

# **FUTURE FORCE WARRIOR (FFW) SMALL COMBAT UNIT MODELING AND SIMULATION**

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## **ABSTRACT**

The Future Force Warrior (FFW) is the US Army's system of systems concept and technology initiative for Soldiers in the Future Force. The primary objective of Future Force Warrior Advanced Technology Demonstration (ATD) is to integrate and demonstrate technologies, system of systems concepts, and development of warfighting concepts that provide a substantial increase in combat effectiveness for a Small Combat Unit (SCU) operating in the Future Force Brigade Combat Team. These technologies and concepts will then be transitioned to Army Acquisition programs for development and fielding. The FFW program has developed a method using models and simulations to assess the relative combat effectiveness of SCUs equipped with these technologies. The relative combat effectiveness of various configurations can be used by the program management and systems engineers to make design and basis-of-issue decisions resulting in improved capabilities for the SCU. The selected capabilities and configurations will be prototyped and then tested in experimentation during the course of the ATD. In summary, the FFW ATD is conducting research and development to provide our Soldiers with the best equipment we can, and integrated analysis and experimentation gives the engineers the data they need to design the best possible system.

## **1. INTRODUCTION**

### **1.1 Future Force Warrior ATD**

The Future Force Warrior Advanced Technology Demonstration is the Army's Science & Technology initiative to develop and demonstrate advanced capabilities of the Ground Soldier System (GSS). It is a follow-on effort to the Army's Land Warrior program and transitions to Project Manager-Soldier Warrior for System Development and Demonstration as the Ground Soldier System program in 1Q08. FFW is a human-centric integrated System of Systems approach employed to

maximize the effectiveness of Small Combat Unit (SCU) operations. FFW seeks to create a lightweight, overwhelmingly lethal, fully integrated, modular combat system through distribution of capabilities across the SCU. The current system includes a Leader configuration and a Soldier configuration (see Figure 1). The FFW's open architecture design supports TRADOC's Soldier as a System (SaaS) vision, allows future technology insertion, and is extensible to Air and Mounted versions. FFW is a pillar of Army's Future Force strategy, complementing the Future Combat System (FCS), other Future Force programs, and joint platforms.



Figure 1. FFW Soldier & Leader

### **1.2 FFW Integrated Analysis & Experimentation**

The objectives of FFW integrated analysis and experimentation (A&E) are to address the FFW system of systems combat effectiveness for a broad range of proposed capabilities and distributions based on Essential Elements of Analysis (EEA) and input from FFW systems engineers and architects. The military context of this exploratory analysis is the MOUT (Military Operations in Urban Terrain) vignette developed by TRADOC Systems Manager-Soldier and wargamed by FFW user

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representatives and engineers in Map Exercises (MAPEX).

FFW initiated its modeling and simulation program with a series of Map Exercises to establish an operational context in which to conduct its analysis (Alexander, May 2004). These MAPEXs were conducted in seminar mode employing subject matter experts in the areas of FFW candidate hardware and software capabilities; small combat unit tactics, techniques, and procedures (TTPs); and the emerging Future Combat Systems Operational and Organizational concepts. Participants would alternately discuss concepts, plan how the small unit will carry them out, execute the wargame step, record the action, and discuss the results. Various data collection tools and processes used to facilitate the exercises matured through the series. The output of the MAPEX is a detailed script of the fight that can be used as input to a simulation, the next step in our integrated analysis process.

Exploratory analysis is a technique for exploring a complex system with many interrelated independent variables, called factors to determine the combination which provides the best value of the system. A three-step process was followed (Figure 2). First, the MOUT vignette was simulated with various combinations of 18 factors. Second, least-squares regression was used to estimate the marginal contributions to combat effectiveness of each factor and selected second-order interactions. Third, cost-benefit analysis was done by comparing the benefits estimated by regression with cost, weight, and power consumption constraints for each factor.

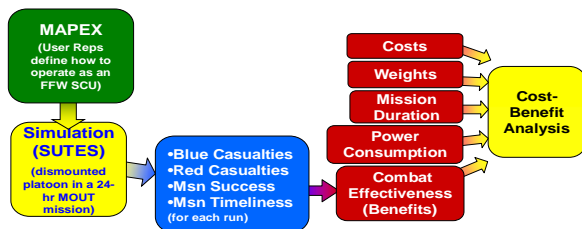


Figure 2. Exploratory analysis process

The simulation used was Small Unit Team Exploratory Simulation (SUTES) developed for the FFW program to model FFW Small-Combat Unit operations. SUTES represents the effects of basic functions of combat operations such as attrition, target acquisition and mobility. It does not depend heavily on encoded behaviors, but on scripting to prescribe entity actions.

The combat effectiveness analysis was done to determine how small-unit combat effectiveness and affordability varies as the SCU is improved from current forces and equipment to FFW. This analysis, which was done for three base cases and FFW, showed that FFW SCU combat effectiveness increased by 40% compared to Base Case 3, by 80% compared to Base Case 2, and by 105% compared to Base Case 1. Similarly, the blue force casualties were reduced from a range of 2.8 to 6.2 for Base Cases to 0.2 for FFW.

Armed with this data, the program can develop the most promising candidate systems and configurations for entry into experimentation. Output data from technical and operational experiments can be used to update the models and refine the simulations.

## 2. MAP EXERCISES

MAPEXs were the mechanism by which the military context was set for Exploratory Analysis, as well as other FFW analysis. During a MAPEX, the vignette was wargamed in one-, five- or ten-minute timesteps, with user representatives assigned roles as leaders within the SCU. The MAPEX controller stepped the wargame forward and explained the tactical situation for the upcoming period of time. Role-players specified the activities of the Soldiers they were gaming in terms of tactical behaviors, including operation of FFW equipment as required. After the role-players had assigned Soldier activities for the time period, engineers studied the activities and equipment usage of each component of the Soldier ensemble. The first two MAPEXs featured a Military Operation in Urban Terrain (MOUT) vignette and are discussed below. From these exercises, a detailed script of SCU actions over the 24-hour period emerged and formed the basis for simulation scripting.

### 2.1 MAPEX I

The purpose of MAPEX I was not to do analysis directly, but to prepare for analysis to be done during future exercises. The focus of the MAPEX was on clarifying operational and organizational concepts and specifying actions by simulated Soldiers during the vignette in accordance with those concepts. As an aid to preparation for the follow-on analysis exercises, the initial dispositions and tasks given to small units and individual Soldiers were entered into a JCATS simulation (Figure 3) as they were discussed in the MAPEX. Numerous implementation details of vignettes, equipment, operational architectures, TTP, and other concepts needed to be clarified in order to simulate a military operation that reflects the concepts sufficiently to allow analytic comparison.

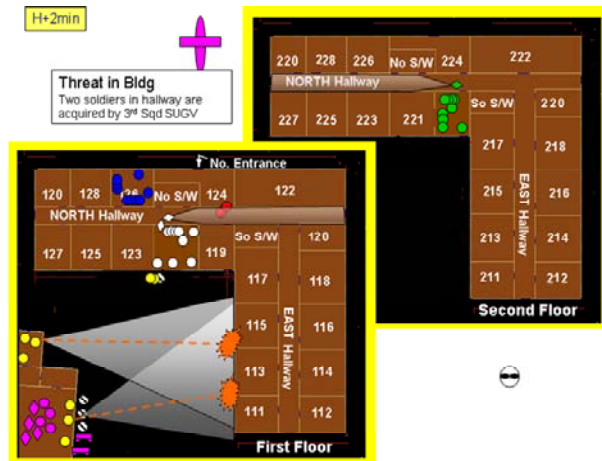


Figure 3. JCATS screenshots from MAPEX I

The tactical mission chosen for this exercise was dismounted infantry operations in urban terrain, in a building-clearing operation. In the portion of the MOUT vignette that was simulated, an FFW company attacked dismounted and separated from its Infantry Fighting Vehicles to seize an objective in a city, focusing on the actions of one of its platoons as it seized and defended a building.

## 2.2 MAPEX II

The purpose of MAPEX II was to wargame the FFW operational architecture and TTPs in accordance with a broader scope of the 24-hour MOUT vignette, of which MAPEX I was a subset (Alexander, November 2004). The goal was to record a typical set of FFW Soldier-borne system usage patterns for this operation (“duty-cycles”), and to record the gamer actions in sufficient detail that the operation could be scripted in a simulation. MAPEX II, along with MAPEX I, provided the specification of the vignette used in the Exploratory Analysis Simulation. The output of MAPEX II was this detailed vignette script, power consumption profiles for equipment usage, and insights and observations by the SMEs. Figure 4 is a concept sketch of the completed vignette.

The concept of the MAPEX was that a group of “Gamers” were assigned roles within the small combat unit such as Platoon Leader and Squad Leader, and a group of “Technical Representatives” were assigned responsibility for each piece of Soldier-borne or small-team equipment. The MAPEX proceeded by stepping the Gamers through each subsequent timestep, of periods of 1, 5, or 10 minutes, to cover a 24-hour period. At each step, Gamers applied their military and technical judgment to the activities being gamed. When all Gamers had discussed the upcoming timestep to determine what the Platoon Leader would direct and how the other Gamers

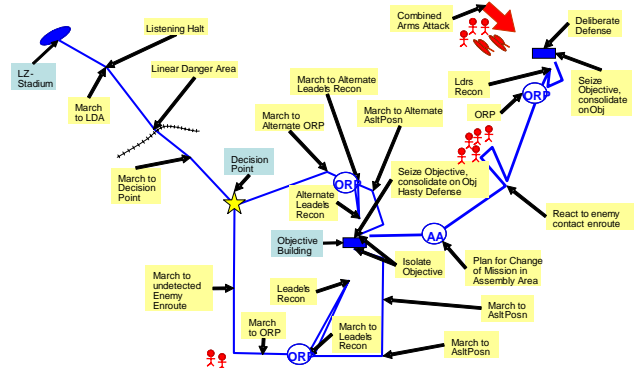


Figure 4. Concept sketch for MAPEX II vignette

intended to portray their small unit actions, each Gamer entered Soldier and equipment activities in a web-based tool called the MAPEX Master-Event-Schedule-List Webtool (MMW). These activities were recorded in a database.

Once the Exercise Director advanced the exercise to the next timestep, the Technical Representatives were able to begin entering data about equipment usage of the prior timestep, based on recorded Soldier activities. Technical Representatives were assigned one or more components of Soldier-borne systems, or were responsible for one type of UAV, UGV, or Unmanned Ground Sensor (UGS). Choices such as “OFF”, “IDLE”, “NOMINAL”, and “PEAK” were provided, with the intention that Technical Representatives would define each choice in terms of power usage. In this manner, power consumption profiles for each Soldier in the gamed platoon were developed based on these gamed Soldier activities and related equipment usage requirements.

## 3. MODELING APPROACH

### 3.1 Essential Elements of Analysis

The FFW program has established a set of Essential Elements of Analysis (EEA) as the basis for operational analysis of the systems under study. These EEA were developed early in the FFW program under the direction of the Technical Program Office, and modified thereafter to conform to evolving requirements. The EEA are based on the Ground Soldier System Capabilities Development Document (GSS-CDD), the TRADOC Systems Manager–Soldier (TSM-S) Key Performance Parameters, FFW program Exit Criteria, and other FFW program management guidance. These EEA were prioritized by

the program's System Engineering. From this prioritized list was derived the set of issues to study during Exploratory Analysis. A large number of the EEA address system-level questions, not engineering design issues, so analysis to support those EEA requires force-on-force modeling of the Small Combat Unit conducting military operations. Figure 5 shows a sample of the EEA hierarchy.

### 3.2 Experimental Factors

From the Essential Elements of Analysis, key issues were developed as candidates for examination during Exploratory Analysis. These issues were addressed by 18 experimental factors (see Table 1). Each of these factors was modeled in simulation at two levels, a basecase and an improved case.

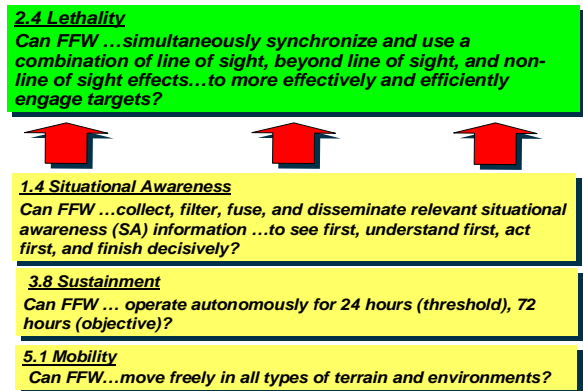


Figure 5. Essential Elements of Analysis hierarchy

TITLE	DESCRIPTION
<u>HMFS</u>	Helmet-Mounted Fused Sensor Distribution: <u>Basecase</u> => Fused Sensor on Team Leaders and above and Grenadier, PVS-14 on others; <u>Improved Case</u> => Fused Sensor and HMD on all Soldiers
<u>HUD</u>	Helmet-Mounted Display: <u>Basecase</u> => HMD on Team Leaders and above and Grenadier, others depend on wrist-mounted display; <u>Improved Case</u> => HMD on all Soldiers
<u>HAPTICS</u>	Haptic Alerts and Comms: <u>Basecase</u> => Alerts not available; <u>Improved Case</u> => Haptic alerts are available, reducing the time Soldiers must divert attention from sensing and shooting
<u>BFT</u>	Blue location update rate and accuracy: <u>Basecase</u> => friendly positions are updated every 10 sec and have a location error not greater than 10m; <u>Improved Case</u> => friendly positions are updated every 3 seconds and have a location error not greater than 3m
<u>IFF</u>	Interrogation Friend or Foe: <u>Basecase</u> => No active interrogation; <u>Improved Case</u> => All Soldiers can interrogate, all friendly Soldiers and vehicles have transponders
<u>SA</u>	Situational awareness update rate, ie, Red location update rate: <u>Basecase</u> => targets are updated on the COP every 30 sec; <u>Improved Case</u> => targets are updated every seconds
<u>COMMS</u>	JTRS Cluster 5 capability vs squad network-only intercom distribution: <u>Basecase</u> => Team Leaders and above JTRS Cluster 5 and squad network capability, team members have squad network only; <u>Improved Case</u> => all Soldiers have JTRS Cluster 5
<u>ISS</u>	Individual Soldier Sensor capability: <u>Basecase</u> => not available; <u>Improved Case</u> => two per Soldier
<u>CEFC</u>	BLOS fire control device on grenade launcher to enable Beyond Line of Sight (BLOS) capability: <u>Basecase</u> => Grenadiers cannot fire cooperative engagement; <u>Improved Case</u> => Grenadiers can fire cooperative engagement
<u>TGTLOC</u>	Capability to get targetable location data and transmit the data: <u>Basecase</u> => Leaders and grenadiers have target location and transmission capability; <u>Improved Case</u> => all SCU members have capability
<u>REDXF</u>	Reduced-Exposure Firing: <u>Basecase</u> => Leaders and Grenadiers have REDXF; <u>Improved Case</u> => All SCU members have REDXF
<u>WPNSIGHT</u>	Weapon Sight Type: <u>Basecase</u> => All have medium-range thermal weapon sights (TWS); <u>Improved Case</u> => Riflemen and Automatic Riflemen have long-range TWS
<u>MULES</u>	Number of MULEs per platoon limits quantity of munitions that can be carried by the platoon: <u>Basecase</u> => none per platoon; <u>Improved Case</u> => two per platoon
<u>AiTD</u>	Aided Target Detection capability to highlight possible targets on UxV feeds: <u>Basecase</u> => no AiTD capability – all feeds must be monitored continuously; <u>Improved Case</u> => AiTD for all UxV sensor feeds
<u>2UAVS</u>	Number of Class I UAVs per platoon: <u>Basecase</u> => none; <u>Improved Case</u> => two Class I UAVs per platoon
<u>RNCOS</u>	Number of Robotics Specialists per platoon: <u>Basecase</u> => one RNCOS per platoon; <u>Improved Case</u> => one RNCOS and one Robotics Specialist
<u>SBRC</u>	Soldier-Borne Robotic Waypoint Control capability: <u>Basecase</u> => Separate operator control units are the only means of controlling robotic assets; <u>Improved Case</u> => each Soldier has a body-borne device capable of waypoint control of robotic assets
<u>SUGVS</u>	Number of Small Unmanned Ground Vehicles with sensor capability per squad: <u>Basecase</u> => none; <u>Improved Case</u> => 1 per squad

Table 1. Analysis factors

## 4. EXPLORATORY ANALYSIS SIMULATIONS

Exploratory Analysis is a technique for exploring a complex system with many interrelated independent variables to determine the combination which provides the best value of the system (Alexander, 2005). A three-step process was followed. First, four segments of the MOUT vignette (as scripted in the MAPEX) were simulated with various combinations of the experimental factors and measures of effectiveness were recorded for each simulation run. Second, a least-squares fit was done to estimate the average contribution to combat effectiveness of each factor and combination of factors. Third, cost-benefit analysis was done to estimate the combination of factors which maximizes combat effectiveness given a set of cost, weight, and power constraints. Various cost, weight, and power constraints were explored to allow estimation of the most cost-effective SCU configuration under a range of constraints.

### 4.1 Small Unit Team Exploratory Simulation

The simulation used was Small Unit Team Exploratory Simulation (SUTES) developed internally and custom built for the FFW program. It was intended as an interim tool while other Army-sponsored simulations such as OneSAF Objective System and Infantry Warrior System were built and validated. SUTES was built to be a screening tool used to explore a wide range of factors, each modeled at a basic level of fidelity. As such, SUTES is not an engineering model. In general it represents physics implicitly, not explicitly. For example, it models weapon accuracy with tables of inherent error over range, not with a flyout model. It represents combat operations at an individual Soldier and vehicle (or “entity”) level. SUTES represents the effects of basic functions of combat operations such as attrition, target acquisition and mobility. It does not depend heavily on encoded behaviors, but on scripting to prescribe entity actions.

### 4.2 Experimental Design

Varying one factor at a time while holding all the others constant will not uncover synergistic relationships. Therefore, an experimental design was built to provide the most efficient combinations of factors. Eighteen factors were studied, with 46 anticipated second-order interactions, which led to a run matrix of 128 cases. For statistical power, it was decided to run 20 replications of each case.

## 4.3 Measures of Effectiveness

The goal of the FFW program is to increase the combat effectiveness of the Small Combat Unit. In order to analyze the output of the simulation, we must define this notion of combat effectiveness. Considering the EEAs and the operational context of the MOUT vignette, four Measures of Effectiveness (MOE) were measured in each run - Lethality, Survivability, Mobility, and Mission Accomplishment (Schamburg, 2005). A single measure of combat effectiveness was calculated as a weighted sum of these four MOE (see Figure 6).

Measure of SCU combat effectiveness:

$$MR = \sum_{i=1}^4 v_i z_i$$

where  $z_i = \frac{y_i - y_{min}}{y_{max} - y_{min}}$  and weights,  $v_i$  chosen so that  $\sum_{i=1}^4 v_i = 1$

$y_1$  = (Lethality) the number of enemy casualties

$y_2$  = (Survivability) the number of friendly survivors

$y_3$  = (Seizing the Objective) whether or not the small combat unit seized the objective (zero if the small combat unit does not seize the objective and one if the small combat unit seizes the objective)

$y_4$  = (Mobility) time to complete the mission

$y_{max}$  = maximum possible  $y_i$  value

$y_{min}$  = minimum possible  $y_i$  value

Figure 6. Measure of combat effectiveness

## 4.4 Maximum Potential Benefit

It is useful to consider the overall estimated benefit of each set of components (as used by a “factor”). Maximum Potential Benefit is calculated as the sum of a factor’s main effect with all beneficial second-order effects (Alexander, 2005). It is a theoretical number, since all listed benefits cannot appear in the cost-benefit solution simultaneously. It is intended, rather, as a guide to the potential of a given factor to contribute to combat effectiveness. See Figure 7. Note that the units of measure of the y-axis relates to the proportion of combat effectiveness (0 to 1) that the factor and its beneficial second-order effects could provide for each of the four segments. Therefore, the theoretical maximum for the y-axis is 4.0. A value of zero means that the factor provides no benefit, and a negative value would mean that the factor is detrimental to the SCU’s performance.

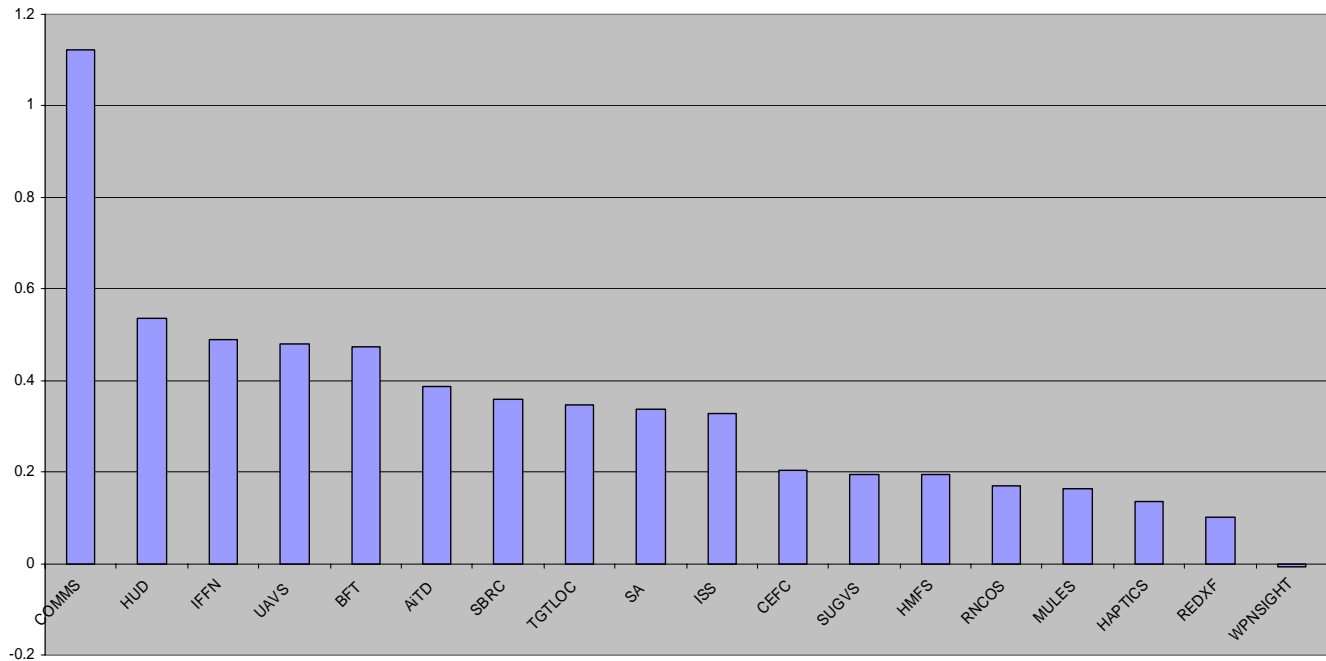


Figure 7. Maximum potential benefit

#### 4.5 Cost Benefit Analysis

Cost-Benefit analysis of the 18 experimental factors utilizes a Mixed Integer Program (MIP) that was designed to maximize the sum of the mission response function varying whether each of the 18 factors are in the base or improved case. The MIP contained constraints limiting the total economic cost, the rifleman combat load weight, and the mission duration. It was determined that power consumption is a function of mission duration, factors selected for inclusion at the improved level, and weight allowed. Various cases of the MIP were run to explore a range of costs, weights, and mission durations. Nine cases were run assuming 24-hour mission duration (the operational threshold requirement) with low, medium, and high allowable levels of cost and weight. Four additional cases were run to explore the effect of mission duration. Two cases set a short duration (12 hours) using low-cost, low-weight constraints and high-cost, high-weight constraints. A similar pair of cases was run with long duration (72 hours). The Cost Benefit analysis results in a series of possible system configurations of the various 18 factors that maximizes combat effectiveness while minimizing the costs, weight, and power required. This kind of information is instrumental in helping program management and system engineers conduct trade-offs to optimize the final product.

#### 5. COMPARATIVE ANALYSIS

Once we were comfortable with our modeling approach and the exploratory simulation, we were ready to apply our processes to comparative analyses of capabilities of proposed FFW system configurations with the capabilities of other Soldier systems either fielded or under development. In the analyses described above, we were only comparing various configurations of proposed FFW capabilities to each other. But to answer the question of whether or not our research and development is advancing the state of Soldier systems, we must compare an FFW configuration to some reasonable basecases.

The approach for the comparative analysis (Alexander, 2006) was similar to the exploratory analysis. The list of experimental factors were modified to reasonably reflect three basecases and an optimal FFW configuration. In lieu of repeating the MAPEX for wargaming the basecases, information on capabilities and TTPs was gathered from SMEs within TRADOC and the appropriate operational behaviors were scripted. The same MOUT vignette was simulated in four segments using SUTES. The same MOEs of lethality, survivability, mobility, and mission accomplishment were evaluated for each of the vignette segments.

## 6. RESULTS

Basecase 1 modeled the capabilities of the current Soldier as equipped for operations today in Operation Iraqi Freedom or Operation Enduring Freedom. Basecase 2 assumed an integrated Soldier system with communications, navigation, and increased lethality subsystem fielded to Team Leaders and above in the small combat unit. Basecase 3 used the same system as Basecase 2 but fielded to all members of the SCU. The FFW configuration modeled the optimum system of improved case capabilities. FFW demonstrated a two-fold (105%) improvement in combat effectiveness when compared with Basecase 1, an 80% improvement over Basecase 2, and a 40% improvement over Basecase 3 (Figure 8).

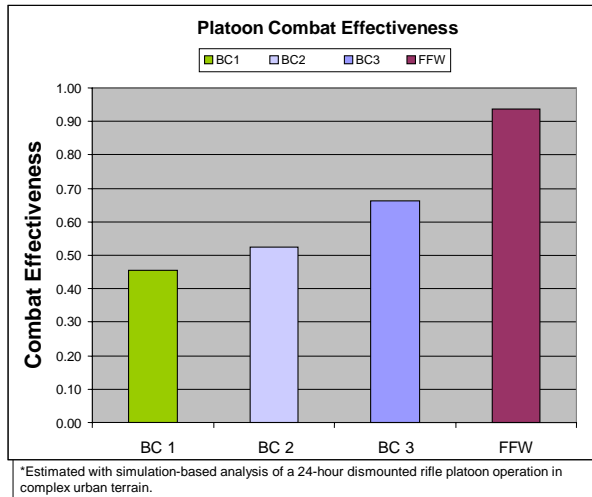


Figure 8. Results of Comparative Analysis

When combat effectiveness is studied by tactical phase (Figure 9), several interesting observations are made. In the defense phase the three Basecase platoons performed at the same level of combat effectiveness, while the FFW platoon was much more effective. The defense phase was very stressful, in that it involved a dismounted rifle platoon defending against a BMP mechanized infantry company reinforced with T72 tanks. The Basecase platoons would not normally be assigned this mission, and they are uniformly unable to accomplish it. The FFW platoon, however, has adequate capability to accomplish this very stressful mission. Similarly, the Day Infiltration phase requiring a reaction-to-contact is easily accomplished by both Basecase 3 and FFW platoons because they are the two cases where the distribution of equipment fully enables net-centric operations where situational awareness is at a premium. The other two cases, with partial or no support of net-centric operations and situational awareness are less capable in this circumstance.

When error bars are plotted for each case and each segment (one sample standard deviation above and below the average), it is observed that the FFW and Basecase 3 platoons not only performed on average better than the Basecase 1 and 2 platoons, but with much more consistency, implying a lower risk to mission accomplishment. Again, the key differentiator is the full support of these two platoons for netted effects, net-centric operations, and widely distributed situational awareness. The Basecase 2 platoon includes only leaders in the digital network, (and Basecase 1 includes no one), while Basecase 3 and FFW include all members in the digital network to some degree.

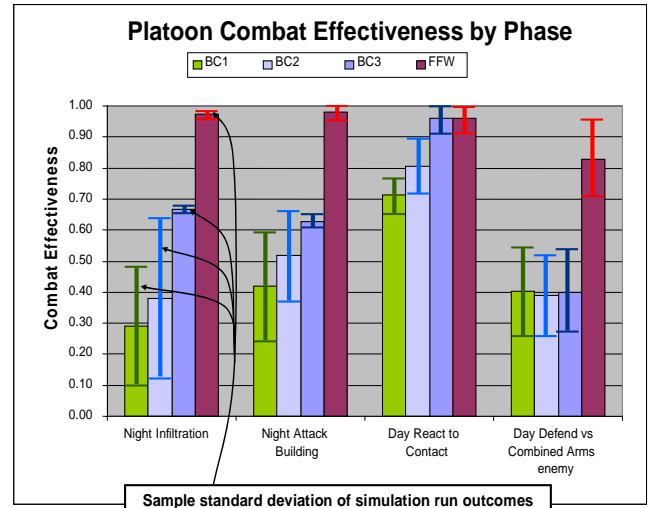


Figure 9. Combat effectiveness by phase

## CONCLUSIONS

The Future Force Warrior Advanced Technology Demonstration program has developed a methodology by which to assess the contribution of new warfighting capabilities to overall small combat unit effectiveness. The methodology allows us to optimize the design of new Soldier systems and compare these designs to others to support programmatic decisions.

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