Mission Integrated Simulation

A Case Study of Simulation Supported Ranger Missions

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Cover: The ranger unit on the move.
Photograph by Per Wikberg.

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Sammanfattning

Syftet med denna studie var att utforska användningen av verktyg för 3D-modellering och simulering som ett uppdragsintegrerat stöd för att förbereda, genomföra och utvärdera en insats – i detta fall ett jägaruppdrag. Visionen var att förbättra planeringsprocessen och genomförandet samt ge bättre underlag till utvärderingen genom att låta en insatsstyrka ha tillgång till en interaktiv 3D-modell över aktuellt insatsområde. Studien genomfördes under en åtta dagar lång övning under vilken en jägarinsatsstyrka (14 personer) hade som uppgift att spränga ett objekt. Under planeringsfasen användes en 3D-modell över insatsområdet och spelmotorn VBS2 för taktiska förövningar och virtuell terrängrekognosering. Styrkan innästlade och etablerade sig i området, genomförde uppdraget och urnästlade sig. Övningen avslutades med en utvärdering. Data insamlades med hjälp av observatörer, enkäter, GPS, röstinspelning, hjälmmonterade kameror och intervjuer. Preliminära resultat presenterades och diskuterades med deltagarna vid utvärderingen.

Sammanfattningsvis indikerade resultaten att möjligheten att göra virtuell rekognosering var ett värdefullt planeringsstöd, men att det krävs information vid sidan av det som återfanns i den 3D-modell som användes. Resultaten indikerade att den spelbaserade förövningen upplevdes som mindre värdefull med de förutsättningar som förelåg. Möjligheten att i spelet värdera styrkor och svagheter med olika handlingsalternativ upplevdes som begränsad. Värdet av tillgången till 3D-modellen låg främst i att den gav en bättre spatial förståelse för insatsområdet. Resultaten visade också att möjligheten att återuppspela händelseförloppet i modellen förbättrade möjligheten att dra slutsatser från genomförandet. Studien påvisar att uppdragsintegrerad simulering i detta fall inte ersätter konventionella verktyg och processer. Emellertid ger 3D-modellen möjlighet till ett mer intuitivt sätt att tänka kring avstånd och skjutvinklar jämfört med traditionella kartor och flygbilder. En central slutsats är att 3D-modellen måste ha en tilläckligt bra upplösning. I ett mer komplext scenario kan man möjligen förvänta sig att en virtuell modell kan reducera tids- och resursåtgång för insatsplanering. Möjligheten att exploatera ett koncept med uppdragsintegrerad simulering bör därför utredas vidare. Genom att utnyttja tillgängliga verktyg och plattformar och att fokusera på lösningar som är möjliga att realisera inom 5-10 år borde det var möjligt att öka effektivitet och förmåga vid insatser med begränsade investeringar.

Nyckelord: 3D-modeller, After Action Review, Datorspel, F-REX, Modellering och Simulering, Planering, Spelbaserad träning, VBS2

Summary

The purpose of this study was to explore the potential benefit of using 3D-modeling and simulation as mission integrated tools to prepare, execute and evaluate a ranger mission. It was envisaged that for the ranger task force's execution of the mission, having access to an interactive 3D-model of the mission area would add value to the planning process, enhance performance during the execution and provide means for enhancing the debriefing. The study was undertaken in the context of an eight day exercise in which a 14 personnel strong ranger unit had the task of destroying an antenna. During the planning phase game-based mission rehearsals were undertaken by using a model of the mission area in VBS2. The unit established in the area and performed reconnaissance, executed the mission task, and subsequently left the area. The exercise was concluded by a hot wash-up and After Action Review (AAR). Data was collected by observers, questionnaires, GPS, voice recording, helmet mounted video cameras and team interviews. Preliminary results were presented and discussed with participants during the AAR.

In summary the results indicated that the possibility to do a virtual reconnaissance was a perceived as valuable. However, additional information is needed besides the information available in the present 3D-model. Results also indicate that using the game to do an interactive mission rehearsal was valued relatively less. The usage of the model for identifying the strengths and weaknesses of different alternatives was also perceived as limited. The value of having access to a 3D-model was rather by creating a better mental model of the target area. Replaying the mission in the model gave also a better overview of the actual chain of events and thus enhanced the possibility to draw event-based conclusions. A conclusion is that mission integrated simulation does not replace any conventional tools or procedures. Still, a virtual 3D-model which is "good enough" gives a supplementary perspective which increases the understanding of the shortcomings of any representation of reality (2D map or 3D virtual world). Still, the 3D-model offers a more intuitive way of thinking of distances and angles compared to a traditional 2D map. The study also concludes that an adequate level of detail in the model of the mission area is necessary. Given a more complex mission context, the usage of the virtual model is expected to reduce the amount of time that needs for other planning preparations. Consequently, the conclusion is that the concept of mission integrated simulation is worth further exploration. By utilizing already available tools and platforms and focusing on solutions that might be realized within 5-10 years it should be possible to enhance efficiency and ability with limited investments.

Keywords: 3D-models, After Action Review, F-REX, Game-based Training, Modeling and Simulation, Planning, Serious Games, VBS2

Content

1 Introduction

This report presents an experiment aimed at showing how current technology in the domain of modelling and simulation can be applied to support all phases of a mission. The aim of this mission integrated simulation concept is also to reuse information and models throughout the mission as well as afterwards in order to increase individual and organizational knowledge. The experiment was conducted within the Swedish Armed Forces' Research and Technology Development field of Modelling and Simulation, specifically by two projects aimed at studying game-based training and modelling of geographical information.

This chapter gives an introduction to the experiment as well as the mission (military exercise) that has been the setting of the experiment. The study was performed in the context of a ranger mission. The expectations that the experiment is aimed at testing are also presented.

The experiment was performed within an exercise with personnel from the Swedish Army Ranger Battalion, and support with modelling and technical setup of VBS2 was provided by Swedish Armed Forces' International Centre and Land Warfare Centre.

1.1 Scope and aim of the experiment

The scope of this experiment is to test and evaluate modeling and simulation (M&S) support to mission planning, rehearsal, execution, debriefing and evaluation. The vision is to use and adapt currently available modeling and simulation technology to increase capability in terms of enhanced planning, increased preparedness and enhanced learning from combat missions at company, platoon or group level. Furthermore, this technology and the methods employed should enable support to the mission with short time for preparations, for example in terms of creation of mission specific models. The application of currently available tools will also keep the costs at a minimum.

The purpose of this study was to explore the potential benefit of using M&S tools such as VBS2, high resolution terrain and object data in 3D as well as data recorded during the mission as a tool to prepare, execute and evaluate a mission. Furthermore, the study aims at investigating the demands that addresses the limitations of these tools and models. The study has been restricted to focus on planning, rehearsal and debriefing.

1.2 The concept of mission integrated simulation

As outlined in Figure 1, available information such as geographic information, as well as specific intelligence information or up-to-date geographical information can be gathered and used to construct a 3D virtual model of the mission area. This model can be used for mission planning as well as game-based training/mission rehearsal in the actual geographical area with the latest available information about conditions and enemy location etc. 3D-models together with real-time data from the mission can be used for enhanced command and control tools as well as for re-planning in the field. Furthermore, the collected data can be used to support after action review (AAR) and can also be fed into the training game for replay and enhanced learning. Modeling and simulation tools can be used to analyze lessons identified, which increases the ability to understand what and why things happened, which in turn creates lessons learned. Models developed together with the recorded actual course of actions can also constitute a validated training scenario for future training.

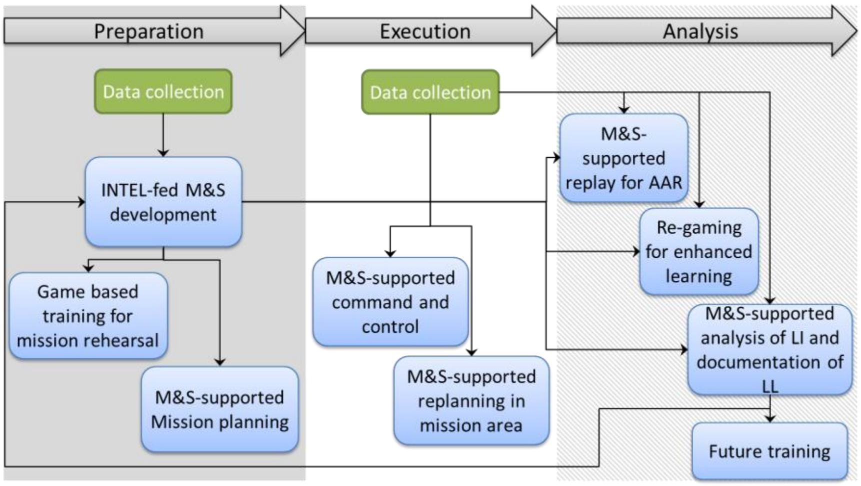

Figure 1. Possible components in a modelling and simulation supported mission concept. Information about target, geography and enemies etc. is gathered from available sources as well as targeted intelligence collection before a mission and used to build models for training and planning. Information updated during execution is used for decision support and replanning. Finally, all the available information is used for enhancing after action review, learning, Lessons Identified and Lessons Learned and implemented in future training.

1.3 M&S tools for planning, training and analysis

This study has focused on three aspects of the concept described in Figure 1: *game-based mission rehearsal*, *planning* and *AAR*. The initial ambition was to model the mission area for game-based training and planning, collecting data during execution and re-use the same model and game for AAR.

As an example of how to increase the usage of existing and procured M&S technology, Virtual Battlespace 2 (VBS2[1]) was chosen as the M&S tool for demonstrating the usage of 3D virtual models for planning and mission rehearsal. VBS2 is a 3D simulation training system for dismounted soldiers, operated from the first person perspective on standard desktop computers.[2] VBS2 has been used at the Swedish Land Warfare Centre and a few other places for several years[3] and after the procurement of an enterprise license late 2012 VBS2 is on the way of being rolled out to several training sites and regiments.

For the purpose of this study, the capability to feed data back into the VBS2 model was however not explored. Instead a tool developed at FOI, F-REX, was utilized for replay and analysis of recorded data after mission using GPS-data, and voice and video recordings.

The tools selected are just examples of possible systems to use, and have not been compared to any other systems. A requirement in selecting the tools is availability, ease of use and usefulness as well as access to administrators. During this experiment, VBS2 has been provided by Swedish Armed Forces, whereas F-REX has been provided by FOI. The present study does not aim at evaluate these systems as such.

Virtual Battlespace 2 (VBS2) is a simulation system based on a virtual 3D environment where dismounted soldiers, weapon systems, platforms, vehicles, etc. and their interactions are simulated[4]. The system supports land, air and maritime simulation, and is designed for training on soldier, group and platoon level. VBS2 is built on the commercial game ARMA 2 providing the same virtual environment in a tactical first person shooter

[1] http://products.bisimulations.com/products/vbs2/overview. Accessed 2013-12-09.
[2] White Paper: *VBS2*, 2012, Bohemia Interactive Australia Pty Ltd; http://www.vbs2.com.
[3] Oskarsson, P.-A., Allberg, H., Nählinder, S. & Hedström, J., *Användning av VBS2 inom Försvarsmakten*, 2012, FOI Swedish Defence Research Agency; FOI-R--3541--SE.
[4] White Paper: *VBS2*, 2012, Bohemia Interactive Australia Pty Ltd; http://www.vbs2.com.

software, but is developed into a serious game for training. This includes an interface for easily creating customized training scenarios, a real-time editor allowing the user to change the scenario during execution for example regarding enemy forces. It also includes a functionality for AAR. VBS2 is normally run over a network, allowing a large number of trainees in the same scenario. VBS2 also integrates support for interaction with other simulation systems (through DIS or HLA), as well as support for a number of third party products in support of training or model and scenario generation.

VBS2 is used today by the Swedish Armed Forces (Swedish Armed Forces) as well as armed forces from a number of other countries, as a tool for teaching and training for example tactics and procedures for groups and platoons in both offensive and defensive situations. The Swedish usage has mainly been focusing on training the commander in tactics, giving orders and communication within the group. For this type of training VBS2 has a feasible level of fidelity creating an effective learning environment.

Figure 2 shows a screenshot from the interface of the VBS2 runtime environment.

One of the features of VBS2 is the possibility to import real-world terrain areas, and create and configure new 3D-models. Presumably, this gives the possibility to use the system not only for training but also to support planning and execution of real missions by importing a 3D-model of the mission area as well as the possibility to feed recorded data from the real mission back into the system for debriefing and lessons learned. For the context of national defense in Sweden a lot of terrain data are available, including a large amount of data regarding tree positions, type and density. This kind of data can be used to create a 3D-model for VBS2 or other systems.

Figure 2. Interface of the VBS2 runtime environment.

F-REX, “FOI Reconstruction and Exploration”, is a toolset developed to support evaluation by constructing mission histories and exploring them through multimedia presentation in the main application, the F-REX Studio[5]. The toolset also contains several applications for recording and collecting necessary data including – but not limited to – GPS tracks, computer screenshots and radio communication. One of the most important features of these data collection tools is time synchronization. All recorded data must be time-stamped and tagged by its source in order for the Studio to correctly visualize the contents and enable the analyst to see it in its right context. The F-REX toolset was developed using experiences drawn from several years of usage of an earlier R&E

[5] Andersson, D., Pilemalm, S. & Hallberg, N., *Evaluation of crisis management operations using Reconstruction and Exploration*, 2008, Proceedings of the 5th International ISCRAM Conference – Washington, DC, USA, May 2008 (F. Fiedrich and B. Van de Walle, eds.).

framework, MIND[6] and consequently uses a similar representation of the mission history, shown in Figure 3.

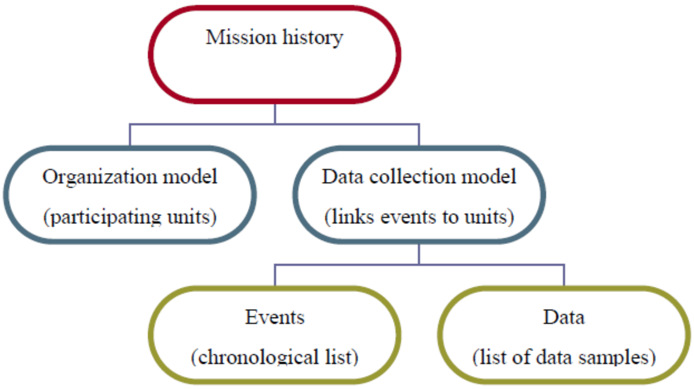

Figure 3. F-REX representation of a mission history. The organization model holds information on the organization, mostly known prior to the operation starts, such as participating units, planned events, incidents and injects, area of operation and more. The data collection model on the other hand holds information about what really happened such as reports, recorded data and observations.

The F-REX Studio plays back the entire mission history from the start to the end, with elementary functions such as pause, resume, rewind and fast forward. This, together with the filtering functionality, enables the analysts to shift between different foci and observe the chain of events in a meaningful context to make extended conclusions from simultaneous incidents occurring at different locations by multiple actors. A screenshot of F-REX Studio in action is given in Figure 4.

The analysis process described above can be more or less time consuming depending on input information known by the analysts and research questions asked. For a traditional AAR though, detailed analysis may not be necessary as the AAR itself can be part of the analysis. In these cases F-REX serves merely as a tool that will help visualize for the participants what actually happened and therefore raise the debriefing discussions from *what happened* to *why it happened*. An analyst will regard this AAR as another opportunity to collect data about the exercise and feed that back into F-REX and the mission history, extending it with a layer of metadata that can be used as input for further analysis.

[6] Jenvald, J., *Simulation and Data Collection in Battle Training*, 1996, Linköping Studies in Science and Technology, Thesis 567, Linköping, Sweden: Linköpings universitet.
Morin, M., *Multimedia Representation of Distributed Tactical Operations*, 2002, Linköping Studies in Science and Technology, Dissertation No. 771, Linköping, Sweden: Linköpings universitet.

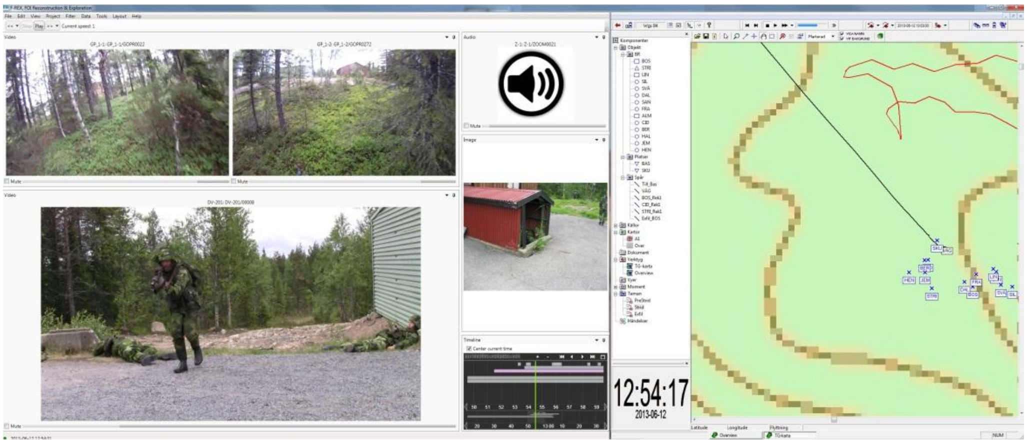

Figure 4. Screenshot illustrating the F-REX visualization.

1.4 Swedish Army Ranger Battalion (AJB)

The study was performed at the Swedish Army Ranger Battalion (AJB) in Arvidsjaur, Sweden. The Ranger Battalion is the Swedish Armed Forces' main resource capable of fighting and intelligence gathering far behind enemy lines where other units could not operate or achieve the same effect. It is a rapid response unit to be employed on missions in environments or locations in which the desired effect cannot be achieved using conventional land forces, or used for providing support that other units need in order to accomplish their goals anywhere in Sweden or in adjacent areas.

The ranger unit can operate in all environments but with a particular capability in sub-arctic conditions. The core unit of the battalion is the ranger platoon – formed around five squads. Some of the squads are specialized on operations in mountainous terrain. The platoons are organized in a flexible way in order to allow for adaptation to the mission-specific requirements.

Units or personnel from the battalion have recently been engaged in several international missions including Afghanistan, Bosnia, Kosovo, Pakistan, Ukraine and Tchad. The unit is trained by the Norrland Dragoons' detachment in Arvidsjaur.

Execution of a ranger mission follows a five step mission cycle (Figure 5), as summarized below.

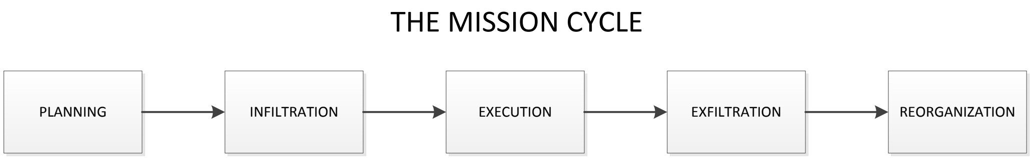

Figure 5. The five step cycle of a ranger mission.

Mission Planning. The planning phase is initiated when the unit receives the order and ends when the last material checks have been performed. The planning phase includes two important functions: to *imagine a desired outcome* and to *arrange a configuration of possible actions* in time and space to obtain that outcome. The phase includes such actions as development of order, technical and tactical mission rehearsal and feed-back to superior commander.

Infiltration to mission area. The infiltration phase includes transportation to a location as close as possible to the target and the subsequent approach by foot or on skies to the target area.

Execution. The execution phase includes:

- *Establishment* in the area in form of a base to enable on-site planning, preparations and recovery.
- *Reconnaissance* by the collection of additional intelligence about the target in order to assess whether the plan is possible to execute.
- *Execution* of task by realizing the plan.
- *Withdrawal* from the target area.

Exfiltration. The exfiltration phase includes movement by foot or on skies from the target area to a location where it is possible to use other means of transportation.

Reorganization. The reorganization phase includes *debriefing* of the task force in order to review the mission in chronological order, *maintenance* of equipment and *recovery*. The purpose of the debriefing is to obtain additional information about the enemy and ensure that observations and experiences are exploited in forthcoming missions.

1.5 Mission integrated simulation for ranger missions

Implementation of the concept of mission integrated simulation (Figure 1) is dependent on the specific characteristics and needs of each military unit. Since in this study a ranger mission is in focus, a more concrete solution was outlined with the support of officers from AJB. Besides tactical and distributed training, features already distinctively implemented in VBS2, a number of additional ways to utilize simulations were identified. Some of these already exist in VBS2, while others need additional tools. The following lists the M&S support envisioned for a ranger mission.

Support planning of missions based on 3D data of target objects and surrounding environment. Based on available geographic information and information obtained by dedicated intelligence systems, a 3D-model can be created. Different options in terms of own and enemy behavior can then successively be tested in the virtual environment. In addition, the virtual environment can also enhance a spatial knowledge about the target area. This functionality is already implemented in VBS2.

Support command and control. During the execution it might be possible to register GPS-positions, voice communication, etc. and stream it to a command post where the chain of events can be visualized on-line in the 3D-model. Some direct support from the commander can also be imagined, such as suggesting approach routes by navigating in the model. Neither on-line import nor visualization of GPS-data are implemented in VBS2. Consequently, the realization of this functionality must currently depend on other tools.

Task force re-planning in the mission area. If intelligence information indicates that the precondition for the mission has changed since the mission planning phase, it might be necessary to execute a re-planning. In principle, this could be done in a similar way as described above. The important difference is that the re-planning is executed in the mission area with a less optimal infrastructure and less technical support to modify the virtual environment.

After Action Review (AAR) of mission. Data from GPS, voice recorders, etc. can be imported into the 3D-model and replayed in order to support debriefing after the execution of a mission. Although functionality to support AAR is implemented in VBS2 it is designed to replay the chain of events from the runtime environment of VBS2. Visualization of data from physical environments needs support from additional tools.

Lessons Learned (LL) database. Collected data from the mission and the AAR can be imported to the 3D-model and adapted for a Lessons Learned database. Examples of how to utilize this database includes tactical training, development of improved tactics, demonstrations, planning of new missions etc.

The primary foci of this study have been the support of mission planning and After Action Review.

1.6 Expectations

The experiment was set to probe a number of assumptions. In general it was envisaged that for the task force's execution of the mission cycle, having access to an interactive 3D-model of the mission area would add value to the planning process, enhance performance during the execution and focus the debriefing.

The planning process. The possibility to do a "virtual reconnaissance" of the terrain regarding advance routes, deployment areas etc. in a 3D-model was expected to add value to the planning process. As such it should, in hindsight of an executed mission, be perceived to have given an accurate impression of the mission area. It should also give inputs to comprehend the mission area which are difficult or impossible to obtain from a 2D geographical map or similar terrain representation. Finally, it should not be necessary to do any re-planning due to substantial differences between the terrain model and the real target area.

Another feature expected to add value was the possibility to do an interactive tactical mission rehearsal in the 3D-model. The enhanced possibility to test different alternative tactical behavior should enhance the possibility to identify the strengths and weaknesses of different alternatives and thus have an impact on the selection of a final plan. In addition, it should also result in a set of different rehearsed alternative chain of actions to fall back on in case the main alternative had to be changed. Ideally, the plan outlined after the tactical mission rehearsal should correspond to the final plan selected for the execution in the mission area.

Some concerns for the planning process were also identified. Firstly, one might expect unrealistic expectations on the 3D-model. Although the model has a high resolution it should be viewed as an approximation in the same way as any 2D geographical map.

Secondly, as analyzing the 3D-model was not assumed to replace other activities, it was reasonable to expect that the mission planning might be too time and resource consuming using the M&S tool.

Execution. Ideally, the expected enemy behavior and other challenges as expressed by the platoon commander in advance of each phase of the mission cycle should correspond to the actual chain of events. In addition, in case the plan fails the task force should be able to fall back on one of the alternative solutions developed during the mission rehearsal in the 3D-model.

In order to do so, there should be a correspondence between how the soldiers perceived the execution of the virtual mission rehearsal and the live mission execution in terms of realism, difficulty, how they performed and acted and how motivated they were.

In addition, there should be a similar correspondence regarding the relative importance of some "core success factors" for the virtual and real execution. These factors include planning, access to updated intelligence, soldier competence, communication and level of training in coordinated teamwork.

Debriefing. Replaying the mission in the model is expected to give a better overview of the chain of events and thus enhance the possibility to draw event-based conclusions from the mission. However, it is also a concern that the debriefing might focus on details that are less relevant.

2 Method

This chapter outlines the method employed in the experiment. This includes the overall experimental setup, characterization of the experiment's participants and a description of the exercise that was used as the base for the experiment. Furthermore, experiment preparations, data collection and analysis procedures are described.

2.1 Experimental setup

The study was undertaken by implementing selected parts of the mission integrated simulation concept in a military exercise. Experimental preparations before the exercise included reconnaissance in the mission area and subsequent creation of a terrain model in VBS2 of this specific area (see further section 2.4). The exercise was eight day long and based on a mission where a ranger unit had the task of destroying an antenna. The exercise comprised all the steps in the cycle of a ranger mission as described in section 1.4.

During the planning phase the 3D-model in VBS2 was used to complement the planning process. Game-based mission rehearsals were also undertaken in VBS2. A technical expert in VBS2 from Swedish Armed Forces' Land Warfare Centre supported the setup of computers as well as the VBS2 software environment during the planning and game-based mission rehearsal. The VBS2 computer equipment used during the experiment was also provided from the Land Warfare Center. During the mission rehearsal, enemy forces were played by the experimental staff and the VBS2 specialist.

During the live execution data was collected by observers and by GPS, voice recording and helmet mounted video cameras. In addition, data was also collected by questionnaires and team interviews with the participants. Data was compiled and analyzed, and preliminary results were presented and discussed with participants during the AAR.

2.2 Participants

The task force was formed by two ranger squads with six soldiers in each and two officers as unit CO and deputy. For the first squad and the CO, the exercise was the final test after completing one year of training to obtain ranger status. The other squad came from the mountain ranger unit and had already completed the ranger training.

Most soldiers in the first squad had one year of service. However, the CO and the deputy had served five year as officers before entering the one year ranger program. Consequently the average year in service is quite misrepresentative (mean value, MV=2.4, standard deviation, SD=2.4). Reported field experience varied between 3 and 6 (MV=4.6, SD=1.1) on the seven degree scale where 1 corresponded to no experience at all and 7 to very experienced. Reported experience relevant for the task had the same minimum and maximum values (MV=4.4, SD=1.4).

In contrast, the more experienced mountain ranger squad (MV years in service=3.5, SD=0.5) reported slightly higher values for both field experience (MV=5.5, SD=0.5) and experience relevant for the task (MV=5.2, SD=2.1).

Only the first squad participated in the planning activities with VBS2. Two thirds of the first squad reported having experience in using PC games. Typically they estimated to have spent 20 hours a week but most also reported that they in general have not played after they entered the ranger course. Only one of the soldiers had experience of using VBS2.

The first squad was very motivated for both the exercise as such (MV=7.0, SD=0.0) and the fact that VBS2 was to be a part of the exercise (MV=6.2, SD=1.0). Expectations were high for VBS2 and the possibility to do virtual reconnaissance (MV=5.8, SD=1.2).

However, there were significantly lower expectations ($p<0.005$, $t=5.0$, $df=5$)[7] for the possibility do a tactical mission rehearsal of the plan (MV=4.2, SD=1.0).

Expectations regarding the possibility to replay the chain of events during the debriefing showed a similar pattern. Expectations were high (MV=6.5, SD=1.4) regarding whether this would enhance the possibility to draw conclusions. In comparison, there were lower expectations ($p>0.05$, $t=2.7$, $df=5$) for the possibility do a tactical mission rehearsal of the plan (MV=5.5, SD=0.8).

2.3 The exercise

The exercise took place in a national scenario, with the task of the ranger unit to destroy an antenna or similar object. The exercise comprised all the steps in the cycle of a ranger mission as described in section 1.4. The planning phase was performed during three days at AJB in Arvidsjaur, offering an indoor environment for planning, preparation and game-based mission rehearsal. Transportation to the mission area and establishing the troops in the area was performed on the fourth and fifth days, including reconnaissance. On sixth day the mission was executed, and the subsequent two days was used for leaving the area, transportation back to the regiment and a hot wash-up.

After receiving the order, the planning started using printed maps. After a few hours the three person strong planning team was given the opportunity to use VBS2 for visualization of the virtual 3D-model of the mission area, which was subsequently used in the development of the plan. The following day the group of six soldiers and the platoon commander did mission rehearsal in VBS2, first on the main plan and after that on a second plan. During the five days spent in the mission area, all soldiers and commanders were equipped with GPS sensors and during the assault element of the mission additional data collection was undertaken, as described below. The exercise terminated by a hot wash-up on the last day. A selection of the collected data was replayed during this debriefing session, using the F-REX tool.

The addition of the experiment to the exercise did not change the overall exercise method, although it gave additional tools for planning, mission rehearsal and AAR.

2.4 Experiment preparations

SWEDINT[8] supported the project by preparing a VBS2 model of the mission area. The model, covering an area of 400 km^2 (20×20 km), was based on an elevation model with a resolution between the elevation points of about 5 m, draped with color aerial ortophotos. The geographical data was provided by GeoSE[9]. The ambition was to base the VBS2 3D-model on an elevation grid with 2 m resolution and to use a vegetation model with each individual tree in the area placed on correct coordinates. Such data, with individual tree position, species and size generated from laser scanning of the terrain, was available from the Swedish private company Foran Sverige AB. However, the tool for building the VBS2 3D-model could not handle the resulting number of individual trees. The new version of VBS2 has the capability for handling the preferred higher resolution data, but the

[7] These three values indicate the confidence, strength and basis of the obtained result. The p-value is the probability that the result is due to chance (and not due to systematic differences). In this case, the p-value is well under the normal limit (level of significance) of $p\leq 0.05$. The F-value is the test statistic, i.e. the ratio between “observed systematic variance between groups” and “observed variance between groups which is not systematic (error variance)”. Of course, F should be as high as possible but at least over 1.0. Degrees of freedom (df) is the number of entities which are free to “vary” when estimating the test statistic. Compared with the other two values, df is not as easy to translate into a pragmatic concept. However, it is important as it determines the exact form of the distribution of the probability distribution in the test statistic.

[8] SWEDINT, the Swedish Armed Forces’ International Centre, is one of the units having most experience from using VBS2 in Swedish Armed Forces.

[9] GeoSE is the Swedish Armed Forces’ support function for provide and maintain geographical information.

corresponding tool for model building was not upgraded correspondingly. Hence, the model that was finally used for the experiment was 400 km^2 based on the 5 m elevation grid, and the tree data was not used.

A generic Nordic woodland terrain model draped with color ortophotos was used. In close proximity of the target object, in an area of approximately 5×5 km, the model was refined additionally. The same terrain model was prepared from the orthophotos, but more carefully inspected to conform to fitting the borders between forest and open areas, as well as roads. The average tree height was adjusted to fit the actual area (from inspection and experience estimated to measure about 10 m). Furthermore, a reconnaissance was done in this area close to the target object, where photos and videos of the terrain and GPS-points of the object and roads of importance were collected. This data was used to refine the VBS2 model, for example in respect to tree types, tree density, under vegetation, rocks, smaller lakes, creeks and swamp terrain. Also the exact location of a road was added to the model based on the data collection in the terrain. Despite this, small trees and bushes, typical for subarctic terrain, were missing in the model. Also, smaller variations in elevation were missing, like ditches, holes and stone cairns. The small trees and bushes may slow down the reconnaissance phase in the real-world, as it would be harder to move at high pace and gather intelligence than what could be predicted from analyzing the model. Also, swamps were modelled only by fitting a photo to a flat surface. A first model was produced at SWEDINT three weeks before the experiment and subsequently updated after the reconnaissance in the actual terrain was done two weeks before the experiment.

Preparation of the 3D-model was somewhat delayed due to limited access to data (late deliveries). However, an estimated time for preparing the model was set to about three days by the military personnel responsible for the task. With a bit more streamlined process time could be shortened to about 24 hours when processes are more stable, given that data are accessible.

2.5 Data collection procedure

Data for the study was collected during the exercise. Data collection included observer protocols, participant questionnaires, GPS, voice recording, helmet mounted video cameras and team interviews.

All soldiers and commanders were equipped with GPS sensors throughout the time spent in the mission area (five days). Voice recording was performed on platoon commanders and group leaders, and helmet cameras were mounted on these commanders as well as on the machine-gunner. This data collection was performed only during the mission execution at the target object. GPS devices were also attached to enemy forces during relevant parts of the exercise. Sound and video recordings were also taken at the site of the objects during the assault. This data was collected for analysis and selected parts were replayed during the hot wash-up for debriefing purposes as well as for discussion of the game-based planning and rehearsal.

Data collection through forms and discussion was performed at the beginning of the exercise, after the game-based mission rehearsal and after the hot wash-up.

Observations. Observations were undertaken by the military umpires from AJB who followed the task force during the preparation and execution. The instructors used two different protocols to document their observations. The observations were overall performed for the purpose of the exercise, although some additions were made in order to collect extra information useful for the experiment.

One of the protocols was based on AJB normal observation protocol for documenting the execution of a mission cycle. As such it is based on the different sub-phases of the mission cycle. For each sub-phase, a number of actions, judged necessary for a successful execution are listed. The observer assesses whether these have been undertaken or not and, if applicable, makes a note. For this study, the protocol included a sub-phase for the tactical mission rehearsal in VBS2. A number of actions, judged relevant for the virtual mission rehearsal, were extracted by officers from AJB from the other sub-phases.

The other protocol was also based on the mission cycle. At the initiation of each phase, the umpire interviewed the platoon commander on his expectations on the phase regarding enemy behavior and what would be the major challenges. In addition, the umpire also documented whether any of these concerns were conclusions based on the outcome from the use of VBS2. Then, during each phase the umpire documented timing of events he judged to be of major importance, such as when the unit arrived at the base area. Finally, after each phase the umpire judged whether the commander's assessment corresponded to the actual chain of events. In addition he also judged the unit's performance regarding a number of features. Overall performance, preparedness in details, preparedness for alternatives, risk taking, tactical correct behavior and influence from external factors were judged on a seven degree Likert scale. In addition, any enemy engagements were documented in terms of reason for engagement and outcome. Finally, any unexpected events were characterized.

Questionnaires. Three different questionnaires were distributed during the exercise and answered primarily by the first team. The second team, the mountain ranger squad, only answered one survey which captured their experience.

A *background (pre-exercise) questionnaire* was filled in at an early phase of the exercise and included questions on the participants experience, expectations on the exercise, judgments on the importance of factors for the successful execution of a mission and expectations on VBS2 and F-REX. Most judgments were made on a seven degree Likert scale. One question was included at the end of the survey in which participants were given the opportunity to put forward other issues, conclusions, recommendations, etc. that that they found important.

A *questionnaire after the game-based mission rehearsal* was answered by the first team directly after using VBS2, in order to document their opinion on the system and the task. The questionnaire included questions regarding the realism of the model, the scenario and the task, the performance of the team, assessments on the importance of factors for the successful execution of the task in VBS2, whether VBS2 met the participants expectations in the planning process, perceived utility and limitations and whether they would use it again in a similar task. Most judgments were made on a seven degree Likert scale. One question allowing the participants to give any other feedback was included at the end of the survey.

A *post-exercise questionnaire* was answered directly after the debriefing. It included the same questions as the questionnaire after the mission rehearsal. However, the focus of the questions was the participants' opinions in hindsight of having executed the mission. It also included questions on whether the replay of the mission had focused on the relevant factors and if it had enhanced the possibility to draw conclusions.

Team interviews. Two team interviews were undertaken with the first team, the platoon commander and the umpires. The first one was undertaken after the game-based mission rehearsal during the planning phase. The interview focused on how the 3D-model affected the planning and the plan, and what tools would be useful for ranger mission planning, what aspects in the 3D-model and the game that were perceived as important, how limitations in the model were taken into account, and how the gaming experience affected the tactical behavior.

The second team interview was undertaken during the debriefing session, directly after filling out the post-exercise questionnaire. It was conducted as a discussion focusing on the expectations (Section 1.6) which were presented in bullet format.

GPS positioning. GPS receivers where used for logging the position over time for all individuals of the unit. Garmin eTrex Legend HCx outdoor GPS receivers were used. A log interval of 20 s was chosen, with regard to the speed of movement by foot and the available space for the track log, and proved useful. Once every 24 hours the log from each receiver was collected and batteries replaced. Hence, a complete position history for each individual solider could be obtained for the whole live exercise.

Video recording. During the assault element of the live exercise, head mounted video cameras (HMC) were used on six of the soldiers. GoPro cameras were used as HMC. Two video cameras were operated in the target area by two observers, and one hand-held video camera was used by an umpire following the unit. The cameras were collected after the assault phase of the exercise. Each video camera was time-synchronized manually before mounting.

Voice recordings. Recording of sounds was also conducted during the assault using digital voice recorders mounted on the combat vests of 6 soldiers (the same that were equipped with HMC). One sound recorder was mounted in the target area. Each sound recorder was time-synchronized manually before mounting.

2.6 Analysis

Data from observers regarding timing of major events were compiled in order to give a brief, yet comprehensive, description of the chain of events during the exercise. The purpose of this description was to give a frame for interpreting the other obtained results.

Quantitative data from the Likert[10] scale ratings were primarily analyzed with descriptive statistics. However, the questions which recurred over questionnaires were analyzed from repeated measures using MANOVA or ANOVA[11] test in order to identify any indications on changes over time in opinions etc.

Qualitative data put forward in the questionnaires there the participants were allowed to freely express themselves as well as data from observer protocols were analyzed by identifying comments which were similar in content. Each comment was given a brief summary. If comments of the same type were given by several participants, they were summarized together.

During the team interviews, comments and conclusions regarding the topics that were initially the focus, as well as any other comments that resulted from the discussions were written down. This qualitative data was considered in respect to whether it was a general view expressed by several of the team participants, or whether it was the opinion of one participant only. The team interviews were summarized with the objective to give a supplementary view of topics and comments that were hard to capture in the questionnaires.

Data from GPS, voice recorders and head mounted cameras were compiled in F-REX and used to illustrate selected events from the exercise during the debriefing. Selection of these events was done by the exercise manager. However, special attention was given to the execution phase and whether the VBS2 had prepared the participants for the events that occurred. Compiled events were also used as “anecdotal evidence” for the analyses and conclusions put forward in this report.

[10] The Likert Scale is a psychometric scale commonly used in surveys and questionnaires. The scale is named after its inventor, psychologist Rensis Likert. When responding to a questionnaire item, respondents specify their level of agreement to a statement, normally on a 1-to-5 or 1-to-7 rating scale.

[11] The MANOVA (multivariate analysis of variance) is a type of multivariate analysis used to analyze data that involves more than one variable at a time. Repeated Measures MANOVA determines whether a set of multiple variables differs significantly within a group between each time data is collected (i.e. over time).

3 Results

The results are presented here in two parts. Firstly, a summary of the chain of events from the exercise is given. Although these are not in themselves the interest of this study, they are presented here in as a base to which results and conclusions can relate. Secondly, the results are presented and related to the expectations (section 1.6). The results are subsequently summarized.

3.1 Chain of events and precondition for conclusions

This section summarizes the actual chain of events from the exercise.

Planning phase. Before using the 3D-model, a framework for a plan was developed. The target object was located on a hilltop, and the road up to the object as well as the object was missing in the printed map. However, the road up the hill to the object and a fictitious representation of the target object on the correct position was present in the virtual model. Although not an effect of the 3D representation, this information enabled a more detailed planning something that would not have been possible using only the map.

The unit started using the 3D-model for terrain inspection as soon as access to VBS2 was given. This occurred four hours after receiving the mission task and the initial planning phase had until then been by using available paper maps over the area. The most used feature in VBS2 was the possibility to “fly” over the terrain looking down at the ortophoto portion of the 3D-model. After the soldiers who were involved in the planning got more familiar with the terrain they started to define insertion points, march routes and bivouac areas using a combination of the VBS2 model and paper maps.

After the plan was developed, 6 soldiers and one commander (half of the unit participating the in the live exercise) rehearsed the mission in VBS2. This was performed twice, once at the end of the second day of the planning phase, when the main plan was rehearsed, and once at the beginning of the third and last day of the planning phase, when a backup plan was rehearsed. Only the assault element of the mission was played in VBS2, each game-session lasting between 10 and 20 minutes. The first game session was preceded by an introduction to VBS2 and allowed testing the game controls for about an hour. Apart from the two mission rehearsals, the participants were allowed to use VBS2 freely during the days of planning. Including the introduction to VBS2, the participants spent a total of a couple of hours in front of VBS2, mainly to freely explore the model as well as to get a grip of the tool itself.

During the planning phase the two first questionnaires were filled and the first team interview was performed.

Infiltration. Advancement to and establishment of the bivouac followed the plan into detail and the rehearsed route was used. After arriving in the area two reconnaissance patrols were sent out the first night. Results from detailed object reconnaissance showed that the terrain to the west of the object was unsuitable for the planned assault due to gravel piles and debris protecting the object from supportive fire. The plan needed to be adjusted and further reconnaissance detailed out a plan to attack from the east in cover of the dense woods.

Execution. During the assault the unit ended up with time pressure because of choosing a relatively long distance for the initiation point. This forced the commander to alter the plan to an alternative very similar to one of the back-up alternatives developed during the VBS2 mission rehearsal. Since this alternative was not well scouted and the unit had to move swiftly because of the time pressure, it ended up in tactical disadvantage. About 150 m from the object one soldier set of an alarm charge and the element of surprise was lost.

However, the unit fought their way into the object, very much as rehearsed in VBS2, and solved their mission objectives.

Exfiltration. Initially the exfiltration was very slow when the unit faced an enemy patrol watching the road they had to cross to escape the area. After detailed reconnaissance of the area they found the most protected spot for a road cross and awaited a lull in the patrol awareness. A quick dash over the road was successful and the unit could then take advantage of the vast wooded areas between roads. Enemy patrols mostly used vehicles on the roads the first night after the assault and was not able to get reinforcements to support the pursuit. In the morning after the assault, the enemy used a dog patrol to search an expected road crossing. The unit did actually cross that specific road and the dog found the track from the unit. After a few hours the unit realized it was followed and set up an assault to ambush their followers. After a short firefight, the enemy patrol was defeated and the exfiltration could continue. However, the enemy inserted a new dog patrol to resume the pursuit. After a few more hours the unit ambushed this enemy patrol as well. During the fight, a small part of the unit was assigned the task of looking for additional pursuers. At the late evening the unit was reunited and went into a holding area to await the coming pick up from helicopters.

Debriefing. A hot wash-up was performed in the same way as it is usually done, i.e. the team gathers for half an hour and through an open discussion note things done well and issues for improvement. This hot wash-up was complemented by presenting data from the experiment (GPS, sound and video recordings) using F-REX for one hour, and followed by the post-exercise questionnaire and the second team interview.

Summary of results regarding chain of events. The judgment is that the obtained data on the chain of events indicate no major deviations from the ranger mission cycle. Consequently, the conclusion is that the exercise has given an adequate context for analysis of the collected data. However, due to the limited number of participants, the basis for statistical results is limited. Hence, quantitative results should be viewed with some caution before any conclusions are drawn.

3.2 Results in regard to expectations

In advance of the exercise some expectations on the result were formulated, see section 1.6, regarding the use of modeling and simulation support for planning, execution and debriefing of the exercise. The results are presented here with respect to these expectations.

3.2.1 Using VBS2 for planning

An assessment on whether access to VBS2 to support planning led to the expected outcome was undertaken in two stages, after completing the planning process and in hindsight after completing the exercise.

Results obtained after completing the planning process. Data from the questionnaire after the mission rehearsal in VBS2 indicated that the members of the unit found the software being of average difficulty to handle (mean value, MV=2.8, standard deviation, SD=0.8; 1= very easy, 7 very difficult). In general (5 out of 6) the participants did not report that their earlier software experience had hindered them during the mission rehearsal.

The mission rehearsal using VBS2 felt motivational (MV=5.3, SD=0.8). However, this was a significantly lower assessment when compared to the participants own expectations indicated in the pre-exercise questionnaire ($p<0.05$, $F=7.4$, $df=1$).

The participants also assessed their performance during the VBS2 mission rehearsal as high (MV=5.3, SD=0.8). Correspondingly, they assessed the task as being easy (MV=2.7, SD=1.0; 1=very easy, 7 very difficult). Still, they judged the correctness of their tactical behavioral as significantly lower (MV=4.0, SD=1.1) than the performance assessment ($p<0.05$, $t=3.2$, $df=5$).

The realism was reported as being average for “planning in the terrain model” (MV=4.8, SD=1.2), “mission rehearsal” (MV=3.7, SD=1.2) and “scenario” (MV=4.5, SD=1.1). There were no significant differences between these expectations even if there was a tendency of lower perceived realism for “tactical mission rehearsal” ($p=0.06$). Interviews with the team indicated that the virtual model was perceived as an additional picture to help visualize, as a complement to the picture obtained by studying the map. An example of a shortcoming with VBS2 is though that in the current VBS2-model there was no difference in character of the ground such as how wet it is. Thus it was not possible to distinguish dry forest ground from mire. How swampy the wetland is is somewhat possible to get an indication of by studying shades in the orthophoto. The 3D-model was however perceived to help thinking through the mission element by element and analyze what is needed in the different steps. Finally, it was judged as less important to have the right equipment during the mission rehearsal, as the game and reality was anticipated to differ too much to make a meaningful representation of equipment in the game.

In the questionnaire, it was also reported that the use of VBS2 was beneficial for the planning process although the opinion varied (MV=5.0, SD=1.6). In the question allowing the participants to put forward other comments on this issue, half of the soldiers reported that they had experienced restrictions in the use of VBS2. This was primary regarding terrain details that were of importance when advancing toward the object, such as presence of ground vegetation and density of vegetation, wetlands and lines of sight. In addition the ranger soldiers also mentioned lack of their specific weapon systems in the environment. In the team interview, they reported that they were aware of possible limitations in the model. Information that affects the line of sight is very important for planning, and the team mentioned accurate position of trees, undergrowth, stones, apertures between trees and minor differences in elevation as important factors that might not be represented correctly enough in the virtual 3D environment.

The Repeated Measures MANOVA on questionnaire data showed no differences regarding the possibility to do virtual reconnaissance and the possibility do a mission rehearsal of the plan compared to the expectations reported in the pre-exercise questionnaire. The 3D-model and the tools in VBS2 reportedly enabled reconnaissance in the virtual world. This reconnaissance is something that otherwise would have been done once on site during the mission. The participants stressed that the virtual reconnaissance helped making decisions and faster reaching decisions of how to design the plan, in this case to attack from south.

The participants also reported that they would like to use VBS2 (with its current functionality) again if they were assigned a similar task in the future (MV=5.8, SD=1.0). In addition, the following summarizes paragraphs some further opinions put forward in the team interview after the VBS2 planning.

Benefits of using a virtual 3D-model. Benefits of using the 3D-model include the possibility to visualize the area, which enables recognition once on site. The feeling of having been there gives security and comfort. This especially applies for spatial arrangements such as angles between positions or objects in the terrain. It also gives a feeling of adding safety to the assault, for example regarding limit of fire and avoidance of friendly fire. It is anticipated that if the assault was to be performed at night time or otherwise with reduced visibility, the model would be of great support.

Influence from having or not having experience from the 3D-model. Only one of the two groups did participate in the planning and mission rehearsal in the virtual model, but this was not thought to have a negative influence. Still, it was anticipated that it would have been better if everyone would have had this experience. The participants’ assessment indicated that the soldiers in the group that has planned and trained in the virtual model were more confident. In case of traditional planning, it is also common that only part of the team have seen the model.

Experience in gaming. The game-based rehearsal was performed twice, on the main plan and a backup plan. The roles were different during the second game session, which complicates the comparison between sessions, but the second session went faster since the experience in handling the game controls were higher. The increased experience also gave more room to focus on tactics instead of handling the game.

Virtual model replacing conventional tools. The usage of the virtual model was expected to have reduced the amount of time needed to be spent on reconnaissance. In general it is believed that this tool does not replace any conventional tool, but that it speeds up the planning process.

Requested improvement for planning. A number of suggestions for improved functionality for planning were put forward. One was to find positions in the terrain that are associated with higher risk, such as narrow passages. This type of terrain analysis was anticipated to be performed faster and more accurate by a computer tool compared to estimates from the soldiers. It would also be of interest to have a tool that automatically generates for example a range of march routes, based on user-specified conditions such as the routes being protected, not too steep and not too swampy. Similarly it would be appreciated to have a tool that could determine positions that are protected from enemy fire from user-specified expected locations, or concealed from the air. Another desirable feature would be to calculate the field of vision from different positions, or to find positions in the terrain from where visibility is high or specified objects are visible.

Results regarding how VBS2 supported planning obtained in hindsight after completing the exercise. The three level Repeated Measures MANOVA indicated no difference regarding the possibility to do virtual reconnaissance and mission rehearsal of the plan compared to what was reported in the two earlier questionnaires. Consequently, expectations on the feasibility for reconnaissance and mission rehearsal obtained pre-exercise and after the planning process corresponded to the perceived outcome after the exercise.

Correspondingly, in the final team interview it was noted that the virtual planning created a reconnaissance plan in terms of more specified information needs. The plan was also subsequently used in the mission area to prepare for the execution. However the participants also stressed that the model could be improved although it was judged to be “good enough” to prepare for the on-site reconnaissance. Some changes were also made compared to the virtual planning based on information collected on-site. The major change was to exclude the fire support from the machine gun due to low visibility. Still it was stressed that the participants did not feel deceived by the 3D-model. They were aware that they could not expect the model to fully correspond to reality. Finally, they agreed that the possibility to do virtual reconnaissance was more valuable than the game-based mission rehearsal.

In addition, questionnaire data indicated no differences regarding perception of whether it was beneficial to use VBS2 for the planning process and whether the participants would like to use VBS2 (with its current functionality) again if they were assigned a similar task in the future. As in the questionnaire after the planning, high scores (MV between 5.0 and 6.0) were obtained on these questions.

In the final team interview, it was agreed that the virtual planning had taken some additional time and resources, especially as the unit had to be trained on the system as well. Still it had the benefit of creating a better mental model of the target area. It was also perceived by the participants that this enhanced the possibility to discuss the plan with those who did not participate in the reconnaissance patrol.

However, results from the post-exercise questionnaire also clearly indicated that realism and resolution of the 3D-model was insufficient. Both regarding planning and mission rehearsal, the participants especially mentioned terrain details such as vegetation, height differences and line of sight. The same issues were also raised during the final team interview. The resolution was not perceived as sufficient. However, it was also noted that aerial photography in combination with the 3D-model gave a good perception of the conditions in the target area.

Regarding other potential use of VBS2, training cooperation on Close Air Support, Artillery and MEDEVAC was mentioned.

Summary of obtained results regarding VBS2 for planning. Results indicate that the possibility to do a “virtual reconnaissance” was a valuable asset. However, the resolution seems to be insufficient and only provided the unit with a rough overview of the target area. Additional information is needed besides the 3D-model, for example from a high resolution aerial photo. Consequently, the expectation regarding virtual reconnaissance was only partly met.

In addition, the unit did a re-planning of the mission based on information collected in the mission area. Consequently, the expectation that it should not be necessary to do any re-planning due to substantial differences between the terrain model and the real target area was not met. However, it is also important to note that the final solution for the execution was the one defined in the simulation-supported planning.

Results also indicate that possibility to do an interactive virtual mission rehearsal was relatively less valuable. The possibility to identify the strengths and weaknesses of different alternatives and thus have an impact on the selection of a final plan was limited. Instead, the most valuable aspect was rather creating a better mental model of the target area. Still, the plan outlined after the mission rehearsal corresponded to the final plan selected for the execution in the mission area. Consequently, the expectation as formulated before the experiment was not fully met.

The results give no support to the concern that there would be unrealistic expectations on the 3D-model.

Finally, the results give no support to the concern that the simulation-supported mission planning might be too time and resource consuming.

3.2.2 Performance during execution

Planning phase. The assessment from the exercise manager was that there was sufficient time available for planning. After completion of mission planning, the assessment from the umpire was that the unit had performed slightly below average regarding efficient use of time, relevant focus and quality of plan. The assessment was that the observed shortcomings could be overcome with a better elaborated time plan for the process.

Infiltration. The expectations of the commander before the infiltration were that the enemy would be established in the area patrolling the object perimeter. He judged that the enemy would have a restricted endurance. The main challenges would be to find suitable advance routes and bivouac area. The initial plan for bivouac area was changed due to insights gained using VBS2. In addition, assault direction was also changed due to the mission rehearsal in VBS2. Initially, the plan was to come from the north-east. This was changed into an approach from the east. After completion of the infiltration phase, the umpire judged that the commander’s assumptions about expected enemy behavior had been correct. He also judged the unit’s performance as high. The infiltration had gone according to plan with minimal friction.

Execution. By the time of the initiation of the execution, the commander expected the enemy to have low morale and static behavior. The major challenge was expected to be enemy patrols coming in from the side during the assault. These expectations were not specifically gained from VBS2. After completion of the execution phase, the umpire judged that the commander’s expectations on enemy behavior had not been completely correct. The enemy had been more alert than expected. Still he judged the unit's performance in terms of correct tactical behavior as high. However, preparedness for alternatives and details was judged below average. The overall judgment on mission success was judged as 5 on a 7 degree Likert scale where 1=complete failure and 7=complete success.

Exfiltration. By the time of the initiation of the exfiltration, the commander expected the enemy to use search patrols, dogs and surveillance lines. He thought that the major challenge would be enemy posts along the major roads. These expectations did not come as a conclusion from using VBS2 as a support tool for planning. Instead it came from his former experience of using dogs in units protecting air force bases. After completion of the exfiltration phase, the umpire judged that the commander's expectations on enemy behavior had not been completely correct. The expectation regarding the enemy's countermeasures had been correct. However, the major challenges were not standing patrols along the roads. Instead, the enemy had used their dog patrols in a more active and persistent way than expected. Consequently, the ranger unit was unprepared when the dog patrol was spotted by their post. Correspondingly, the umpire judged the unit's preparedness for alternatives as low (judged 2 on the seven degree Likert scale where 1=very low preparedness). In addition, the umpire judged the unit's performance in terms of correct tactical behavior and its risk-taking as average. The umpire's overall impression of whether the unit had solved the task successfully was low (judged 6 on the seven degree Likert scale).

Results from the two questionnaires. A Repeated Measures MANOVA comparing data on perceived "realism", "difficulty", "performance" and "tactical correct behavior" showed no overall differences between data obtained from the questionnaire after planning and the one from after the exercise. However, the real mission was perceived as significantly more difficult ($p \leq 0.01$, $F=27.3$) than the virtual mission rehearsal (MV=5.5, SD=0.6 as compared to MV=2.7, SD=1.0). In addition, there was no overall difference when all three occasions were compared in a three level repeated measure. However, there was a significant difference regarding whether the participants perceived the exercise as motivational between pre-exercise and post-planning questionnaires.

Results indicated that the virtual mission rehearsal and the real execution were perceived as being roughly equal with the exception of difficulty. No differences were found between the three occasions regarding the participants' judgments on the importance of factors for the successful execution of the task.

Some of the factors for the successful execution of the task were only assessed in the pre- and post-exercise questionnaire: "a well-executed tactical and technical mission rehearsal", "functioning communication equipment" and "communication with rear command". A two level repeated MANOVA showed no overall differences in the reported perceived importance of these before and after the execution. However, the univariate test showed a significantly decreased level of importance (from MV=6.3 to MV=3.8) for "a well-executed tactical and technical mission rehearsal" ($p<0.05$, $F=8.0$) when expectations were compared to opinions after the exercise.

Results from team interview. The plan was changed based on on-site reconnaissance but in the end the unit fell back to the original plan. During the team interview it was stated that this would have occurred anyway. It was time pressure that called for the change. The experience from the virtual mission rehearsal was of limited value as the level of detail was too low. The terrain in the mission area was perhaps also less suitable; *"a forest is a forest and the details are of less importance"*.

The opinion that the simulated virtual skirmish had limited correspondence to reality was also expressed: *"you get a general idea of the execution but no more than that"*. In addition the participants called for access to high resolution aerial photos. The details of the 3D-model must be taken with some skepticism. The undergrowth changes every year and thus also line of sight etc. A combination of a 3D-model and newly taken photos might be a good combination. “*You must in any case collect information on-site.”*

However, it was noted that the participants had acquired a spatial overview of the target area in advance of actually being there. It was also noted that even though only one of the squads participated in the simulation-supported planning, this had no negative effect on the mission.

Finally, it was noted that 3D-models might be an appropriate tool for the command level above the ranger squad unit (which was not participating in the exercise).

Summary of obtained results regarding performance during execution. Results indicate that expected enemy behavior and other challenges expressed by the commander did not fully correspond to the subsequent chain of events. However, the result is somewhat inconclusive as much of the commander’s expectations did not stem as a result from the simulation-supported planning. Instead, and not surprisingly, other experiences largely formed his expectations on this.

The ranger unit did fall back on a plan developed during the mission rehearsal in the 3D-model, which was according to expectation. However, without the game-based mission rehearsal the unit would still fall back on a planned alternative, which makes the interpretation of the expectation inconclusive. Still, the participants reported that the 3D-model had given them a spatial mental model which presumably should have enhanced the execution compared to a situation in which they would have relied exclusively on a 2D-model.

Results also indicate that the execution of the virtual mission rehearsal and the real mission was perceived as equal in terms of realism, how the unit performed and acted and how motivated the participants were. However, this was not the case regarding perceived difficulty. Consequently, expectation on how the participants perceived the different executions was not fully met.

In addition, there should be a similar correspondence regarding the relative importance of some “core success factors” for the virtual and real execution. Such factors include planning, access to updated intelligence, soldier competence, communication and level of training in coordinated teamwork. The participants’ perception regarding these factors for the virtual and real execution largely corresponded. However, this was not the case for “a well-executed tactical and technical mission rehearsal” when expectations were compared to opinions after the exercise. Consequently, expectations were not fully met.

3.2.3 Using F-REX for debriefing

The two-level repeated MANOVA showed no differences regarding whether F-REX enhanced the possibility to focus on relevant aspects of the mission and whether it increased the possibility to draw conclusions when the pre-exercise questionnaire and the post-exercise questionnaire was compared. Scores were in general high (MV=5.5-6.3).

This result was also supported by the team interview. There it was stressed that the in hindsight perspective and the possibility to allocate time to analyze was appreciated. This possibility would be valuable in other exercises as well. It is important to have sufficient quality of voice recording in order to evaluate the commander’s actions. Presumably, the after action replay will give an idea of the limitations of simulation-supported planning which in turn would be beneficial the next time. The unit found that the effort was well worth the time.

Summary of obtained results regarding using F-REX for debriefing. In summary, the results supports the expectations that replaying the mission in the model is expected to give a better overview of the chain of events and thus enhance the possibility to draw event-based conclusions from the mission.

In addition, there were no indications that the debriefing focused on details which were less relevant.

3.3 Summary of results

Obtained data. The conclusion is that the exercise has given an adequate context for analysis of the collected data. However, quantitative results should be viewed with some caution before any conclusion is drawn.

Simulation supported planning. The possibility to do a “virtual reconnaissance” was a valuable asset. However, additional information is needed besides what was included in the 3D-model. The expectation regarding the accuracy of the model was not met.

In addition, the unit did a re-planning of the mission based on information collected in the mission area. Consequently, the expectation that it should not be necessary to do any re-planning due to substantial differences between the terrain model and the real target area was not met.

Results also indicate that the possibility to do an interactive mission rehearsal was a less valuable asset. The ability to identify the strengths and weaknesses of different alternatives using the tool was limited. Instead, the valuable aspect was rather creating a better mental model of the target area. Consequently, the expectation regarding mission rehearsal was not fully met.

The results give no support to the concern that there would be unrealistic expectations on the 3D-model. In addition, the results give no support the concern that the simulation-supported mission planning might be too time and resource consuming.

Execution. Results indicate that expected enemy behavior and other challenges expressed by the commander did not fully correspond to the subsequent chain of events. Instead – and not surprisingly – other experiences largely formed his expectations on this. Consequently, this expectation was not met. The unit did however fall back on a plan developed during the mission rehearsal in the 3D-model, thus indicating that this expectation was met.

Results also indicate that the soldiers perceived the execution of the virtual mission rehearsal and the live execution as largely equal on the measured factors. However, some deviations were identified such as perceived difficulty and the importance of “a well-executed tactical and technical mission rehearsal”. Consequently, the expectations on how the participants perceived the different executions are not fully met.

Using F-REX for debriefing. In summary, the results support the expectations that replaying the mission in the model gives a better overview of the chain of events and thus enhances the possibility to draw event-based conclusions from the mission. In addition, there were no indications that the debriefing might have focused on less relevant details.

4 Conclusions

The present study has successfully tested some of the aspects of mission integrated simulation. As such, conclusions have mainly been drawn regarding M&S support for planning, virtual mission rehearsal and support for debriefing. These are summarized in the following section. A particular focus has also been on aspects regarding the 3D-model and how a access to a better model might support the mission. Conclusions regarding this are presented in a dedicated section. Finally, some possible directions of further exploration related to the concept of mission integrated simulation are presented.

4.1 General conclusions

A number of expectations regarding the M&S support for planning were formulated, the most essential concerning giving an accurate impression of the mission area, insights difficult to obtain from conventional sources and testing different plans through interactive game play. These were only partly met. However, and possibly more important, was that the soldiers participating in the study indicated that they would like to use the simulation-support for the planning again and that they would recommend others to use it as well.

The support for virtual reconnaissance was considered more valuable than interactive mission rehearsal. Still, important information was absent in the model. Subsequently, the planning had limited effect on the unit's perceived performance on the defined performance indicators during execution. The largest value of having access to a virtual model of the mission area seems to be the enhanced ability to create mental models. This also increases the ability to refer to features of the target object and terrain once in the mission area, also in communication with team members that have and not have been on reconnaissance in the real terrain. The access to the game and the 3D-model did moreover provide a help to think through the mission element by element.

The reported relatively higher perceived value of the virtual reconnaissance might be described by the difference in functionality. For the virtual reconnaissance, it is most interesting to get a picture of the overall situation, the terrain. Consequently, for the virtual reconnaissance it is the overall experience that is of interest and the important thing in the 3D-model is to be able to see how to get to the target object in order to do reconnaissance on the site.

The access to the 3D-model enabled the creation of a better idea of how the plan can work, for example by assessing/measuring what would be a reasonable distance for observation from different places in the terrain. The virtual model gave a basis for placing reconnaissance points and to formulate reconnaissance questions in advance that only needed to be confirmed or rejected once on site. The more detailed plan possible to develop in the virtual model gives directions on where to focus the reconnaissance. The fact that VBS2 offers simple tools in terms of an interactive map with orthophoto, enabling zooming, panning, measuring distances, etc. was also helpful. In addition, the ability to visualize inclination and elevation was perceived to be helpful to determine risks and lay out march routes. The usage of the 3D-model in the planning was believed to increase the speed of decision making regarding design of the plan.

For the interactive mission rehearsal, high levels of details and accuracy of the geographical model is important close to the target object. That means to be able to determine how far one can see and decide how to exploit minor differences in elevation, density in foliage, ditches, culverts, and details in these objects. The terrain model used in this experiment represented a fairly low fidelity since it was based on a 5 m elevation grid with vegetation rendered from built-in VBS2 models based on the ortophotos. Since accurate intelligence information regarding the target object was missing the simulation tool gave limited added value for the planning during this study.

In this context, it is important to note that data to produce a higher fidelity model is already available in terms of 2 m elevation models (known as NNH) from GeoSE, derived from data from laser scanning of (almost) the whole of Sweden. Similar data can be obtained for any mission area, provided access to vehicles (UAV) which can carry adequate sensors.

Perhaps the context of this study, a ranger mission in a forest terrain with a limited number of artifacts, was less suitable for having use of the interactive mission rehearsal. The difference between different forest areas is less apparent compared to a terrain with more artifacts and buildings. Consequently, the mission rehearsal might have been perceived as more valuable if the mission had been executed in an urban environment. If the mission would offer a setting where it is easier to perceive the relations between the virtual representation and the real mission environment, the virtual mission rehearsal might be more efficient compared to live mission rehearsal in an unrealistic terrain or terrain similar to that of the mission. In such a case it is presumably easier to consider the action with the reference of virtual reality.

Another aspect to consider is the relative uncomplicated scenario with a quite independent and small ranger unit. Coordination between the subunits close to the target is perhaps to large extent of routine character. A more complex mission including Close Air Support, artillery, other kind of units, etc. might have enhanced the value of virtual mission rehearsal.

The enhanced debriefing and AAR functionality added by the experiment was appreciated. This included the greater ability to get a hindsight perspective as well as increased time allocated for debriefing. F-REX enhanced the possibility to focus on relevant aspects of the mission. The replay gave a good overview of the chain of events and thus enhanced the possibility to draw event-based conclusions.

In summary, it is believed that mission integrated simulation does not replace any conventional tools or procedures. An adequate level of detail in the model of the mission area is necessary. Still, a virtual 3D-model which is “good enough” gives a supplementary perspective which increases the understanding of the shortcomings of any representation of reality (2D map or 3D virtual world). The 3D-model offers a more intuitive way of thinking of distances and angles compared to a traditional 2D map. Given a more complex mission context, the usage of the virtual model is expected to reduce the amount of time that needs to be spent on other planning preparations. It is also believed to reduce the amount of time needed for reconnaissance in the mission area. The support for debriefing/AAR was assessed as an effort well worth the time. Consequently, the conclusion is that the concept of mission integrated simulation is worth exploring further.

By utilizing already available tools and platforms and focusing on solutions that might be realized within 5-10 years it should be possible to enhance efficiency and ability with limited investments.

4.2 Better 3D-models

As mentioned previously, the results indicate that the participants thought that having access to a virtual 3D terrain model was advantageous in the preparation phase. However, they experienced limitations regarding the usefulness of the 3D-model in certain aspects. A major reason for this was the rather low fidelity of the model, e.g. due to poor correspondence between features in the model and the real world and poor resolution of the visual images. This should not come as a surprise, given the low resolution and limited content of the data used for creating the VBS2 model.

We believe that the effect of using 3D-models in the preparation phase could increase significantly if better 3D content (up-to-date, higher resolution, more details) was used. We also note that this is fully achievable today with existing technology. Only a few years ago, advanced 3D-modeling functionality was available only through expensive solutions from large companies, but thanks to recent breakthroughs in image processing technology, 3D-models can now be created from ordinary photographs using a standard PC without having to rely on proprietary data formats or additional system-specific information. Likewise, the recent years have also seen rapid technical developments regarding UAV technology, and the availability of UAV systems on the market has increased significantly only the last few years. High-quality and high-resolution 3D-models of important assets or areas can be produced in short time frames and to low costs. In practice, they could be produced using data from existing UAV systems (e.g. Swedish "Svalan/Korpen").

Advantages of using higher-fidelity 3D terrain models in the mission preparation phase may include the following:

- Better prior knowledge of the area gives better mental preparedness of the troops.
- More details about the target area allows for detailed planning.
    - Identify possible entry/exit points (windows, doors, ladders).
    - Detect obstacles (fences, ditches, walls).
    - Plan for cover (containers, rocks, bushes, walls).
- Use line-of-sight analysis to identify advantageous observation points and unobservable areas.
- Better decisions and understanding regarding limit of fire and avoidance of friendly fire.
- Mission execution in low-light conditions using 3D maps as navigation support.

4.3 Aspects to investigate further

This study was set off to test and evaluate M&S as an integrated support to mission planning, rehearsal, execution, debriefing and evaluation. The study has due to its limitations provided insights to only some of the aspects of the concept of mission integrated simulation. Consequently, there is room for exploration both in terms of supporting more functions and in terms of a deeper understanding of and development of the aspects investigated in this study. In addition to this, among the many imaginable a few aspects for future research are mentioned here.

Integration of a wider scope of exercise and mission activities between different kind of units and platforms. The underlying geographical data can be used for various analyses to support mission planning beyond reconnaissance and mission rehearsal. For example, to create route hypotheses, detect inaccessible areas, support orientation in low visibility environment or to identify suitable observation positions.

Import of real-time data to the virtual model in order to enhance command and control. By importing GPS tracks to the simulated environment, it is possible to visualize the simultaneous motion of avatars representing the different units, platforms and soldiers.

Images collected with a UAV can also be geographically linked with the simulated environment, so that intelligence gathered from those images (IMINT) can be visualized and analyzed within the environment, e.g. the enemies' current state and activities at the target area and the current status of the terrain (water level in rivers, how wet the swamps are right now, etc.).

Efficient utilization of high resolution terrain data. From standard geographical content, that may be delivered annually from a geo-information facility (e.g. GeoSE), one can get the general view and a basic understanding of the area of interest. Today it is possible to get a 3D-model that is ready for employment in a tool like VBS2 within a day with commercial (civilian) UAVs. With a designated system these lead times can be shortened even further. Such a highly detailed 3D-model can be combined with a larger, less accurate terrain data model in order to get a unified virtual terrain for both large-scale and more detailed analysis.

Procedures for implementing mission integrated simulation. The perceived border between mission supported simulation and simulation for entertainment in terms of commercial first person games might be vague. A distinct procedure and routine is presumably a prerequisite in order to create the adequate mind set. In this context it is important to realize that the corresponding mission rehearsal in a real terrain similar to the one in the target area is also a simulation.

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