, blowing holes in building structures, making "dings" in building structures with rifle fire, and shooting out streetlights and eliminating corresponding illumination.

Entities and objects that are not part of the synthetic environment database, such as humans, tanks, trucks, aircraft, *etc.,* are represented as models that exist in a library so that as they are instanced by networked or local scenarios, they can be displayed appropriately. A model of standard objects is provided along with the SVS. This includes a proprietary human animated character set that represents own and opposing forces, as well as some neutrals (civilians). A third-party software package – DI-Guy by Boston Dynamics, Inc. Is available as an option.

Human Behavioral Capabilities

Part of the SVS software is dedicated to simulating the perceptual-motor capabilities of the human interacting with the virtual environment. These include:

- Movement – This includes walking, running, crawling depending on posture, turning left/right, walking up/down stairs, climbing over low objects, detecting collisions with structures and objects, etc. Maximum movement rates are set based on research on human capabilities. SVS present visual and aural stimuli, but rely on user capabilities for detection and location (given system performance constraints).
- Health status – Human entities in the SVS can be wounded or killed. Health can be affected by direct and indirect fire munitions, and by chemical contaminants. Effects of specific munitions or wounds can be tailored by the user.
- Night vision devices – SVS provides rudimentary NVG (night vision goggle) and thermal imaging simulation

Weapon Employment

Weapon employment in the SVS is designed to be as natural as possible. The user aims the intended target in the virtual environment using either the weapons "iron sights" or, in the case of the Land Warrior configuration of the SVS, through use of the simulated video display sighting system. To engage the target, the user squeezes the trigger and fires the round, with accompanying audio feedback. Using appropriate weapon ballistics supplied with SVS, or customized by the user, the round trajectory is computed, including wind effects. The trajectory is assess for intersection with geometry in the virtual world, and if found, the entity/object is determined and appropriate hit effects are applied, *e.g.,* wounding or death of human entities, "dings" on walls of buildings, puffs of dirt on the ground, etc.

Each weapon carries a standard load for the magazine, and when depleted, the user must reload the weapon. This, in most cases, is accomplished by removing and replacing the weapon clip. This simulates replacing an empty magazine with a full one.

- SVS can be supplied with the following weapon mockups:
- M-4
- M-16
- M-16/M-203
- M-240
- M-249
- Remington Pump Shotgun
- M-9 Pistol

Additionally, SVS functionally simulates other weapons that do not have a physical mockup available. These include an AK-47, AT-8, and an RPG-18.

The user has the option of employing simulated tracer rounds for specifically-defined round intervals. Tactical aiming lights (visible and infrared (IR)) can be employed. Laser range finding is also supported using the weapon as the interface. Firing the weapon optionally creates a muzzle flash that can be spotted by other participants in the exercise.

Standard Weapon

The standard weapon, *i.e.,* a non-Land Warrior system, operates as described above. The user has the option of displaying a crosshair or replica "iron sight" graphic on the display screen that represents the aimpoint of the weapon as it moves through space.

Augmented Display Weapon

With the Land Warrior augmented display, the output of a simulated daylight video sight attached to the weapon is displayed on a user-defined device, such as an HMD or a simulated weapon-mounted sight. Crosshairs on this display represent the aimpoint of the weapon.

In addition to being used as a weapon sight, this second display channel can be used to display magnified binocular imagery on a specially configured device.

Supporting Functions

The SVS system provides the user with capabilities beyond those associated with employment of a specific weapon. Two specially integrated buttons on the rifle are used to select and activate these functions, along with the trigger for selected functions. These are summarized in the following sections.

"Hand-thrown" Munitions

The ability to "throw" munitions is simulated by calling up a fluctuating graphic on the screen that indicates the strength of throw desired. The direction of throw is determined by the weapon aimpoint. The user activates the "throw" with the weapon, and the munition is launched in the desired direction and distance. Munitions able to be launched in this manner include:

- Grenades – fragmenting and flash/bang
- Smoke – User selectable colors
- Flares – White

The user also has the ability to hand emplace C4 explosive charges to objects in the virtual environment that can be subsequently detonated.

"Surrogate" Weapon-Launched Munitions

Flares of various colors can be launched into the sky using the weapon as a surrogate launching device by selecting and activating this function.

Environmental Effects

- SVS allows a number of environmental effects to be set at runtime. These include:
- Time of day (24 hours –day – night)
- Weather
- Wind strength and direction
- Fog – intensity and color

These can be preset or varied during scenario execution.

Figure 6 below is an engagement detection algorithm flowchart

Training scenarios can be constructed by a number of means: force-on-force engagements with networked human-in-the-loop SVS simulators; separate computer-generated-forces (CGF) applications that operate in the SVS networked environment (*e.g.*, US Army's ModSAF or OneSAF), or via an SVS scenario authoring capability. Separate SVS products support scenario development (Authoring) and control (Battlemaster).

SVS Authoring

AIS Authoring station provides full scenario development capability for the SVS virtual simulation system. Built upon the SVS Stealth simulation visualization system, the Authoring station uses Stealth 3D visualization capabilities to assist in drag-and-drop scenario creation through the Scenario Development Tool (SDT). SVS-internal computer-generated forces (CGF) can populate the scenario with dynamic, responsive human entities.

The SVS Authoring Station provides all of the features required to visualize the combined-arms synthetic battlefield. Freely move through the virtual world or "attach" to other entities in your simulation. Once attached to an entity, you can observe the exercise from either the entity's first person point of view, or from a third person "over the shoulder" point of view.

The SDT enables the operator to create customized scenarios in any synthetic environment, including cluttered urban areas. The SDT allows static models to be placed through a 3-D 'drag-and-drop' interface. It also enables the creation of multi-state objects, such as smoking and flaming vehicles, as well as shrouded weapons, doors that can open/close, and fenced areas. SVS Authoring allows for the creation of "persistent objects"(POs) compatible with ModSAF and the OneSAF such as chemical zones, lines and points. These scenarios can be created beforehand and saved as files that can be loaded at simulation run-time.

The Authoring's embedded computer-generated infantry forces capability enables the user to add dynamic friendly or opposing forces to the simulation exercise. These forces can be given scripted behaviors such as move, shoot, and follow and can further react to external events such as engagement by opposing forces. AIS authoring is also ModSAF and OneSAF interoperable for additional simulation development capabilities.

SVS Battlemaster

SVS Battlemaster station is a simulation monitoring and control and after-action review tool. Built upon the SVS Stealth simulation visualization system, the Battlemaster station extends Stealth capabilities to provide start- to-finish simulation exercise control. These capabilities include an Exercise Controller for real-time simulation initialization and control; and an AAR capability to review simulation activities recorded by the Battlemaster Station

As with all SVS simulation products, the Battlemaster features real-time 3D graphics and directional audio and provides native support for Distributed Interactive Simulation (DIS) network protocols and the High Level Architecture (HLA).

The Battlemaster station provides full simulation management and control. Simulation entities can be paused, teleported, revived, resupplied, and re-initialized. All distributed environmental effects can be controlled such as wind, fog, rain, snow, and time-of-day. In addition, the exercise controller provides an artillery tool to enable the exercise controller to provide real-time dynamic munition effects during a scenario.

The Battlemaster's inherent capability to record internal simulation events can be replayed through an (AAR) feature. These recorded data files can be replayed through a VCR-like interface that supports jumping forward and backward and pausing the simulation. The Battlemaster supports helpful 3D display features such as firing identification lines, entity overlays and wireframe modes that assist in the AAR capability.

Commands and signals for SVS Computer Generated Forces *(CGF)*

1. Indigenous SVS CGF are simple, deterministic entities that perform specific behaviors in response to specific commands. Their behavior is scripted using a combination of 3D graphical inputs and a graphical user interface (GUI) selection mechanism. This differs from semi-automated forces (SAF) such as OneSAF in that SAF employ some level of autonomous "reasoning" based on some programmed artificial intelligence. Thus, with

SAF you can, for instance, specify a start point and an end point and the SAF will determine its own path using terrain reasoning and obstacle avoidance. SVS CGF must have the path completely specified, and it will blindly follow this defined path. Signal and command data are available internal or broadcast.

The current command set for SVS CGF consists of:

- Run, walk, crouch, crawl
- Stand, kneel, prone
- Aim, stop aiming
- Stop, resume
- Timer, play sound, change path
- Send signal, wait for signal
- Die, revive
- Shoot at point, stop shooting
- Detect incoming
- Detect entity

The current signal set for SVS CGF is:

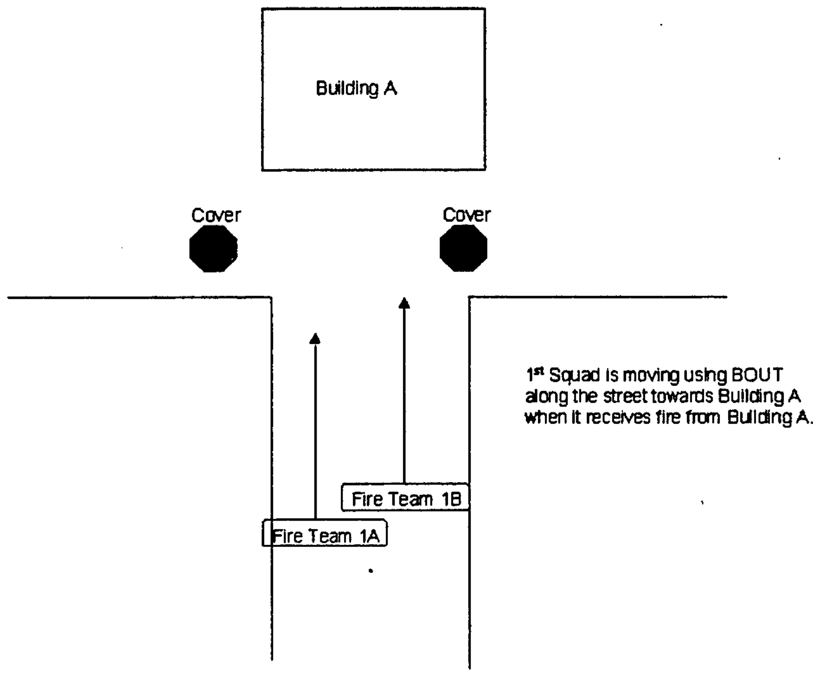
- (Alpha, Bravo, Charlie, Delta) Halt
- (Alpha, Bravo, Charlie, Delta) Move out
- Attack
- BMP-Go
- Delta heavy weapons go
- Dismount
- Follow me
- Open fire
- Pause
- Resume
- Smoke
- Start
- Stop
- Suppress
- Withdraw

Current triggering cues are manually executed via a menu selection (as from the Battlemaster station), or as seen, may be generated by other CGF. It is possibly for commands to be generated via the speech recognition system discussed as a potential addition to the Virtual O/C/SVS system.

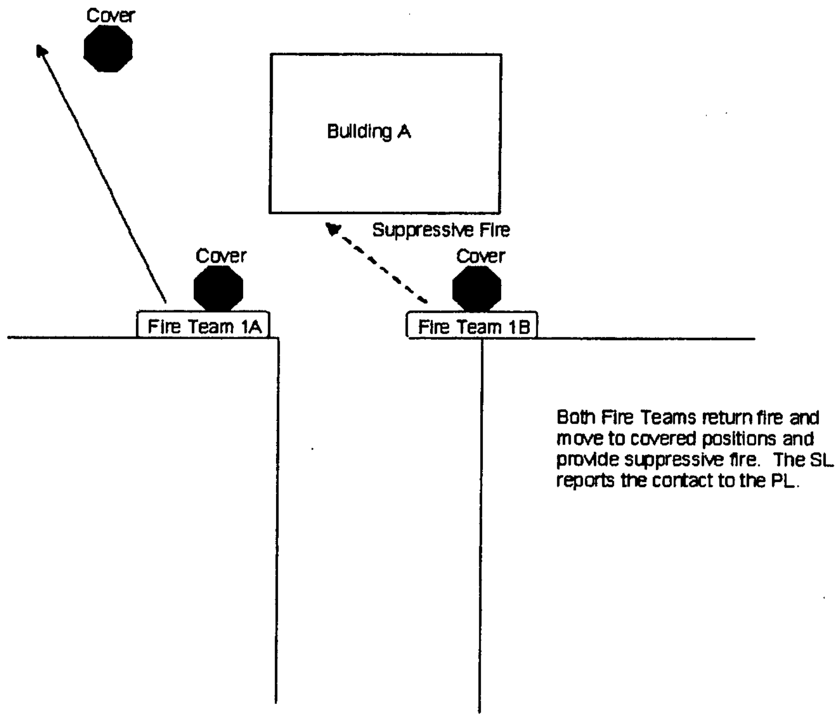
APPENDIX C

BUILDING CLEARING SCENARIO

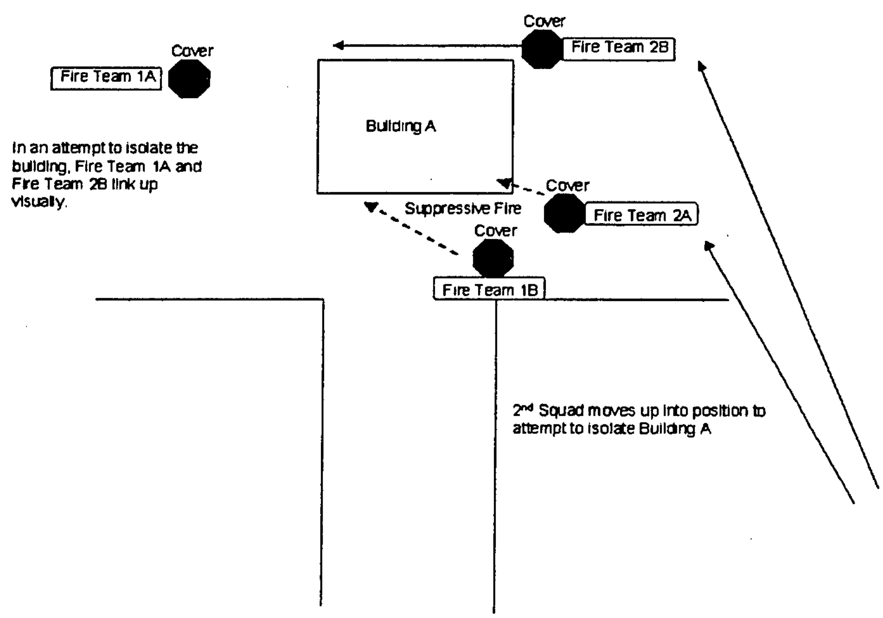
The following figures and narrative present the example building-clearing scenario used throughout this report.



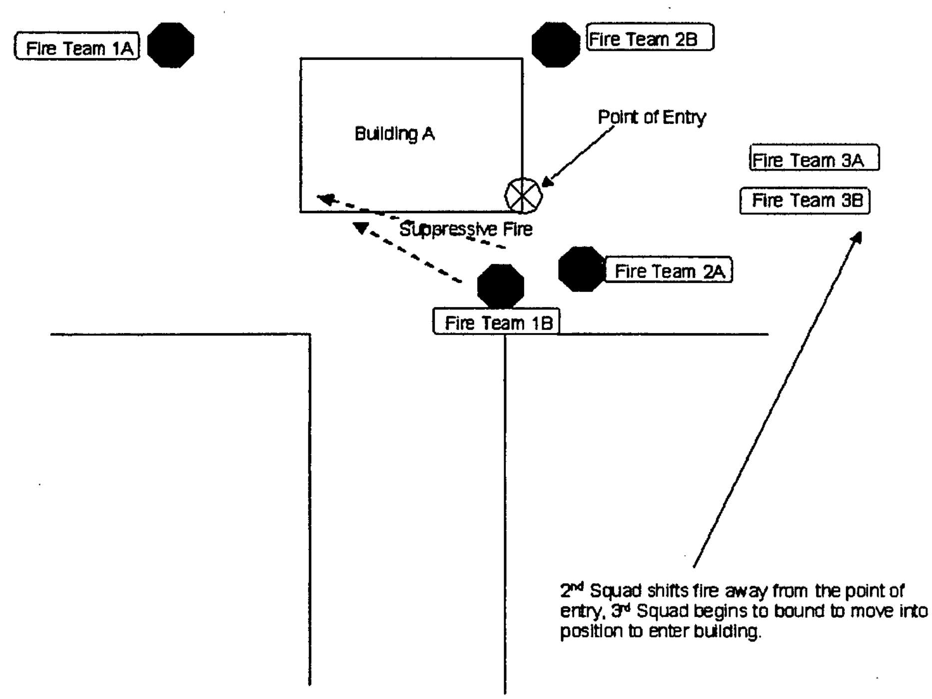
PL – Identifies a base of fire position and directs the squad in contact to move there. PL also attempts to move forward to gain better situational awareness.



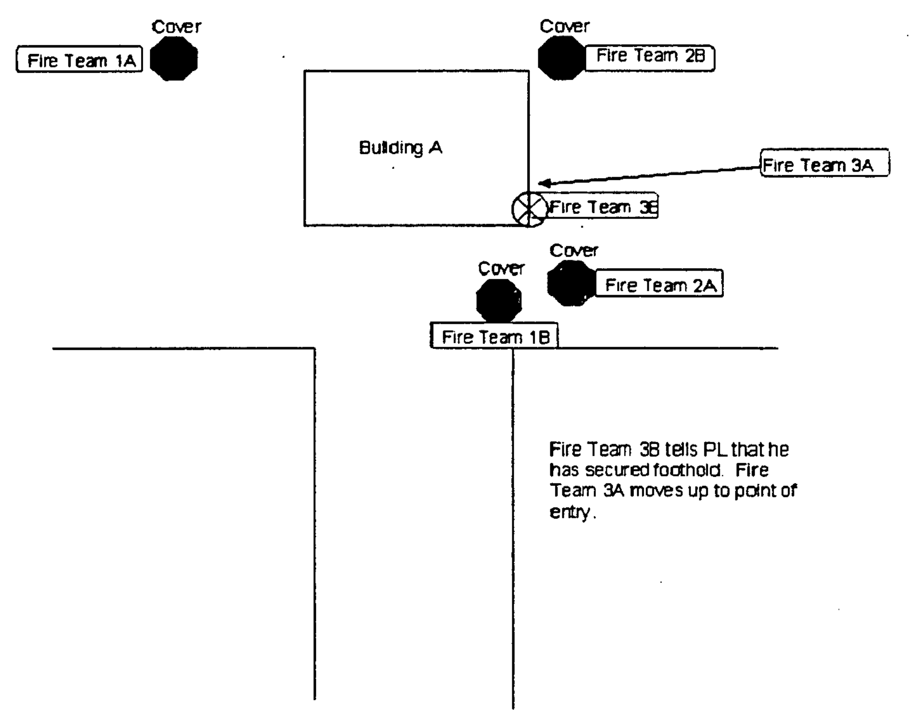
SL of squad in contact – Establishes base of fire with his squad, establishes local security, and adds "suppressive fires against the enemy. Reports to PL when base of fire position is established.



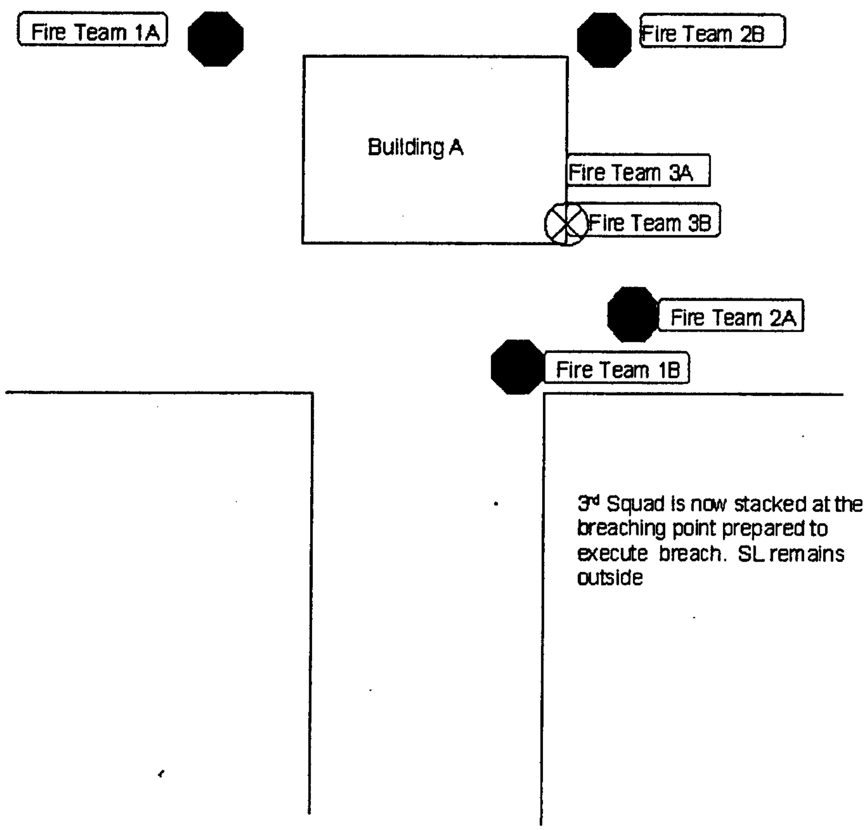
PL – Orders 2nd squad to link up with squad in contact, moves up to link up with the next squad. The goal is to isolate the building so that additional enemy forces cannot enter the building.



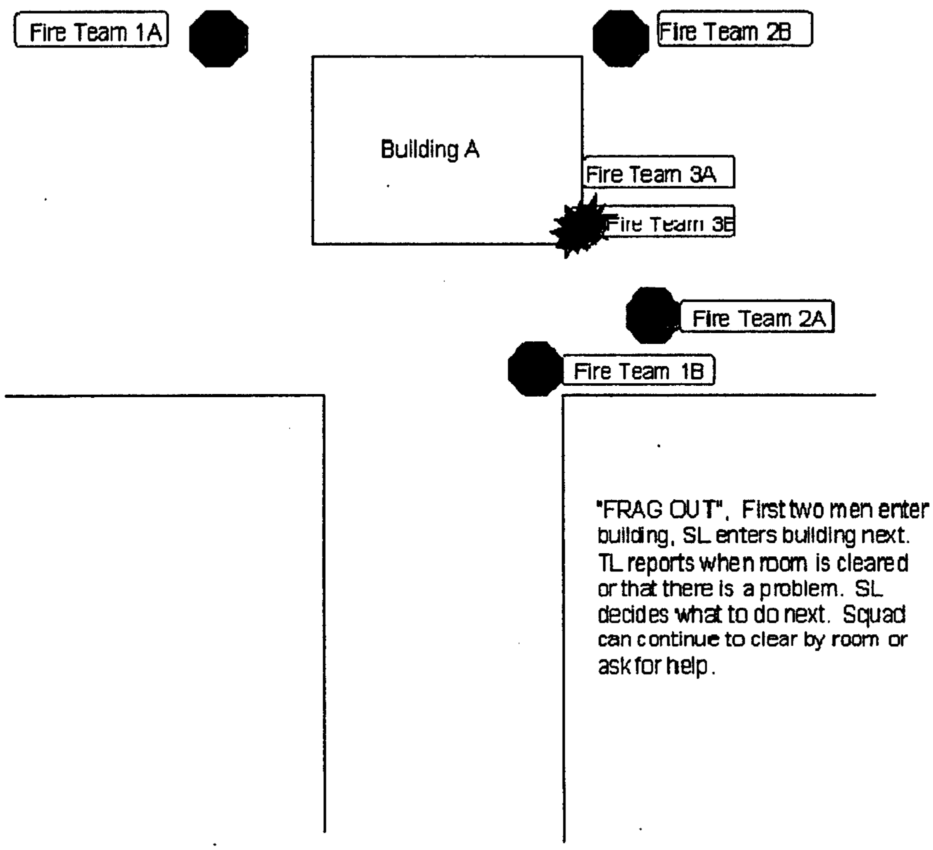
PSG – Orders remaining squad to move (if required).
PL – Assesses situation and provides subordinates with his assessment.
1st Squad – Continues to provide suppressive fires and adjust position as required.
PL – Determines the entry point for the building.



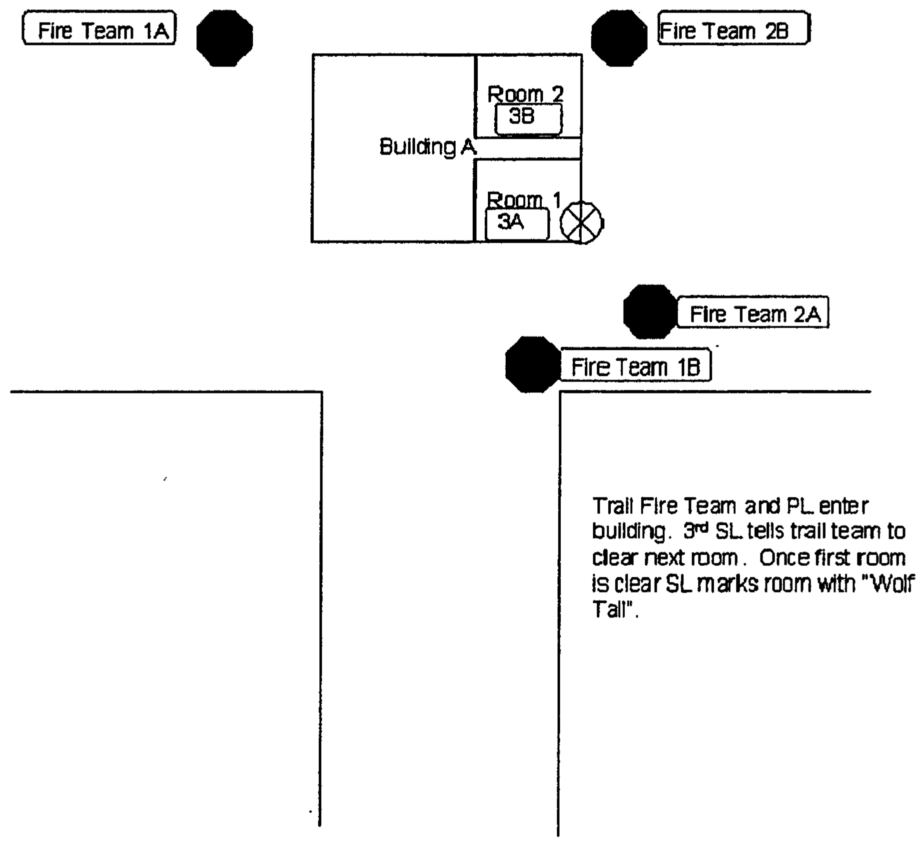
1st Squad – Splits squad up to allow one fire team to move to a point to continue with isolation building.
2nd Squad – Moves to the other side of the building to complete isolation of the building.
3rd Squad – SL tells his squad to prepare to move to the entry point. Moves his squad to desig entry point on order.
PL – Gives order to 1st and 2nd squads to lift and shift fires.
1st and 2nd Squads – Lift and shift fires on order.
PL – Gives order to 3rd squad to move to entry point.
3rd Squad – moves squad to entry point.



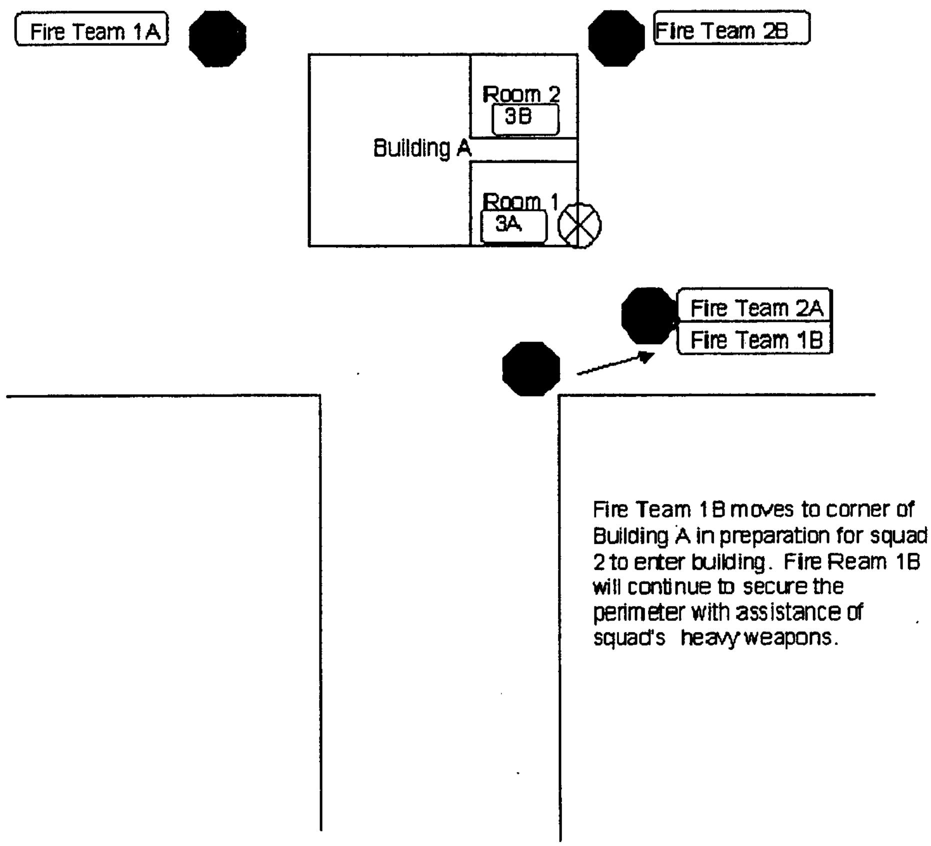
3rd SL – Tells PL that his squad has arrived at the entry point and has secured a foothold.
3rd Squad is now "stacked" outside the breaching point and is preparing to execute the brea



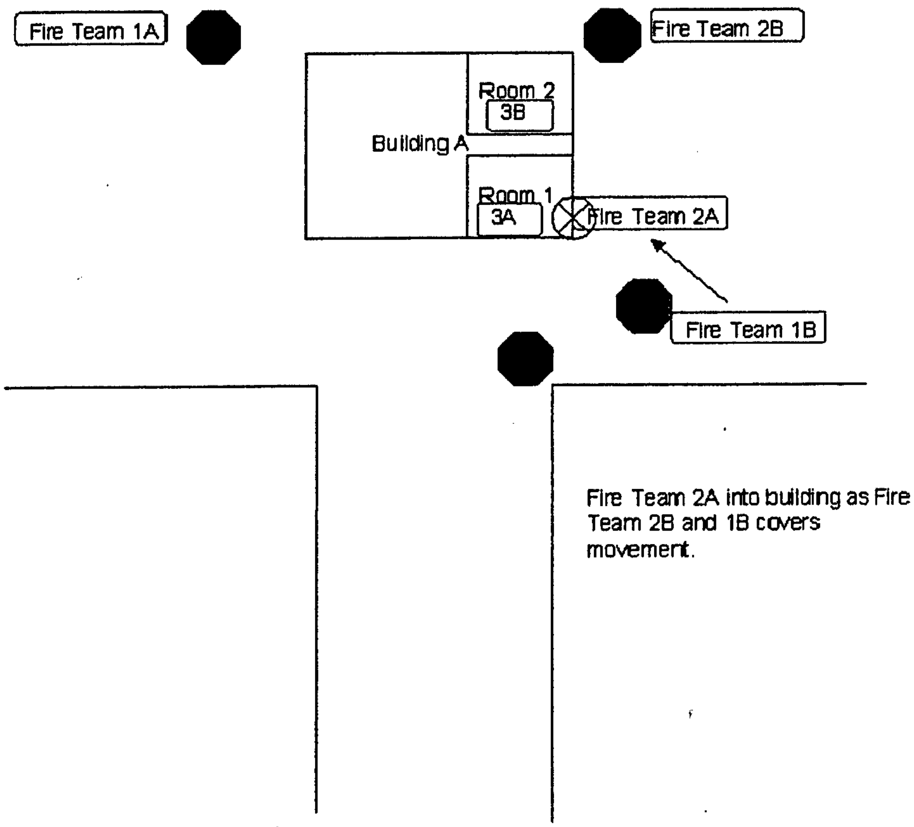
3rd SL – Calls trail fire team forward to the entry point, executes breach. Once the smoke has cleared second man tosses in flash or fragmentation grenade and enters breach after detonation. Soldiers begin clearing the first room according to established procedures. Assaulting fire team leader is responsible for clearance of the first room, then determines whe additional personnel are required for clearing room.



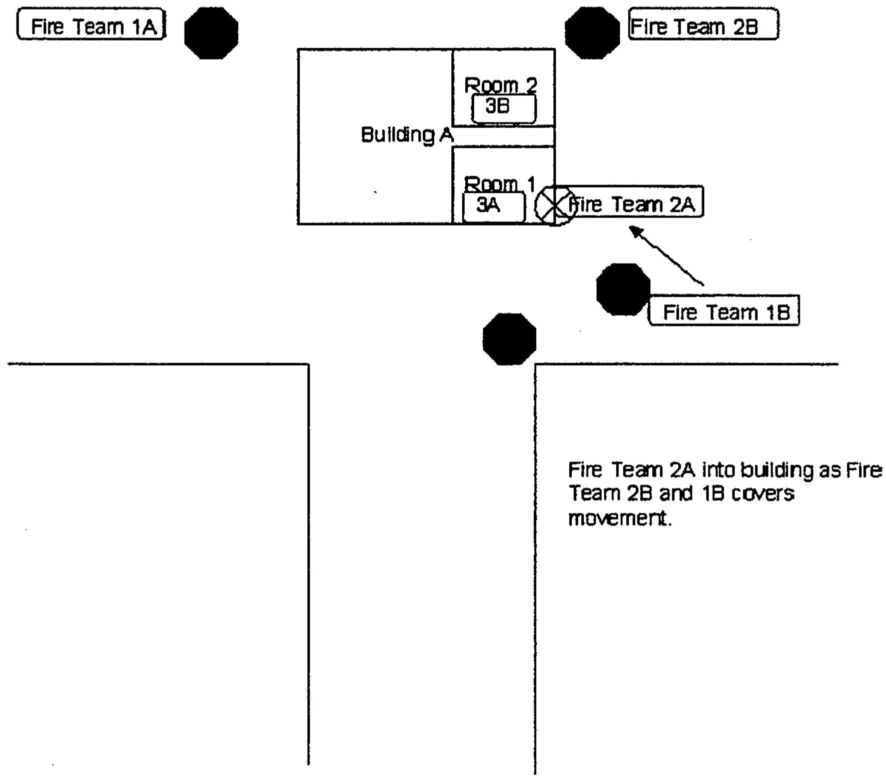
3rd SL – Determines that first room is clear and tells trail team to begin clearance of the second room. 3rd SL enters first room and after verifying that it is cleared marks the room according to established procedures.
PL – Orders 2nd Squad forward to the entry point. Orders 1st Squad to secure the perimeter of the building. May ask for the heavy weapons squad to come forward to assist 1st Squad in securing the perimeter.



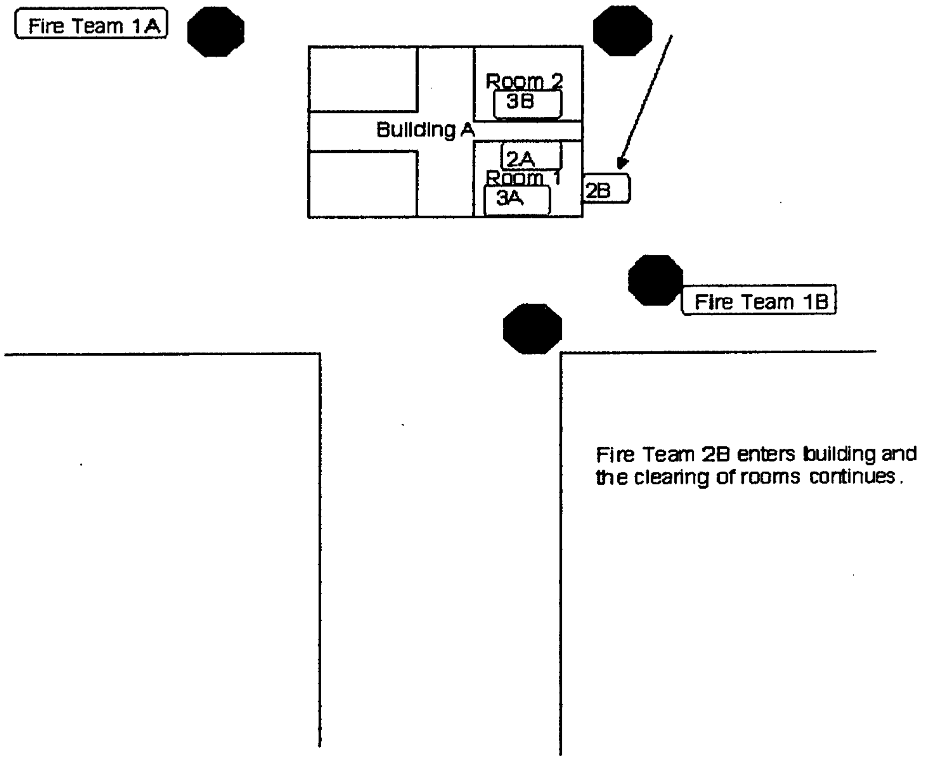
1st Squad – Coordinates with weapons squad and continues to secure the perimeter of the building. It is imperative that the building remains isolated during clearance.



3rd Squad – Continues to clear the second room, signals 2nd Squad when to enter the building. 2nd Squad continues to next room to begin clearing.



2nd and 3rd Squads – Continue clearing the building and upon clearance of the building inform the PL that the building is now clear.
1st Squad – Continues to secure the perimeter of the building with the assistance of the weapons squad.



Platoon Sergeant – Calls for resupply of ammo, prepares for consolidation.
PL – Reports to Company Commander when the building is cleared and asks for additional instructions. Insures that consolidation activities are conducted prior to movement.

APPENDIX D

DETAILED SCENARIO ANALYSIS

The goal of the following table is to illustrate the types of results that occur from a detailed analysis of the scenario. The goal of the detailed analysis is to generate a list of the ways the Soldier Visualization System (SVS) environment will need to be instrumented to detect the actions of the trainees to support the student evaluation portion of the Virtual O/C. This table presents the results of an examination of the sample scenario broken down into stimulus events (the first column, labeled **Scenario Event**) and the related required detailed trainee actions (the second column, labeled **Detailed Expected Trainee Behaviors)**. Each detailed action is annotated with:

- Who should perform the action (part of the action description),
- A more general description of the correct action, later used in the development of a related learning objective (the column labeled Target Description),
- A discussion of how such an action might be detected in the context of the simulation (the column labeled How Detected), and
- What information or data would be needed for that detection mechanism to work (the column labeled Data or Information Required).

Detailed Expected Trainee Behaviors are specific actions that the trainee is supposed to take in the context of this generic building-clearing scenario. These behaviors and the content of the next column (Target Description) form the basis for detailed learning objectives. How Detected and Data or Information Required columns will have some redundancy in the table, but are repeated in the Requirements section without duplication. These two columns refine the requirements for instrumenting the simulation.

The column labeled "Comments" is for additional information regarding how a particular issue may be handled from the perspective of instrumenting the simulation environment or otherwise obtaining the information described in other columns of that row of the table.

Scenario Event	Detailed Expected Trainee Behaviors	Target Description	How Detected	Data or Information Required	Comments
	Lead Squad (#1)				
Scripted action: 1st Squad takes fire from unknown location.	Takes Immediate cover	Moves (and/or orders squad to move) to nearest suitable cover	1) Recognize suitable cover given friendly and hostile orientation	Entities available for cover, including its location, which side of the entity provides cover, and how many individuals can be covered behind it	
This action requires the simulation to trigger the fires based on the particular squad's movement and location as it approaches the building.			2) Recognize movement of SL and/or move order to subordinates	SL movement direction and/or move order indications (including who the message was sent to)	
			3) Recognize destination of movement and/or destination in move order	SL arrival	Granularity and periodicity of movement information must allow for an arrival at some destination to be detected.
			4) Recognize that action was taken	Period of performance	Coach is responsible for

Scenario Event	Detailed Expected Trainee Behaviors	Target Description	How Detected	Data or Information Required	Comments
			within the acceptable period of performance		evaluating that actions were taken in a timely fashion.
	Locates the enemy	Takes appropriate action to try and determine the location and strength of enemy unit initiating fire	Detecting this action will be recognized by examining subsequent behaviors, such as the content of the report to the PL and the location of moves made in taking cover.	Whether or not the visible indications of the incoming fires (*e.g.*, muzzle flash, smoke) were rendered in the display being viewed by the SL.	The coach's instructional response to subsequent behaviors will be sensitive to whether the SL *could have seen* the incoming fire indications on his/her display
	1st SL reports to PL	Sends report to PL with adequate and accurate information within the acceptable period of performance	1) Recognize that the report was sent	Message sent indication	
			2) Recognize the content of the report	Whatever data were sent in the message that are interesting: 2. Where the fires are coming from, as best as can	Gaining access to the content of the message can be accomplished in a number of ways, such as speech recognition technology or a

Scenario Event	Detailed Expected Trainee Behaviors	Target Description	How Detected	Data or Information Required	Comments
				be determined 3. Size of the enemy unit, if known, 4. Injuries 5. Squad location	GUI driven messaging approach where the SL must type in specific information (perhaps with the help of dictation software).
			3) Recognize who the report was sent to	Recognize To: in message sent from SL	These data can be obtained in the same fashion as in item 2) above.
			4) Recognize that the report was sent within the acceptable period of performance	Period of performance	Obtained from SME's and incorporated into the coach's evaluation knowledge base.
Scripted Action: Enemy fires again after squad takes cover.	1st Squad suppresses the enemy	Squad returns fire IAW with ROE, ammunition conservation considerations and in the direction of the enemy unit	1) Recognize the correct direction of fire needed from squad's current location to the enemy's location	Vector details from squad to enemy	This should be truth, but only used with a tolerance derived as indicated below.
		If the enemy force	2) Knowledge of	Inferred from other	This would be a

Scenario Event	Detailed Expected Trainee Behaviors	Target Description	How Detected	Data or Information Required	Comments
		is large SL should move heavy weapons squad forward. Must request heavy weapons from PL.	how sure the SL is about the enemy's location	behaviors (*e.g.*, movements, move order data)	heuristic in the coach used to derive a reasonable tolerance for assessing direction of fires
			3) Know when, how fast, and at what the squad is firing	6. Firing rates 7. Firing direction 8. Target being fired at 9. Ammunition remaining	Assessing the reasonableness of the return fires must take into consideration, among other things, the presence or absence of civilians (which can be a scenario specific feature)
			4) Enemy fires	10. Firing rates 11. What enemy is firing at	This will be used to determine if suppressive fires are working
1st squad establishes a base of fire allowing other squads to begin movement	SL identifies Base of Fire (BOF) location	SL identifies a secure base of fire position that provides direct line of sight to enemy location and maximum	1) Reports to PL the BOF location,	BOF location information extracted from message	SL can use grid coordinates or landmarks. Getting this information can be accomplished via speech recognition,

Scenario Event	Detailed Expected Trainee Behaviors	Target Description	How Detected	Data or Information Required	Comments
		perimeter coverage of building			requiring the user to use a GUI to send the message, etc.
			2) Knowledge of suitable BOF location(s)	Simulated world entity information including attributes indicating BOF suitability. Need to know line of sight data, distance from target.	In some situations this information can be pre-programmed into the simulated world and this information given to the coach at scenario startup.
			3) Correlation between the identified BOF location and entities in the simulated world		Must be able to tell exactly where the SL is intending to go in semantically meaningful terms to support human useful evaluation (*e.g.*, went behind an abandoned tank, or went behind motorcycle)
	SL orders a team to BOF	SL orders the appropriate first team to move to the BOF IAW with TTP (*e.g.*, uses	1) Knowledge of which team should move first, if there is a preference	12. Line of sight vectors for each team to enemy 13. Angle of	Presumably, the team with the better line of sight to the enemy should cover the

Scenario Event	Detailed Expected Trainee Behaviors	Target Description	How Detected	Data or Information Required	Comments
		BOUT technique) and other team ordered to provide covering fires		fire for each team	other team's movement.
			2) Knowledge that the covering team received a covering order	Message sent indications, including what was ordered and from and to who	
			3) Knowledge that the team to move received the move order after the covering order was given	Message sent indications, including what was ordered and from and to whom	The sequence of orders will be assessed by the SL coach
	SL orders second team to BOF	To be continued			
Scripted Action: PL orders next squad to move. This requires the simulation to support a triggering condition that recognizes the squad in contact has successfully					

Scenario Event	Detailed Expected Trainee Behaviors	Target Description	How Detected	Data or Information Required	Comments
moved to the base of fire.					
Squad #3 Actions					
PL orders 3rd squad to move to a designated entry location to prepare to assault the building	3rd SL moves squad to assault position once covering fire is provided by 1st and 2nd squads	Squad moves quickly to correct location using proper cover and concealment and correct movement techniques (bounding overwatch in this case)	Detection of this summary behavior occurs during detailed behaviors listed below.		PL could tell Squad Leader where the entry point is, or give the SL information that indicates a good entry point (*e.g.*, the south and west faces of the building are bad) allowing the coaches to see if the SL selects a good entry point
	SL reports to PL acknowledging the order to move	The SL reports promptly and with the correct information	1) Recognize that the report was sent		
			2) Recognize the content of the report	SL acknowledging PL's order	See notes above regarding detecting message content
			3) Recognize who the report was sent to	Recognize To: in message sent from SL	
			4) Recognize that	Period of	

Scenario Event	Detailed Expected Trainee Behaviors	Target Description	How Detected	Data or Information Required	Comments
			the report was sent within the acceptable period of performance	performance	
PL "Roger, out" This scripted action must be triggered by SL's response	SL orders Team A to move & Team B to cover	SL issues orders promptly once covering fire has been provided by other squads	1) Recognize that the order was sent	Message sent indication	Mistakes that could be coached include: 14. The order is late 15. The order could have a bad location 16. The order might not contain an order for Team B to cover
			2) Recognize the content of the order	Need to know: 17. Move destination 18. Which team is moving 19. Which team is covering	See notes above regarding detecting message content
			3) Recognize who the report was sent	Recognize To: in message sent from	

Scenario Event	Detailed Expected Trainee Behaviors	Target Description	How Detected	Data or Information Required	Comments
			to	SL	
			4) Recognize that the report was sent within the acceptable period of performance	Period of performance	
	Team A moves to entry point	Team A moves only after being given orders, using proper movement techniques and proper cover and concealment	1) Recognize that team received the order to move		
			2) Recognize movement was in 3-5 second sprints (assumes adequate cover)		
			3) Recognize team arrived at some location		
			4) Recognize location was desired location		
			5) Move started and finished with acceptable period of performance		
	Team A leader	Once all the	1) Knowledge that	20. Need to	Note that this

Scenario Event	Detailed Expected Trainee Behaviors	Target Description	How Detected	Data or Information Required	Comments
	reports to SL that they are in position	members of Team A are in the proper (stacked) position at the building entry point, the team leader provides a timely report to the SL	all team members are in position	know: 21. Correct location for each team member 22. Actual location of each team member	means we need to know the location of both the human team member's locations and any simulated members comprising the rest of the team (if they are not all human).
			2) Recognize that the report was sent	Message sent indication	
			3) Recognize the content of the report	Was the report In position or something else	
			4) Report issued within acceptable period of performance		
	While Team A Moves: Team B Covers	Team B provides the correct level of suppressive fires while Team A moves	1) Is the enemy engaging or not (determines if Team B should fire or not)	Enemy firing information: • Rate of fire • Direction of fire	
			2) Where Team B is located relative to the enemy.		
			3) Recognize if and how much	Team B firing information:	

Scenario Event	Detailed Expected Trainee Behaviors	Target Description	How Detected	Data or Information Required	Comments
			Team B is firing rate	• Rate of fire • Direction of fire	
			4) Recognize where Team B is looking (should be both towards enemy and towards Team A)		
	SL Reports to PL that Team A is in position	SL reports to PL, in a timely fashion and using correct communications techniques, that Team A is in position	1) Recognize that the report was sent	Message sent indication	
			2) Recognize the content of the report	Was the report In position or something else	
			3) Recognize who the report was sent to	Recognize To: in message sent from SL	
			4) Recognize that the report was sent within the acceptable period of performance		
	3rd SL moves with lead team for command and	SL follows Team A over to building entry point	1) Recognize movement of SL	SL movement onset and direction	This is a case where one human team member must

Scenario Event	Detailed Expected Trainee Behaviors	Target Description	How Detected	Data or Information Required	Comments
	control				follow another human team member in the simulated world.
			2) Recognize destination of movement	SL arrival	See earlier notes above
			3) Recognize that action was taken within the acceptable period of performance	Period of performance	
PL orders other squads to cover Team B's move to building entry point.	Team B moves to building entry location	This movement action should be identical to the Team A move so refer to that move for details			
Simulation must be able to trigger this action in response to SL reporting to PL.	Team B reports to SL that they are ready	Team leader reports to SL in a timely fashion, in the correct manner, when team is actually ready			
	3rd SL reports to PL when set at assault location	SL reports to PL with accurate information	1) Recognize that the report was sent	Message sent indication	
			2) Recognize the	Was the report In	

Scenario Event	Detailed Expected Trainee Behaviors	Target Description	How Detected	Data or Information Required	Comments
			content of the report	position or something else	
			3) Recognize who the report was sent to	Recognize To: in message sent from SL	
			4) Recognize that the report was sent within the acceptable period of performance	Period of performance	
PL acknowledges SL report and gives permission to proceed. This scripted action will need to be triggered by SL report.	SL orders assault team to enter the building	SL gives the order to the team leader in the proper way, after Team A signals it is ready	This message would be handled like all others, so the detection mechanism and data required entries will not be repeated here.		
	Assault team leader places charge at entry point of building and fires the charge				
Soldier tosses grenade into room and yells FRAG OUT!!					

Scenario Event	Detailed Expected Trainee Behaviors	Target Description	How Detected	Data or Information Required	Comments
This event must be triggered by a human trainee blowing a hole in the building's wall.					
Two Soldiers enter room correctly and the second one calls, "Next man in left/right." This must be triggered event based on how the entry point comes into existence	Assault team leader enters room and looks around, assesses the situation, fires if necessary	The team leader enters the room, yelling correct phrase, moves in the correct direction upon entering the room, gazes around the entire room and engages any enemy IAW ROE	1) Recognize team leader movement into room	Team leader now inside room indication	The simulation must provide a specific indication that an entity is inside a specified zone
			2) Recognize direction of movement once in room, relative to other team members in room	Path vector of movement or analysis of path to identify a right or left turn after entering room	
			3) Recognize phraseology yelled as room is entered	Handled the same as other spoken or issued human generated	

Scenario Event	Detailed Expected Trainee Behaviors	Target Description	How Detected	Data or Information Required	Comments
				communication	
			4) Team leader has not stopped in front of entrance to room	Detailed location data for team leader, once stationary	It is not always easy to decide that something is stationary. This depends on velocity vectors being close enough to zero for a long enough period of time to be considered stationary.
			5) Recognize that team leader movement is consistent with whatever he yelled		This comparison is done using data from the spoken message and the movement turn vector
			6) Knowledge of sweep of visual gaze about the room	• What angular range would cover the whole room • What angular range did the Team Leader sweep through	Direction of gaze information can be processed inside or outside the simulation, but how long the user spent doing the sweep can be problematic, especially if the

Scenario Event	Detailed Expected Trainee Behaviors	Target Description	How Detected	Data or Information Required	Comments
					rendering engine lags the physical head-turning by too far
			7) Knowledge of any visually obscured parts of the room that have not been visually inspected	Either a yes/no answer to this question from the simulation derived from all the visual sweeps of all entities in the room, or the raw visual sweep information to be processed outside the simulation	
			8) Knowledge of a legitimate target in view of team leader	"Hostile enemy combatant visible to team leader" indication (a yes/no)	Making a determination based on this kind of data is sensitive to how much of the enemy was visible in the scene rendered on the team leader's visual display and for how long
			9) Knowledge of team leaders' fires	• Rounds fired • Destination of	This will be used to determine if

Scenario Event	Detailed Expected Trainee Behaviors	Target Description	How Detected	Data or Information Required	Comments
				rounds	firing is a correct behavior
	Team leader gives order to remaining team member	Team leader correctly tells remaining team member what to do, using correct phraseology and in a timely fashion and consistent with tactical situation in room being cleared.	1) Order given 2) Order content 3) Period of performance Note: This order no different than others, except the "whom the order is to" will not be examined, since it is not ambiguous in real life.	See previous orders	
			1) Knowledge of intensity of engagement in the room being cleared	• Enemy firing data • Friendly WIA or KIA count • Friendly ammo situation	This information is used to determine whether last team member is needed in room.
Fourth team member responds "Standing Fast"					
	Team leader reports to SL status once inside	Team leader tells SL that room is clear or that	Report from team leader to SL		

Scenario Event	Detailed Expected Trainee Behaviors	Target Description	How Detected	Data or Information Required	Comments
	of the room	contact with enemy has been made.			
	SL enters room	SL enters room, after being told that the room is cleared, in a timely manner	1) Recognize that the SL is inside the room	Team Leader presence inside the room is indicated	The simulation must provide a specific indication that an entity is inside a specified "zone"
			2) Period of performance		
	SL reports to PL that room is cleared	SL correctly reports to the PL that the room is cleared, in timely manner			
PL responds, ordering other squads to move to support the trail fire team of the assaulting squad moving into the building					
	SL marks, or orders marked, the cleared room with a Wolf's tail.				
PL orders					

Scenario Event	Detailed Expected Trainee Behaviors	Target Description	How Detected	Data or Information Required	Comments
assaulting SL to continue clearing the building. This cannot occur until any other squad movements, have occurred, and they may be under the control of human trainees.					
	SL orders trail fire team into the building and to the entrance to the next room	SL orders the trail fire team into the building once the other squads are appropriately moved to insure ongoing security.	Handled like other move orders		
	Trail team clears rooms working with lead team to coordinate actions		Teams must coordinate actions to avoid fratricide	Team locations, Status reports	

APPENDIX E

KNOWLEDGE BASE OF INFORMATION AND RULES REQUIRED FOR VOC

This appendix presents the various types of information and rules needed by the Virtual O/C. They are grouped by type: 1) Behavior Description, 2) Action Execution and Detection, 3) Immediate Feedback samples.

Behavior Description

The following table presents annotations of the detailed trainee responses associated with the sample scenario. These annotations describe some of the correct (target) and incorrect (bug) trainee behaviors that the VOC will detect and critique. Note that this table is dealing only with individual trainee actions (*i.e.,* actions that the Individual Coach will monitor and evaluate), not collective team behaviors or longer-term issues such as the overall pace of movement through the major phases of the scenario.

Scenario Event	Detailed Expected Trainee Behaviors	Target and Bug Description
	Lead Squad (#1)	
Scripted action: 1st Squad takes fire from unknown location.	Takes Immediate cover	**Target**: Moves (and/or orders squad to move) to nearest suitable cover **Bugs:** Does not take cover Moves to covered location too far away
	Locates the Enemy	**Target**: Takes appropriate action to try and determine the location and strength of enemy unit initiating fire **Bugs:** Unable to determine enemy location Unable to determine enemy strength
	1st SL Reports to PL	**Target**: Sends report to PL with adequate and accurate information within the acceptable period of performance **Bugs**: Does not send report. Sends report late. Report is not accurate.

Scenario Event	Detailed Expected Trainee Behaviors	Target and Bug Description
Scripted Action: Enemy fires again after squad takes cover.	1st Squad Suppresses the Enemy	**Target**: Squad returns fire IAW with ROE, ammunition conservation considerations and in the direction of the enemy unit **Bugs:** Squad does not return fire Squad expends too much ammunition Squad returns fire on wrong location **Target**: If the enemy force is large, SL should move heavy weapons squad forward. Must request heavy weapons from PL. **Bugs:** SL does not request heavy weapons squad. SL requests heavy weapons squad too late.
1st squad establishes a base of fire allowing other squads to begin movement	SL identifies Base of Fire (BOF) location	**Target**: SL identifies a secure base of fire position that provides direct line of sight to enemy location and maximum perimeter coverage of building **Bug:** SL does not order a team to BOF position

Scenario Event	Detailed Expected Trainee Behaviors	Target and Bug Description
	SL orders a team to BOF	**Target**: SL orders the appropriate first team to move to the BOF IAW with TTP (*e.g.*, uses BOUT technique) and other team ordered to provide covering fires **Bug:** SL moves both teams at same time
	SL orders second team to BOF	
Scripted Action: PL orders next squad to move.		
	Squad #2 Actions	
Next Squad (2nd) begins movement for position to isolate building		
	Moves to covered and concealed location	**Target**: Moves quickly and to location within a 3-5 second movement (bound) **Bugs:** Squad moves too slowly (stays exposed too long). Squad moves to a position that provides poor cover or no cover.
	Uses smoke to conceal move	**Target**: Determines if use of smoke is feasible. **Bugs:** Smoke is available but not used. Smoke is used, but does not conceal movement.
	Location provides clear fields of fire to routes to building	
	2nd SL reports to PL when set	

Scenario Event	Detailed Expected Trainee Behaviors	Target and Bug Description
		Target: SL reports using voice, radio or hand & arm signals. **Bug:** SL uses voice when hand and arms signals would be appropriate
1^{st} and 2^{nd} squads provide suppressive fires as 3^{rd} squad moves to the assault location		
	1^{st} and 2^{nd} squad provide accurate fires during 3^{rd} squads movement	**Target**: Squads fire on building in accordance with the ROE **Bugs:** Squads do not fire on building. Squad has poorly placed fires with no effect on the enemy.
PL Orders 1^{st} and 2^{nd} Squad to lift and shift fires as 3^{rd} squad approaches assault position		
	Fires from 1^{st} and 2^{nd} squads are lifted prior to the arrival of 3^{rd} squad	
	Squad #3 Actions	
PL orders 3^{rd} squad to move to a designated entry location to prepare to assault the building	**Summary behavior**: 3^{rd} SL moves squad to assault position once covering fire is provided by 1^{st} and 2^{nd} squads	**Summary Target**: Squad moves quickly to correct location using proper cover and concealment and correct movement techniques (bounding overwatch in this case) **Bugs:** Squad moves too slowly (stays exposed too long). Squad moves to a position that provides poor cover or no cover.
	SL reports to PL acknowledging the order to move	**Target**: The SL reports promptly and with correct phraseology

Scenario Event	Detailed Expected Trainee Behaviors	Target and Bug Description
		Bugs: Slow response Incorrect phraseology
PL "Roger, out"	SL orders Team A to move and Team B to cover	**Target**: SL issues orders promptly once covering fire has been provided by other squads **Bugs**: Slow to order move Wrong destination in move order Does not order cover
	Team A Moves to entry point	**Target**: Team A moves only after being given orders, using proper movement techniques and proper cover and concealment **Bugs**: Slow to begin move Go to wrong location Moves without orders
	Team A leader reports to SL that they are in position	**Target**: Once all the members of Team A are in the proper (stacked) position at the building entry point, the Team Leader provides a timely report to the SL **Bugs**: Late report Reports when not in position Incorrect phraseology
	While Team A Moves: Team B Covers	**Target**: Team B provides the correct level of suppressive fires while Team A moves **Bugs**: Shoots when not needed

Scenario Event	Detailed Expected Trainee Behaviors	Target and Bug Description
		Doesn't shoot when needed Shoots when risk of fratricide is too high Doesn't look towards enemy location Doesn't look towards Team A
	SL Reports to PL that Team A is in position	**Target**: SL reports to PL, in a timely fashion and using correct communications techniques, that Team A is in position **Bugs**: Reports before hearing from Team A Slow to forward report to PL Incorrect phraseology
	3rd SL moves with lead team for C2	**Target**: SL follows Team A over to building entry point **Bugs**: Doesn't follow assault team Leads assault team Goes somewhere else
PL orders other squads to cover Team B's move to building entry point.	Team B moves to building entry location	**Target**: This movement action should be identical to the Team A move so refer to that move for details **Bugs:** Moves before other squads can cover Does not go to correct location
	Team B reports to SL that they are ready	**Target**: Team leader reports to SL in a timely fashion, in the correct manner, when team is actually ready **Bugs:** Slow to report Reports before they are in position

Scenario Event	Detailed Expected Trainee Behaviors	Target and Bug Description
	3rd SL reports to PL when set at assault location	**Target**: SL reports to PL with accurate information **Bugs:** Slow to report Reports before they are in position Incorrect phraseology
PL acknowledges SL report and gives permission to proceed.	SL orders assault team to enter the building	**Target**: SL gives the order to the Team leader in the proper way, after Team A signals it is ready **Bugs**: Orders assault before getting PL permission Slow to order assault
	Assault Team Leader places charge at entry point of building and fires the charge	
Two computer generated Soldiers enter room correctly and the second one calls, "Next man in left/right."	Assault Team Leader enters room and looks around, assess the situation, fires if necessary	**Target**: Team leader enters the room, yelling correct phrase, moves in the correct direction upon entering the room, gazes around the entire room and engages any enemy IAW ROE **Bugs**: Slow to enter Yells incorrect phrase Moves incorrectly Blocks entrance Passes window Shoots when unnecessary Does not shoot when necessary Does not visually sweep the room

Scenario Event	Detailed Expected Trainee Behaviors	Target and Bug Description
	Team leader gives order to remaining team member	**Target**: Team leader correctly tells remaining team member what to do, using correct phraseology and in a timely fashion and consistent with tactical situation in room being cleared. **Bugs**: Orders Stand Fast when he was really needed Orders him in when not needed Incorrect phraseology Slow to decide
Fourth team member responds, "Standing Fast"		
	Team leader reports to SL status once inside of the room	**Target**: Team leader tells SL that room is clear or that contact with enemy has been made. **Bugs:** To slow to report Reports wrong status Incorrect Phraseology
	SL enters room	**Target**: SL enters room, after being told that the room is cleared, in a timely manner **Bugs**: Too slow to enter Entered when obviously unsafe
	SL reports to PL that room is cleared	**Target**: SL correctly reports to the PL that the room is cleared, in timely manner **Bugs**: Slow to report Incorrect phraseology

Scenario Event	Detailed Expected Trainee Behaviors	Target and Bug Description
PL responds, ordering other squads to move to support the trail fire team of the assaulting squad moving into the building		
	SL marks, or orders marked, the cleared room with a Wolf's tail.	
PL orders assaulting SL to continue clearing the building.		
	SL orders trail fire team into the building and to the entrance to the next room	**Target**: SL orders the trail fire team into the building once the other squads are appropriately moved to insure ongoing security.
	Trail team clears rooms working with lead team to coordinate actions	

Action Execution Rules and Detection

The following table contains the rules governing the details of how each expected behavior is supposed to be executed. For each of the rules there is also presented the mechanism by which we will detect, in the SVS simulated environment, the fulfillment or violation of the rule. The second column therefore represents the information the simulation environment must provide in order for the Virtual O/C to evaluate the rule or criteria in the first column. This table is focused on what information the simulation must provide, not how it is going to extract and provide it, the "how" is presented in the Discussions section of this report.

Take Immediate Cover	
Rule	**Automated detection mechanism**
Begin moving within 3-5 seconds after receiving enemy fire	Knowledge of when the enemy began shooting at unit and when they began moving
Seeks first available cover	There may be more than one object in the environment that can provide cover and the Virtual O/C will be able to determine that the element under fire has moved to the closest one that will provide adequate cover.
Cover must provide adequate protection from small arms up to 12.7mm.	Knowledge of simulated objects available for cover, including the object's location and which side of it provides cover from the enemy.
Does not expose any portion of body to direct fire.	Friendly unit does not move from behind cover until safe to do so.
Determines Enemy Location	
Rule	**Automated detection mechanism**
Uses visual cues, i.e., smoke, movement to determine enemy location	Knowledge of enemy location, and whether or not the visible indications of the incoming fires were rendered in the display being viewed by the Soldier.
Uses audio cues, i.e. gunfire, personnel or vehicular movement to determine enemy location.	Sound cue location and direction information.
Reporting Enemy Location	
Rule	**Automated detection mechanism**
Reports enemy location within 30 seconds of contact	Time of contact with enemy and time of message sent to higher, if any
Enemy location is accurate within 100 meters (6-digit grid coordinate).	Known enemy location, location content of the report
Reports to appropriate leader (SL or PL).	Message sent indication
Provides Suppressive Fires	
Rule	**Automated detection mechanism**

Provides accurate fires on enemy.	Vector details from squad to enemy and firing vectors and round destinations of friendly unit.
Provides volume of fire to force enemy to cease or significantly reduce fire.	Enemy firing information
Does not expend ammunition needlessly (ammo conservation).	Ammunition remaining, firing rates, firing direction, rates of fire
Firing in Self-Defense	
Rule	**Automated detection mechanism**
Does not fire unless there is an imminent threat or has been fired upon.	Enemy location, and recent enemy behaviors.
Responds with the appropriate level of fire.	Firing rate, direction of fire, impact point of rounds, weapon being used.
May require use of non-lethal ammunition.	Type of ammunition selected.
Establishing a Base of Fire	
Rule	**Automated detection mechanism**
Able to direct accurate fires at specific enemy known or suspected position.	Enemy location, and base of fire location
Within effective range of all assigned weapons.	Friendly location, enemy location, range of weapon systems available
Selects a location that does not limit communication with higher.	Location of base of fire, and line of sight obstructions
Does not expend ammunition needlessly (ammo conservation).	Rate of fire, ammunition remaining, enemy behavior and status
Use of Smoke	
Rule	**Automated detection mechanism**
Uses smoke only when tactically appropriate, i.e., blind enemy observers, defeat trackers, screen an assault, create a deception, conceal movement, or obscure enemy observation posts.	Employment of smoke by Soldier. Location of enemy, enemy action. Tactical situation related to use of obscurants
Uses appropriate color smoke for situation. (White for screening, red for emergency, etc).	Type of smoke selected, tactical situation related to use of obscurants
Uses amount of smoke consistent with the situation. Does not use a smoke grenade when a smoke pot is required or vice versa.	Type of smoke selected tactical situation related to use of obscurants
Reporting to Platoon Leader	
Rule	**Automated detection mechanism**

Reports to PL in a timely manner.	Message sent indication, recognize who the report was sent to, when the message was sent and when the message was required
Uses report format consistent with the situation.	Content and form of the report
All reports are consistent with unit SOP.	Content and form of the report
Reports are required usually when one of these actions occurs: Change to friendly status (WIA, KIA). Change in friendly location. Contact with enemy forces. Call for artillery, mortars or heavy weapons. Logistics reports. The most common reports are: ACE Report (After Contact, Ammunition, Casualties, Equipment) SALUTE Report (Enemy Contact) SITREP NBC Reports	Incident type information and type of report sent. When unit has WIA/KIA expectation would be for WIA/KIA report.
Reporting to SL	
Rule	**Automated detection mechanism**
Reports to SL in a timely manner.	Message sent indication, recognize who the report was sent to, when the message was sent
Uses report format consistent with the situation.	Recognize content and form of the report
All reports are consistent with unit SOP.	Recognize content and form of the report
All reports are accurate and sent to the correct recipient.	Recognize who the report was sent to and its content and form
Movement Techniques	
Rule	**Automated detection mechanism**
Uses appropriate movement formation and technique.	Enemy situation, current location, movement formation and technique
Changes formation and technique as required.	Enemy situation, current location, move order, destination, movement formation and technique
When using bounding overwatch does not stay exposed for more than 3-5 seconds.	Time spent moving, whether or not unit was behind cover at start and end of moves

Signals action prior to movement when bounding moves from one covered position to another covered position.	Signal indication, start of move indication
Reports when "Moving".	Message sent indication, including "from" and "to" and movement indications
Reports when "Set".	Message sent indication, including "from" and "to" and indications of not moving
Correct Orders to Subordinates	
Rule	**Automated detection mechanism**
Uses order appropriate with the situation.	Recognize content of message sent
Uses most effective method of communicating order.	Recognize how order was transmitted (radio, voice, hand signal), recognize "to" and "from" for order
Does not use voice or radio when hand and arm signal is required.	Indication that stealth is required in situation, method of communicating used
SL Moves Teams to Establish Base-of-Fire Position	
Rule	**Automated detection mechanism**
Uses team with best firing position to cover other teams movement.	Team location, team field of view, team weapons fan
Moves team with poor position to better BOF position.	Current location, destination, BOF location information
Provides Cover to Other Elements	
Rule	**Automated detection mechanism**
Provides covering fire when required or requested.	Enemy situation, request from friendly unit.
Provides accurate and timely fires.	Firing rates, firing direction, impact point of rounds.
Uses weapons/ammunition consistent with tactical situation.	Weapon selected, target engaged.
Does not expend ammunition needlessly (ammo conservation).	Ammunition remaining firing rates.
Breaching Operations	
Rule	**Automated detection mechanism**
Moves tactically to the breach point.	Current location, destination, formation, movement technique.
Reports when set at the breach point.	Message sent indication, report contents.
Has breach kit on hand and complete.	Equipment on hand
Prepares breaching charge properly.	Breach order to CGF or Soldier
Uses correct amount of explosive for desired effect.	Breach order to CGF or Soldier
Allows adequate time for exposed personnel to take cover.	Alert message sent to squad, when charge is set off

Takes cover.	Current location, destination.
Executes breach on order.	Breaching event indication, order sent indication, message acknowledged.
Reports whether breach was successful or not to higher.	Breaching status and time, Message sent indication, contents of message.
Building Entry	
Rule	**Automated detection mechanism**
Moves on order to the entry point.	Time of order, Unit location, movement start time and destination.
Moves tactically to entry point.	Unit formation, movement technique.
Reports when set at entry point.	Time of reaching destination, message sent indication, contents of message.
First man tosses concussion or fragmentation grenade if required.	Time of order to entity tossing grenade (human or CGF)
First man moves into room moves right or left.	Soldier (human or CGF) location, direction of movement.
First man tells second man to move into room right or left.	Message sent indication, contents of message.
Second man moves into room moves right or left.	Soldier (human or CGF) location, direction of movement.
TL enters room (if required)	TL location, direction of movement, enemy actions in room, when TL entered.
TL moves right or left.	TL location, direction of movement.
TL sweeps room visually.	TL location, TL direction of gaze information
TL acquires and engages enemy if encountered.	Enemy actions, TL action on contact.
TL orders last man in room, or tells last man to stand fast.	Message sent indication, recipient, message contents.
TL reports room cleared to SL.	Message sent indication, contents of message, when message sent, status of room being cleared.
SL reports room cleared to PL.	Message sent indication, contents of message, when message sent, status of room being cleared.
Marking Cleared Rooms	
Rule	**Automated detection mechanism**
Room is marked immediately after clearance.	TL or SL marking action indication
Marking is done IAW unit SOP.	Marking procedural details
Marker is clearly visible in both day and night conditions.	Location of marker information
Marker is not removed without permission.	Marker removal indication
Requesting Support from Higher	

Rule	Automated detection mechanism
Request for support must be submitted in a timely manner.	Tactical information requiring assistance, Message sent indication, contents of message, when message was sent.
Request for support must be IAW unit SOP.	Contents and form of message.
Request for support must be tactically sound (e.g., requesting heavy weapons support to engage enemy squad).	Message contents, enemy situation, friendly action
Rotating Fire Teams	
Rule	**Automated detection mechanism**
Lead Fire Teams are rotated whenever tactically possible.	Tasking of team over time
Teams are rotated before teams are exhausted.	Team effectiveness, duration as lead fire team
SL rotates teams before TL requests to be rotated.	SL Orders follow on team to take the lead. Message content.

Feedback Samples

The following table presents some samples of the immediate feedback that can be provided to an individual Soldier's incorrect behaviors.

Take Immediate Cover	
Behavior	Feedback
Target: Moves or orders squad to nearest suitable cover	
Bug: Does not take cover	You should seek a position that provides good cover and concealment. Take cover now.
Bug: Moves to covered location too far away	You should have selected a position that was not so far away. You exposed yourself too long.
Locates the Enemy	
Target: Takes appropriate action to try and determine the location and strength of enemy unit initiating fire	
Bug: Unable to determine enemy location	H- You need to be able to identify enemy positions quickly. L – Do you see the enemy yet?
Bug: Unable to determine enemy strength	H- Have you determined the strength of the enemy unit yet? L – What size element is opposing you?

1st Squad Suppresses the Enemy	
Target: Squad returns fire IAW with ROE, ammunition conservation considerations and in the direction of the enemy unit.	
Bug: Squad does not return fire	H – You need to return fire and suppress the enemy unit L- Return fire now!
Bug: Squad expends too much ammunition	H- Your ammunition expenditure is way too high for the current situation L- You're firing too much ammo
Bug: Squad returns fire on wrong location	H- You need to acquire the correct target before engage them L – What are you shooting at?
SL Orders a Team to Establish a Base of Fire (BOF) Position	
Target: SL orders the appropriate first team to move to the BOF IAW with TTP (*e.g.*, uses BOUT technique) and other team ordered to provide covering fires	
Bug: SL does not order a team to BOF position	H- You need to move a team up to set up a BOF position L – Get that BOF position set up now!
Bug: SL moves both teams at same time	H- You need to have one team cover while the other team moves L- You shouldn't move both teams at once.
Uses Smoke to Conceal Move	
Target: Determines if use of smoke is feasible, and uses smoke to conceal movement of teams.	
Bug: Smoke is available but not used.	H- You should use smoke to cover your move. L – You have smoke, use it!
Bug: Smoke is used, but does not conceal movement.	H – The smoke was poorly placed and did not have the desired effect. L- The wind blew the smoke the wrong way.
Moves to Covered and Concealed Location	
Target: Moves quickly and to location within a 3-5 second movement (bound)	
Bug: Squad moves too slowly (stays exposed too long).	H – You need to move and get to your next position within 3-5 seconds. L- You moved too slow
Bug: Squad moves to a position that	H – The position you selected provides

provides poor cover or no cover.	poor cover and compromises your unit. L- This position has no cover.
1st and 2nd Squad Provide Accurate Fires During 3rd Squads Movement	
Target: Squads fire on building in accordance with the ROE	
Bug: Squads do not fire on building.	H- You need to provide accurate fires to cover the other squad's movement. L – Fire on the building, what are you waiting for.
Bug: Squad has poorly placed fires with no effect on the enemy.	H- Your fire has no effect on the enemy position in the building. L- What are you firing at?
1st SL Reports to PL	
Target: Sends report to PL with adequate and accurate information within the acceptable period of performance	
Bug: Does not send report.	H- You need to report all information to higher. L- Send that report to the PL now!
Bug: Sends report late.	H- All reports is sent as soon as possible. L – Your report is late!
Bug: Report is not accurate.	H- Check your reports for accuracy before you send them. L- Check your report, it doesn't look right.
Bug: Report is sent to wrong person.	H- Verify the recipient of the report before you send it. L – Whom did you send that to?