ASSESSING THE BENEFITS OF IMPLEMENTING TACTICAL ENGAGEMENT SIMULATION CONCEPTS

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Abstract

The workload of trainers for Army live force-on-force exercises is substantial due to the need to support the simulation of tactical systems and collect information on system employment. These activities pull trainers away from the important functions of coaching, mentoring, and presenting formal feedback. The fielding of new weapon and reconnaissance, surveillance, and target acquisition (RSTA) systems under force modernization will increase trainer exercise control and feedback (CAF) functions to a point that cannot be supported without interventions. Further, force modernization adds substantially to existing deficiencies in the intrinsic feedback needed to cue and guide performance during exercises and the extrinsic feedback needed to identify corrective actions for future exercises. Advances in tactical engagement simulation (TES) and instrumentation are the primary tools for reducing trainer workloads and addressing gaps in feedback, and the Army needs to know which concepts for new TES and instrumentation systems offer the greatest benefits. The goal of this project was to develop and apply an online database for assessing benefits of new TES and instrumentation concepts. This goal was addressed in three phases. First, we defined the set of trainer CAF functions and feedback gaps by examining 155 new and emerging weapon and RSTA systems. We identified 228 trainer CAF functions and 96 feedback deficiencies, with many of the functions and deficiencies applying to multiple tactical systems. Second, we developed information that could be used to weigh the value of addressing a specific CAF function or deficiency. We weighted CAF functions according to their tendency to distract trainers from coaching and mentoring responsibilities. We weighted trainer CAF functions and gaps in feedback according to the number of tactical systems to which the function or deficiency applied and the nearness of the tactical systems to their fielding dates. Third, we tried out the database by defining and assessing the value of 15 high level TES/instrumentation concepts. Collectively, the top five concepts eliminate 59 percent of the CAF functions and 75 percent of the feedback deficiencies.

About the Authors

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USE OF TACTICAL ENGAGEMENT SIMULATION AND INSTRUMENTATION SYSTEMS TO SUPPORT LIVE TRAINERS

The workload of trainers for Army live force-on-force exercises is substantial due to the need to support the simulation of tactical systems and collect information on system employment. These activities pull trainers away from coaching and mentoring units and delivering feedback.

The major automated tools available to help trainers perform exercise control and feedback (CAF) functions are tactical engagement simulation (TES) and instrumentation systems (IS). A TES system simulates the employment of a weapon system during force-on-force training between the unit being trained and a live opposing force. For example, to simulate direct-fire engagements, weapons are equipped with a TES system called the Multiple Integrated Laser Engagement System (MILES). MILES emits an eye-safe laser when the soldier fires the weapon. MILES sensors on soldiers and equipment detect engagement by the laser and produce an audio and/or visual cue for a kill, hit or near miss. For indirect-fire and area weapons, the Simulated Area Weapons Effects (SAWE) system simulates artillery, mortars, chemical attacks and minefields. SAWE compares the location of exercise players with the area affected by the ordnance and assesses casualties and battle damage electronically.

The IS is an electronic data collector that monitors position location and the TES devices on soldiers and vehicles and captures exercise player activity. The IS feeds training analysis facility (TAF) workstations with data. The workstations convert the data into computer-generated graphics that provide a top-down view of player location, status (alive or dead), movement, firing activity, etc. The IS also records voice communications, supports exercise control communications, and displays exercise videos prepared by mobile crews.

TES and IS work together to support exercise CAF functions, and functions can be moved back and forth between the TES and IS systems. For example, the processing accomplished to assess casualties may be conducted within a TES system or it may be accomplished within an IS. When we use the term TES throughout the remainder of this paper we are referring to the combined activities of TES and IS.

The Army is at a crucial point in the evolution of TES. The Army is defining the TES that will be used at maneuver combat training centers (CTCs) and at home stations to support force-on-force live training in the early part of the next century. In addition, as part of the Force XXI initiative, the Army is fielding a large number of new tactical systems over the next ten years. This paper describes an approach taken to assess the value of implementing new TES concepts in terms of their ability to automate trainer CAF functions and address gaps in training feedback.

BACKGROUND

Report on Live Domain Research Requirements

The Army Training Modernization Directorate (ATMD) Report on Live Domain Research Requirements states that force modernization initiatives “will make current training support systems obsolete” and predicts a spiraling workload for trainers and degradation in combat readiness if action is not taken to upgrade support for live training (Faber, 1996). The ATMD identified the need for a series of studies to help define requirements for supporting future live training, emphasizing automated tools to reduce trainer workloads.

Training Analysis and Feedback Aids (TAAF Aids) Study

At the request of ATMD, the Army Research Institute (ARI) examined over 140 new and emerging tactical systems to identify their impact on trainers for live force-on-force exercises (Brown, Nordyke, Gerlock, Begley II, & Meliza, 1998). In addition to weapon and digital communications systems, we examined reconnaissance, surveillance, and target acquisition (RSTA) systems such as unmanned aerial vehicles. Our goal was to decide how units would be provided with the intrinsic feedback they needed during exercises to cue and guide performance and the extrinsic feedback they needed to assess their strengths and weaknesses. That is, would the intrinsic and extrinsic feedback be provided by interaction with actual equipment, by TES, or by trainers. We also identified cases where there were likely to be gaps in feedback. In performing this work, we assumed that future TES systems would have the same capabilities as current systems. We relied heavily on information that the Army's maneuver CTC observer/controllers (OCs) and TAF analysts provided to us concerning the CAF functions that they perform relative to existing tactical systems.

We concluded that trainer CAF functions and gaps in the feedback given to units will increase greatly with force modernization. Proliferation of non-line-of-sight (NLOS) engagement capabilities, smart weapons, and non-lethal weapons add substantially to the exercise control functions of trainers. A greater variety of weapon systems will be capable of NLOS engagements, and current methods for simulating these engagements are personnel intensive. In addition, smart weapon systems often make the simulated engagements more complex, such as when a laser designator is involved in deciding the outcome of an engagement. RSTA systems require little additional work to support their simulation, but they add substantially to the work involved in collecting data for feedback sessions.

Need for the Advanced Tactical Engagement Simulation Concepts (ATESC) Study

ATMD identified the need for additional information that could be used to assess the benefits of implementing new TES concepts so that priorities could be established. An important goal of this proposed study was to identify CAF functions and gaps in feedback offering high priority targets for automation. For example, in our interviews with trainers at the CTCs, we found that certain CAF functions were considered to be very disruptive while others were viewed as being directly supportive of coaching and mentoring activities.

APPROACH

The ATESC Study was conducted in three phases. The purpose of the first phase was to make sure we had a thorough and accurate description of the trainer CAF functions required to support force-on-force exercises involving new and emerging weapon and RSTA systems.

The purpose of the second phase was to develop information that could be used to identify CAF function and feedback gaps for which automation was likely to provide the greatest payoffs. The information we developed was placed in an online database to support comparisons of the benefits offered by new TES concepts or combinations of concepts. The third phase involved applying the database in examining 14 TES concepts.

Phase I: Defining a List of Trainer CAF Functions and Feedback Deficiencies

We interviewed approximately seventy OCs and analysts that had participated in the Force XXI Advanced Warfighting Experiment during which many of the new weapon and RSTA systems were employed at the National Training Center (NTC). This provided us with more accurate descriptions of what trainers need to do to provide feedback to units. We also reviewed the 1997 and 1998 versions of the Army's Science and Technology Master Plan (Department of the Army, 1997,1998a) to make sure we were current with respect to the planned capabilities for tactical systems. At the conclusion of this phase, we had examined 155 tactical systems and identified 228 trainer CAF functions and 96 gaps in feedback. Most of the CAF functions or feedback gaps applied to multiple systems.

Figure 1 shows how we described the expected sources of intrinsic and extrinsic feedback for tactical systems. In cases where an OC or analyst was identified as the feedback source, we described the CAF function(s) that trainers would have to perform to provide the feedback. Figure 2 shows how we described CAF functions. As we analyzed the intrinsic and extrinsic feedback requirements associated with the 155 tactical systems we found that the analysis of certain systems were applicable to other systems. For those systems where our analyses were appropriate to other systems, we designated the analyzed system as a "representative system." There were 27 representative systems, 112 systems supported by our analysis of the representative systems, and 16 special cases with unique requirements.

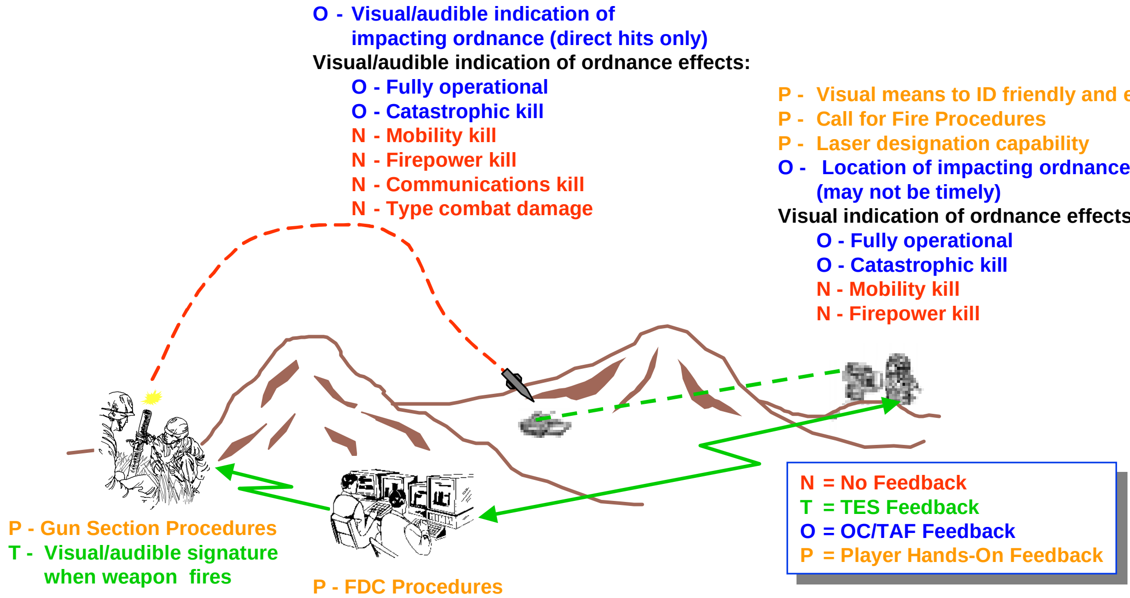

Figure 1. Sources of intrinsic feedback needed by the gun crew, fire direction center, laser designator operator and target vehicle crew relative to employment of a 120 MM precision guided mortar munition .

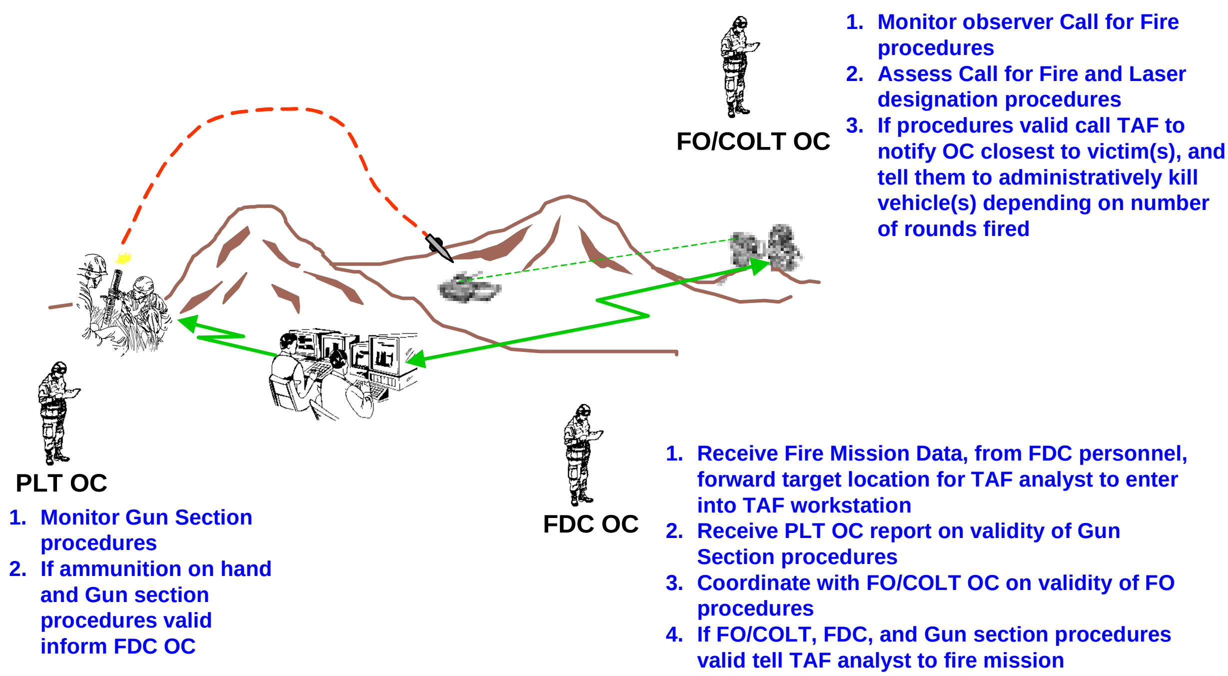

Figure 2. Trainer control and feedback (CAF) functions involved in providing intrinsic feedback relative to employment of the 120 MM precision guided mortar munition

When presenting preliminary findings, we were frequently asked how the data looked when we examined the battlefield operating systems (BOS) combat service support (CSS), and command and control (C2). The ATESC study encompassed the AD, FS, INT, MS and MVR BOSs. Figure 3 shows a distribution of CAF functions by BOS. This chart is used to determine which BOS had the highest number of functions, but and also shows the BOS that needs the most help first.

The mobility/survivability BOS is the source of the largest number of trainer CAF functions due, in part, to the effort required to support the simulation of minefields and other area weapons. Fire support and maneuver also account for a high percentage of trainer CAF functions. Much of this work concerns supporting the simulation of NLOS engagements for both BOSs (e.g. many direct fire weapons gain the ability to engage in an NLOS fashion) and helping to simulate engagements involving dismounted infantry.

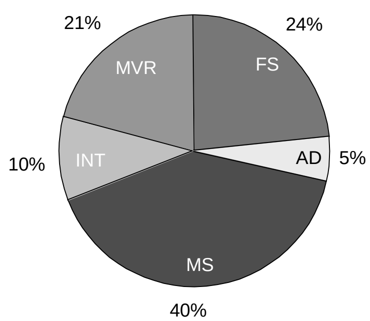

Figure 3. Percentage of trainer CAF functions applying to the air defense (AD), fire support (FS), intelligence (INT), mobility/survivability (MS), and maneuver (MVR) battlefield operating systems.

Phase II. Identifying High Priority Trainer CAF Functions and Feedback Deficiencies to be Addressed by Automation

Table 1 shows the variables considered when assessing the impact of each trainer CAF function on a trainer's freedom to coach and mentor units. This table also shows the weighting factors employed. The weighting factors we used came from OC and TAF analyst input during CTC visits. Using the scoring methodology in Table 1, we scored each of the 228 CAF functions for impact on trainer workloads. High scores indicate there is a major impact on trainer workload and on the ability of the trainer to observe, mentor or perform training analysis. CAF functions with high scores separately. These BOS are air defense (AD), fire support (FS), intelligence (INT), mobility / survivability (MS), maneuver (MVR), are priority candidates for automation under advanced TES concepts.

Two other variables influence the value of automating a CAF function;

- The number of tactical systems supported by the CAF function.
- The amount of time available to prepare for fielding of the tactical system.

CAF functions were weighted in terms of the number of tactical systems supported. Systems fielded in the near term (from present through FY01) were weighted by a factor of three, systems fielded in the mid term (FY02-07) were weighted by a factor of two, and systems to be fielded in the long term (FY08-13) were weighted by a factor of one.

Finally, we re-examined the feedback gaps that had been identified in order to identify cases where either the feedback was essential to the effective simulation of the tactical systems or the feedback was essential for the trainer's assessment of a unit's employment of a tactical system. An example of an essential intrinsic feedback deficiency during live force-on-force operations is when a Firefinder radar cannot provide counterfire targeting information on the point of origin of incoming artillery unless the radar receives artificial stimulation to simulate projectile trajectories. An example of an essential extrinsic feedback deficiency is when the trainer lacks access to information about where rounds "impact" when they do not hit a target, making it difficult for the trainer to assess fire control, fire distribution, and massing of fires.

We used Microsoft Access 97® to design an ATESC database to facilitate our analysis of the adverse impact of CAF functions on trainers, identify unattainable feedback, and quantify the value of ATESC concepts developed during the third phase of this study. The database provided us the flexibility to experiment with variables and to alter the scoring and weighting methodology. The online database is available to support additional analyses by the Army or by TES developers. For example TES concepts yet to be developed may be examined using the database.

No.	Variable	Scoring Criteria	Weighting
1	**CAF Function Characteristics**		X1
	1a. Function completion time	Less than 1 minute = 1 2 - 5 minutes = 2 6 - 10 minutes = 3 11 - 20 minutes = 4 21 - 30 minutes = 5 31 - 60 minutes = 6	
	1b. Number of times function performed by one person during an exercise	1 time = 1 2 - 5 times = 2 6 –10 times = 3 More than 10 times = 4	
	1c. Function complexity	Cognitive = 5 Human computer interface = 4 Human coordination = 3 Navigation = 2 Physical action = l	
	1d. No. of personnel who perform the function (The CAF functions under analysis are individual functions vice collective functions. This variable addresses the average no. of trainers who perform the function during an exercise. For example: Firemarkers mark the location of impacting ordnance, but there may be 18 firemarkers who perform this function during an exercise.)	1 - 2 persons = 1 3 - 5 persons = 2 6 - 10 persons = 3 More than 10 persons = 4	
	1e. Function training requirement	Has required skills = 0 Less than 1 hour = 1 2 - 4 hours = 2 5 - 8 hours = 3 9 - 40 hours = 5 41 - 80 hours = 10 Function Characteristics Total	
2	**Function's potential to distract trainer from observation or analysis duties**	No distraction = 0 Distracted less than 1 minute = 1 Distracted 2 - 5 minutes = 3 Distracted 6 - 10 minutes = 5 Distracted more than 10 minutes = 7	X5
3	**Function's potential to overwhelm trainer**	None = 0 Little = 2 Moderate = 5 High = 10	X5

Table 1. Variables Used in Assessing Adverse Impacts of Control and Feedback Functions (CAF) on OC and TAF Trainers.

Phase III. Assessing the Benefits of Implementing TES/IS Concepts

Scoring Method

Beginning with TES concepts developed during the TAAF Aids Study we described 14 high level TES concepts. To determine the contribution each concept made in reducing the burden on the trainer and data deficiencies we used the following methodology. First, we identified elements of trainer provided-feedback that the concept would automate, and then identified the CAF functions that produced the feedback. For example, to provide a visual/audible indication of impacting artillery to the fire support observer and targeted victims (intrinsic feedback), trainers must execute 15 CAF functions (i.e., receive fire mission data from OC and enter into TAF workstation). Second, we identified data deficiencies eliminated by the concept, i.e., shooter-to-victim pairings for direct fire engagements (extrinsic feedback). Third, we identified the tactical systems and BOSs affected by the concept. To quantify the benefits of each high-level TES concept, we summed the scores of all CAF functions automated by the concept, data deficiencies eliminated by the concept and systems supported by the concept.

Sample TES Concept

The 14 high level TES concepts are described in Brown et al. (in preparation). One of the TES concepts addressed is that of fielding a light weight (LW) Player Detection Device (PDD). The PDD is an instrumentation device worn by soldiers in tactical engagement simulation training exercises. Because of the current PDD's excessive weight (16 pounds) and bulk, some CTCs do not require all soldiers to wear the assembly. Consequently, almost all dismounted operations are uninstrumented. Soldiers may kill and be killed through the MILES TES without the PDD, but no engagement data is transmitted to the IS. For area effects weapons such as artillery, mortars, mines and chemical attacks, OCs must manually assess dismounted casualties using laser control pistols. Since there is no transmission of the soldier's location to the IS without the PDD, OCs observe and report information on dismounted activities to the TAF using radio control nets. The TAF records the information for use in AARs. A LW PDD will provide a practical assembly to instrument dismounted operations.

The purpose of the PDD is to simulate the effects of direct and indirect fire by receiving coded laser beams and radio signals from opposing weapons. The SAWE MILES II PDD is two systems in one. The MILES II technology is an improved MILES system that reacts to direct fire only. The SAWE system assesses the wearer of the PDD for indirect fire and area weapon effects. This concept proposes that the LW PDD be upgraded in two ways. First, upgrade the LW PDD to provide extrinsic feedback on shooter to victim pairings. Second, upgrade the PDD to provide extrinsic feedback on the type weapon fired (NOTE: The Objective Individual Combat Weapon will permit the individual soldier to engage point targets with 5.56-mm ammunition and area targets with air-bursting 20-mm ammunition). The fielding of the LW PDD will dramatically reduce OC workload in assessing indirect fire and chemical casualties. The proposed upgrades will also reduce OC data collection requirements for shooter to victim pairings and will support simulation of 20-mm area fire engagements.

The LW PDD concept automates 18 of 228 CAF functions. Three of the CAF functions are in the high distraction range, thirteen are in the medium distraction range, and two are in the low distraction range. The concept also addresses 17 of the 96 gaps in feedback. The concept affects 31 of the 155 tactical systems analyzed, and 23 of these will be fielded by FY01. The light weight PDD concept falls roughly in the middle of the priorities within each of four prioritization schemes employed.

PRIORITIZATION SCHEMES

To quantify the benefits of each high-level TES concept, we summed the scores of all CAF functions automated by the concept, data gaps eliminated by the concept and systems supported by the concept. The scores for each of the 14 concepts were displayed using bar charts with proposed TES concepts along the X axis and the total CAF function and unattainable feedback scores for each concept along the Y axis. The bar charts rank ordered the concepts from left to right in descending order based on data priority displayed. The table above the bar chart depicts the number of tactical systems by BOS supported by each concept. Figure 4 shows the 14 concepts rank ordered by the number of OC, TAF Analyst, and Firemarker functions eliminated. Implementation of the first three concepts in Figure 4 automates 62 percent of the OC, TAF analyst, and Firemarker functions performed, and eliminates 58 percent of the feedback gaps. Figure 5 shows the 14 concepts rank ordered by the number of feedback gaps that are eliminated by each concept. Implementation of the first three concepts in Figure 5 eliminates 82 percent of the data deficiencies identified during the study. These charts addressed concept priorities using the function score, and feedback gap scores but did not include scores for systems fielded.

Next, we evaluated each concept for its total impact by considering CAF functions, feedback gaps and fielded systems simultaneously. We used a method called the Hierarchical Additive Weighting Method (HAWM). The HAWM process provides a mathematical analysis to objectively quantify the three combined concept scores. Figure 6 shows the 14 concepts rank ordered based on considering OC, TAF Analyst, and Firemarker functions, feedback gaps, and systems fielding.

The bar chart in Figure 6 does not consider the technical feasibility or the cost of implementing each concept. However, we discovered safety, technical and cost issues during our research that impact on priorities for concept implementation. The concept "*Virtual artillery and mortar effects*" is technically feasible but expensive. This strategy integrates a heads-up virtual monocle into the combat vehicle crew (CVC) helmet, dismounted soldier's helmet and vehicle gunnery sights to produce 3D visual effects. This concept requires extensive research and testing from a safety aspect, on the effects of using the heads-up monocle on the individual soldier and crewmember helmets that allow players to view virtual battlefield effects, i.e. impacting artillery and mortar rounds. This concept is obviously not a candidate for implementation in the near future.

SYSTEMS BY BOS

AD	0	0	0	8	0	7	0	0	0	0	0	0	0	0
FS	0	20	22	0	0	0	0	0	0	0	0	2	0	0
INT	0	0	0	0	0	0	0	0	0	9	0	0	15	3
MS	19	0	0	1	13	1	0	9	0	0	1	0	0	0
MVR	0	11	0	57	0	31	13	22	35	0	1	0	0	0
TOTAL	19	31	22	66	13	39	13	31	35	9	2	2	15	3

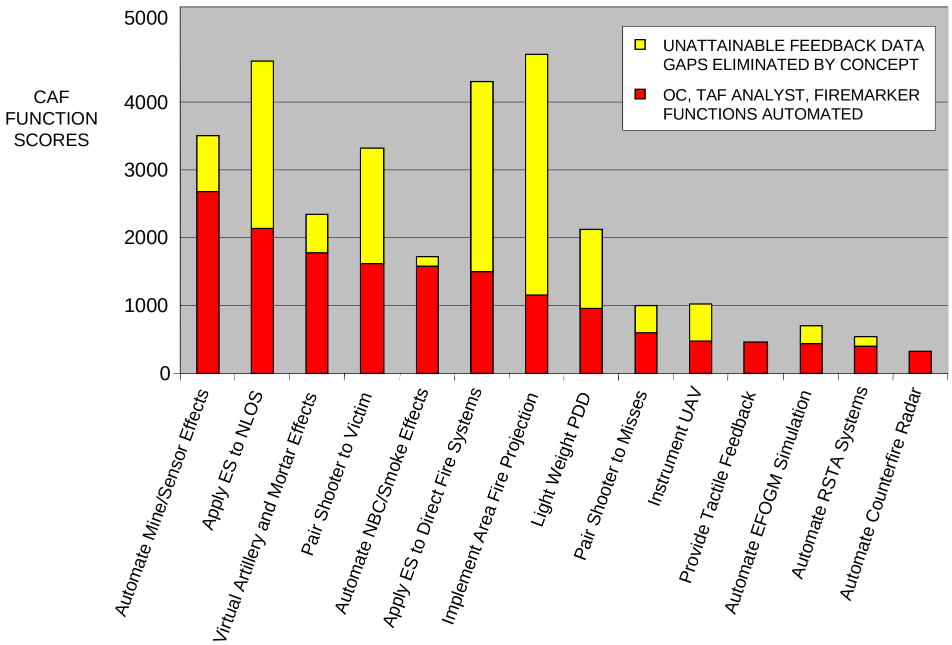

Figure 4. Prioritization of TES concepts based on OC, TAF Analyst, and Firemarker workload reduction.

SYSTEMS BY BOS

AD	0	7	0	8	0	0	0	0	0	0	0	0	0	0
FS	0	0	20	0	0	0	22	0	0	2	0	0	0	0
INT	0	0	0	0	0	0	0	9	0	0	15	0	0	3
MS	0	1	0	1	9	19	0	0	0	0	0	13	1	0
MVR	13	31	11	57	22	0	0	0	35	0	0	0	1	0
TOTAL	13	39	31	66	31	19	22	9	35	2	15	13	2	3

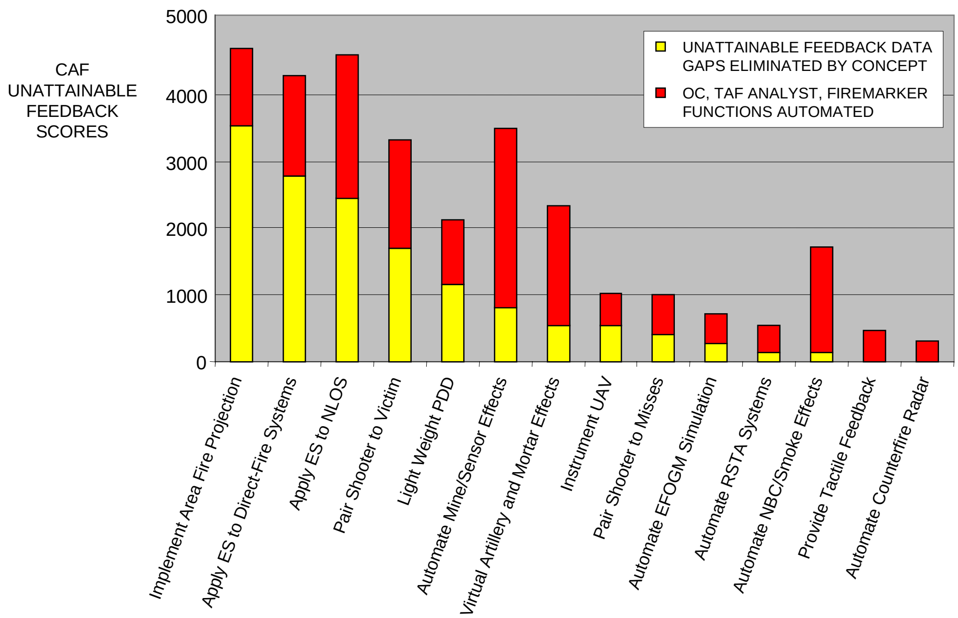

Figure 5. Prioritization of TES concepts based on the amount of feedback gaps eliminated (feedback gaps in the simulation of systems that will become available by adoption of the concept).

SYSTEMS BY BOS

AD	0	0	7	8	0	0	0	0	0	0	0	0	0	0
FS	0	20	0	0	0	22	0	0	0	0	2	0	0	0
INT	0	0	0	0	0	0	0	0	9	0	0	15	0	3
MS	0	0	1	1	19	0	9	13	0	0	0	0	1	0
MVR	13	11	31	57	0	0	22	0	0	35	0	0	1	0
TOTAL	13	31	39	66	19	22	31	13	9	35	2	15	2	3

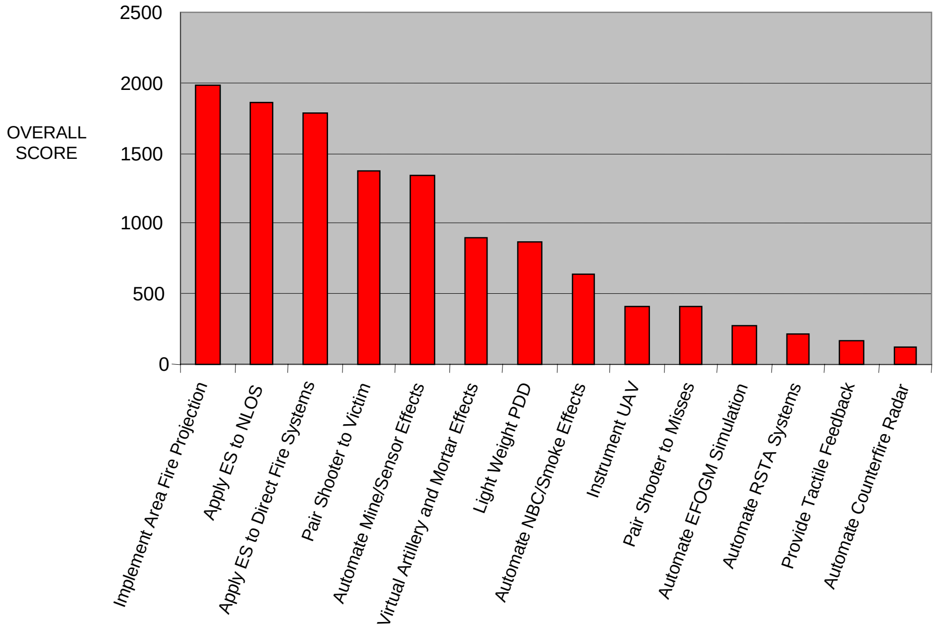

Figure 6. Prioritization of TES concepts based upon workload reduction, feedback gaps eliminated, and systems fielding scores.

The concept "*Apply Embedded Simulation (ES) to direct fire systems,*" proposes sensors on the vehicle provide information on the gunnery solution to a virtual simulation model that determines hits and misses. We discovered however that there are position location registration issues that preclude implementation of this concept in the near term.

An example of the problem is shown in Figure 7. In this example, the BLUFOR player is actually located along the southwestern ridge of a hill mass. However, the instrumentation system reports the player's location 10 meters north of his actual position causing the virtual simulation model to position the BLUFOR player on the opposite side of the hill. If an entity's instrumented location has a minor error, the virtual simulation model will contain the same error and promulgate the error during firing events by that entity. In Figure 7, the BLUFOR entity actually hit the target, but the LOS simulation model calculated a miss because of the instrumented position location error of the shooter and the target vehicle.

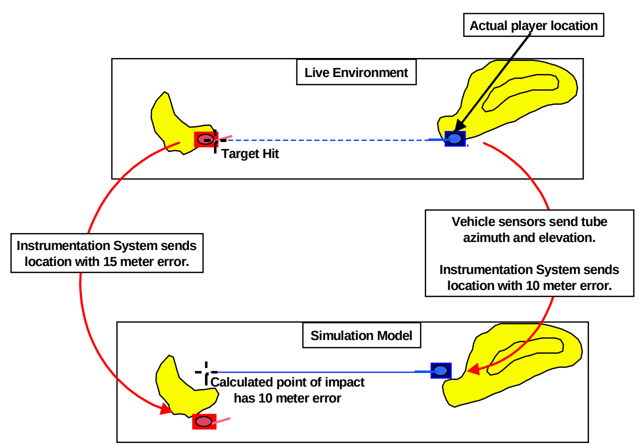

Figure 7. Inherent error in instrumented position locations.

In Figure 8, we realign concept priorities, to account for the problems with both concepts, and move the two concepts to the end of the priority list.

SYSTEMS BY BOS

AD	0	0	8	0	0	0	0	0	0	0	0	0	0	7
FS	0	20	0	0	0	0	0	0	2	0	0	0	22	0
INT	0	0	0	0	0	0	9	0	0	15	0	3	0	3
MS	0	0	1	19	9	13	0	0	0	0	1	0	0	1
MVR	13	11	57	0	22	0	0	35	0	0	1	0	0	31
TOTAL	13	31	66	19	31	13	9	35	2	15	2	3	22	39

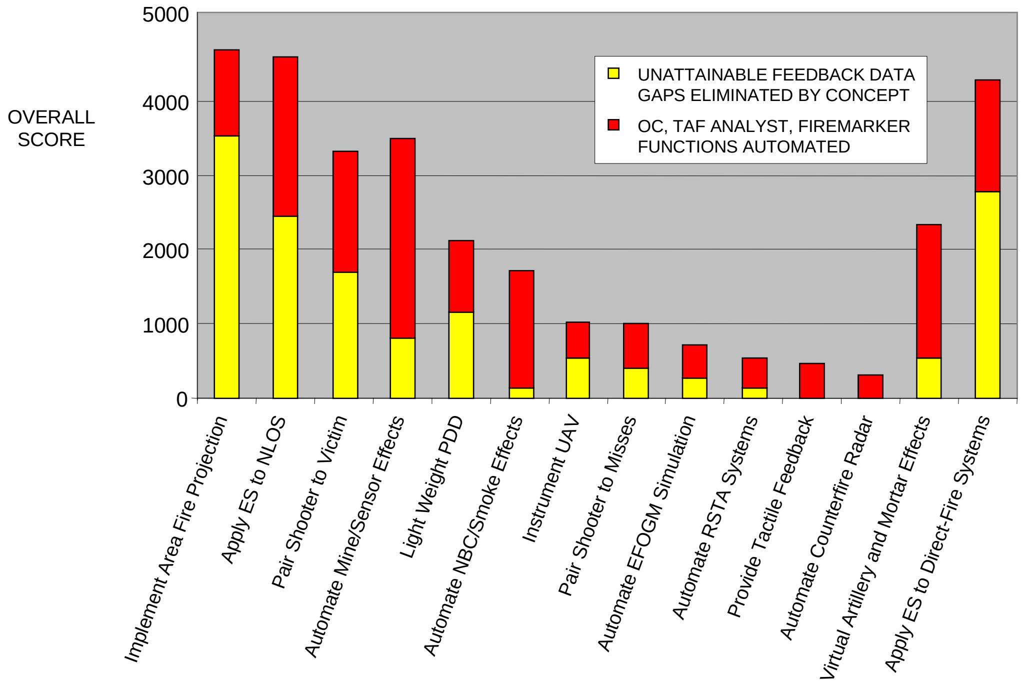

Figure 8. Prioritization of TES concepts based upon soldier safety considerations and technical feasibility

Figure 8 provides our recommended priorities for concept implementation. The top five TES concepts support 70 percent of the systems analyzed. They will eliminate 59 percent of the CAF functions and 75 percent of the feedback deficiencies.

DISCUSSION

Our analyses indicate that successful implementation of selected high level TES concepts can greatly reduce the workloads of OC/TAF Analyst trainers. The online database developed under this effort can be reused to assess the value of implementing additional TES concepts and/or combinations of concepts. The database can also be used to separate OC CAF functions from TAF analyst CAF functions, because it is the OC we are trying to free up for participation in coaching and mentoring activities.

The TES and IS systems currently in use have been developed in a stovepipe fashion over time. One of ATMD's goals in requesting the current study was to establish a framework for an integrated TES system that can address all types of engagements including those involving smart weapons and non-lethal weapons (Faber, 1996). The database developed in the current project can be applied to assess the extent to which various combinations of concepts serve to integrate the various types of engagements .

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