The Importance of Modeling and Simulating for Ground-Based Air Defence

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Tactical exercises and electronic warfare in peacetime are set narrow limits. Exercises of weapon systems of ground-based air defence (AD) are area-intensive and costly in terms of materiel and personnel and involve high expenditure on organization and budgetary funds. Military flight operations are also always subject to increasingly higher restrictions in the field of tactical flight maneuvers. Radar and radio emissions need to be harmonized with the civilian co-users. On the other hand, there is a high degree of training in quality and quantity required to prepare the crews of weapon and warfare systems for their missions. This requires that the training capability in surface-to-air missile units of the Luftwaffe has to be ensured independent of restrictions in multinational combine. Simulations — particularly the simulation in a pool with other systems and facilities — are definitely decisive and goal-oriented here, because they allow the joint employment of the weapon systems of the Luftwaffe to be experienced down to the operators' level.

For the units of ground-based AD of the Luftwaffe the use of simulation is actually nothing substantially new. According to the principle "train as you fight, fight as you train" it was only consistent that weapon systems with system-inherent simulation capabilities were procured for the Luftwaffe. This simulation capability has been intensively made use of within the scope of combat commanders' training for as long as anyone can remember. The possibility for this simulation-assisted training has existed with the NIKE Herkules weapon system already and was continued and intensified with the HAWK, ROLAND, and PATRIOT weapon systems. But this simulation was hitherto not focused on the respective weapon system and the pure firefight, the so-called "engagement operations" (EO). With the introduction of the PATRIOT weapon system this was, within the scope of the then technically available possibilities, extended to the combine of several weapon systems. This, however, concerned only a "purebred" configuration, i.e. the combine consisted exclusively of PATRIOT weapon systems. But with the preparation and planning of multinational missions abroad in which different systems and procedures are ap-

PATRIOT Launcher System. Pictures: Authors

plied, it becomes apparent that this approach is insufficient and that in the interactive simulation pool a considerable part of the training is the training in the different command and fire control systems (CFCS). Especially interservice as well as joint aspects and multinational (combined) approaches are thus possible to be realistically, effectively and efficiently studied, evaluated and trained within the scope of modeling and simulation (M&S). Moreover, peace-related restrictions on the operation of CFCS in realistic environment can be largely disregarded when using simulation.

Air Defence Weapon Systems at the Center for Tactical Training and Advanced Training AD AF, USA.

Conceptual Scope

According to the Concept of the Bundeswehr, modeling and simulation include the development, provision and use of methods, models, scenarios and data in the following four areas of application:

- Analysis and planning
- Requirement determination and procurement according to Customer Product Management (CPM)
- Employment in missions and operations, and Training and exercises.

As far as the ground-based AD is concerned, these four areas are applied in different forms. In the Analysis and Planning area of application, the analysis requirement is satisfied with short lead times and little expenditure in time primarily on the basis of simulations in order to support mission-relevant planning work. The quick and nearly effortless integration of new models, modules and alternative scenarios and data into an M&S pool is of decisive importance here. The analysis of real and experimental command structures and systems and procedures by means of the Concept Development & Evaluation (CD&E) method is also of paramount significance for the AD of the Luftwaffe.

Different system concepts for the realization of the required capabilities need to be studied and assessed within the scope of Requirement Determination According to CPM. As for the AD of the Luftwaffe, this encompasses the support in the maintenance of the operational readiness by an early testing of products to be changed/modified as well as prototype systems and demonstrators in a combined system. An AD simulation pool can — especially through detailed and thus also complex simulations — be used for the employment in the area of operations to attain a quick adaptation of operational principles and procedures to changed parameters. This comprises for instance the adaptation to changed mission and threat situations in an environment marked by rapid changes or the evaluation of possibilities for an integration of multinational AD forces into a coalition, even outside preplanned NATO command structures, if necessary. Moreover, the simulation pool will contribute to the technical support and training and/or sustainment training of personnel — in individual cases also of units — employed in operations over a longer period of time.

The increasing relevance of missions and operations outside NATO — e.g. within the scope of the EU or in coalitions with UN mandate — will, in future, require different operational procedures and principles which may deviate from standardized NATO procedures and which, depending on the situation, necessitate intensive training and exercises in advance of the mission. For instance, realistic training within the scope of accomplishing the task "ballistic missile defence" can thus be achieved with justifiable financial expenditure only by the inclusion of simulators. A realistic representation of this threat is possible to an only very limited extent at a few firing ranges which are specifically equipped for that (e.g. NATO Missile Firing Installation (NAMFI), White Sands Missile Range, Pacific Missile Range Facility). The goal-oriented integration of a simulation pool of ground-based AD into training and exercise projects will thus considerably contribute to expanding and deepening the knowledge of the command and operator personnel, particularly under the aspect of interservice and multinational cooperation.

The sub-concept Modeling & Simulation in the Bundeswehr specifies the parameters for the application of M&S in the armed forces. Based on that, the capability aimed for by the Luftwaffe according to the concept draft for the "Application of M&S and the Networking of Simulators in the Luftwaffe" is established as the capability to be able to operate within a networked simulation and test infrastructure by use of simulation. Simulation is described in there as the process, which allows comprehending the developing and proceeding of real occurrences and events in artificial conditions. It continues by defining the Luftwaffe Simulation Pool as the Joint Simulation of several fire control and/or warfare systems as well as other weapon systems of the Luftwaffe in a joint and combined effector pool on the basis of an interactive simulation network. Weapon systems of other Services and other nations are also possible to be included in a simulation pool. For that purpose, the Luftwaffe should be able to plan, experiment, train, execute and assess virtual missions and operations in a joint and combined and multinational framework with its local command control and weapon system simulators from its different garrisons, locations and bases. The required flexibility in training is gained by particularly the use of this so-called "distributed simulation" which makes it possible to project and exercise different types of operations. In addition, this simulation pools offers the possibility to advance and test operational procedures in a composite system. The Bundeswehr Simulation and Test Environment, which provides the network components to link up the respective locations/bases and simulation components with each other, support the simulation pool.

Parameters for an AD Simulation Pool

Fulfilling the operational task of the Luftwaffe's ground-based AD and ensuring the continuous operation readiness will require different forms of training methods which allow to comprehensively convey the complexity of the weapon systems to the respective operator according to the job description. Especially against the background of specific employment capabilities of the ground-based AD of the Luftwaffe, e.g. the NATO Response Force, it is essential to consistently ensure — both at the Center for Tactical Training and Advanced Training of the German Air Force Air Defence in the United States, with Development Tasks (successor organization of the former German Air Force Air Defence School) and in the operating units — the capability for interactively networked simulation and to complement it with new capabilities. Particularly the simulation in combine with other AD systems plays a central role here. By way of interactively networked simulations it is possible to clearly expand training schemes of the simulation possibilities given within the weapon system. The dueling situations, which can only be projected here, allow training and exercising that comes very close to real world occurrences and improves thus the operational readiness of the personnel of an AD weapon system.

In view of the parameters prevailing for weapon system training the main effort is presently placed on the use of simulators and CFCS/CDS-inherent simulation technology. In future, the AD weapon system/CFCS are intended to be additionally linked with each other by use of standardized, interactive simulation procedures with systems and interfaces on the basis of the two prevalent standards, the "Distributed Interactive Simulation" (DIS) and "High Level Architecture" (HLA). The integration of other weapon systems of the Luftwaffe as well as the employment in interservice and multinational simulation structures is also possible with these standards. Simulations are also applied in the field of mission planning, Force Operations (FO), and for the assessment of AD plannings. The result of such simulations is, for instance, fed into the assessment of the distribution of the AD weapon systems in an AD employment zone and serves thus the support, analysis and verification of the mission planning.

PATRIOT Launcher.

In this context, the Center for Tactical Training and Advanced Training of the German Air Force Air Defence (Ctr for Tac Tng and Adv Tng of the AF AD) in the United States is attached particular importance, as a substantial task for further development is the assistance with preparatory work in the development of tactical composite simulation/AD systems, the support of modeling for simulations in integrated AD as well as the operating of simulation and analysis tools within the scope of studies on the effectiveness and efficiency and also as a contribution to national collection of information and experiences from a tactical-operational point of view.

Simulation Pool in the United States

For the ground-based AD of the Luftwaffe the Ctr for Tac Tng and Adv Tng of the Air Force AD in the USA is the central agency for training and extension training as well as for the further development of tactical and technical procedures and concepts. Within the scope of the transformation and in consideration of the targets and standards of M&S and CD&E this Center was to be established and/or adapted in such a way to enable it to meet the new and future challenges.

With the setup of a planned AD simulation pool, which will extend the present capabilities of the ground-based AD of the Luftwaffe within the scope of M&S and CD&E to a considerable degree and thus ensure among other things the linking of the ground-based AD of the Luftwaffe to the Bundeswehr Simulation and Test (S & T Bw) Environment and to the national and/or multinational CD&E process, the Ctr for Tac Tng and Adv Tng of the Luftwaffe AD in the USA makes also a substantial contribution to the capability adaptation of the armed forces a such.

By this AD simulation pool, which completely interlinks for the first time the mission and training systems of the Ctr for Tac Tng and Adv Tng of the Luftwaffe AD in the USA (in the main fire direction centers and command posts), the Ctr for Tac Tng and Adv Tng of the Luftwaffe AD in the USA will be capable of conducting joint and combined studies of aspects of the ground-based AD, making the extension of the training scope as well as a realistic designing of the training and advanced training possible, and realizing a distinct increase in the training quality. In addition, such a pool will support the conducting of experiments — especially in the field of national and multinational interoperability — and the mission preparation, the development of new weapon systems, the further development of existing weapon systems, and the national/international development of concepts. Interaction with systems of the Army and Navy by a linkage via a Wide Area Network (WAN) would become possible in the course of national interservice, joint training. The interaction of the ground-based AD of the Luftwaffe with the NATO Active Layered Theatre Ballistic Missile Defence Integration Test Bed (NATO ALTBMD ITB) will also be possible, thus ensuring the participation of the Luftwaffe in developments within the scope of the integrated AD of NATO.

NATO ALTBMD ITB

NATO initiated the Active Layered Theatre Ballistic Missile Defence (ALTBMD) program in 2005 to meet the growing threat by ballistic missiles posed to troops in operations. It is to ensure protection in the area of operations against the threat by ballistic missiles. The development and procurement of a NATO-organic Command Control and Information System financed with NATO funds and based on existing components of the NATO nations or on the ones still under development and in which the weapon systems and sensors of the "Theatre Ballistic Missile Defence" available in the NATO nations can be integrated, is in the planning. To minimize the risk in respect to the integration of weapon systems into the ALTBMD architecture to be drafted, the development of an "Integration Test Bed" (ITB) is an integral element of the program.

The ALTBMD ITB will be based on modeling and simulation tools available within NATO or on national level and will also aim at integrating existing national hardware and software. Aside from real systems as "hardware in the loop" (HWIL) these can also be national experimental and laboratory facilities with the ap-

purtenant simulations or models ("software in the loop" (SWIL)). Among other things, they are intended to make it possible that experiments and studies on the reduction of development and interoperability risks of architecture components, mission concepts, and prototypes can be conducted in a cost-efficient way. The ALTBMD ITB is to support prioritized applications in the order stated:

Systems Integration, Test and Verification (IT&V); Risk Reduction (RR) during Systems Engineering Phase as well as Operations and Training (O&T).

Architecture and functional Core Elements of an AD Simulation Pool

The functional core elements of the architecture of the Simulation Pool AD of the Luftwaffe allow the projection and examination of all operationally relevant scenarios for the ground-based AD AF and will consist of primarily the following elements:

- A higher echelon unit (HEU), usually CRS and/or AOC
- The SAMOC (surface-to-air missile operation center), and
- The PATRIOT weapon system with PATRIOT simulation pool interface.

They will be complemented by:

- Weapon system simulations
- Recording and analysis tools
- Simulation tools
- Additional aids and infrastructure components, as well as
- The LAN/WAN transition (changeover) for a link-up via the S & T Bw to national and international simulation and test facilities such as the NATO ALTBMD ITB.

Five Local Area Networks (LAN) will link up the individual system components. The simulation network will be based on DIS and HLA and made compatible with the future S & T Bw. The simulators will exchange their status information via this network and will be stimulated with a defined air warfare scenario-by-scenario generator. The TDL (tactical data links) networks will connect with the actually used data links, i.e. Link 16, Link 11B, ATDL-1, and LLAPI, and serve for tactical real-time communication. As this data exchange defines the joint information area for engagement operations (EO) it should, as an essential factor for achieving realistic behavior for operators and weapon systems, be identical to reality. This is achieved by replacing, e.g. for Link 16, the transmission medium "radio" by "Ethernet" by use of terminal emulators without having to modify the behavior of the weapon system.

The Force Operation (FO) Network will provide the infrastructure for the ADaTP-3 data pool, which is required for the FO pool. The Voice over IP (VoIP) Network will allow secured voice communication by means of VoIP telephones. All connected computer systems will be made available data file and printing services via the service network and network management and maintenance will be performed through it as well.

Mission Support by Simulation Pool AD AF

In the past, the mission reality of the Bundeswehr was particularly characterized by the fact that the number of areas of operation has continuously increased whereas the available time to prepare for new missions has gotten shorter. Regional hot spots can expand with almost no advance warning time and require an immediate intervention of the international community. In such cases the mission contingents are locally confronted with very different political and tactical challenges. These short preparatory times are then possibly opposed by a very long duration of the mission. Short lead times inevitably mean a more difficult mission preparation.

This is not only true for the necessary logistic measures for the deployment of the mission contingent, but especially also for the mission-preparatory training and extension training of

Grafic of the MEADS System.

the soldiers. If there are no experiences and information from the planned area of operations available yet, it will be necessary to more or less base the measures to be taken on the experiences gained from other, similar-type missions.

With the aid of M&S it is possible to review operational regulations and/or operational procedures and to adapt or amend them, if necessary. Particularly in the field of the ground-based AD AF it is possible to model many and diverse mission scenarios in the simulation in great detail and, if necessary, to exercise them in interaction with the forces already employed in operations. With such an AD simulation pool the Ctr for Tac Tng and Adv Tng AD of the Luftwaffe in the USA will be able to support the ground-based AD AF before and during a mission by analyzing and assessing the situation in the area of operations from the viewpoint of the ground-based AD of the Luftwaffe with the aid of the projected capabilities. By taking account of the respective threat, e.g. ballistic missiles (type, range, possible launch positions, degree of operational readiness, etc.) it is possible to determine the probable threat posed to the assets. If forces of the ground-based AD of the Luftwaffe are already in the area of operations, the deployment and mission planning of these forces can be optimized in respect to the threat situation after a respective analysis with the aid of the AD simulation pool in a "reach-back" procedure, i.e. in a recourse action via digital data links. The capability for reachback will both reduce the demand for planning and analysis capacity in the area of operations and minimize the so-called "footprint" in the mission. The Ctr for Tac Tng and Adv Tng AD of the Luftwaffe in the USA can study the disposition of Forces/assets for the contingents to be activated in advance of the mission and give a recommendation for the optimal composition of forces and provide planning aids for the actual mission.

Participation in Exercises by Use of a Simulation Pool

Multinational exercises, as e.g. Joint Project Optic Windmill (JPOW) under Dutch lead, have been based on a simulation structure for some years already. On national level, some interservice, joint experiments with comprehensive simulation networks took also place already with Common Arrangement (2004) and Common Umbrella (2006) in which original weapon systems (partly via interfaces) were integrated just as actual and future systems on simulation basis. Also, networks with tactical data links were employed in parallel with the simulation networks in all cases.

In future, the Ctr for Tac Tng and Adv Tng AD of the Luftwaffe in the USA as the central agency in the field of AD for training and extension training and tactical groundwork is planned to participate as an interactive component in national and multinational experiments and exercise projects, which involve the field of ground-based AD AF. In addition, it is intended to enable it in future to accompany the conduct of exercises more specifically by the integration of recordable and evaluation-capable systems for TDS and other data and to analyze them afterwards.

PATRIOT PAC-3 Missile.

Further Development of PATRIOT and MEADS

In the past, the constant advance of the PATRIOT system has required a continuous adaptation and further development of the operational procedures and thus also of the training and extension training. The introduction of the PAC-3 guided missile and the planned changeover to the new PDB 6 weapon system software represents just further developmental steps here. Up until the replacement by the MEADS weapon system, the PATRIOT system is highly likely to be subjected to further modifications and developments.

With the help of an AD simulation pool it is possible to test planned changes to a certain degree in the simulation in advance already and to study them inter alia in respect to their effects on existing mission concepts. The results of such tests are always subject to the restrictions that the systems involved (at least part of them) are simulation systems, but it is nevertheless possible to project technical processes and operational procedures in high congruity with reality. Unlike individual experiments within the scope of exercises, which usually have to be conducted within a tight time frame, an AD simulation pool, being a constant test bed, makes it possible to conduct continuous and detailed studies. The Ctr for Tac Tng and Adv Tng AD of the Luftwaffe in the USA would thus be capable of analyzing and assessing planned developments of weapon systems already before their technical realization.

Surface-to-Air Missile Operations Center (SAMOC).

Possibly necessary operational procedures and training doctrines can be checked and adapted early enough and will be available in time for the fielding of new weapon system components.

Interoperability with Command Systems Outside the Ground-based AD

In the light of multinational and interservice, joint missions, the interoperability of the ground-based and/or seaborne AD systems of Army, Luftwaffe and Navy is attached paramount significance. As part of the NATO Integrated Air Defence System (NATINADS), the requirements demanding interoperability for the AD systems of the Luftwaffe are not new at all. The integration of respective simulation systems of the Army or the Navy into the simulation pool allows an analysis of the present methods of operation and their further development with regard to the procedural interoperability. By the link-up of actual systems (e.g. simulation interfaces or tactical data links) it is additionally possible to study and assess the technical interoperability. Furthermore it would be possible to combine both actual and simulated CFCS/CDS of Army and Navy within the scope of operation procedures in a joint information area.

The AD simulation pool is planned to integrate a higher command post (higher echelon unit, e.g. CRC or AOC) into the network pool and simulate it. If available, the NATO Air Command and Control System (ACCS) should be linked up with it. The simulation-technical connection via an encrypted WAN link allows already that first studies be made on the interaction of weapon systems of the ground-based AD AF with ACCS.

Outlook

The targeted AD simulation pool would allow a complete simulation combine of all AD weapon and training systems, both among one another and in external simulation networks, to be realized for the first time. The application possibilities will be many and diverse and decisive for the mission preparation and execution with the CFCS/CDS. The Ctr for Tac Tng and Adv Tng AD of the Luftwaffe in the USA was announced to be introduced as a national contribution to NATO Active Layered Theatre Ballistic Missile Defence ITB as of 2009 in addition to the German simulation models and CFCS components.

In this way, a significant national contribution to the NATO ALTBMD program will thus also be made with the simulation pool, the participation in the developments within the scope of the program will be ensured, and an additional load on the AD units avoided. The road to a simulation pool of the Luftwaffe is set out. Weapon system-overlapping, interactive simulations are practiced in exercises; data on flight path and progress of flying objects (missiles) are distributed to all participants in independent simulation networks today already and the reactions of the individual weapon systems are put into the network generating the required interactivity in this way. The simulators and/or simulation interfaces of the connected systems simulate the sensors and effectors of the weapon systems employed and feed them into the simulation network. With its present and future modeling and simulation capability, the ground-based AD of the Luftwaffe will make a decisive contribution to such a simulation pool of the Luftwaffe. In particular, this will allow extending the cooperation with the flying forces of the Luftwaffe. The networked simulation with the most sophisticated weapon system of the Luftwaffe, the EUROFIGHTER, will make the transition to a new quality of training and mission preparation possible, if e.g. combined air warfare operations within the scope of "Conventional Counter Force" (CCF) can be exercised in a real-time simulation network in close collaboration with the ground-based AD. ■

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