New Ways for Ground-Based Air Defence Personnel Training Using Simulation Technologies

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Abstract. Armed forces around the world have more and more sophisticated weapon systems, sensors and C2 systems. The training on these systems is very demanding and exploitation of simulation technologies is a key requirement for successful personnel preparation. The area of ground-based air defence (GBAD) is not different. However, the special needs for GBAD training require also special simulation technology. This paper presents key attributes of such a simulation technology and brings one of possible solution (concept) for effective and cheap GBAD personnel training and education.

Keywords: Air defence · Modelling and simulation · Ground based air defence

1 Introduction

The last two decades have brought tremendous progress in the development of simulation technologies. Thanks to more powerful hardware and more sophisticated software, it is now possible to implement solutions that could not be solved at all a few years ago. Special attention in this area is represented by military technologies, or technologies that enable the training of military personnel. A special category of users in this respect is ground-based air defense personnel. This category has special requirements for training, resulting from the uniqueness of the use of ground-based air defense technologies. The specificity is mainly the fact that it is a ground element, which is mostly interested in airspace and related aspects of direct and procedural management. Thus, ground-based air defense units must not only strictly adhere to the current division of airspace, but also respond to a ground situation that could endanger them. The second category of interest is the operation of their own weapon systems, which personnel must know flawlessly and be able to control. Together, it is a complex set of tasks, whose training and coaching on simulation technologies requires a high degree of authenticity, not only visual, but especially procedural. This article aims to summarize and present the existing knowledge of the Department of Air Defense (University of Defense) in the field of modeling and simulation for the purpose of training ground-based air defense personnel.

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2 Development of Air Defense Simulation Technologies and the Needs for Future Functionality

Simulation technologies have been available in a figurative sense since the 1960s. Since the beginning of the existence of more complex air defense missile systems, simple simulation algorithms have been implemented in the weapon systems themselves. Most of them were simple algorithms enabling simulation of missile launches and guidance to a simulated or real target in training mode. This ensured the basic requirements for the training of personnel on real systems, where the simulation technologies were not evolved yet. However, this functionality only allowed the practice of shooting itself. It was not yet possible to train staff and unit commanders more comprehensively in more complex scenarios, including other aspects of combat activities, such as synchronized activities in the airspace with its own air force, training in larger combat groups (clusters) and the like.

Over the last ten years, however, due to the advent of powerful computer technology, there have been opportunities to expand the originally limited training opportunities on simulators and trainers. Thanks to the graphical performance, the battlefield can be simulated more or less visually realistic. Thanks to the computing power, it is now possible to simulate for example missile movements in real or nearly real time based on real properties such as missile engine thrust, maneuverability, destructive effect of combat charge, missile guidance method etc. However, all these possibilities hide one aspect, which in many cases prevents the use of simulation technology. Companies and programming teams that are able to program these processes do not have knowledge of real systems. In order to create a simulation environment for the training of ground-based air defense personnel, it is necessary to merge a team of programmers with a team of experts in the field of air defense. Otherwise, created products will be inaccurate and will not have adequate training value. Paradoxically, this can lead to a situation where the resulting product causes bad habits and knowledge, which can then cause the failure of the real combat mission in real combat environment. In the development of simulation technologies by a commercial entity, close coordination with the so-called Subject Matter Experts is necessary, i.e. experts with deep knowledge of the matter.

3 Aspects of Advanced Air Defense Simulators and Requirements for Modern Simulators for Air Force Training

Current military air force simulators are usually not very robust. Very often these are so-called “single role” simulators, such as flight simulators and trainers, simulators for unmanned aerial vehicle (UAV) operators, fire simulators, etc. These simulators are designed to train a narrow range of users from military operational personnel and are unable to provide a wider range of tasks. However, current trends show [1, 2] that it is more advantageous in terms of training benefits to train a more comprehensive range of personnel together and thus enable coordination between different types of troops during simulated missions. In the case of ground forces, there is a wide range of more complex simulators such as Presagis, OneSAF, VBS3, etc. However, for the ground-based air

defense there are no such options. Usually, simulations for ground-based air defense are solved separately, where the emphasis is mainly on trainers, without wider possibilities of involvement in the simulation of joint or more complex operations.

The simulator, designed for ground-based air defense training should have the ability to implement a wide range of tasks. This would provide a more realistic simulation of both command and control centers and tactical units. A comprehensive simulation environment for ground-based air defense training should include the following entities:

1. Air Force Command and Control Centers, in which at least the following could be simulated:

    a. Positive and procedural control of subordinate forces and resources.
    b. Allocation of simulated weapons (air and ground).
    c. Sensor models and their fusion.

2. Air Force (airborne):

    a. Basic models of Wing Operation Centers (WOC) in terms of procedural management.
    b. Models of aircraft (airplanes, UAVs, helicopters, etc.)
    c. Tactical procedures and techniques used in the preparation phase and then for combat operations [3, 4].

3. Ground-based air defense forces

    a. Basic models of ground-based air defense operations centers (SAMOC - Surface to Air Missiles Operation Center) in terms of procedural control, e.g. [5].
    b. Models of ground-based air defense weapon systems (models of ground-based air defense batteries, or just stand-alone vehicles), e.g. [6].
    c. Tactical procedures and techniques used in the preparation phase and then for combat operations.

4. Sensors

    a. Modeling of detection capabilities of radars and other sensors (e.g., air observer equipment, etc.).

5. The enemy

    a. Modeling the capabilities and actions of enemy forces and resources.

6. Environment

    a. Modeling of the battlefield from the environment point of view, weather, terrain, etc., e.g. [7].

However, the requirements for modeling and simulation are, from the point of view of complex simulation of air force activities, highly dependent on the user, because each of them (num item 1 to 4) needs different information inputs in real operation. For a realistic simulation, aircraft pilots need the most reliable modeling of the view from the cockpit and models of instruments in the cockpit, as well as a credible visualization of enemy assets however this is not the case for GBAD units. Personnel or service of ground-based air defense means have different requirements. Next, the staff of operating centers or radar sensors have also completely different requirements in the form of yields of radar information and information important mainly for the decision-making process.

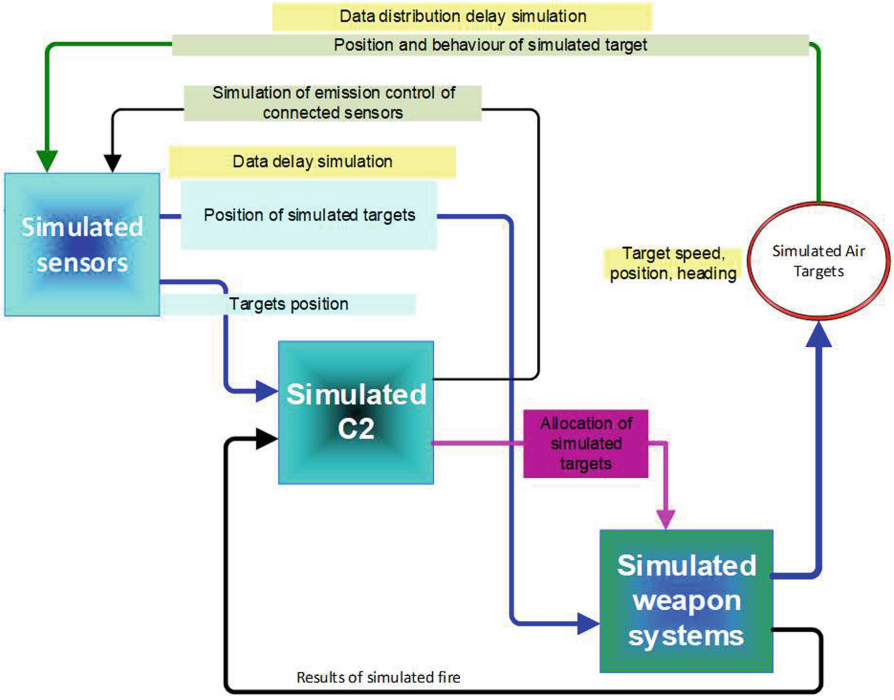

Fig. 1. Simulation loop for ground-based air defense applications.

From the point of view of requirements for a modern simulation environment, it is necessary to simulate not only the process of firing against air targets, but also the flow of information from sensors, commands from superior command and control elements and distribution of reports from subordinate simulated elements to superiors (see Fig. 1). Such an environment then contains the following functionalities:

1. Simulation of information processing

    a. Fusion of information from simulated sensors.
    b. Distribution of this information to relevant subordinate entities (firing element models, etc.).

c. Registration of information from subordinate entities (status of entities, e.g. combat-ready/damaged/destroyed).
d. Registration and distribution of information from superior entities (if simulated) to subordinate entities.
e. Registration of hostile or potentially hostile simulated targets.

2. Decision-making process

a. Analysis of the simulated air situation

(1) Prediction and evaluation of the position of simulated own and enemy air objects, e.g. [8].

b. Registration of statuses of subordinate simulated entities (ground-based air defense weapon systems models).
c. Status change of the subordinate simulated entities.
d. Allocation of weapon systems.

(1) Commands to fire simulated aircraft entities and deconfliction with assignment of targets to ground-based air defense entities.
(2) Commands to fire to simulated ground-based air defense entities.

e. Calculations for procedural control

(1) Calculations of the range of firing units depending on the position, speed and maneuver of the target.
(2) Calculations of the intersection of air target routes with the areas where the firing units operate and the algorithm for allocation the target to the unit in case two or more units have a target within its range.

3. Monitoring and saving of the state of combat and evaluation of simulated combat.

a. Calculation of simulated missile consumption.
b. Simulation of the delay in calculating the ammunition replenishment time.

Another "challenge" for future ground-based air defense simulators is the prediction of target trajectories. In current command and control systems, as well as simulators, the prediction of the target position is generated based on the calculation of the straight flight trajectory, which in cases of air combat or ground-based air defense is out of the question, because the target will try to maneuver and get out of range of weapon systems. Correct prediction of the trajectory of targets (whether in real systems or in simulators) should have a more realistic prediction, e.g., in the form of the application of Apollo circles. A similar prediction would thus take into account the current course of the enemy target and the position of the defended object with the calculation of the probability of change of the target course based on a possible maneuver.

However, the most important function of the ground-based air defense simulator is the procedurally correct allocation of targets to the relevant subordinate weapon systems during the simulated combat activity. In the simulation environment, the target allocation process must be linked to criteria and conditions that allow the target to be optimally allocated:

1. Evaluation of whether the target has already been allocated to another simulated weapon system. This evaluation must be performed periodically after certain time intervals, usually given by the information recovery interval.
2. Assessment of the availability of a sufficient number of simulated aircraft at a distance to the target to allow approach, combat and return to the nearest or designated landing position. The distance to the target must be constantly recalculated in the simulation environment.
3. Evaluation of whether a sufficient number of simulated activated means (units, batteries) of the ground-based air defense is available.
4. Assessment of whether the fire density of the available simulated ground-based air defense systems is greater than the enemy density. If not, the simulated ground-based air defense grouping is overwhelmed and the command and control algorithms must reallocate available aircraft resources to cover the reduced ground-based air defense capabilities.

The whole target distribution algorithm in the simulation is conditioned by activated/inactivated simulated radar sensors. The algorithm is executed only if the target is within range of the simulated radar station. In the case of an activated radar network, it is necessary to perform an evaluation for a positive display of targets to the operator. This evaluation would be performed based on the presence of targets in the detection area of at least one simulated combat-ready radar. This simulation would then be performed either in the presence of a DMR (digital model of relief) and evaluating the radar visibility depending on the relative position of each target and each radar. The change in the displayed data should also be influenced by simulating the recovery time of the radar information.

4 Conclusion

The above described concept of extending existing simulation technologies with advanced elements that will allow not only realistic, but especially comprehensive training of ground-based air defense personnel was tested in the research activities of the Department of Air Defense, University of Defense (PROKVES 2016–2020 project). To support these extensions, several experimental software was created, e.g. [9, 10], which confirmed the correctness of the arguments defining the requirements for advanced simulation technologies of ground-based air defense. The list of attributes and properties of the simulator in the article contains the most important characteristics that a ground-based air defense simulator should have in order to be used for modeling and simulation of combat operations involving multiple air force entities. Thus, not only more than one ground air defense unit (two or more - the so-called clusters), but also coordination with air elements of the air force, such as aircraft, helicopters, etc.

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