THE ROLE OF INSTRUMENTATION IN SIMULATING WEAPONS INTERACTIONS ON LIVE TRAINING RANGES

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ABSTRACT: *Instrumentation is the principal mechanism through which simulated interactions take place on military training ranges (short of using real bullets). Instead of being ìlive simulations,î these training exercises are really ìinstrumented live trainingîactivities in which only a few things are simulated. Live ranges, therefore, are very different from virtual simulations, and it is important that these differences be understood by those who want to include live and virtual in a federation. This paper presents a brief description of the weapons interactions that take place on battlefields and how instrumentation is used to simulate these interactions on typical combat training ranges. Interactions are classified according to weapon type for combinations of shooter/target pairings found at Army and Marine Corps Combat Training Centers (CTCs). The main instrumentation functions required are Time-Space Position Information (TSPI), State Vector Tracking, Platform Interface, Data Communications, Processing, Real-time Casualty Assessment (RTCA), and provision of Training Feedback. Available techniques for providing each function are explained along with the salient points to consider when implementing live-virtual federations involving the CTCs.*

1. The Role of Instrumentation in Training

The purpose of a military training range is to provide a real battlefield where troops can engage in highly realistic, simulated combat. The battlefield is normally instrumented so that instructors and observers are kept well informed of activities on the battlefield. However, that is not the most important purpose of the instrumentation. In addition to performing event data collection and situation awareness, instrumentation also provides the means for simulating weapons engagements. Instrumentation lets troops engage each other without firing bullets, shells, bombs, or missiles. It lets them interact realistically but safely. This is the important thing to realize: Instrumentation is replacing the bullets.

Because situation awareness capabilities are beginning to be designed into next-generation combat vehicles, it has been postulated that there may be less need for instrumentation at training sites in the future. However, <u>unless the embedded instrumentation implements all of the required functions</u> (including engagement simulation), it is not meeting the real training requirements. Furthermore, the embedded instrumentation must provide <u>all</u> of the combat interactions that would be encountered on the real battlefield, or else the combatants cannot have a fair fight.

Instrumentation requirements are driven by the engagements that need to occur on the battlefield in order to conduct effective training. It follows, then, that for virtual simulators to properly federate with a so-called "Live Simulation," the federation designers need to thoroughly understand the required engagement interactions and the instrumentation that implements these in the real (live) world. In previous studies of such requirements [1], we have found it useful to consider engagement instrumentation in terms of an interaction matrix. In developing such a matrix, we grouped weapon interactions according to the types of participants involved as shooter and target pairs. Figure 1 is an example of such an interaction matrix, drawn to illustrate the types of shooter and target pairs expected in training missions at a typical ground combat training center (CTC).

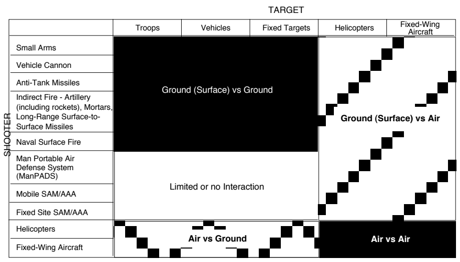


Figure 1. Classification of Possible Weapons Interactions

In Figure 1, the top row lists types of targets that may be involved in combat training interactions; the first column lists the types of shooter participants that may be involved. Participant types are differentiated according to the general class of interaction that needs to be supported by the instrumentation. For example, small arms are differentiated from such crew-served weapons as ManPADs because of the type of target against which they are likely to be effective.

The classifications shown in Figure 1 may be obvious, but the distinctions are important when considering implementation options to support the types of interactions expected at a training site. Some of the required interactions are not currently supported by instrumentation. This shortfall results in less of a fair fight, at least with respect to those particular interactions. Sometimes, test controllers administratively compensate for such instrumentation shortcomings by precluding either side from using unsupported weapon types or kinds of engagements. Other times, observer/controllers accompanying the troops handle instrumentation shortcomings by declaring ìadministrative killsî when, in their judgement, personnel would have been taken out by an air strike or exposed themselves too long in clearing a minefield. In still other cases, controllers at the central facility may declare a kill based on an inappropriate action of one combatant or another.

The point of the above discussion is that things may be happening on the live range that are not captured automatically by instrumentation. Failure to deal with these current shortfalls can invalidate a federation effort even before the simulated battle begins.

2. Principal Instrumentation Functions

Instrumentation, the principal mechanism that makes simulated engagements possible on training ranges, may provide the following functions. Each is discussed further in the following subsections.

- ***Time-Space Position Information (TSPI) or State Vector Tracking (SVT)***—Estimating participant position, velocity, acceleration, attitude, and attitude rate data as a function of time.
- ***Platform Interface***óCapturing participant sensor indications, switchology, on-board display information, voice data, and other input or output data that may be relevant for simulating participant interactions.
- ***Data Communications***óTransferring data between participants and sometimes also between participants and a central instrumentation element or control center.
- ***Processing***—Computer processing to (1) aid in participant tracking (such as dead reckoning, filtering, and smoothing), (2) run the weapons simulations, (3) handle data input and output to and from participants, (4) address overall data management and storage needs, (5) aid in communications between participants and between participants and any central data collection and processing points, and (6) present results graphically or in tabular reports.
- ***Real-time Casualty Assessment (RTCA)***óDetermining the effects of simulated engagements, including shooter-to-target pairing, kill or damage assessment, and notification.
- ***Feedback***óProviding the results of the interactions and engagements and delivering the overall training to the participants, both in real time and post-mission or after-action review.

2.1 TSPI and state vector tracking

The principal methodologies for providing TSPI and SVT of air and/or ground exercise participants are: (1) radar systems, (2)†inertial systems (often combined with other systems), (3) ground-based multilateration systems, and (4) the Global Positioning System (GPS). These complicated technologies are briefly described, and key characteristics that may influence implementation of live/virtual federations involving these technologies are briefly discussed.

2.1.1 Radar systems

Radar systems have been used for position location and, in some cases, velocity estimates for decades and continue to be used on several training and test and evaluation (T&E) ranges, primarily those supporting air combat training. Radar is used chiefly for aircraft and missiles and for exercises that typically have relatively small numbers of participants. Radar data are only measured at the radar source; consequently, knowledge of a participant's TSPI requires some connection to the radar tracking it. Although some SVT and aircraft system data may be collected with radar systems through the use of encoding transponders, such links typically do not provide the combat system data needed for high-fidelity training applications.

Two relevant characteristics of radar-based tracking are whether the track is “cooperative” or “non-cooperative.” A cooperative radar track relies on an on-board radar transponder to enhance the signal return. Transponders can also be used to encode limited quantities of data (e.g., altitude and participant identification) that can be sent back to the radar source and forwarded to a range system core. A non-cooperative track depends on only the signal reflected by the participant's metallic skin. No transponder is needed in this case; however, the track is generally weaker and less accurate, and no opportunity exists to transmit any other participant information. In either case, TSPI obtained with radar instrumentation is not likely to be as accurate as simulation designers might hope. [2] Special instrumentation radar, such as the FPS-16s found at some test ranges, can locate targets to within 5 meters in range and a few tenths of a mil in azimuth and elevation angle (relative to the radar). Most search or surveillance radar, however, have track uncertainties of hundreds or even thousands of feet.

2.1.2 Inertial systems

Inertial systems are widely used in aviation and in training and T&E applications. Such systems measure attitude and acceleration rates and can be excellent for providing incremental state vector data based on the movement of the participant. They can also be used to determine attitude and pointing information on ground participants. Since inertial systems measure motion of the platform, inertial data are obtained on-board. Knowledge of a participant's inertial-based state vector data at some other site, therefore, requires data communications connectivity to the participant.

The key characteristic of inertial data used for state vector tracking is that, by their nature, inertial systems tend to drift over time. Relatively inexpensive systems can provide accurate data over the short term (seconds to minutes), but even expensive systems will suffer drifts of thousands of feet over an hour. For this reason, inertial systems are typically used in concert with other tracking systems that provide periodic drift corrections and increase the accuracy of the overall state vector data.

2.1.3 Ground-based multilateration systems

This type of system uses a set of reference stations (known, surveyed) located throughout the range's land area from which are determined individual distance measurements between each station and a transponder carried by the participants. Measurements from three or more stations are used to determine the position of each participant in three dimensions. Using more than three stations produces an "overdetermined" solution that can be used to improve the overall accuracy of the solution. Many of today's range systems, including TACTS/ACMI/MDS and NTC Air Warrior systems, use a ground-based multilateration system in concert with inertial data to develop aircraft participant state vector data.

Important characteristics of ground-based multilateration systems are: (1) they rely on some combination/filtering mechanism to determine a position from three or more individual ranges, and (2) the accuracy and coverage they provide are very dependent on the geographical locations of the individual ranging stations relative to the participant. Typical systems of this type have three-dimensional position accuracies of 25 to 50 feet in areas of the range with good tracking geometry. Because some combination/filtering of individual ranges is needed to derive position solutions, multilateration systems use some kind of central processing where the ranges are gathered from each station. If this processing is available on-board a participant, the solution can be known on-board. Typically, however, the ranges are measured at the ground stations and sent to a central processing facility on the ground. In the NTC Air Warrior system, this is known as the Control and Computation Subsystem (CCS) and is located at Nellis AFB, NV.

2.1.4 Global Positioning System (GPS)

GPS is a satellite-based multilateration system in which the reference stations are satellites. Because receiver clock drift is also an unknown, a GPS receiver needs to be able to measure ranges and time from a minimum of four satellites to determine a TSPI estimate. Usually up to eight satellites are visible; consequently, the receiver may choose a subset of satellites that provides best geometry. The GPS position estimate is generally computed within the on-board GPS receiver, so the TSPI can be made available on-board. Having this information available for other participants or for a central core requires a datalink.

Several possible GPS implementation mechanisms are possible, so GPS accuracy capabilities can vary widely. Key characteristics that affect the GPS-based TSPI solution accuracy are:

- ***Receiver type***—Commercial coarse/acquisition (C/A)-code receivers and military P-code (so-called ìauthorizedî) receivers are available. (In addition to C/A-code and P-code, there is Y-code, which is encrypted P-code.) The P-code receivers provide more accurate positioning when operating independently; however, they are more costly and are controlled items. Either type of receiver can provide accurate data when differential corrections are applied properly (see below).
- ***Single- vs dual-frequency***—Closely related to receiver type is the ability to use both GPS frequencies, L_1 and L_2, that are transmitted by the satellites. P-code receivers use both and, therefore, are able to remove errors due to the signal transmission through the ionosphere (a major error source) autonomously.
- ***Differential corrections***—By locating a GPS receiver at a nearby surveyed reference location, much of the GPS tracking error can be removed from participant units operating within a few hundred miles of the reference receiver. If the true position of the reference receiver is known, its error can be determined and subtracted from the data of the other, because many error components will be common to both receivers.

Several differential correction techniques are available. Differential GPS can reduce typical C/A-code receiver errors from 100 m (95th percentile) to only a few meters. But large error reductions depend on careful implementation of the differential correction system.

- ***Wide Area GPS Enhancement (WAGE)***—This emerging technique is somewhat similar to differential corrections, but in WAGE, the SV clock and ephemeris corrections (errors) are transmitted in the satellite's downlink messages. The technique works only with authorized, P(Y)-code receivers, and currently very few of even these receivers are programmed to use WAGE. However, by eliminating the need for a local reference station and differential correction uplink, WAGE has great promise for the future. In addition, some of the techniques developed in the WAGE project are being incorporated into the operations of the GPS ground segment, which should result in a twofold or threefold improvement in authorized (P/Y-code) receiver accuracies within a few years. This could result in GPS accuracies of 5 meters spherical error probable (SEP) without the complications of differential correction.

- ***Carrier and code treatments***—Several measuring and smoothing treatments can be applied to the GPS code and carrier measurements. These mechanisms can greatly enhance the accuracy of the range estimates that determine the overall position. Carrier phase tracking, a more specialized technique, can reduce range measurement errors to centimeters.
- ***Position, velocity, and orientation***—Typical GPS provides position and velocity; however, using the carrier measurements to estimate relative positions of two or three GPS antennas on the participant can enable determination of participant orientation (i.e., attitudes).

This brief discussion shows that simply "using GPS" to provide elements of the state vector is not necessarily a complete solution for all TSPI or SVT requirements. Depending on the techniques applied, GPS can provide a wide range of data types and accuracies and comes at widely varying cost.

2.2 Platform interface

Interface to the participant platform to obtain sensor outputs, switch settings, and trigger pull data has always been a major technical challenge in instrumented training systems. The data are available on the platform, but the mechanism for providing those data to the instrumentation system is often difficult or costly. Some of the issues that need to be considered when attempting to understand the capabilities of an instrumented range include: (1) whether the platform is multiplex (MUX) bus-equipped, (2) whether other interfaces are already available, (3) the necessity for platform modifications, and (4) physical location and attachment of the instrumentation.

MUX bus-equipped platforms often make the interface problem easier to solve because the data of interest are all available on the bus. Interface hardware is often simplified, but bus access can be difficult. If the MUX bus can be accessed, MUX bus issues that must be addressed include: bus and mission computer-loading concerns, talker/listener issues, availability of required data, and whether the data are in a convenient format.
Platforms not equipped with a MUX bus have interface issues related to what types of mission data are available and where they can be accessed. For conventional analog and discrete interfaces, data line access issues remain. In addition, interface issues include specific connector configurations and conversion between analog and digital data. In additional, when interfacing to weapons or propulsion control circuits, safety issues may need to be addressed.

Individual platforms cannot be generalized in terms of interface type. Operational platforms are often modified to incorporate the latest technology to support mission requirements. Because not all of the platforms are modified simultaneously, different versions of platforms usually need to be instrumented. These different versions often have different platform interface requirements that require different interface implementations. Consequently, vastly different interfaces and different types of data may be available for different versions of the vehicle (e.g., M1A1, M1A2, and M1A2 SEP).

Finally, operational platforms are generally restricted to few modifications to participate in an instrumented exercise, and the modifications permitted are often required to be temporary. Several instrumentation-related modifications may be necessary to enable proper functioning of the instrumentation. Such modifications might include attaching antennas, sensors, strobes, or pyrotechnic devices. Finding a compromise that enables the instrumentation to function properly while not making permanent modifications to the platform can be a significant engineering challenge.

2.3 Data communications

Data communications enable tracking, sensor, and engagement data to be sent between participants and between participants and a central processing system. There are numerous issues in designing data communications systems for instrumented training. Some of the key issues of importance to any instrumented range system are:

- ***Frequencies***—These include allocations (where transmission will be permitted), bandwidth limitations, non-interference with tactical circuits, and many other technical issues.
- ***Media access***—These include such schemes as time division multiple access (TDMA), code division multiple access (CDMA), and others. The mechanism selected may determine which transmitter transmits when, and will affect data latencies, capacity per channel, and update intervals.
- ***Message sizes***—These determine the type and quantity of data that can be transmitted in a single message. They are affected by bandwidth and other limitations.

- ***Network architecture***—Whether the data communications architecture is a star topology (all participants connect directly to a central node), a mesh (all players connect to each another), or another architecture affects update rates, relaying, message types, etc.
- ***Training arena size***—The need to cover a large area has implications on transmitter power, number and length of ìhopsî or relays required, and message propagation time delays and the effect of these delays on data latencies and throughput. Many interacting constraints and tradeoffs must be dealt with in all except the smallest arenas.
- ***Security***—The data may be classified and, therefore, require some encryption scheme.
- ***Performance***—These parameters include transmission distances supported, message reliabilities, total throughput, etc.

In addition to the basic datalink technology issues that need to be addressed, instrumentation system designers need to determine whether a datalink that is an interparticipant link will also be the link to a central node, or whether a dedicated participant-to-central-node link will be employed.

2.4 Processing

Many of the data processing functions have already been introduced. Briefly, these include:

- ***Tracking-related processing***óThis typically involves some kind of filtering to determine estimates of position and velocity, differential GPS correction processing, and interpolation/smoothing/dead reckoning of participant data to check data quality or to fill in missing points. The degree of tracking-related data processing required will depend on the required tracking accuracy and the tracking instrumentation used, and is likely to vary between system types.
- ***Communications-related processing***—Essen-tially controls the range datalink system. These functions include network management, message building, message computing, and data distribution.
- ***Input/output (I/O)-related processing***—Includes sensor data processing, and processing for such output as pyrotechnics and synthesized audio.
- ***Data management***—Addresses all of the processing functions necessary for recording and playback of the mission data collected by the link.
- ***Real-time casualty assessment (RTCA)-related processing***—Provides the estimated results of simulated weapons engagements. (RTCA is described in more detail in Section 2.5.)

With advances in distributed processing, many of these functions, which traditionally have been performed at a central processing facility, can now be performed at individual participant instrumentation packages.

2.5 Real-time casualty assessment

The RTCA function is the critical function for determining the fidelity of weapons system engagements and, therefore, is one of the most important areas in implementing live/virtual ground combat training federations.

The goal of RTCA is to realistically simulate all of the aspects of the engagement, not simply the weapon's trajectory. Overall, realism needs to be maximized while avoiding negative training (i.e., reinforcing wrong behavior). Because instrumented training ranges typically have many participants (thousands at some of the CTCs), the techniques of implementing RTCA and their associated costs are major factors in designing a suitable range system. In addition to financial constraints are other constraints on participant instrumentation, such as size, weight, electrical power, and operating environment. Existing RTCA instrumentation is the result of painful tradeoffs between these constraints and the desire and need for engagement realism.

In general, the basic functions of instrumentation for RTCA include: (1) shooter/target pairing, (2) impact prediction, (3) damage assessment, (4) notification of engagement results, and (5) applying the engagement results. RTCA methods appropriate in training depend on the engagement and weapon types. Engagement types needing to be realistically simulated include direct or indirect fire and adjusted or non-adjusted fire.

- Direct fire is engaging a specific, identified target, as in a tank-vs-tank engagement; indirect fire involves firing on a defined area to engage whoever may be there, as in an artillery barrage against an area.
- Adjusted fire essentially involves changing the aimpoint by observing where the previous rounds struck (e.g., machine gun tracer rounds can be self-adjusted by the gunner).

Weapons include ballistic and guided weapons. Weapon type is important because simulated ballistic weapons are heavily dependent on knowledge of the shooter and target state vectors (including weapon-pointing direction) to estimate exactly where a simulated ballistic round will hit. Pointing angles are difficult if not impossible to measure accurately enough to support ballistic flyout simulations. Guided-weapons simulations are less dependent on such accurate knowledge, since a realistic guided-weapon simulation will guide equally well against a target with a slightly erroneous position as it will against a target with a perfectly accurate position.

Both indirect- and direct-fire RTCA are important requirements. Indirect fire, however, is more forgiving with respect to instrumentation accuracies because it is more easily implemented with results based on area effects, which can mitigate participant position errors and data latencies. Direct-fire RTCA is particularly difficult because, by its very nature, it must provide a reasonable result with respect to what a knowledgeable participant, fully aware of weapon capabilities, would expect if he were the shooter or target of such an engagement. In this respect it also must not provide negative training.

2.5.1 Shooter/target pairing

Because of the particularly stressing requirements of direct-fire RTCA, the technologies and possible methodologies must be addressed in more detail. The first step in such an RTCA is <u>shooter/target pairing</u>–i.e., determining who is shooting at whom. Three different technical approaches are currently used for RTCA shooter/target pairing:

- ***The target receives a narrow beam from the shooter***—In this mechanism, the target "knows" it is being engaged by shooter "A" because it can determine that shooter "A" is pointing at it. The most common example of this approach is the Multiple Integrated Laser Engagement System (MILES) used at Army and Marine Corps ranges.
- ***The shooter's weapon orientation is measured to determine aiming direction***—In this mechanism, pairing is done by the range instrumentation system determining what participant is being aimed at by the shooter. The measurement is made every time a shooter pulls a trigger (indicating that a shot is being fired). When potential targets are clustered, algorithms are employed to determine what is the most likely target being shot at (e.g., the one most threatening to the shooter). This method of pairing is implemented at TACTS/ACMI/MDS air ranges and on the Deployable Force-on-Force Instrumented Range System (DFIRST) ground system.

- ***The weapon trajectory is simulated to determine an impact or detonation point relative to a target***—This process involves actually simulating the path of the weapon being fired and determining whether or not it damages the target. For ballistic weapons, this requires extremely accurate weapon-pointing data and shooter and target position data to determine an impact point, plus (for air-to-ground weapons) an accurate representation of the terrain at the impact points. The impact point is then compared to known target locations to determine the likely affected target and the resulting damage. Examples of this approach include the NTC Air Warrior ballistic and guided-weapon simulations, employed in engagements against ground targets.

2.5.2 Damage assessment

Once target pairing is accomplished, RTCA must <u>determine the result</u> of the simulated engagement to provide feedback to the shooter and the target participants. One method of doing this is by determining actual impact. Impact point can only be determined when a weapon trajectory has been simulated. As mentioned previously, such determination for ballistic weapons has strict requirements on positioning and pointing accuracy. For example, a 0.3-mr angular accuracy—which is typically achieved with pedestal-mounted optical instrumentation—still yields a 1-m error over a 3-km range. One meter is a significant error in determining an impact point, since vehicles are generally no more than a few meters in size. When nominal TSPI errors are added (usually a few meters or more), an impact point estimate at this level of precision is little better than a guess. It is worth noting, however, that impact determination is successfully employed for indirect-fire weapons because they generally involve area effects for which a few meters inaccuracy has less impact on fidelity of the casualty results.

Another method for determining an engagement result is to use probabilistic methods, including probability of hit (P_h) and probability of kill (P_k). These methods essentially use pairing conditions, such as range and aspect angle, to determine the likelihood of a hit or a kill. Different ways of implementing this approach are based on a "cookie cutter" method for indirect fire (i.e., determining regions for various damage levels) or on various P_h and P_k tables, such as those from the Joint Munitions Effectiveness Manual (JMEMS) or the Army Material Systems Analysis Agency (AMSAA).

Because different RTCA methods require different accuracies to produce credible results, not all instrumentation will support all methods.

2.5.3 Notification of results

Once the engagement result has been determined, the RTCA function must notify the participants of the results. The crew of the target vehicle can be notified via audio tone, voice synthesis, or visual display. Other participants, including the shooter, can be notified with visual cues, such as strobe or pyrotechnic devices on the shooter and the "hit" player. RTCA must also ensure that the instrumentation system core is notified of the result for mission feedback and archiving.

In addition to visual and audio cues, RTCA results can be signaled to a limited extent physically. For example, a tank that has suffered a firepower kill can have its capability to fire simulated rounds disabled, and one that suffered a communications kill can have its radio disabled, etc.

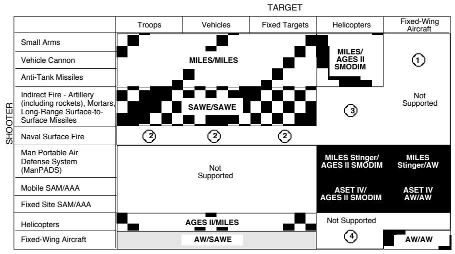
2.6 Feedback

The final function of instrumentation to be considered is feedback to the participants. This is a critical function since it provides the basis for lessons learned. Feedback needs to be provided over three different timelines. *Immediate feedback* (e.g., engagement results) is needed during the training mission to provide participants a real-time sense of the results of their actions and to influence the collective results of the mission. Once a training mission is completed, *consolidated feedback* is presented in the form of a mission debrief or after-action review (AAR) to provide the overall results of the mission to the participants while their actions are still fresh in their minds. Finally, the data collected from the training mission may need to be *archived* for take-home packages and future analysis. Analysis of archived data can take advantage of the time available to examine the results of the mission in detail. With some of the proposed use of digitally-archived data, "what if" scenarios—i.e., studying possible outcomes of alternative actions—are even possible.

The different services all have feedback over the three different timelines mentioned, but they also have different approaches to obtaining and using feedback data. The Army and Marine Corps emphasize the use of Observer Controllers (OCs) to provide a personal level of feedback as a substantial supplement to the automatic digital data collected by range instrumentation. Instrumentation should support the OCs in performing their roles. In addition, the Army makes extensive use of video cameras and radio recordings to capture events for AAR.

3. Current Ground Instrumentation Subsystems And Technologies

As an example of the functions and characteristics of range instrumentation systems, we can consider instrumentation implemented at Army CTCs. Most of the current ground CTCs use elements from a common set of ground instrumentation components or technologies. The engagement types simulated or supported by these instrumentation subsystems at the NTC are depicted in Figure 2. These include MILES, simulated area weapons effects (SAWE), the Air-to-Ground Engagement System II (AGES II), the Smart On-board Data Interface Module (SMODIM), and the Aircraft Survivability Equipment Trainer IV (ASET IV). In the following paragraphs, we briefly describe each kind of instrumentation whilepointing out the technology implications for live-virtual interaction.



① Uncertain of ability to simulate Vehicle Cannon vs Fixed Wing via MILES/Air Warrior

② JRTC supports this interaction via SAWE/SAWE

③ Uncertain of ability to simulate Indirect Fire vs Helicopters via SAWE/AGES II SMODIM

④ Uncertain that any Air-to-Air engagements involving Helicopters are supported

Figure 2. Current Engagement Simulation Instrumentation at the NTC

3.1 Multiple Integrated Laser Engagement System (MILES)

MILES is one of the most commonly used engagement simulation subsystems for ground instrumented training. Different versions of MILES (e.g., MILES, MILES II, and MILES 2000) are in use at all of the Army CTCs, as well as at Marine Corps and other ground training sites. MILES implements a direct-laser engagement system in which multiple laser bursts of pulse-coded data are sent from the shooter to a target equipped with MILES laser sensors. The coded bursts contain shooter ID and weapon-type codes as well as strings of kill codes. The target determines the engagement result based on how many kill codes it has detected with its photocells and what type of weapon ID was coded into the bursts.

MILES instrumentation includes laser transmitters mounted on potential shooters and laser sensors mounted on potential targets—usually all participants. Lasers are used to indicate direct fire from weapons ranging from small arms to tank main guns. A Stinger missile surrogate with MILES transmitter has also been devised for use against sensor-carrying aircraft in the NTC Air Warrior MDS. The sensors are mounted on belts and vests worn by individual combatants, installed on vehicles, or mounted on aircraft instrumentation pods.

Although MILES represents the best technology that has been available for direct-fire RTCA for many years, and tens of thousands of units are in use, there are several limitations and drawbacks to the technology. One important limitation in the context of live-virtual federations is that MILES provides no information about where a weapon is pointing (except by inference at the instant a hit or kill is scored). MILES-equipped shooters cannot engage virtual targets (because they cannot notify the virtual simulator where their weapon is pointing and cannot tell if a target is in front of the gun or not). Virtual shooters cannot engage MILES-instrumented targets on the live range because they cannot generate a laser beam for detection by the MILES sensor belts. It may be possible for the virtual player to effect the kill in another way (through data communications to the player), but this would entail a significant change to the range instrumentation system and would be a one-sided solution. It would not provide a fair fight.

Another particularly important drawback is that, because the lasers must be used around real people training on the range, MILES must use eye-safe, relatively low-power lasers. The efficacy and maximum range of the lasers are in turn affected by smoke, dust, fog, dirty sensors, and sensor shadowing—all common occurrences on a training battlefield.

3.2 Simulated Area Weapons Effects (SAWE)

SAWE has been implemented for indirect-fire engagement simulation in a number of ground training systems, including at the Army CTCs. The SAWE subsystem consists of a participant package with a C/A-code GPS receiver and a UHF radio receiver, and the central instrumentation to communicate with the participants and sources of simulated indirect fire. The SAWE radio receives the location of indirect-munitions lethal areas for such indirect-fire weapons as artillery, mines, bombs, and chemical weapons, and compares the participant's GPS-based location with that of the lethal area. Based on the proximity of a participant to this lethal impact area, SAWE determines damage to the participant.

Indirect-fire impact points are input into SAWE at the central instrumentation system. Sources of these data may include artillery or naval gunfire simulations, minefield simulations, and chemical weapon simulations. In AWMDS, aircraft no-drop weapon scoring (NDWS) impacts, although not indirect fire per se, are also input into SAWE.

SAWE instrumentation can support virtual-to-live interactions by interfacing the virtual side to the SAWE equipment at the central instrumentation core. It is also possible for indirect-fire missions from the live side to be sent across an interface (DIS or HLA) and, therefore, provide for a fair indirect-fire fight. Although such things are possible, much remains to be done before it becomes a reality at the CTCs of today.

3.3 Air-to-Ground Engagement System II (AGES II) and Smart On-Board Data Interface Module (SMODIM)

The AGES II subsystem equips helicopters with MILES and an eye-safe laser designator for helicopters to engage MILES-equipped ground forces and vice versa. Because helicopters involve a variety of weapon systems and survivability mechanisms, the AGES II simulation accounts for countermeasures and other survivability equipment in the MILES-based simulation. In a sense, AGES II brings helicopters into the ground-combat training scenario as a “fast-moving, flying tank”—i.e., it adds the equipment necessary to extend the ground instrumentation system to include helicopters. Helicopters, therefore, are included as instrumented participants; however, they are currently included only within the ground-combat training context. This distinction is important because helicopters can be engaged operationally by fixed-wing aircraft; yet, AGES II provides no capability for direct aircraft-helicopter engagement simulation using current instrumentation.

In addition to AGES II, helicopters can also be equipped with SMODIM interface units to provide an access to on-board avionics and weapon systems data. The SMODIM has a MIL-STD-1553 interface capability and can access a variety of helicopter data for downlink to the range instrumentation system. However, the limited capacity of the data communications subsystems currently installed at the CTCs precludes downlinking of very much data. GPS receivers were not part of AGES instrumentation originally, but will be added to some in the near future.

The helicopter instrumentation has a two-way data communications capability, and some angular data could be captured and downlinked via the SMODIM interface. Therefore, it appears theoretically possible to implement some kinds of live-virtual engagement capabilities using this instrumentation. However, there are caveats. The angular data, when available, come from the aircraft's inertial navigation system and may not be sufficiently accurate for some engagement simulation purposes. Furthermore, although it is a promising engagement simulation capability, the AGES II/SMODIM configuration is not widely available at Army CTCs (i.e., relatively few are actually deployed).

3.4 Aircraft Survivability Equipment Trainer IV (ASET IV)

ASET IV, an Army training system consisting of a six-vehicle module designed to emulate enemy air defenses, helps to train aircrews in evading and engaging enemy air-defense assets. The ASET IV suite consists of:

ï Command, control, and communications (C^3) unit with an identification friend or foe (IFF) radar capability for aircraft surveillance.
ï A radar-guided surface-to-air-missile (SAM) system, emulating weapons such as the SA-8.
ï Two infrared (IR)-guided SAM systems, emulating weapons such as the SA-9.
ï Two antiaircraft artillery (AAA) units, emulating such weapons as the ZSU-23-4.
ï Six ManPADs, emulating such weapons as the SA-14.

The units have MILES interfaces and capabilities to engage helicopters via their MILES lasers. They can also engage AWMDS pod-equipped aircraft at the NTC only.

4. Conclusions and Recommendations

Developing a HLA federation containing live and virtual federates is likely to be anything but a ìplug-and-playî operation. In the virtual world, everything is simulated except for the person being trained. In the live world, as little as possible is simulated—just about everything except the actual bullets are annoyingly real, including the heat, cold, dust, equipment breakdown, exhaustion, hunger, etc. Simulating the bullets—or more precisely, the engagement simulation—is the major instrumentation challenge. The challenge has been met by range instrumentation in many ingenious ways. However, today's instrumentation, designed to meet the requirements of live-live interactions, may not properly support live-virtual interactions even between types of participants whose interactions are well-supported on the live side. Unfortunately, these limitations and incompatibilities may not be understood by the designers of simulators and trainers who may very well be intending for their products to be used in such mixed federations.

We recommend that simulator designers acquaint themselves with the characteristics of range instrumentation subsystems, and that the two communities work together to determine the changes that may be required to permit valid federation in the future.

5. References

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Author Biography

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