DIS, HLA, AND BEYOND: BUILDING A COHERENT MODELING AND SIMULATION INFRASTRUCTURE IN THE NETHERLANDS

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ABSTRACT

In order to support its research, development and engineering activities in the area of distributed simulation for materiel procurement, training, and operations, TNO Physics and Electronics Laboratory has developed (and continues to enhance) an Electronic Battlespace Facility (EBF). In the vision of TNO-FEL, the EBF will form the basis of a coherent Netherlands defense modeling and simulation infrastructure. This paper presents an overview of the EBF, including its architecture. We also describe how the facility is being used in research and operational support projects. Finally, current work and plans for the future evolution of the EBF are discussed.

INTRODUCTION

TNO Physics and Electronics Laboratory has developed (and continues to enhance) an Electronic Battlespace Facility (EBF) to provide simulation services for research, development, engineering, and training purposes (see fig. 1). The EBF is an important instrument in support of TNO-FEL's R&D program in these areas. In order to be able to meet the constantly changing requirements of its prime customers, the Royal Netherlands Armed Forces, for R&D in support of procurement, training, and operations, flexibility should be a key characteristic of the EBF. Based on earlier experience with DIS (Distributed Interactive Simulation) based simulations, and expectations as to future developments of distributed simulation technology, most notably the emerging High Level Architecture (HLA), the EBF has been designed with flexibility and application development efficiency in mind [1]. This paper provides an overview of the EBF architecture and organization, current R&D issues, and plans for its future evolution to a key component in the Netherlands Modeling and Simulation infrastructure.

Figure 1: Mock-ups, VR-station (left), and scenario management console (right) in the Electronic Battlespace Facility

2. ARCHITECTURE OF THE EBF

TNO-FEL's Electronic Battlespace Facility (EBF) provides services for scenario management and analysis of distributed interactive simulations, as well as the rapid development of new simulators and tools to be evaluated on the EBF, or to extend the facility itself. A flexible and extendible architecture was deemed essential in order to keep the system up-to-date with state-of-the-art technology and to facilitate the reuse of available components. For research purposes, flexibility is a main requirement in order to enable rapid prototyping, e.g., before finalizing the specification of new simulators. The base software layer for the Electronic Battlespace Facility is the Advanced Simulation Framework (ASF). On top of the ASF, a software tool kit, the Platform Framework (PLF), has been developed that provides a set of modules to allow the rapid development of both manned and unmanned simulators. Figure 2 presents the EBF software architecture with the ASF, the PLF, and some of the generic support components. The ASF and PLF layers are described in more detail in the following two sections. After that we describe a new component architecture which extends some of the ideas of the HLA and which is planned to form the basis of the next generation of ASF.

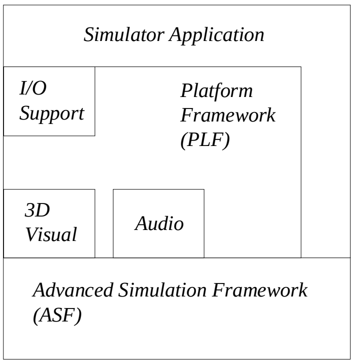

Figure 2: EBF Software Architecture

2.1 The Advanced Simulation Framework

In order to meet the requirements with respect to flexibility and rapid prototyping, an object oriented, layered architecture was developed for the EBF. The Advanced Simulation Framework (ASF) provides the EBF applications with a connection to the distributed virtual environment. It abstracts applications, such as simulators and scenario management tools, away from the underlying communication infrastructure, providing the programmer with a user-friendly application programmer's interface [2].

The design of the ASF was mainly inspired by the emerging HLA and one of the main objectives for its development was to ease the migration from DIS to HLA at a later stage. The ASF forms an abstraction layer, or 'middleware', isolating the simulation application from the underlying interoperability standards. This enables the migration of the EBF from DIS to HLA with minimal changes to the simulation applications. The object oriented design of the ASF promotes both the reuse of existing software components and facilitates the extension of the software framework itself.

In the ASF two subsystems are distinguished. Figure 2 depicts the multi-layered approach of the ASF. The *Environment* is protocol-independent and provides an interface to the simulated battlespace. It reflects the up-to-date status of the simulation objects (or entities) and allows the application to add or delete objects. Furthermore, the application can subscribe to relevant simulation events, thus enabling the ASF to discard non-relevant information at an early stage. The application can receive and issue unique events such as simulation management events. The Environment shields the application from the partially protocol-dependent ObjectServer.

The *ObjectServer* represents the underlying run-time infrastructure. It exchanges object information with other simulations and provides the Environment with up-to-date status information of the battlespace. The ObjectServer is protocol-dependent, i.e., if another protocol has to be supported, this subsystem needs to be (partially) replaced or extended. The ObjectServer currently relies on DIS, but experiments with an HLA-RTI based version of ASF have been conducted, and a migration is currently being prepared.

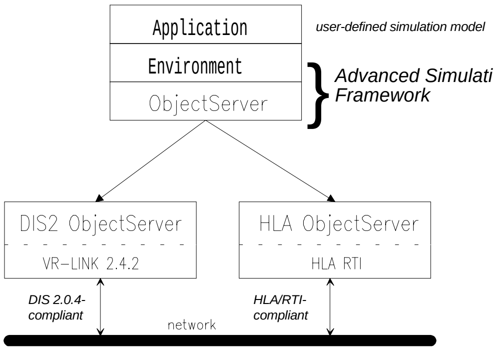

Figure 3: The Advanced Simulation Framework

The interface between the Environment and the ObjectServer is a subset of the HLA Interface Specification [3] to establish compatibility in the future with HLA. The interface between the simulation application and the Environment is based on a subset of the HLA Services:

- Federation Management: joining and leaving federations;
- Declaration Management: publishing and subscribing to objects and events;
- Object Management: instantiate/delete (a simulation object), update/reflect (an attribute), send/receive (an event);
- Time Management: real-time and scaled time simulation based on a 'receive order' message delivery scheme.

The HLA Ownership Management Service is not yet supported by the ASF baseline but will be provided after the migration to HLA.

2.2 The Platform Framework

The Platform Framework (PLF) is an open, scaleable and extendible architecture for cost-effective development of manned and unmanned simulators (ground-based vehicles, naval platforms, fixed and rotary wing aircrafts). The PLF is implemented as a software layer on top of the ASF and provides common functionality required by vehicle simulators. The object-oriented design of the framework enhances reusability of simulator components, such as weapon systems and sensors, in both manned and unmanned simulators. The PLF is prepared for a migration from the DIS standards to the High Level Architecture (HLA) standards, because the ASF abstracts the PLF from the underlying distributed simulation standards [4].

The PLF enhances software reuse by standardizing the interfaces between the framework components. Low-fidelity components can be substituted by high-level components, and vice versa, as long as the components comply to the PLF interface standards. Simulators based on the PLF are tailored to user requirements by specialization of generic components. New simulators can be developed in less time and with less effort.

The framework consists of four major components:

1. *Subsystems*: physical platform parts such as weapons, sensors, radios and engines.
2. *Personnel*: onboard human or artificial operators.
3. *Environment*: representation of the battlespace and its objects.
4. *Support Modules*: I/O and audio-visual tools

Figure 4 illustrates the top level object model diagram of the Platform Framework with a number of subsystems.

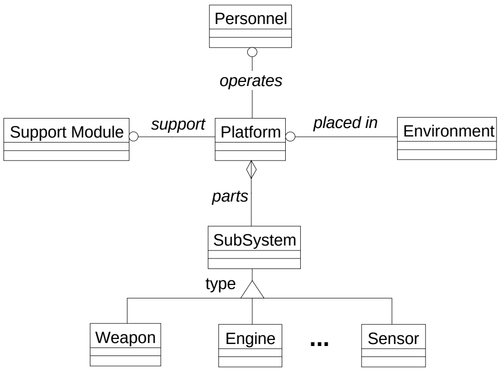

Figure 4: Platform Framework Architecture

2.3 A Component Architecture for Simulator Development

In order to further enhance the simulation development process, and promote re-use of not only entire simulators, but also of simulator components, a component architecture for simulators has been developed in the framework of a national collaborative project under the name of "SIMULTAAN" [5]. Because it is expected to play a central role in the future evolution of the EBF architecture, a brief overview of the key concepts of the SIMULTAAN architecture is given here.

The component architecture is based on the same concepts as the High Level Architecture (HLA), but extends these ideas down to the federate component level. The SIMULTAAN Simulator Architecture (SSA) facilitates interoperability between the components of a federate and between federates of a federation. Like HLA, it includes a set of Rules, an Interface Specification, and Object Model Templates. The SSA Rules are rules with which a SIMULTAAN federate or component has to comply. They define the responsibilities and relationships in a SIMULTAAN federation. The SSA Interface Specification (SSA-IF) is a formal, functional description of the interface between the application and the Run-time Communication Infrastructure (RCI). The SSA Object Model Templates (SSA-OMT) are standardized formats to define the functionality of federates and components and their respective interactions.

The Run-time Communication Infrastructure (RCI) provides the run-time interface services for communication between components in a federate and between federates in a federation, according to the SSA Interface Specification. The RCI can be regarded as middle-ware, and hides the complexities of the underlying interoperability standards from the SIMULTAAN component or federate developer. This way component development time can be reduced.

Another result of the project is the SIMULTAAN Object Repository (SOR). The SOR will contain SSA compliant simulators, components and tools. It may also contain configuration, initialization, and validation data for components, simulators, and tools. In this way SIMULTAAN will support the process of simulator development (e.g., requirements analysis, design, composition and validation). The SOR allows controlled access by the SIMULTAAN partners.

Although the SIMULTAAN concepts are based on HLA, some important differences can be identified. The main differences between HLA and the SIMULTAAN approach can be summarized as follows:

- An abstraction layer (or middle-ware) has been realized to hide the complexities of the underlying interoperability standards.
- The various interoperability standards are shielded from the developer to enable migration from DIS to HLA with minimal changes in the application code.
- Mechanisms for communication between the components within a federate are provided.
- The exchange of simulator components between SIMULTAAN partners is encouraged by the SOR.
- Multiple Communication Servers can be used to allow dedicated high-speed inter-component communication with minimal changes in the application code.

3. USING THE EBF

The Electronic Battlefield Facility has already been used in a number of RD&E projects. Examples are:

- the evaluation of the Electronic Warfare Control Processor (EWCP), a component from a command and control system proposed for ships of the RNL Navy;
- the EUCLID project "Mission and Battle Simulation" involving the simulation of fighter allocator/controller stations in a complex air warfare scenario.
- the development of a prototype simulator, based on immersive virtual environment technology, to support the training of Forward Air Controllers (FACs) for the RNL Army;

Furthermore, plans to use the EBF for research on tactical team training, and doctrine development for the new "FENNEK" armed reconnaissance vehicle for the RNL and German Armies are currently being finalized. A concise description of each of these projects is provided below.

3.1 Evaluation of an Electronic Warfare Control Processor

The Electronic Warfare Control Processor (EWCP) is a shipborne softkill scheduler that directs the deployment of the available softkill assetts, e.g., distraction and seduction chaff, infrared decoys, active off-board decoys, and on-board jammers, under varying circumstances. Its main objectives are: to shorten the reaction times of softkill deployments in complex multiple threat scenarios, to increase the effectiveness of the softkill countermeasures, and to ease the workload on Surface Warfare (SuW) and Anti Air Warfare (AAW) operators during threat situations. On behalf of the Royal Netherlands Navy (RNLN) TNO-FEL has developed a technology demonstrator in which softkill scheduling techniques and methods are implemented and subsequently evaluated in simulated scenarios. For this purpose, the Electronic Battlespace Facility provides the means for an assessment of the EWCP under pseudo-operational conditions [6].

The EWCP demonstrator is embedded in a two-tiered simulation environment: the lowest represents the synthetic battlespace in which a navy frigate operates, and the uppermost simulates the functionality of the sensors, weapons, and the Combat Direction System (CDS) on board the frigate itself. The lower tier is based on the EBF and provides the frigate model with an environment where operational AAW and ASuW scenarios can be prepared, executed, played back, and analysed. The upper tier simulates the sensors, the parts of the CDS that interface with the EWCP, and any softkill assets deployed by the EWCP.

Because of its open architecture, the upper tier may also be used for research and development of other modules of the CDS, e.g., sensor fusion and situation assessment modules, and the hardkill and hardkill/softkill schedulers. The EBF in this case is also used for research on future architectures for the CDS, incorporating blackboard and distributed database concepts.

3.2 Complex Air Warfare Demonstrator

Within the framework of the EUCLID 11.3 research program "Mission and Battle Simulation" TNO-FEL has participated in the investigation of training and technology requirements for a future Complex Air Warfare Training System. This program has focused on the operational, training, and technical requirements, and has addressed the issues of defining training and training environments based on training objectives and the demands on adaptability of training [7].

The CAWTS, as developed in the program, is a virtual training system that consists on a number of DIS compatible components that can be configured in various ways as prescribed by a training curriculum. The main components of a CAWTS are:

- exercise controller and instructor stations;
- scenario and tactical environment generation tools;
- manned simulators.

Once the individual and team training objectives have been identified, a training environment can be designed.

During the program, a number of technologies were investigated that are required in the design of a CAWTS. In the final Complex Air Warfare Demonstrator (CAWD), the following technologies were used:

- longhaul networks: a public ISDN connection linked three separate local area networks across Europe;
- an Exercise Controller station;
- a Tactical Environment System (TEMS), including Computer Generated Forces (CGFs);
- an Artificial Intelligence Station, controlling two of the CGFs simulated by the TEMS, in order to provide a highly realistic behaviour of the controlled entities. The interface between the AI controller and the controlled CGFs relies on the DIS protocol;
- Generic Cockpit Stations (5 of these were used in the CAWD), consisting of a workstation based pilot environment equipped with aircraft controls;
- a Full Mission Simulator, consisting of a replicated cockpit and wide-angle out-the-window visual system;
- a Command & Control Station (ICARUS) used by the fighter allocators and controllers.

The ICARUS Command and Control station was developed at TNO-FEL (see fig. 5). It represents one Fighter Allocator, who manages the available fighters for interception, and two Interceptor Controllers who are responsible for direct control of the air defence fighters. Furthermore, the simulator is equipped with a so called ICARUS Manager, who can assume the roles of other required functionaries, and take control of the own defence CGFs. During the final demonstration of the CAWD, the ICARUS C2 station and the TEMS were linked locally at TNO-FEL on the EBF, which in turn was interconnected through an ISDN line to other local area networks at sites elsewhere in Europe.

Figure 5: ICARUS (Interceptor Control and Allocation Rehearsal Using Simulation).

3.3 Training of Forward Air Controllers

The Forward Air Controller (FAC) is an army officer who plays an important role in Close Air Support (CAS) operations. His task is to guide the pilots in their operation such that they engage the correct enemy targets, without endangering friendly forces. The Forward Air Controller takes position in the very front line of the battlefield - keeping an eye on both enemy and friendly forces while observing the flight manoeuvres of the CAS aircraft. The FAC maintains a radio connection with the CAS pilot to brief the pilot such that the operation will be safe and successful.

Current FAC training practice is that trainees are first taken through a short but intensive theoretical course, after which they are directly exposed to live exercises with real aircraft. Due to a lack of experience, the first training runs are usually unsuccessful, making the valuable flight time ineffective. It is assumed that a FAC training simulator will fill the gap between theory and real-life exercises.

Initiated by a demand for more effective training tools at the Netherlands Integrated Air Ground Operations School, the use of VE technology for training Forward Air Controllers was subject of a study by TNO-FEL. In close co-operation with the Royal Netherlands Army the feasibility of an HMD based training simulator was investigated, and its validity as a solution to improve training effectiveness was assessed.

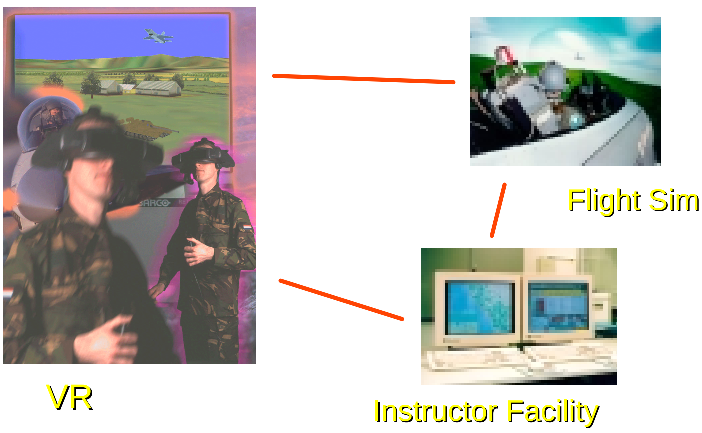

Figure 6: The Forward Air Controller Application comprises three distinct "EBF federates".

A prototype FAC training simulator was built and evaluated (fig. 6). The principal components of the prototype consist of a HMD based simulator for the FAC, and a simple flight simulator for the CAS aircraft. Additionally, an Instructor Console and a Classroom Presentation Station can be linked in. Both the FAC simulator and the CAS flight simulator rely on the ASF facilities. In addition, the CAS flight simulator uses the PLF functionality. The system was evaluated by FAC instructors from the Netherlands Integrated Air Ground Operations School and was used for this purpose in a series of three training courses. The outcome of the evaluation indicates that the traning objectives of the school can be met by a VE based simulator, and has instigated further effort to develop an operational simulator [8].

3.4 FENNEK Armed Reconnaissance Vehicle Simulator

Both the Royal Netherlands Army (RNLA) and the German Army are currently replacing their existing YPR (an M-113 derivative) reconnaissance vehicles by a new armed reconnaissance and surveillance vehicle named "FENNEK" (Figure 7). Compared to the existing vehicles, FENNEK is characterized by the large number of sensors, aimed at enhancing the crew's "situational awareness":

- CCD camera;
- infrared camera;
- laser range finder;
- radar.

In addition to these sensors, a Battlefield Management System (BMS) provides operational information up to battalion level. It is expected that the use of these systems will enhance the situational awareness of reconnaissance teams by allowing better fusion of data from sensors on different vehicles with tactical data obtained from the BMS. These facilities potentially allow for the development of new tactics, where the objective of improved reconnaissance effectiveness and efficiency is of prime importance.

Figure 7: The FENNEK armed reconnaissance and surveillance vehicle

At TNO-FEL a feasibility study is currently underway to investigate how the EBF can be employed to evaluate new tactics and doctrine for the FENNEK reconnaissance vehicle. As a first step, the EBF is being enhanced with a number of FENNEK simulators that enable the operation of teams or platoons of FENNEK vehicles. Typical questions that will have to be answered in the study are:

- What are the consequences of the introduction of FENNEK for communications with other vehicles in the same team, with other teams, and with higher echelon levels?
- What will be the influence of an integrated BMS on operational effectiveness?
- What is the optimal placement of the various sensors on the vehicle?
- What are the best vehicle formations for various missions?
- Will there be an improvement in team combat readiness?
- What are the opportunities for close-in protection?

- etc.

The study will involve both real time human in the loop simulators and computer generated forces of the EBF to evaluate the outcome of scenarios related to the above mentioned issues. The results will be used to develop new tactics and doctrine at the level of squadron, platoon, and below. Recently, a first implementation of a FENNEK simulation model was developed, based on the ASF and PLF software layers of the EBF.

4. EVOLUTION OF THE EBF

Over the past five years the Electronic Battlespace Facility has been in a constant state of evolution and extension from its initial stage to its present day configuration (fig. 8). The facility is currently heavily used to support the RNL Army in its acquisition of a Tactical Indoor Training Simulator (TACTIS), which is the reason for the large number of generic simulators representing tanks (LEO2), armed personnel carriers (PRI) anti-tank APCs (PRAT), and reconnaissance vehicles (FENNEK). In addition to these platform level simulators, there are two systems for Computer Generated Forces, e.g., ModSAF, obtained under a Data Exchange Agreement between the NL and US Armies, and ITEMS, the Interactive Tactical Environment Management System from CAE Electronics. Together with the maritime and air components, these facilities comprise the "Core" EBF.

Other modeling and simulation facilities, available elsewhere within the laboratory, can be linked to the EBF and play a role in several distributed scenarios. These facilities together form the "Extended" EBF, and include:

- The KIBOWI staff level wargame. Research is currently underway to explore various HLA advanced services (e.g., data distribution management, attribute ownership handover, time management) to enable full interoperability of KIBOWI and the EBF, allowing KIBOWI to "drive" scenarios at the platform level (teams, platoons, companies) on the EBF from its own internal model data at the aggregate level (battalion, brigade and above).
- The CIC XXI maritime tactical command & control testbed, which can use scenario management facilities of the EBF for the exploration of new C2 processes and procedures.
- The air command & control simulator ICARUS (see previous section), which provides a fighter allocator and 2 intercept controller stations.
- The Extended Air Defense Simulation model, a constructive model for the analysis of tactical Ballistic Missile, air-to-air, and surface-to-air engagements.

Finally, communication channels are available to link the EBF to other simulation facilities, anywhere in the world. Collaborative simulations have been conducted in the past with other institutes of TNO Defense Research, with the National Aerospace Laboratory, and permanent links to RNL Army simulation facilities are currently under construction.

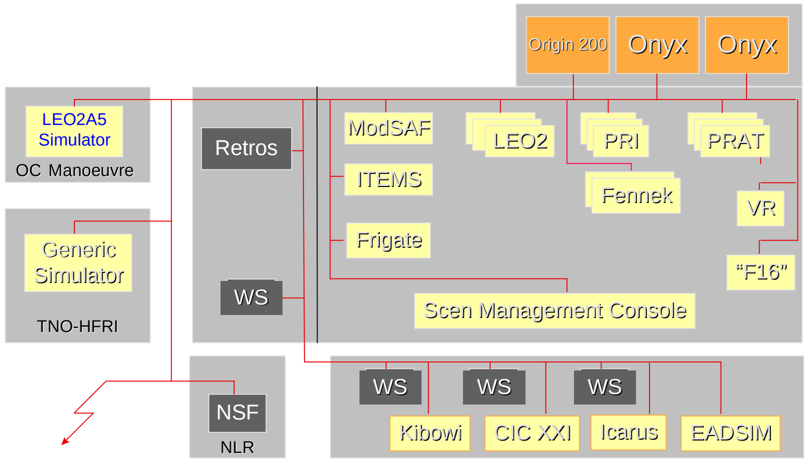

Figure 8: Current EBF configuration: "Core" and "Extended" facilities at TNO-FEL plus extensions to RNL Army's Maneuver School, TNO Human Factors Research Institute, National Aerospace Laboratory (NLR) and others.

Historically, the applications on the EBF have mainly employed platform level simulation models, made interoperable through the DIS protocol suite. Nowadays advanced simulation services, such as those being offered by the HLA, enable interoperability between models of different kinds, e.g., high fidelity engineering level simulations, real-time human-in-the-loop platform level simulations, and constructive or event-driven aggregate level models. Such "heterogeneous simulation interoperability" enables the EBF to support R&D activities across the entire spectrum of operations, from detailed system engineering, through engagement and mission evaluation through theater level analysis (fig. 9). Enhancing the functionality of the EBF to allow its exploitation for these purposes is a high priority item on the agenda at TNO-FEL.

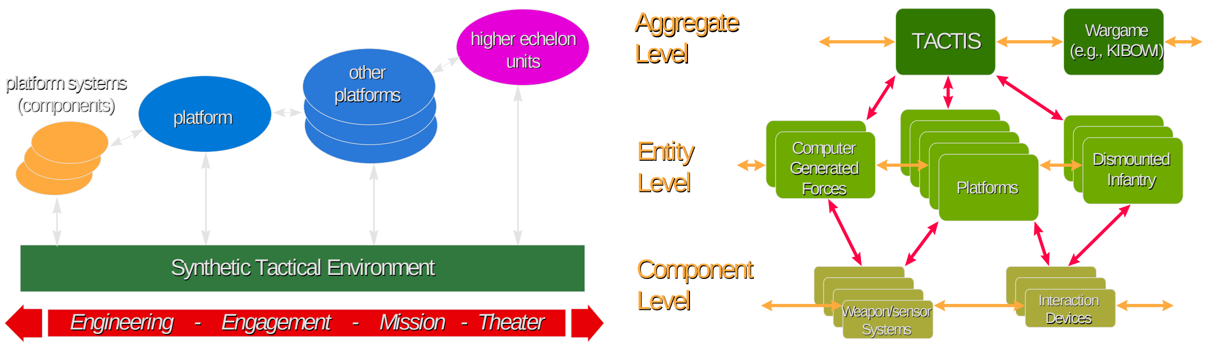

Figure 9: (a) Heterogeneous Simulation Interoperability integrates models across the full spectrum of operations; (b)Horizontal Interoperability integrates on the same aggregation level, Vertical Interoperability integrates across aggregation level.

A crucial issue for the simulation of operational scenarios is the inclusion of valid command & control processes and procedures. This becomes especially significant when interaction with higher or lower echelon units plays a role in the scenario. The command & control infrastructure itself that is being used in the simulated scenario can either be (part of) the "live", i.e., operational infrastructure, or also be simulated. In any case, interoperability between the C2 infrastructure and the simulations at the corresponding aggregation level has to be assured (see fig. 10). Note that interoperability between simulation components and C2 facilities amongst themselves is enabled by suitable standards (HLA for simulations, the ATCCIS data model in the case of the RNL Army C2 infrastructure.). The issue of simulation-C2 interoperability is currently a subject for research on the EBF.

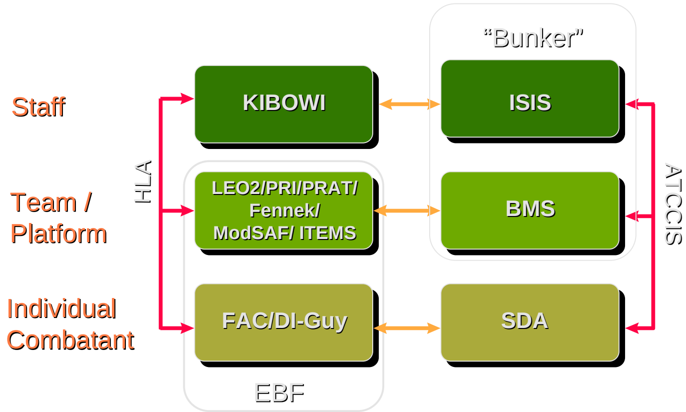

Figure 10: Interoperability between simulation (the EBF) and command & control infrastructure (the Tactical C2 testbed or "Bunker").

As mentioned above, one of the current developments with the EBF is enhancing its connectivity to other defence simulation facilities both inside and outside The Netherlands. In the foreseeable future, the EBF will play an important role in the simulation infrastructure of both the RNL Army, RNL Air Force, and the TNO Defence Research Organisation. Also, incidental experiments with foreign partners, e.g. in the UK and USA, have demonstrated the feasibility of distributed simulations at an international scale. Extending the EBF to become a recognised player in the field of modelling and simulation for all Netherlands Armed Services, Defence Research Institutes, and Defence Industry, enabling a coherent national simulation infrastructure, is a goal for the future.

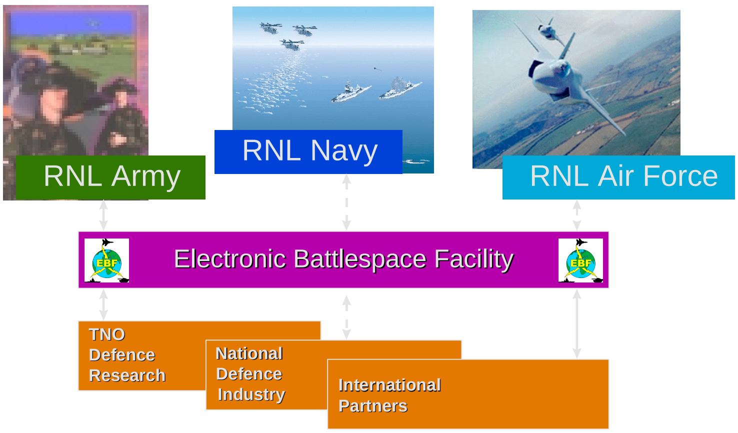

Figure 12: The Electronic Battlespace Facility as key asset in the Joint Simulation Infrastructure in The Netherlands.

5. PRACTICE, EXPERIENCE, AND CONCLUSIONS

To date, TNO-FEL's Electronic Battlefield Facility has proved to be a valuable asset in support of the advanced distributed simulation R&D program. In earlier projects that made use of the EBF infrastructure before the development of the Advanced Simulation Framework and Platform Framework software layers several problems were encountered. The most important of these is that simulation applications need to be aware of implementation details of the underlying communication protocols (i.e., specification of PDUs), complicating the interfaces between different simulators. This was the main motivator for the development of the ASF software layer. Another lesson learned from these early project was that some form of object oriented toolkit was required that supports the reuse of simulation components at the platform level. Without such a software capability, the rapid development of simulators typically required in an R&D program focused at supporting operational military practice, is hardly feasible. The use of the ASF and PLF facilities in later projects resulted in greatly reduced development efforts, e.g., 7 months for the the Forward Air Controller simulator, and a couple of months for the prototype FENNEK simulator. Currently, plans are being made to migrate the ASF "middleware" to the HLA-RTI as underlying communications infrastructure, using the SIMULTAAN architecture as a basis. As far as applications are concerned, the use of the EBF is broadening from mainly training and instruction to materiel procurement, tactics and doctrine development, and operational support. The approach chosen for the EBF, i.e., relying on flexible and extendible standards for interoperability and re-use of simulation assets, has proven to be effective and has laid the foundation for a coherent modeling and simulation infrastructure in the defense community in The Netherlands.

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