Simulating Indirect Fire Effects in Field Experimentation

Mr. Ronald K. Gress, Braddock, Dunn and McDonald

Scientific Support Laboratory, and

Major David L. Click, U. S. Army Combat Developments

Experimentation Command

As the Army's only field experimentation laboratory, the Combat Developments Experimentation Command (CDEC) experiments with developing concepts and material using sophisticated instrumentation to produce objective data on these developmental options. Throughout its seventeen year existence, CDEC has constantly strived to improve its product through improvements in methodology, instrumentation, data analysis and reporting.

One of the basic experimentation techniques has long been the mock tactical engagement between two opposing forces. In such two-sided experimental trials, CDEC seeks to objectively simulate the realities of the battlefield so as to produce the best possible analysis for consideration by the decision makers. Objectivity is achieved by eliminating, wherever possible, subjective human judgements of engagement interactions and replacing them with near-real time computer analysis based upon generally accepted decision rules. Sophisticated instrumentation provides the input data necessary for such rapid decisions.

Within the past three years, CDEC has developed the capability to simulate, in near-real time, direct fire casualty assessment in two-sided field experiments. The next logical step in improving the capability of the command to more completely treat the dynamics of the battlefield is the addition of indirect fire effects.

The purpose of the Indirect Fire Casualty Assessment/Suppression (IFCAS) Study, which this paper describes, is to design and guide the development of an IFCAS system for use in field experimentation.
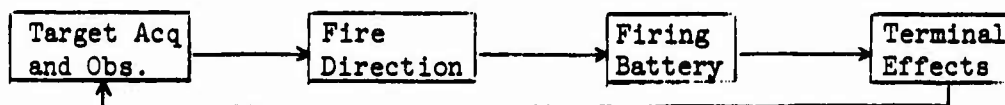
The program has been divided into four phases, in order to focus on goals established by Major General E. R. Ochs, the former CDEC Commander who initiated the IFCAS Study in December 1972. These four phases, and the milestones associated with the second and third phases are defined as follows:

- Conceptualization.
- Concept Testing, during Phase III, Experiment 11.8 (TETAM) in November 1973.
- First record use during Phase IV, Experiment 43.8, Attack Helicopter-Daylight Offense in the summer of 1974.
- Refinement and Documentation.

Each of these phases will be discussed in turn. Since the Concept Test will not be conducted until next month, this discussion will focus on the initial concept, planning for the Concept Test, and the

preparations to date for the first record use of IFCAS next spring. Some tentative long range ideas now under consideration will also be presented.

An indirect fire system may be considered as a series of four functions with a feedback loop:

```
┌──────────┐     ┌───────────┐     ┌──────────┐     ┌──────────┐
│ Target Acq│────▶│ Fire      │────▶│ Firing   │────▶│ Terminal │
│ and Obs.  │     │ Direction │     │ Battery  │     │ Effects  │
└──────────┘     └───────────┘     └──────────┘     └──────────┘
      ▲────────────────────────────────────────────────────┘
```

The first three functions interact to produce the terminal effects, which in turn provide the feedback information to the observation function. Each functional module is composed of many parameters, and within modules those parameters will vary with type of fire mission, caliber of weapon system, and nationality of the system being simulated or experimented with.

The ultimate goal of the IFCAS Study is to produce a modular system with flexible interfaces which will allow any of the first three functions either to be simulated or to be played by participating individuals or units. For example, the fire direction function could be simulated in the software or performed by an actual FDC section. With this flexibility, the IFCAS system could be used either to add the effects of indirect fire to maneuver unit experiments or to directly experiment with indirect fire systems and concepts. The latter, long term goal is two to five years away, at the current level of effort.

The immediate goals of the Study are to integrate indirect fire effects into ongoing maneuver unit experimentation. The Concept Test will involve the simulation of preplanned, single caliber and fuze action artillery fires against a defending infantry platoon reinforced with antitank guided missiles. The fires will support an attacking medium tank company. The mid-intensity scenario is set in Central Europe in the 1975-80 time frame. By next summer, during Experiment 43.8, it is planned to have simulated artillery fire available to both the offensive and defensive forces and to be able to simulate target of opportunity engagements.

Before proceeding with the details of the IFCAS concept, the approach to suppression needs to be discussed. Suppression is a temporal, psychological phenomena about which there exists much subjective opinion but little useful objective data. It is generally agreed that individuals or units are suppressed if their ability to observe, fire or move has been reduced without their having suffered physical injury. To suppress, then, is to cause those human reactions in the target force that result in such reduced fighting efficiency. Objective data on efficiency losses and time durations are practically nonexistent. Therefore, it was decided that our initial approach to suppression would rely on the desire of experimentation players to continue participating in the competition of the mock battle. The initial IFCAS concept is an attempt to create an environment that stimulates suppressive reactions approaching those that occur under live fire. The system is being designed to cue the players of the threat presented by indirect fire, to cause credible casualty assessment based upon personnel postures, and to permit the

470

players to react to this threat in the context of their mission, their competitive spirit, and their risk function. This personal risk function is meant to describe the sum of many factors, including experience, relationships with superiors, subordinates and peers, perception of the threat cues, and judgement of the significance of the threat relative to the total tactical situation perceived by the player at the time of an indirect fire attack.

The Phase I IFCAS Concept will be tested using the Phase III, Experiment 11.8 (TETAM) scenario as an environment. Phase III of Experiment 11.8 is a two-sided, near-real-time casualty assessment experiment to obtain data on antitank missile systems, aggressor tank/armored personnel carrier elements and ATGM launch vehicles in simulated combat. Three ATGM systems (TOW, DRAGON, and SHILLELAGH) when employed on a reinforced mechanized infantry platoon front will defend against an armored threat (reinforced company) in operations representative of a mid-intensity European environment. Artillery fires will only be employed in support of the attacking company against the defending platoon.

Indirect fire produces three major effects: attrition, suppression, and obscuration. Of these, IFCAS addresses the first two. Through near-real time computer simulation in conjunction with the Range Measuring System (RMS), IFCAS will simulate the casualty production of indirect fire and communicate these effects to experimentation players. By informing players of the presence of indirect fire and providing some knowledge of its threat to their survivability, IFCAS will motivate players to take protective measures to improve their probability of survival. Since the players' posture will be input to the IFCAS software routines by controllers and the latest reported posture used to calculate kill probabilities (Pk), the players will be able to reduce their Pk by changing their posture. In this way, it is expected that suppressive reactions approaching those encountered under live fire may be achieved.

Figure 1 presents a schematic diagram of the Phase I concept. During the preparation, the computer will initiate fire events against thirteen preplanned target areas according to a programmed schedule of fires. The FDC controller will cause the appropriate effects simulator to be detonated according to the schedule of fires in synchronization with the computer casualty assessments. After the preparation is completed, the FDC controller may begin to initiate preplanned supporting fires and/or receive fire requests from the threat force commander via radio. During these subsequent supporting fire missions, the FDC controller will insert appropriate time delays for mission processing and times of flight.

Upon receipt of the concentration number, the computer will perform the following tasks which are discussed in more detail below:

- Determine individual round impact points.
- Notify the controller of the impact event to permit the synchronization of the effects simulators during preparatory fire.
- Assess casualties based on target type, posture, range and position from impacting rounds.
- Notify players of assessment results via a light display panel.
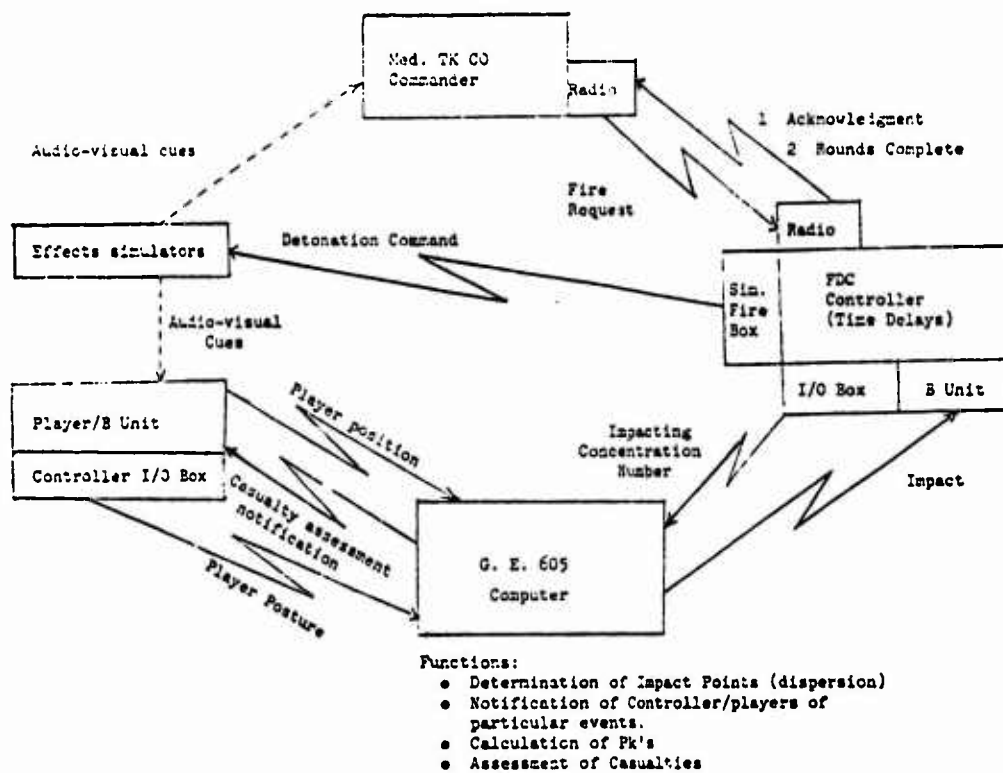
471

Figure 1, Phase I Concept

Controllers with each defensive system will supply the computer with current posture of the crewmen via the I/O box. The Range Measurement System (B units) will supply the computer with the location of each weapon system. With this data, the computer can then determine kill probabilities and assess casualties.

Simulated artillery fire may cause personnel kills, firepower kills and total system kills. Defensive system controllers will assess specific personnel kills singularly, based upon computer notification and player posture. Individual personnel kills will be accumulated by the computer until a total kill is achieved. Firepower and total kill messages will not require controller interpretation or judgement.

The target players will receive cues of impacting artillery from the computer via a light display panel and the detonation of effects sim- ulators. Based on these cues, the surviving players may choose to increase their probability of survival by taking protective measures. The tank commander will be cued that artillery has impacted by observing the detonation of the effects simulators and from receipt of the "rounds complete" message from the FDC controller.

In the concept test a maximum of thirteen different preplanned concentrations may be engaged with a single caliber using point detonating fuzing. The selection of these areas will be made based on the avail- ability and quality of intelligence of the attacking force.

The IFCAS program is being prepared to permit up to five batteries to be used during preparation. One battery will provide subsequent supporting fires after preparation.

The location of the impacting rounds in a volley is a function of the aim point of each round and the dispersion about that aim point. Therefore, the first step in the determination of the impact points of each round in a volley is to determine the aim points.

In the concept test the aim points will be predetermined and stored in the computer for each of the thirteen predesignated areas. When the FDC controller enters predefined area through his I/O box, the appropriate individual aim points will be called up from memory and dispersion randomly added to each point in order to determine the impact point of each round.

Dispersion will be accomplished by multiplying range and deflection probable errors (PE) times a random number drawn from a normal distribution of zero mean and unit standard deviation, i.e., a N (0,1) distribution. These two PE will be constant for the concept test.

The simulation of casualty effects will be discussed in two parts. First the Carleton function (Reference 1) which will be utilized to generate Pk values will be presented, followed by a discussion of target parameters to be considered, including target posture and component kills.

The casualty effects of each round will be assessed individually using an elliptical damage function. The function approximates the probability of a target, located at (w,v) with respect to the point of impact, being killed (or damaged to a specified degree). The values w and v are orientated with respect to the gun-target line (see Figure 2). This will require a transformation from the map grid coordinate system used for target/impact location (x,y). The equation is in the form:

$$P_k(w,v) = D_o \, \text{Exp}\left\{ -D_o\left(\frac{w^2}{R^2(1)} + \frac{v^2}{R^2(2)} \right) \right\}$$

The parameters Do, R(1) and R(2) may be adjusted to reflect any combination of the following conditions:

- Target Type
- Target Posture
- Round type/caliber (a single caliber will be used in the concept test)
- Angle of Fall (this will be considered constant in the concept test)
- Burst Height (point detonating fuze will be used in the concept test)
- Terrain/Vegetation (typical terrain/vegetation conditions will be used to generate the above constants)

Target posture is extremely important and will be treated during the casualty assessment for the following reasons:

473
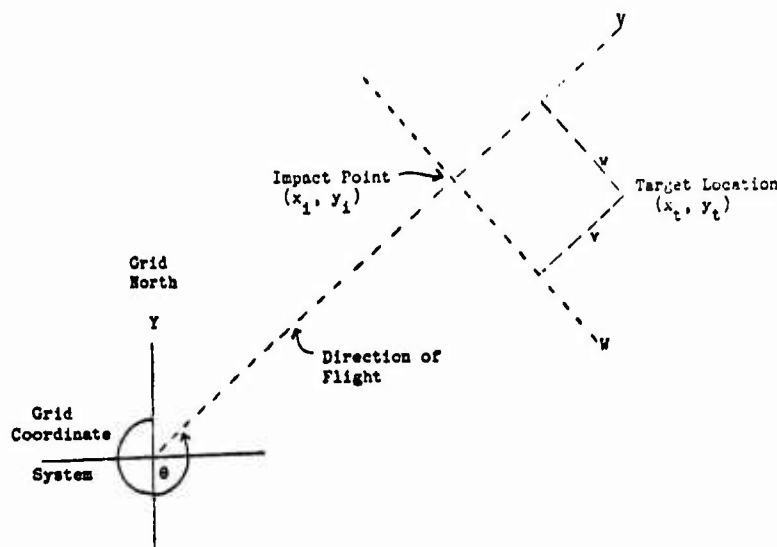
(x, y) = grid coordinate locations of impact point and targets.

(w, v) = required input (transformed coordinates) for Carleton Function.

θ = 360° - (Grid Azimuth of Direction of Flight).

w = $|(x_i - x_t)|$ Cos θ + $|(y_i - y_t)|$ Sin θ

v = $|(y_i - y_t)|$ Cos θ - $|(x_i - x_t)|$ Sin θ

Figure 2. Damage Function Coordinate System

- Casualty effects are extremely sensitive to personnel postures.
- Target posture and suppression are closely related. Unless the Pk reflects the posture of the target, there is little incentive for the target to respond realistically with protective reactions -a higher immediate probability of survival being the incentive.

Each target system will have a controller who will monitor crew posture and enter posture changes through an input/output box as they occur. Personnel casualty assessment would then be based on the last posture category entered prior to the impact of the rounds in question. The posture of the most exposed (least protected) crewman will be the posture reported. Upon receipt of a personnel kill, the posture reported will be changed to that of the second most exposed crewman, the most exposed crewman being declared a casualty by the controller.

Each of the defensive systems are unique and therefore require a slightly different treatment of the casualty effects (see Figure 3). The TOW and DRAGON systems will each be treated as separate man and materiel subsystems, each being assessed individually. A firepower kill assessment will be made against the materiel system and a personnel kill assessment will be made against the most exposed individual. The software will accumulate three personnel kills before a total kill is assessed against the TOW system and two personnel kills for the DRAGON systems.

The probability of a firepower kill against the M551/SHILLELAGH

WEAPON	Pk/POSTURE	Pk GROUP*
Dragon	personnel/erect and exposed	1
	personnel/partially erect in firing position	2
	personnel/prone or protected	3
	firepower/ ---	4
TOW	personnel/erect and exposed	1
	personnel/partially erect in firing position	5
	personnel/prone or protected inside APC	6
	firepower/ ---	7
M551	personnel/erect and exposed	1
	personnel/standing in open hatch	8
	personnel/completely inside vehicle	6

* Pk group refers to the set of constants (Do, R(1), R(2)) to be used in The Carleton function.

Figure 3. Posture Categories and Kill Probability Groupings

being quite small, only personnel kills will be assessed against this system. A total kill message will be transmitted on the third personnel kill.

There will be two systems used to cue the players of impacting artillery in the concept test, a set of lights and the detonations of simulators.

Four lights will be located on each of the defensive systems for IFCAS messages, three of which will be shared with the direct fire system.

- A survive light will indicate that an assessment has been made for either direct or indirect fire but that the target system has survived.
- A personnel kill light will permit the gradual attrition of the crew. This message is unique to indirect fire and provides an additional stimulus for suppressive reactions.
- A firepower kill light will indicate a firepower kill resulting from either direct or indirect fire.
- A total kill light will signify a total kill by direct fire or the assessment of a total kill by indirect fire due to the attrition of crew members.

To assist the defensive players to discriminate between the two survivability messages (i.e., direct and indirect fire) and to assist in stimulating suppression reactions, noise/smoke simulators will be emplaced on the defensive position and their detonation initiated by the FDC controller in synchronization with the impacting rounds and casualty assessment.

The IFCAS Concept Test will consist of four record trials which will duplicate one cell (rapid advance tactic on site A) of the baseline matrix

475

of Phase III, Experiment 11.8. Much of the evaluation of the Phase I concept will be based on the comparison of measures between baseline and IFCAS trials.

The following measures of effectiveness (MOE) have been developed in order to assess the effects of IFCAS artillery on all systems involved. The MOE have been catagorized under the two primary effects of artillery:

- The infliction of casualties.
- The suppression of certain weapon systems (This in turn, may indirectly increase the number of casualties by increasing the effectiveness of the threat ground force).

Casualty effects may be determined through the following measures:

- The average number of kills by system and type (total, firepower, and personnel) inflicted by the artillery.
- The average number of firepower and total kills inflicted by the threat force (ground and artillery) with and without artillery.
- The change in effectiveness of the threat medium tank company due to artillery (Firepower (total) kills with artillery)-(Firepower (total) kills without artillery)-(Firepower (total) kills by artillery).
- Loss Exchange Ratio with and without artillery for the total forces and each weapon/target combination.

Suppression effects may be determined through the following measures:

- The percent of the total live time each player is in any given posture.
- The average number of engagements per system type per unit time from the beginning of a trial until the system is killed or the trial is terminated as a function of range by both forces with and without artillery.
- The number of engagements by range for each system type with and without artillery.
- The number of target hand-offs with and without artillery.
- Posture of each player as a function of time with times and ranges (from closest impact point) of each volley.
- Players will also complete debriefing forms for subjective evaluation.

Due to the limited number of IFCAS trials to be executed, much of the data may be only accurate enough to provide subjective estimates of the performance of the Phase I concept. However, this should be sufficient to guide future IFCAS development.

For the first use of IFCAS in record trials in Experiment 43.8 next summer, several significant improvements are required. The software and cueing technology to conduct target of opportunity engagements are being developed and the expansion required to provide artillery support for both of the opposing forces is being planned. At the present time, the instrumentation computer, a modified GE 605, is quite heavily taxed

by the data processing requirements of large scale, two-sided experimental trials. It is questionable that added IFCAS sophistication can be achieved to the degree desired on the current system. Added computation capability is being acquired and hopefully will be operational in time for Experiment 43.8.

To conduct target of opportunity engagements and to provide more cueing information to target systems, an expanded light display panel is being designed. Thirteen lights will be arranged in a cross, with three lights on each arm of the cross and one in the center. These may then be used to provide the artillery forward observer (FO) with sensing information from which to make subsequent adjustments and also used to give more specific cues of simulated impacts to target systems. Each FO and target system will have one light panel. Through software and telemetry, each panel will be identified with its assigned player and the type and content of the light messages may be programmed according to the functions and requirements of the using player.

At present, it is planned for the FO to input his fire request directly to the GE 605 computer through the RMS. This is directly analogous to the TACFIRE communications procedure, but not identical. It is desired ultimately to be able to integrate TACFIRE and FADAC with IFCAS and that possibility is being investigated as a long range goal.

In order to allow an actual firing battery to participate in experiments without actually firing, a Weapons Orientation Measuring System is being considered. Such a system would measure the orientation of each individual piece and provide those actual directions of fire to the computer to allow calculation of individual aim points for each simulated round fired. In this way, artillery and mortar crew proficiencies would be directly incorporated into experimental results as are those of direct fire weapon systems today. Again, this is a long range goal of the IFCAS program.

To summarize, IFCAS is a program at CDEC to, in the near term, add the effects of suppression and attrition from indirect fire to maneuver unit experimentation and, in the long term, to improve our ability to experiment with indirect fire systems. The approach is to simulate casualty effects as accurately as possible and to induce suppressive reactions among the participants by providing them the information necessary to evaluate their risk of being assessed a casualty.

References

1. Snow, Roger and M. Ryan, "A Simplified Weapons Evaluation Model", Memorandum RM-5677-1-PR, Rand Corporation, 1970

2. Winter, R. P. and E. R. Clovis, "Relationship of Supporting Weapon Systems Performance Characteristics to Suppression of Individuals and Small Units", TR-73/002, Defense Sciences Laboratory, Litton Systems, Inc., 1973