Evaluating UAV Impact in the Tactical Context of a Mechanized Infantry Scout Platoon Through Military Simulation Software

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Abstract Military simulation has been established as a computational and scientific tool for assessing the performance in combat of equipment, ranging from land mines to aircraft, and the suitability of tactics, ranging from platoon to division level. To this end, specialized software has been developed, replacing the traditional Prussian dice-throwing, turn-based war games. JANUS is such a suite, allowing human-in-the-loop simulations from squadron to battalion scale based on realistic combat models based on historical conflict data. This paper presents the initial results of a recent large scale campaign of experiments aimed to assess the effects of incorporating a UAV to a typical Hellenic mechanized infantry scout platoon. To the authors best knowledge, this is the first campaign of experiments undertaken by the Hellenic Military Academy. Therefore, there have been key contributions in a number of levels. On the software side, there are the development of a realistic mechanized infantry platoon advance scenario for JANUS, the creation and insertion of an appropriate UAV to JANUS unit database, the assessment of JANUS strengths and limitations for simulations of this scale, and the software development

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for parsing JANUS voluminous output report text files. From a mathematical perspective, there is the statistical analysis and interpretation of simulation results. Finally, there is the experimental aspect, where heavy emphasis has been placed on selecting the experiment independent, dependent, and control variables. Of equal importance was the skill level evaluation of the class III Cadets which have been volunteered as JANUS operators as well as their subsequent training. Ultimately, the software, mathematical, and experimentation aspects combined yield a framework for conducting large-scale defense experiments. As for the simulation per se, results indicate a considerable advantage to UAV possession as a reconnaissance asset, as scout platoons equipped with a UAV were able on average to fire more rounds over longer distances and inflict more losses to enemy forces. Ultimately, these factors enabled friendly units to accomplish their objectives.

Keywords Constructive simulation • Combat model • Defense experimentation • UAV • Military simulation • Wargames • Scout platoon • Descriptive statistics • Termination criteria • JANUS

Introduction

During recent years a rapid increase of the worldwide military conflicts complexity in tactical, operational, and strategic level has been observed. Said complexity combined with requirements regarding operational cost curbing, environmental protection, as well as increased force protection measures, led to the realization that Western armed forces need to focus on modernizing personnel training, on developing and testing doctrines reflecting the context within current conflict occurs, and on implementing new systems or upgrading existing ones in order to satisfy any set of realistic operational constraints and to furthermore achieve the expected goals in the best possible way [1]. Within the typical framework of a nations' armed forces the set of requirements along with the associated expected outcome is determined by the General Staff whereas the assessment of a proposed operational solution is carried out among others by a dedicated military simulation group tasked with defense experimentation. Given the highly technical nature of military simulation and the complex nature of conflict itself, in order to deliver meaningful answers to upper echelons this simulation group should be fully familiar with both the underlying mathematical model [2] and the actual simulation system, typically a combination of specialized software and hardware.

Overview and Goals

KEPYES, the Hellenic Army IT center, has a Military Simulation and Wargames staff section which operates within the general framework of developing, evaluating, and deploying defense experimentation tools and systems in order to assist the Hellenic Army General Staff select the best possible alternative among Hellenic Army operational options.

During spring of 2012 KEPYES Military Simulation and Wargames designed and oversaw the first stage of a larger campaign of experiments [2–4]. In these experiments a group of class III Cadet Officers from the Hellenic Military Academy initially were trained in the use of the latest edition of JANUS version 7.3 war game. Subsequently, they assumed the role of a typical in size and composition mechanized infantry platoon commander in the JANUS digital battlefield. An extensive series of simulations evaluated the impact of providing a suitably equipped UAV as a reconnaissance asset to the scout platoon. Besides this obvious objective, two longer-term goals were to create a defense experimentation framework and a statistical analysis framework in order for reaching conclusions quickly and accurately.

Methodology

In this section the experimentation methodology is outlined. The experiment setup is explained, followed by a detailed outline of the simulation scenario as it was played in JANUS platform, and finally the actual JANUS parameters are listed.

Simulation Setup and Operator Selection

At the early experiment design stages, given that JANUS was the simulation platform of choice, human-in-the-loop simulation methodology [2] has been selected. The latter implies that human operators with continuous, real-time interaction with simulated forces and/or equipment were to be part of the simulation process. In general, human operators must be selected in such a way as not to interfere in any conceivable way with the simulation outcome, unless of course their performance or another aspect of their behavior is to be observed.

As it was stated in the goals section, the immediate experimentation objective was to quantify the effects of adding a UAV to a scout platoon assets. Therefore, any human operator interference had to be isolated. To this end, the original pool of 60 class III Cadet Officers was divided into two equally sized groups A and B in a way that the distributions of the military science course weighted averages were almost identical within the two groups. Cadets of group A were operating a UAV whether those of group B were relying on existing target acquiring systems (Fig. 1).

For the experiment purposes, two personal figures of merit for each Cadet have been computed. $Tmil_i$ is based only on military science courses and is an indicator of each Cadet military skill level, whereas G_i is based on all courses and is an indicator of each Cadet overall skill level. The subscript i ranges over the N Cadets that have been volunteered for this experiment.

$Tmil_i$ is calculated in the following manner. Each applied military training course a had a weight of 0.75, each staff course b had a weight of 0.15, and each leadership course c had a weight of 0.1. Let a_i^A, b_i^A, and c_i^A be the course grades for cadet i for

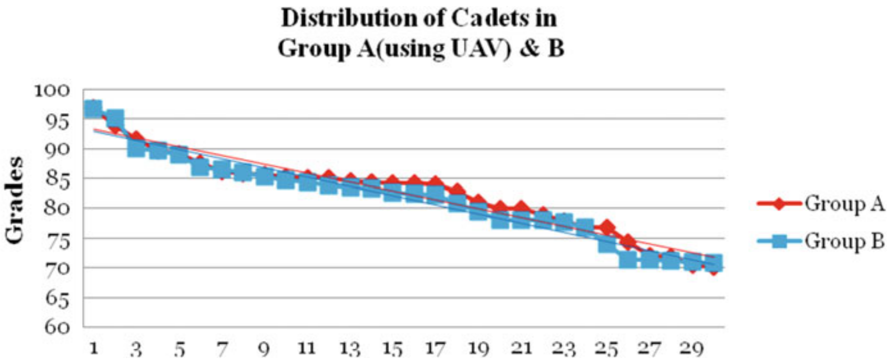

Fig. 1 Weighted course grade average of the Cadets

the first year of studies and a_i^B, b_i^B, c_i^B for the second. Then, the weighted average of the first- and second-year courses yield $Tmil_i^A$ and $Tmil_i^B$, respectively according to the formulae

$$Tmil_i^A = 0.75 \sum_{a_i^A} a_i^A + 0.15 \sum_{b_i^A} b_i^A + 0.1 \sum_{c_i^A} c_i^A, \qquad 1 \le i \le N$$

$$Tmil_i^B = 0.75 \sum_{a_i^B} a_i^B + 0.15 \sum_{b_i^B} b_i^B + 0.1 \sum_{c_i^B} c_i^B, \qquad 1 \le i \le N$$

and finally

$$Tmil = 0.6\,Tmil_i^B + 0.4\,Tmil_i^A, \qquad 1 \le i \le N$$

Let p_i^A and p_i^B be the course grade for Cadet i, where p^A and p^B ranges over courses taught in first- and second-year of study, respectively. First, p_i^A and p_i^B are normalized as percentiles of the respective maximum grades

$$g_i^A = \frac{p_i^A}{\max\{g_i^A\}} 100, \qquad 1 \le i \le N$$

$$g_i^B = \frac{p_i^B}{\max\{g_i^B\}} 100, \qquad 1 \le i \le N$$

Then

$$G_i^A = \frac{1}{|g_i^A|} \sum_{g_i^A} g_i^A, \qquad 1 \le i \le N$$

$$G_i^B = \frac{1}{|g_i^B|} \sum_{g_i^B} g_i^B, \qquad 1 \le i \le N$$

and finally

$$G_i = 0.6\, G_i^B + 0.4\, G_i^A, \qquad 1 \le i \le N$$

The final ranking W_i for each Cadet was the weight linear combination of the military ranking $Tmil_i$ and the general ranking G_i as follows

$$W_i = 0.6\, Tmil_i + 0.4\, G_i, \qquad 1 \le i \le N$$

Once the rankings were available, they have been sorted and every other Cadet has been assigned to group B. This simple scheme yielded two groups whose skill distributions were very similar. Class III Cadet groups A and B can be considered homogeneous for our statistical analysis purposes for the following reasons.

- They are of relatively young age and, thus, their overall experiences are still limited.
- They have quite similar social background and they have received formal primary and secondary education under a centralized education system.
- They have received the same level of training with the same intensity. This is particularly true both for the infantry tactical training at the team and platoon levels and for the JANUS software suite itself.

As a final notice, although the original Cadet pool was of mixed gender, creating separate two subgroups, one for male and one for female Cadets, within each group A and B served no apparent purpose, as human influence to the experiment outcome had to be isolated. Instead, a gender-neutral policy was deemed appropriate for the purposes of this experiment.

Scenario

The scenario is built around blue force alpha, a reinforced mechanized infantry scout platoon operated by a Cadet Officer comprised of 2 Leopard 2A4 and 2 VBL armored scout vehicles. Blue force alpha spearheads the advance of its parent company, blue force beta, which has been ordered to capture an objective point code named P3. On the other side, there is red force, a reinforced tank platoon consisting of 4 M-48A3 MOLF, 1 mechanized infantry squadron, 2 M901 ITV, and 2 armored scout vehicles. Red force, operated as combat outpost, has been assigned the triple task to prevent blue forces from observing the defensive actions undertaken by other red forces in the area, to make blue forces assume battle formation, and to inflict casualties on the blue forces. To this end, red force has deployed its elements in four areas A, B, C, and D, all strategically located close to P3.

The weather conditions correspond to a clear summer day in with excellent visibility with both sides equally lit as the scenario starts at seven am local time. The terrain is mostly plains surrounded by hills with lots of vegetation, providing

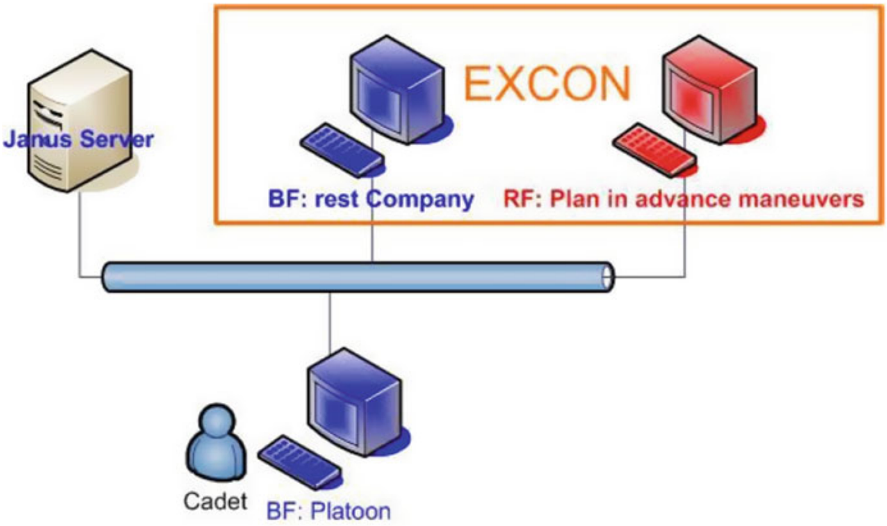

Fig. 2 Simulation network architecture

sufficient cover for both the attacker and the defender. Neither side has access to indirect fire or non-conventional weapons. Finally, all vehicles are in their respective basic configuration and personnel is carrying only standard issued equipment and weaponry. In short, this scenario represents a very common case of infantry combat (Fig. 2).

Part of the scenario were also the following simulation termination criteria, which have been derived from both national infantry military regulations and from NATO guidelines.

- T1: Blue force beta occupies and maintains a garrison to P3 in less than 3 h (victory).
- T2: Blue force beta fails to capture P3 within 3 h (defeat-unacceptable advance delay).
- T3: Blue force alpha losses exceed 30% (defeat-scout platoon in need of replacements).

The actual combat scenario proceeds as follows. As blue force alpha advances, it inevitably encounters the red force elements. At each of these contact points, the blue force alpha commander must assess the current tactical situation and judge as accurately as possible whether blue force alpha can by itself engage and overcome the opposition or not. In the former case, blue force alpha attacks, while, in the latter case, blue force alpha goes into defilade mode and waits for the arrival of blue force beta. In each of these cases, there are four possible outcomes (Fig. 3).

- Blue force alpha can overcome the opposition and its commander decides to attack. In this case, blue force alpha clears the advance path in minimal time with

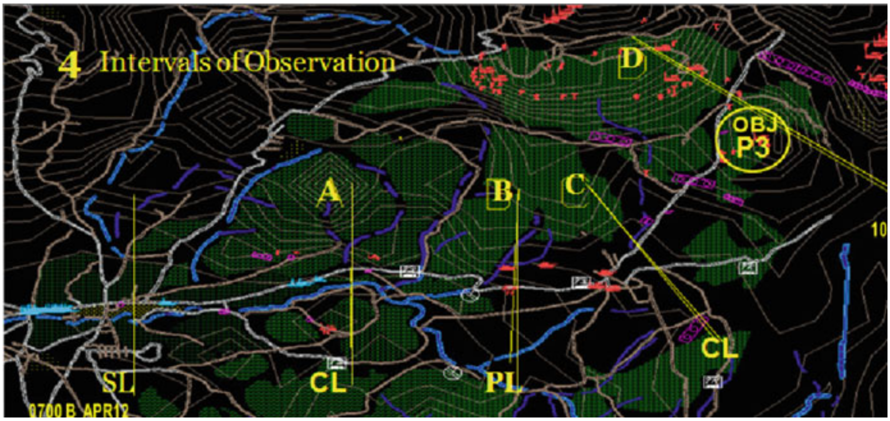

Fig. 3 Main points of target overlay (EXCON view in JANUS)

zero or few casualties. It is the optimal case from the blue perspective, but this case in the "run times" of the scenario appears rarely.

- Blue force alpha can overcome the opposition but its commander decides to wait for blue force beta, the latter being strong enough to overcome any red force element. However, local victory comes at the expense of time. This may endanger the entire mission if termination criterion T2 is met and, thus, commanders who wait too often are penalized.
- Blue force alpha cannot overcome the opposition and its commander decides to wait for blue force beta. As in the previous case, the overall advance is delayed and the termination condition T2 may hold true. However, blue force alpha remains intact and, hence, there is no risk for triggering termination condition T3.
- Blue force alpha cannot overcome the opposition but its commander decides to attack. In this case, blue force alpha either destroys the opposing forces after having suffered heavy losses or it is itself destroyed. Therefore, termination criterion T3 may be satisfied with high probability, which is the toll for an excessively aggressive tactic.

The above implies that the termination conditions T2 and T3 are complementary in the sense that the former excludes an overtly quiet tactic with no or few blue force alpha engagements, while the latter prohibits too risky tactics with blue force alpha engaging opposition at each opportunity. Between these two extrema there is middle ground for a number of tactics as well as limited margin for judgement errors on behalf of blue force alpha commander.

Blue force alpha commander judgement is formulated by skill, accounting for training and experience combined, as well as the reconnaissance data collected by blue force alpha vehicles and UAV, wherever applicable. Given that Cadet skill level distributions within groups A and B are identical as explained earlier, any difference in blue force alpha combat power should be attributed to reconnaissance data quality difference. In turn, since blue force alpha has identical composition across all scenario runs, it follows that any observed blue force alpha performance change should be ultimately attributed to UAV availability or lack thereof.

Experiment Variables and Experiment Hypotheses

Based on combat power definition [6] "*[. . .] elements are maneuver, firepower, protection, leadership and information guide the employment of all infantry forces [. . .]*," the dependent variables of interest in this campaign of experiments were the number of blue casualties and the occupation (or not) of the final objective by the friendly forces. The latter variable is qualitative in nature and outlines the general scenario outcome as a strategic planner would see it. The former variable contains information regarding the actual engagement and is mostly of interest to tactical planners. Other dependent variables to be assessed were the engagement average distance, the time taken to reach each objective, the percentage of missed shots, the number of objectives captured, and the kill exchange ratio of between blue and red forces.

The only control variable was whether blue force alpha had a UAV (or not) at its disposal. In order to ensure that there were no other hidden control variables affecting the experiment outcome, every parameter taken into account by operation planners, such as red force strength, terrain, and weather, has been the same across all scenario runs. Identifying all such possible control variables and the way JANUS handles them required familiarization with the combat simulation software suite. The independent variables were the strength and deployment pattern of the red force, the weather, the terrain, and the strength of blue force alpha and beta.

Finally, the null hypothesis was that the UAVs had no effect to the overall platoon combat power.

JANUS Run-Time Settings and UAV Settings

The weather conditions were typical of a summer Mediterranean day with a clear sky and full sunlight, namely Ambient Light Level 3, with a visibility of 12 Km, 90 degrees wind direction, 11 Km/h wind velocity, 6 Km cloud ceiling, 30% relative humidity, and 29 degrees of Celsius. Blue and red forces were equally lit and neither of them could exploit weather conditions to their advantage.

Defilade time, namely the time required for a stationary unit status to switch from exposed status to partial defilade, was 30 s. Detection cycle, the time required for a unit to complete a target detection cycle, was 3 s. Target list cycle, defined as the longest time for direct fire units to acquire targets and update their target list, was 50 s. Return to duty time, the amount of time a soldier system will be inactive while performing first aid, was 15 min. The hit and kill probability has been the

Table 1 JANUS database parameters for the new UAV

Parameter	Value
Speed (Km/h)	48–96
Flight time (min)	60–90
Altitude (m)	152
Sensor type	Classified
Machine type	Electrical rotor
Range of control	Classified

Table 2 Simulation results

Performance indicator	Group A	Group B
Percentage of victorious runs	10	0
Average shots (standard deviation)	90 (36.77)	74 (30.41)
Average engage distance	1,581 m	1,369 m
Average casualties	16	20

same in each of the 30 runs for each of the two groups. Finally, in each scenario execution JANUS linear congruential pseudo-number generator seed was always the same integer value.

Although JANUS database has a UAV type, early trial scenario runs have shown that its specifications and operating mode are unsuitable for a scout platoon. Thus, a new UAV type had to be created. The specifications used for the creation of a T-mini UAV model in JANUS database are summarized in Table 1. A run speed factor of 4.00 will run at approximately 10 min of simulated time for every minute of real time.

Results

Using the JANUS Analyst Workstation and its Post Processing capabilities, a large report file in text format has been generated for each scenario run from the JANUS binary event recording files. These ASCII report files were in turn parsed using a custom shell script in order for data of interest to the specific experiment to be isolated and extracted among the detailed account of each combat event.

In total 8 scenario run from both Cadet groups that were deemed as outliers and were not examined further. Simulation data from the remaining 52 runs were processed using descriptive statistics and survival analysis in MATLAB and STATA and yielded the results of Table 2. Points A, B, C, and D have been used as references in Figs. 4 and 5.

As it is shown in Table 2, 10% of group A commanders accomplished the mission in contrast to group B, where no commander managed to do so. Additionally, blue forces in group A on average fired 20% more rounds over a 14% longer distance and, in principle at least, had better chances to inflict losses to the red force elements

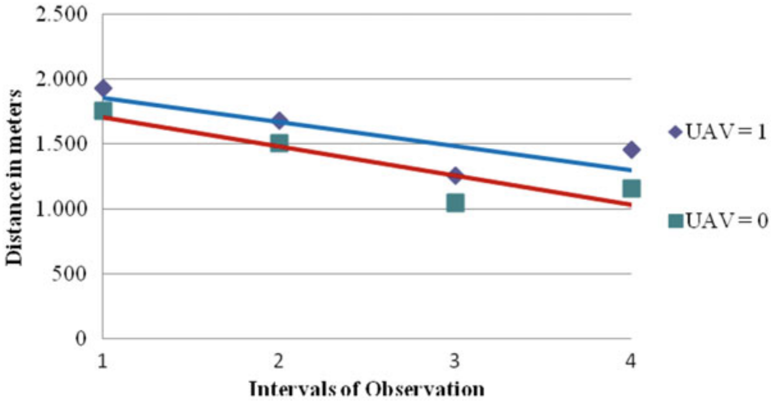

Fig. 4 Average distance of shots for blue force alpha

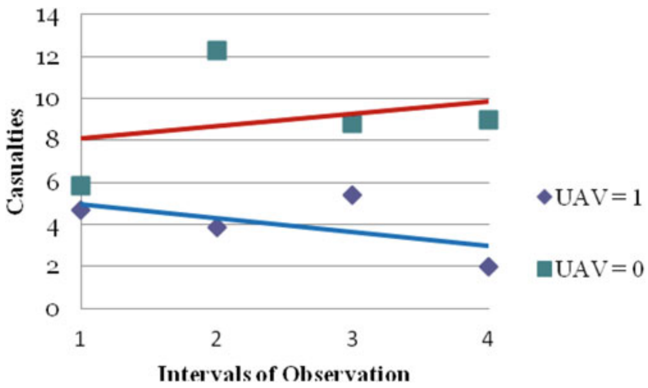

Fig. 5 Average number of casualties for blue force alpha

from a safer distance. At the same time, blue forces in group A suffered on average 20% less casualties. Notice that the above results are statistically significant as p was less than 0.05.

One of JANUS known limitations [5], circumvented in modern simulation platforms, is its lack of human behavior modeling. In any scenario execution friendly and enemy units carry out their orders with a varying degree of efficiency independent of combat events and general troop morale and affected primarily by unit operational status and type—for instance a sniper is better in target acquiring than a regular infantryman. Simulation results should be interpreted therefore under this light.

Conclusions

This paper outlines a summary of the results obtained from of a recent large scale campaign of experiments, which took place at the premises of the Hellenic Military Academy using the JANUS military simulation suite. These experiments have been conducted under the supervision of KEPYES Military Simulation and Wargames staff section with the assistance of class III Cadet volunteers acting as JANUS operators. To the best knowledge of the authors, this is the first time that a campaign of experiments of this scale took place at the Hellenic Military Academy. This implied that KEPYES Military Simulation and Wargames staff section had to develop most analytical and software tools from start, including a bash script for parsing JANUS long output, STATA and MATLAB functions to compute statistical quantities of interest, and to determine the dependent, independent, and control variables. Though not a trivial task, an initial Hellenic experimentation framework, covering software, mathematical, and experimentation aspects, has been established to serve as a future guideline.

In parallel to developing this framework, the actual simulation runs took place. The simulation scenario entails the advance of a mechanized infantry scout platoon, a common and realistic situation in ground combat, and aims at evaluating the effects of adding a UAV to this platoon as a reconnaissance asset. Results obtained through statistical analysis revealed that UAV possession considerably improves battlefield survival probability. A quantitative review indicated that UAVs compared to existing observation and target acquisition systems extended effective visibility, which in turn translated to more accurate shots over 14% longer distances on average as well as to 20% less casualties on average.

Major efforts have been placed on ensuring that human factor did not influence the simulation outcome. To this end, it was imperative that the JANUS volunteer operator pool be divided into two equally sized groups A and B of comparable capabilities. This has been achieved by ranking the Cadets according to a weighted average of their course grades, sorting the result, and assigning every other Cadet to group B. This practice resulted in two groups whose ranking distributions were extremely similar. Group B operators relied only on reconnaissance data from their scout platoon vehicles, whereas group A operators could additionally deploy a UAV.

To obtain more accurate conclusions besides the general trend, more experiments need to be conducted regarding the UAV integration into army tactical echelons. Moreover, it should be underlined that a detailed knowledge of combat model used by the simulation software is a prerequisite for defense experimentation.

References

1. NATO WG CD and E, 2011
2. Code of Best Practice “Experimentation”, DoD Command and Control Research Program (CCRP) Publication Series, Alberts, David S., Hayes, Richard E, July 2002

3. Code of Best Practice “Campaigns of Experimentation”, DoD Command and Control Research Program (CCRP) Publication Series, Alberts, David S., Hayes, Richard E, March 2005
4. Guide for Understanding and Implementing Defense Experimentation (GUIDEx), The Technical Cooperation Program (TTCP), Version 1.1 February 2006
5. JANUS Model Documentation, KEPYES 2012.
6. FM 3-21-71 Mechanized infantry platoon and squad (Bradely fighting vehicle), US Army 2002.