THE ROLE OF C3I IN FIELD ARTILLERY SIMULATION

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1. INTRODUCTION

In the years 1997 and 1998 the simulation model SMART, which stands for Simulation Model ARTillery, to support the Dutch army in decision making. Main goal was to derive the optimal number and type of Howitzers, and organisation of batteries and platoons in a battalion. Two scenario settings were used to evaluate the performance of the field artillery system. In the first scenario a division appearance in a general defence task (full war) was simulated. In the second simulation a scenario of a brigade in a Peace Enforcing scenario was analysed. In the model the following components were explicitly modelled:

- Detection resources
- Command and Control cells
- Fire units
- Units of the enemy

In this model the enemy is modelled as a black box and the actions of own forces do not influence the operations of enemy troops. As a consequence damage to own facilities was modelled as a parameter and only inflicted a possible damage after each round of fire.
In this model the Command and Control structure is inflexible. Networks and lines of communications are hard-coded and require a major adaptation in the model when changed.
In the near future specific research questions of the Dutch army are expected concerning the Command and Control structure and lines of communications in the field artillery. We expect SMART to be not flexible enough to support these research themes. Therefore the decision was made to build a new research tool called SMARTER (Simulation Model ARTillery Extended and Revised)

This paper consists of 5 chapters and is build up as follows. In chapter 2 the goal of the tool will be described. In chapter 3 we will describe how we think SMARTER can be used in a scenario setting. Chapter 4 will describe the elements, processes and measures which will be implemented in the tool SMARTER. In chapter 5 this paper will be concluded.

2. GOAL SMARTER

As mentioned in the introduction several research questions from the Dutch army concerning the field artillery system are to be expected. These can vary from the number of howitzers in a battalion, unto questions concerning the optimal organisation structure in which detection resources, C2 and weapon systems work together to optimise the total system.

At this moment the organisation of a brigade is given and all target information generated from several detection resources will, with no exception, be sent to the Deep battle cell of the brigade. The question is whether this is efficient. Furthermore one might want to research which routes have to be followed before a target detection is translated into a fire mission. In the current model (SMART) it seems that the communication resources have great influence on the overall system performance. At this moment communication is not modelled in SMART. In SMARTER communication will be modelled explicitly to be able to investigate the (requirements)concerning the communication resources.

It depends on the specific research question, to what detail the elements of the field artillery system have to be modelled. Our goal is to build a simulation tool that makes it possible to

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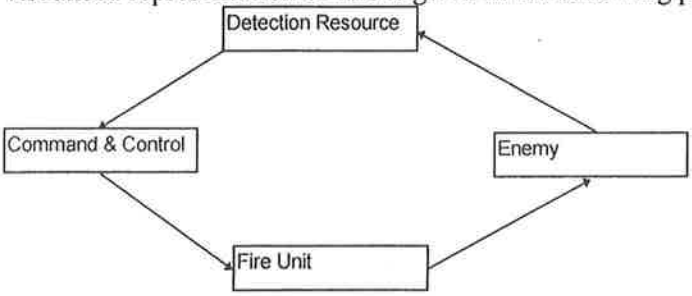
implement in a simulation model in a fast and efficient way, which can be used to simulate a wide variety of field artillery systems, using various resources in different scenarios. In general the elements: Detection resources, Command & Control, Fire Units and a representation of the enemy are needed to be able to represent to most abstract form of the field artillery system. A visualised representation of this is given in the following picture:



3. HOW SMARTER WILL BE USED

3.1 introduction

To be able to evaluate the effectiveness of a field artillery system, the system has to be placed in an operational context (= scenario). In this scenario weather conditions, terrain conditions, the enemy and its capability, and the own organisation have to be defined. In general it is not easy to define a realistic scenario which can be used to evaluate the system.

This problem is not specific for the field artillery system, but for all systems in which the effectiveness of systems, in an operational setting are evaluated. In general the use of scenario's is a matter of discussion when evaluating the results of research models.

Because of the lack on scenarios, TNO-FEL and the Dutch army started the project "scenario development for policy research". In this project the goal is to develop a set of scenario's, which can be used both by TNO as well as the Dutch army, for both OR studies and policy studies.

This project started in the October 1998 and will probably produce the first scenario in the spring of 1999. When the result of this pilot project will be satisfying for both parties, the project will be continued the coming years to produce a database of scenario's which can be used in all OR and policy studies of the Dutch army and TNO.

In the project "scenario development for policy research" a distinction is made between operational and model scenario's. An operational scenario is a problem dependent description of a future (fictive) situation (starting point) and a hypothetical series of events from this situation (development) leading to an endstate. This description concerns the operational input of a part of the Dutch army.

A model scenario is a set of parameters belonging to a (simulation) model. These parameters describe the starting point in the (simulation) model and the development in time. The model scenario will be based on a specific operational scenario.

3.2 Two sided scenario's

In SMARTER the goal will be to be able to evaluate the performance of own troops as well as enemy troops. The reason for this is to be able to observe the damage to own artillery components as a result of enemy fire missions. When different types of fire units are compared, the mobility of the fire units can be a major difference. The mobility of a fire unit can be of major importance in surviving a battle and as a consequence the infliction of damage to own fire units has to be modelled more sophisticated compared to SMART. The infliction of damage to own fire units is a result of the operations of the enemy. Therefore the operations of the enemy have to be simulated in detail.

A spin off of modelling both own troops and enemy troops is that in one simulation run, both a defence and an attack can be analysed. In this case the enemy has to be modelled such that it can represent own troops. Also several decision rules can be evaluated when these rules are not the same for both parties.

We will not implement the possibility of more than two parties in a conflict. The reason for this is that the scope of smarter in general will be the total field artillery systems. Even if there are more parties, e.g. a peace enforcing scenario in which multi national forces operate together against one enemy, we will consider the multi national forces as one party in the conflict.

3.3 Scenario's for SMARTER

As mentioned in chapter 2 the specific research questions determine the level of detail which will be used for the different elements. When tuning the system, i.e. the relevant numbers of resources needed to operate optimally, a detailed description of both sides and elements will not always be necessary.

When fine tuning is done this can be evaluated with use of a description of a detailed scenario. When both the project SMARTER and the project "scenario development for policy research" will be realised in time, we will be able to use the same scenario. This scenario will be used for evaluating the whole system.

4. CONSTRUCTION OF SMARTER

4.1 User interface

Before any result can be generated and analysed from a simulation model this model has to be defined, implemented and run. To facilitate these four steps the user interface of SMARTER will consist of four units. These units are: definition unit , scenario builder, simulation unit and analyser.

The definition unit will be used to define the different standard elements in an artillery system. It will be possible to define the elements and save them so they can be used in several different studies without redefining standard elements. Examples are: a fire unit, detection resources, communication network settings and specific C2 cells.

The scenario builder will facilitate the user to implement a scenario with use of the elements defined in the definition unit. The scenario builder will have a graphical user interface in which a terrain will be displayed and units can be placed upon this terrain.

When a scenario is build, it can be simulated with the simulation unit. One can choose several modes in the simulation unit like single step simulation, and batch simulations. Single step simulation will be used to verify the implemented scenario.

The results and data generated during the simulation can be analysed using the Analyser. In this analyser one can interrogate specific elements used in the scenario, as well as display several predefined tables in which several Measures of Effectiveness (MOE's) can be shown.

4.2 Model elements

4.2.1 Communication:

As mentioned in chapter 2, communication resources can be the bottleneck in the field artillery systems. Therefore communication will be modelled explicitly in SMARTER. We consider communication as a technical resource that can be used to transmit information from one unit to another. In this process from sending and receiving we will not take misinterpreting and other noise as a human factor into account in this model. Communication will be facilitated the use of: Communication resources, links and networks.

We will model communication resources as resources in which messages can be inserted and transmitted through a network. It depends on the type of communication resource and type of network used, whether it is possible to queue messages.

Links are the lines used to transmit messages from one communication resource to another communication resource. This can be a physical line between two units or a frequency used by a set of communication resources. A connection will have a length and as consequence a performance based on length and weather and terrain conditions. Based on probability functions a message will be transmitted correctly or not.

A network determines whether one or several message at a time can be sent. We will consider the protocols CSMA (Carrier Sends Multiple Access) and TDMA (Time Division Multiple Access). These protocols determine if a message can be send at the same time someone else is transmitting data and will determine the minimum amount of time needed to transfer the data through the network.

At this moment this level of detail will be sufficient. If a more detailed representation of communication is needed it will be possible to make use of more sophisticated communication simulation tools as a plug in. For example simulation models implemented in OPNET could be used.

4.2.2 Command & Control (C2)

Command and control on its own has a great complexity. We will not model the internal command and control processes in a command and control unit in detail for the reason that the goal of SMARTER is not to optimise the command and control, but the field artillery as a system. In this system we consider command and control as a resource represented in a command post. However we recognise the need of flexibility in building artillery models concerning the Command and Control. To be able to have enough flexibility in SMARTER, we used the following ideas in the modelling the C2 components in SMARTER:

1. In general C2 components are elements in the model, which transform received information in new information and use this information to make decisions. We think of information as messages that are send to and received by C2 and other elements. In the conceptual model we have recognised a boundary set of messages which can be send to a command and control unit. Each message will start a decision routine. The decision routines will be defined by

"expert systems", in which the decision rules will be determined by several parameters. These parameters will generate the needed flexibility in the modelling of artillery systems. Some of these parameters are the a priori priority of targets, the maximum time between target detection and fire mission etc.

2. Decisions can be translated in orders or requests and will be communicated with other elements in the model.

3. Any C2 component has one or more resources, which can be used to concurrently process information. Delay times will be variables, which can be put in as a parameter for each decision routine to be made.

4. C2 components will have one ore more separate resources for sending information through the communication network. So communication will be a restricted resource in a C2 component, but will have no influence on the time needed to make decisions. The number of communication resources and the number of operators will be separate parameters of the model.

5. We do not recognise C2 elements as known staff elements. Any C2 element will be able to make its own decisions, based on the received information and the units connected to the C2 element. For example: Suppose one set of used detection resources are Remotely Piloted Vehicles (RPV) organised in one company. The RPV company will have a control station which interprets the information generated by the RPV. This control station will only be able to decide to generate a target detection or not. Because no other information is transferred to this control station, no other decisions can be made. On the other hand a C2 component, which has only connections·with other C2 components, will never be able to give orders for a fire mission, because it has no fire units under its command. This C2 element will only be able to give fire requests to other C2 elements, which have fire units under their command.

When these ideas are implemented, we are able to answer a wide variety of research questions. Examples of these questions are:

- How to choose High Pay off Targets (HPT's)?
  In the targeting process, decisions have to be made which targets to fight,how these targets to fight (suppress, neutralise, destroy) and when.
- What ammunition is the most effective?
  As mentioned before it is not always necessary to destroy a target. So different types of ammunition can be used to reach the goals of the artillery system. The choice which ammunition to use in which situation is a typical C2 decision to be made.
- When the decision is made to engage a target, one or more fire units have to be chosen to execute the fire mission. Which fire unit(s) to choose and how many depends on several factors. By varying the parameters of the C2 element, different strategies can be evaluated.
- The time needed to take a decision will depend on the information available in the C2 element and the number of C2 elements used in the decision routine. (See also paragraph 4.2.3). Completion times can be of great importance in the field artillery system and thus will certainly be a subject of research in the near future.

4.2.3 Information systems

Decisions made in a C2 cell are determined on the information available in the cell. If this information is not available a request for the needed information has to be made. Whether information is available or not is determined by the used procedures in the field artillery system. These procedures can be facilitated with information technology (IT). Based on the procedures and implemented IT the C2 cells will have or have not specific information. In SMARTER the implemented IT determines which procedures are followed and how information is distributed among the units.

At this moment the Dutch artillery has the VUIST-1 system. In this system all units within a brigade are subscribed to the network and have information derived from the same basis. Studies are performed to introduce the information system VUIST-2. In this system information is the same from battery till division level. VUIST-2 also facilitates the automation of decision rules like transforming a fire request to a fire mission for a specific fire unit.

If decision rules are automated, decisions will be made much faster and thus C2 cells will be relieved. On the other hand this requires a regular update of all needed information and therefore the number of messages will increase and can cause congestion in the communication networks.

4.2.4 Fire units

In SMARTER the smallest units that are able to deliver projectiles will be fire units. A fire unit is a number of weapon platforms with their weapon systems and ammunition. Usually a fire unit will have the size of a platoon. We chose this approach because in Dutch artillery the doctrine is that all units in a fire unit will work together at the same time on the same fire mission.

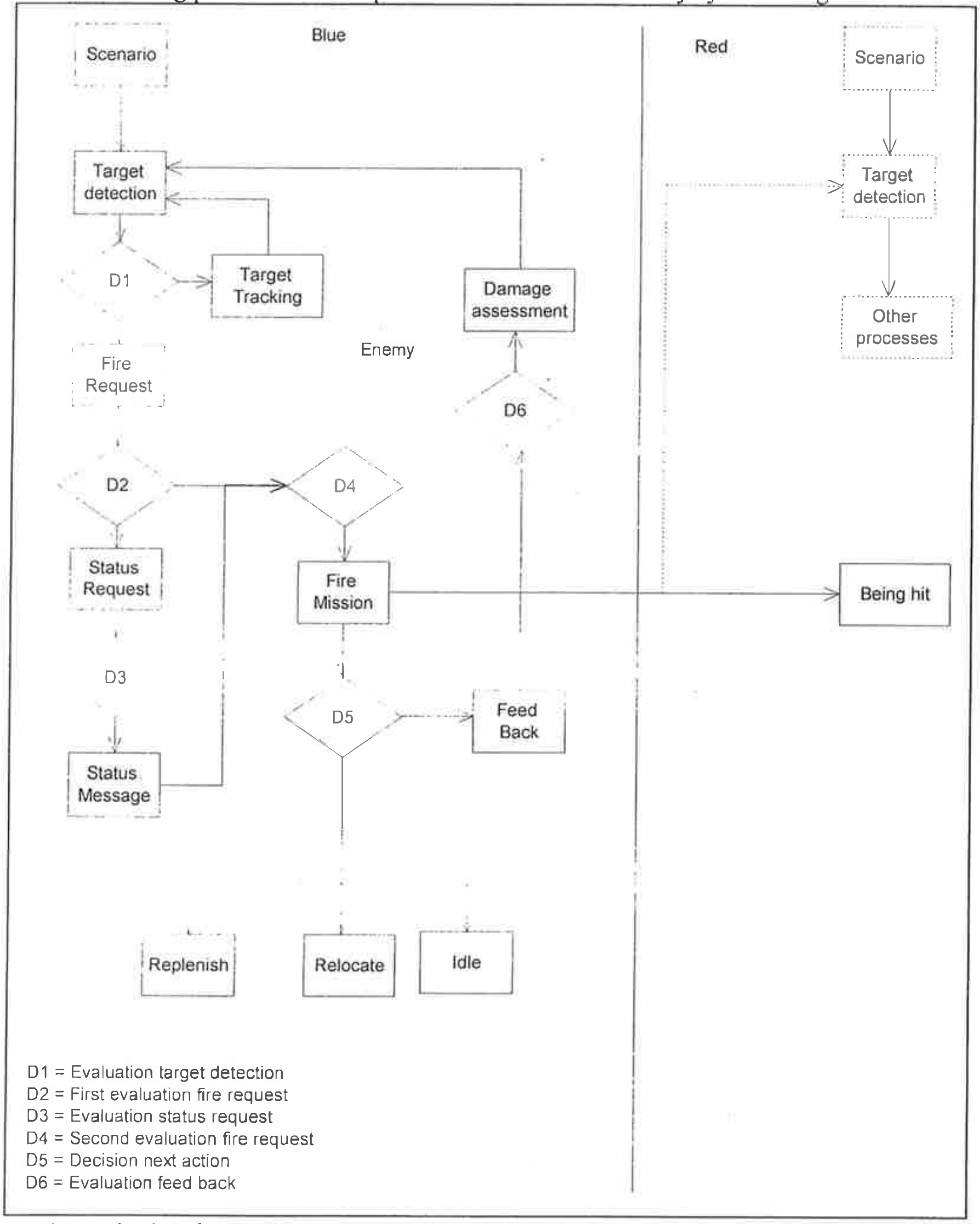
If necessary a fire unit can be modelled as a single platform and this makes it possible to analyse models in which every single platform is modelled. In general one fire unit will receive one fire mission to execute. When a target is too large for one fire unit, the decision can be made (C2 component) to synchronise the execution of a fire mission between two or more fire units.

4.2.5 Detection resources

SMARTER will provide the use of several types of detection resources. These can vary from forward observers (FO) to more technical sophisticated equipment like RPV's. Any detection resource will be able to generate target information. Based on the technical possibilities, detection resources will be able to "see" a restricted range of targets. Detection resources will be used for target detection, damage assessment and target tracking.

4.3 Simulated processes in SMARTER

In the following picture the main processes of the field artillery system are given:



As shown in the picture there are a number of decision processes in the C2 cells. The decision processes of the C2 elements are components of the so called "OODA" loop, which means Observation, Orientation, Decision and Action. In this context, observation is a process of the detection resource. Action is the process "Fire mission" of the fire unit. The decision processes are:

1. Evaluation target detection
   When a target is detected, the decision has to be made whether this leads to a fire request or not. This decision can be based on the observed activity of the target, the initial priority of

the target and - if measurable - the threat of the target. When the decision is made not to engage the target, one can choose to file the target detection and ignore the target, or one can give the order to track the target and wait until the activity of the target changes and a fire request / fire mission is more opportune.

2. Evaluation fire request
   When a C2 element receives a fire request several decision have to be made. First if the C2 element has fire units under its command, the decision can be made to engage the target or to give the feed back that a fire mission is not possible at this moment. If this is not the case, the C2 cell can try to find another C2 element to pass through the fire request or return a message that a fire mission is not possible. Which decision is made, depends on the availability of fire units, the time remaining the target has to be fought, ammunition stock etc.

3. Evaluation status request
   The decision process "evaluation fire request" will depend on the status of other units. If this information is not available at the C2 cell, this information has to be gathered from the unit. This unit evaluates this status request and produces the information needed.

4. Second evaluation fire request
   When extra information is received at the C2 cell, the available extra information can be used to decide whether to fight the target or not.

5. Evaluation feed back
   When a fire mission is executed, the feed back will given that the mission is over. At this point the C2 cell has to decide whether to evaluate the fire mission and its result or not. If the fire mission has to be evaluated, a detection resource must receive the order to perform a damage assessment on the target.

In the picture there is a decision "next action" this will not be modelled as a C2 process but will be a decision process of the fire unit, which consumes no time.

4.4 Measures of effectiveness and measures of efficiency

In the code of best practice developed by NATO AC/243 (Panel 7) TR/8 RSG-19 on Modelling of Command & Control, Chapter 3 describes several types of measures. In this document the following definitions are used:

1. MoFE, Measures of Force Effectiveness
2. MoE, Measures of Effectiveness
3. MOP, Measures of Performance
4. DP, Dimensional Parameters

We will use these definitions to describe the measures which will be used in SMARTER. Following the hierarchy of measures we will start with the MOE's and will end with the MOP's. Because SMARTER is a model developed for the evaluation of the performance of field artillery we think it is not possible to define MoFE's.

4.4.1 MOE

The mission of a force usually will not be defined in measurable units. Therefore a translation of the mission for both the force and the artillery is necessary. In SMART the original mission was to have such an influence on the enemy that the willing to continue the conflict was gone. This mission was translated into a goal where the total strength of the enemy forces at the end of the mission must be lower then a specific value. Strength then was defined as the percentage of the original capabilities of the individual units. When the strength is less or equal to the goal the mission was a success otherwise the mission failed. The strength of the enemy forces can be written in a formula in the following way:

$$\frac{\text{\# Targets Destroyed}}{\text{\# Targets offerd}} \text{ or } \frac{\sum_i \text{Strength Target}_i}{\sum_i \text{Initial Strength Target}_i}$$

Usually we will use the second description for measuring the strength. As mentioned in the RSG-19 paper the values of MOE will depend on the used scenario. In general this measure will be used to evaluate the performance of the simulated field artillery system as a whole. To be able to measure the used systems in a scenario a number of MOP's will be defined.

4.4.2 MOP's

The MOP's will be defined based on the basic components modelled in SMARTER. Each Component will have its own measures to be able to judge the performance of these elements.

The performance of the detection resources will be based on the number of detections and the number of correctly detected targets. In formula:

$$\frac{\text{\# targets detected}}{\text{\# targets offered}} * \frac{\text{\# targets detected correctly}}{\text{\# targets detected}}$$

We also want to measure the performance of the C2 and communication structure. This performance will be based on the capability to process a target detection in time and transform this message in a Fire Mission. However the C2 and communication resources have their own influence on the process we will use the following measure for evaluating the C2 and communication structure:

$$\frac{\text{\# Possible Fire Missions}}{\text{\# Targets detected}}$$

In the model targets will become obsolete after a certain time. Because targets can move, the information of targets is time dependent. Therefore a fire mission is only possible when the decision can be made in time. (When the instruction for a fire mission is given, the fire mission still can be cancelled by the fire unit.)

The measurement of the fire units is more complex. Based on the information a fire unit receives from C2 components, the fire units will be able to perform tasks. On the other hand based on the performance of the fire units (mainly based on the time needed for a fire unit to perform a fire mission) the C2 components will be able to send information to the fire units. (When the occupancy of the fire units is relatively high the C2 components will not be able to send fire missions to the fire units.)

The effectiveness of the fire units can be measured with the following number:

$$\frac{\text{\# Fire missions with effect}}{\text{\# Fire missions}}$$

A fire mission with effect is a fire mission that has effect on the aimed target.

The described measures defined above are the most essential measures defined. In the model more measures will be defined to be able to tune and optimise the system.

5. CONCLUSIONS

In this paper the concepts of the tool SMARTER are discussed. SMARTER will be used to support the Dutch army in several policy studies concerning the field artillery system. It will facilitate the implementation of field artillery simulation models in a fast and efficient way.

One of the main goals in the implementation of the tool was to develop a system in which there is enough flexibility in the C2 elements to be able to research both different levels of C2 and different C2 rules.

Communication is modelled as a resource and can be varied in several scenarios. When necessary an interface with more sophisticated models concerning the simulation of communication will be implemented.

In SMARTER it will be possible to model both own troops as enemy troops. This makes research of attrition to own troops and the survivability more reliable. Moreover when both parties have the same technology and doctrine both attack and defence can be analysed in one scenario and simulation run.