Toolbox for 3D Planning and Risk Assessment of Ammunition Field Depots

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Keywords:
planning of ammunition field storage, risk assessment of field camps, explosive ordnance disposal, EOD, risk management, hazard analysis, damage analysis, explosive safety, industrial foundation classes, IFC, forward operating base, rocket, artillery mortar (RAM) threat

Abstract

A growing number of international missions of the German armed forces leads to an increasing need for ammunition storage in field depots. Therefore improved planning and risk assessment tools are needed. Type and intensity of an international mission determine the number of deployed troops and the terrain available for field camps. This defines also type and amount of required ammunition as well as storage conditions. From limitations of space and available personnel the need of optimized planning arises, including the comparison of different solutions for field depots. During the deployment changes of the mission may occur. The presented 3D planning tool for ammunition field depots allows easy and fast adaptation of the existing storage layout to changed situations. The tool is based on military regulations. It makes intense use of databases, computational geometry and relational algebra. Some risks caused by the stored ammunition and given limitations cannot be avoided. We show how the German explosive safety quantitative risk analysis software (ESQRA-GE) is applied to representative planning scenarios. The ESQRA-GE follows an established risk assessment methodology. Based on the modelling of physical hazards and damage, individual and collective risks are computed. Past experience has shown that, in addition to interior threats caused by stored ammunition, shelling poses a major threat. The level of passive protection against rockets provided by representative structures of the field depot for the ammunition is evaluated employing the code "risk analysis software for forward operating bases – rocket, artillery, mortar (RAFOB-RAM)". The presented 3D tools allow the planning of ammunition field depots following the current technical guidelines of the NATO and the German Armed Forces. They provide functionalities to assess the risk due to stored ammunition and threats resulting from rocket shelling.

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14. ABSTRACT
A growing number of international missions of the German armed forces leads to an increasing need for ammunition storage in field depots. Therefore improved planning and risk assessment tools are needed. Type and intensity of an international mission determine the number of deployed troops and the terrain available for field camps. This defines also type and amount of required ammunition as well as storage conditions. From limitations of space and available personnel the need of optimized planning arises, including the comparison of different solutions for field depots. During the deployment changes of the mission may occur. The presented 3D planning tool for ammunition field depots allows easy and fast adaptation of the existing storage layout to changed situations. The tool is based on military regulations. It makes intense use of databases, computational geometry and relational algebra. Some risks caused by the stored ammunition and given limitations cannot be avoided. We show how the German explosive safety quantitative risk analysis software (ESQRA-GE) is applied to representative planning scenarios. The ESQRA-GE follows an established risk assessment methodology. Based on the modelling of physical hazards and damage, individual and collective risks are computed. Past experience has shown that, in addition to interior threats caused by stored ammunition, shelling poses a major threat. The level of passive protection against rockets provided by representative structures of the field depot for the ammunition is evaluated employing the code risk analysis software for forward operating bases rocket, artillery, mortar (RAFOB-RAM). The presented 3D tools allow the planning of ammunition field depots following the current technical guidelines of the NATO and the German Armed Forces. They provide functionalities to assess the risk due to stored ammunition and threats resulting from rocket shelling.

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Brief presenter biography

Frank Radtke started his working career as a research associate at TU Delft after finishing his studies of civil engineering at the University of Hannover with a Dipl.-Ing.. Since 2009 he has been working at the Fraunhofer-Institute for High-Speed-Dynamics, Ernst-Mach-Institute in the hazard and risk analysis group. His work was mainly focused on ammunition storage safety and counter terrorism.

1 Introduction

In this concept paper we present an integrated approach for planning and assessment of field camps with a main focus on ammunition storage safety and passive structural protection against RAM-threats (overhead and side protection).

Since a couple of years NATO nations face an increasing number of deployed missions. Compared to the cold war era the type of conflict has changed. Instead of one symmetric high intensity conflict a number of smaller asymmetric conflicts with changing intensities occurs. This means that at the beginning of a mission the intensity might be low and thus only a small number of light-armed forces is needed. But when the intensity grows the capabilities have to be adapted which means that more forces with different equipment are sent to theatre. But this also means that a field camp that has been planned for e.g. light infantry might need to accommodate armoured troops as well as artillery. Regarding ammunition storage different amounts and types of ammunition need to be taken into account.

Resources for planning, construction, protection and operation of field camps and field depots are always scarce. To increase complexity a field camp might be operated by different nations potentially having different regulations regarding e.g. safety issues.

Naturally, the main thread originates from a possibly hostile environment. This might be for example rocket, artillery or mortar shelling (RAM-threat). Also in this case, the scenario is constantly changing.

To respond to this situation we are developing a toolbox of different interconnected software tools to support planning and operating field camps with the focus on ammunition field depots and protective structures against RAM-threats.

The first step is the partially automated site planning of ammunition field depots following standard guidelines. If it is not possible to comply with appropriate regulations, a more detailed analysis of the field depot is performed using a risk model. Regarding exterior threats a model is employed describing the risk due to rocket, artillery and mortar (RAM) shelling.

2 Automated Site Planning of Ammunition Field Storage

2.1 Objective

The automated site planning tool is supposed to be mainly used during the planning of an ammunition field depot. But it should also support changes becoming necessary during the use of the facility.

The user should be able to specify local boundary conditions as e.g. geographical conditions and choose from standard configurations which can be adapted to special needs.

As a result the user gets fully usable site plans including the needed resources as for example number and type of ISO containers, geometry and material data, or the amount of concrete for storage buildings.

In addition, it should be possible to enter the military forces and automatically compute their required ammunition.

2.2 Approach

In a first step the deployed military forces are specified which includes the specification of the intensity of the conflict, the number of soldiers and the duration of the deployment. Based on this information and based on regulations and experience of the German Armed Forces the program calculates the required amount and type of ammunition (as an example of the program output refer to Figure 1).

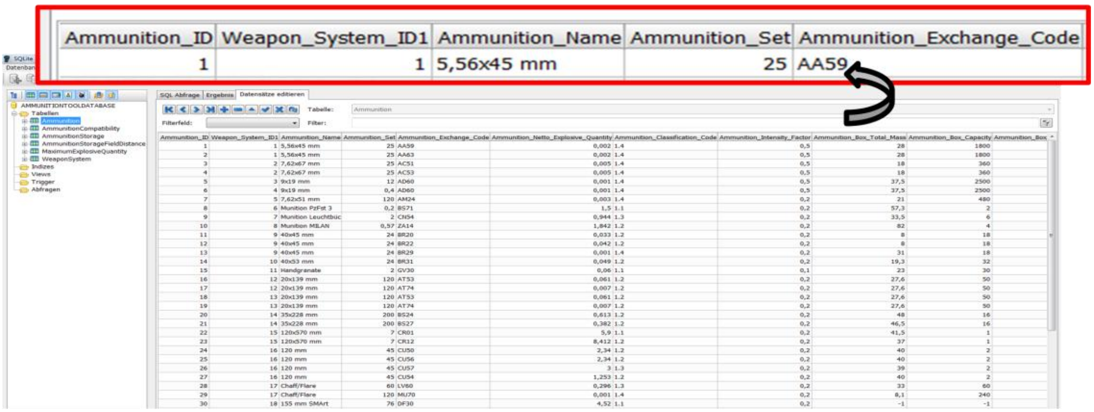

Figure 1: Example of the output of required ammunition generated by the ammunition field depot planning tool.

Based on this information, including the organizational structure of the deployed forces and taking into account the appropriate regulations as e.g. [1, 2] a field depot is generated as qualitatively depicted in Figure 2. Constraints due to the geometry of the storage structure and the packaging of the ammunition are considered as well as typical numbers of ammunition stored within a package.

The software automatically checks if the layout of the field depot complies with the regulations, e.g. safety distances (QDs). In addition, it ensures that the appropriate type of storage structure is used for the stored ammunition. If this is not possible within the given boundary conditions, hazard, damage and risk analysis can be conducted.

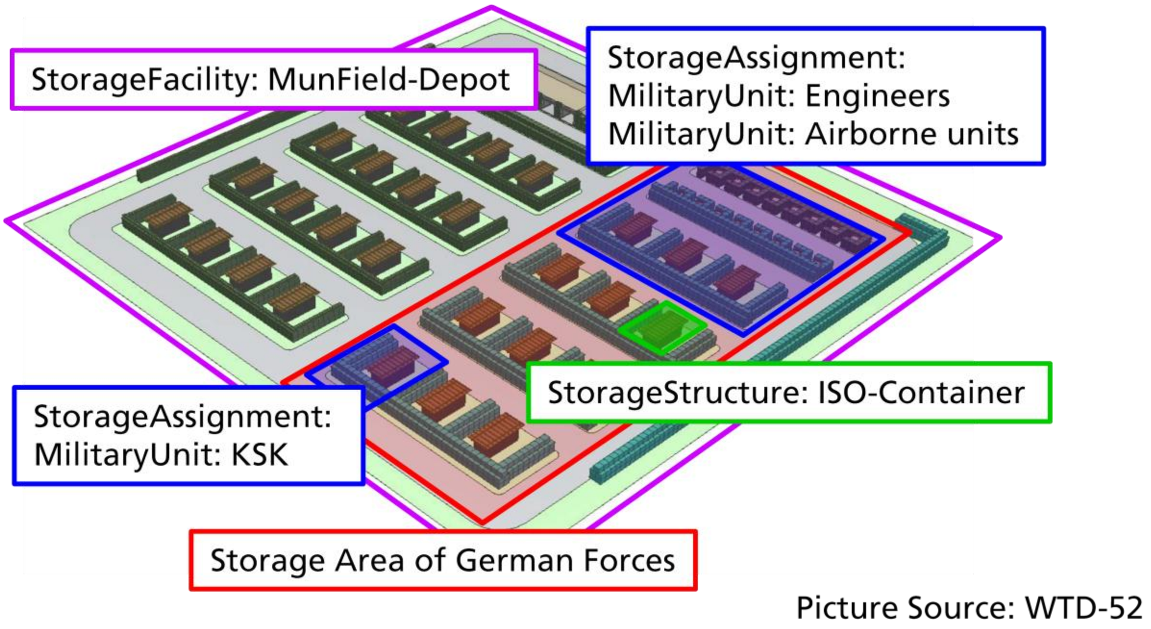

Figure 2: Example of an ammunition field depot; each military unit gets a storage assignment within the storage area of the national forces e.g. the German forces; each storage assignment may consist of different types of storage structures.

3 Risk Assessment of Internal Threads due to Ammunition Storage

If it is not possible to follow the regulations when planning an ammunition field depot, it might become necessary to perform a hazard, damage and risk analysis. Based on this analysis the depot might be optimized to reach an acceptable level of safety.

3.1 Objective

The German explosive safety quantitative risk analysis model (ESQRA-GE) is intended for the assessment of non-standard situations in ammunition storage, where existing guidelines cannot be applied.

3.2 Approach

In Figure 3 the risk management scheme for explosive events employed at EMI is depicted. The first step is the scenario definition. In the presented integrated approach the scenario definition is performed using the ammunition depot planning tool output as described in Section 2. In the future we will directly import this data into the risk analyses software ESQRA-GE.

For a defined scenario the physical hazards as fragment throw or blast can be calculated as shown in Figure 4.

Based on the physical hazards, consequences, e.g. damage of buildings or the number of injured persons, can be computed.

Including the fractional exposure of persons to hazards, and the frequency of an event e.g. an unwanted explosion, the individual risk of persons can be evaluated. In this way a scenario can be adapted such that safety is guaranteed to an acceptable level even if it is not possible to comply with standard guidelines.

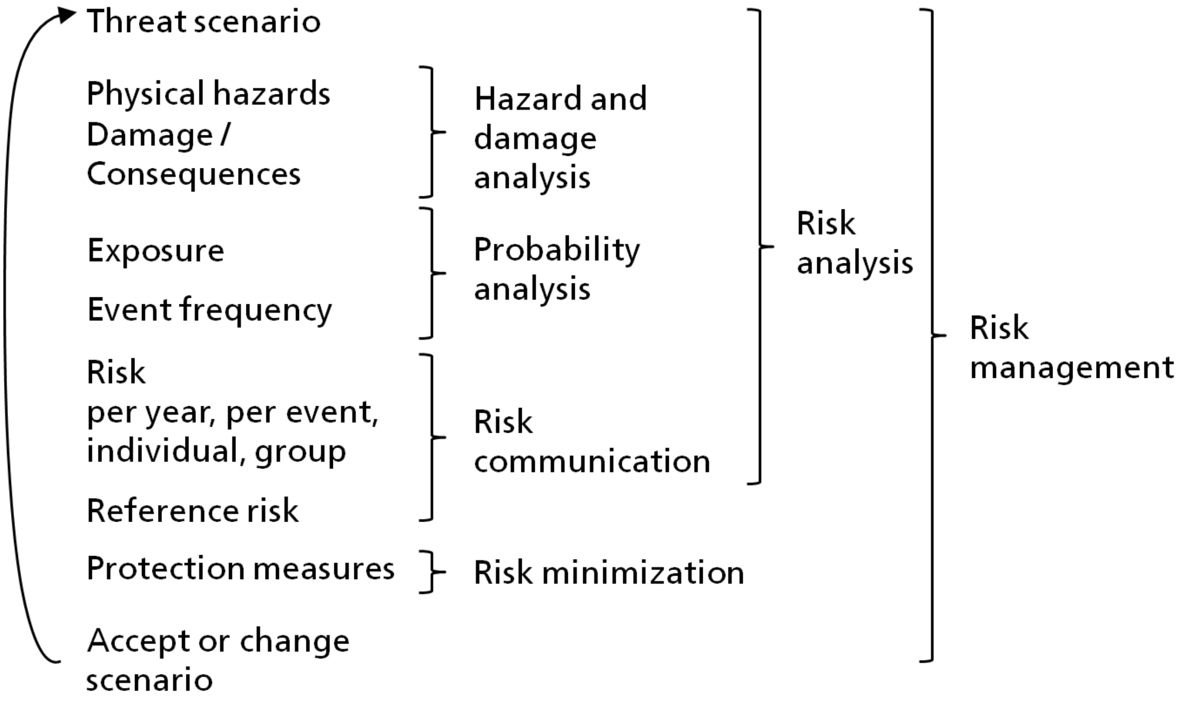

Figure 3: Risk management methodology employed at Fraunhofer Ernst-Mach-Institute (EMI).

The ESQRA-GE is described in more detail in [3–5].

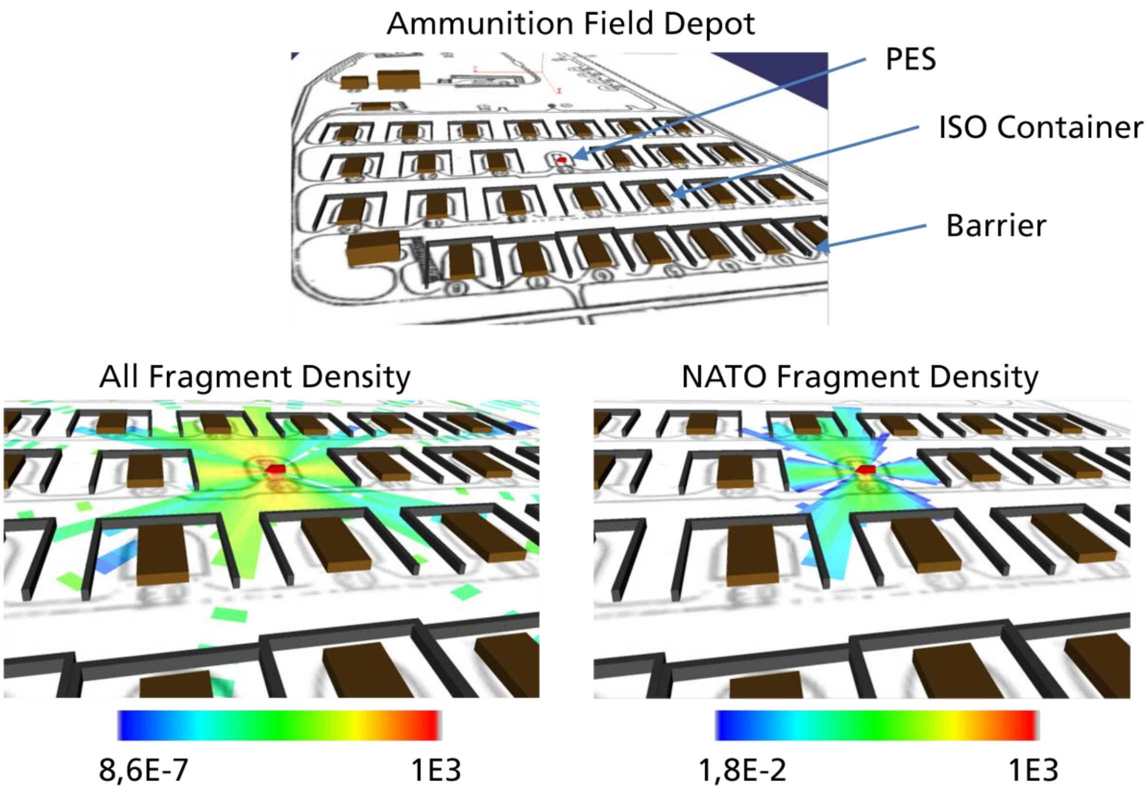

Figure 4: Density of all fragments (left) and density of fragments fulfilling the NATO criterion (right); fragment shadows due to barriers around the storage containers are clearly visible.

4 Risk Assessment of External Threads due to Shelling

So far, we have considered hazards originating from inside a field camp as possible threats. But naturally we also have to take into account a possibly hostile environment. Current missions have shown that a major threat consists of the shelling of field camps with rockets, artillery and mortar shells. Therefore, we develop a risk analysis (RA) tool for forward operating bases (FOB) analyzing the effect of passive protection against RAM. The tool RAFOB-RAM is supposed to use the output of the ammunition depot planning tool as scenario input for a part of the analysed field camp.

4.1 Objective

The aim of the risk analysis model for forward operating bases (RAFOB-RAM) is to assess different types of risk for personnel due to rockets, artillery or mortar shells fired into a field camp as depicted in Figure 5.

Mitigation effects due to passive protection are taken into account. The aim is to detect weak points of the passive protective measures – in particular in the ammunition storage facilities.

For instance, for certain ammunition classes – high energy fragments cause initiation of ammunition. Thus, ammunition storage sites might become hazards sources. Even more, if sympathetic detonation must be considered.

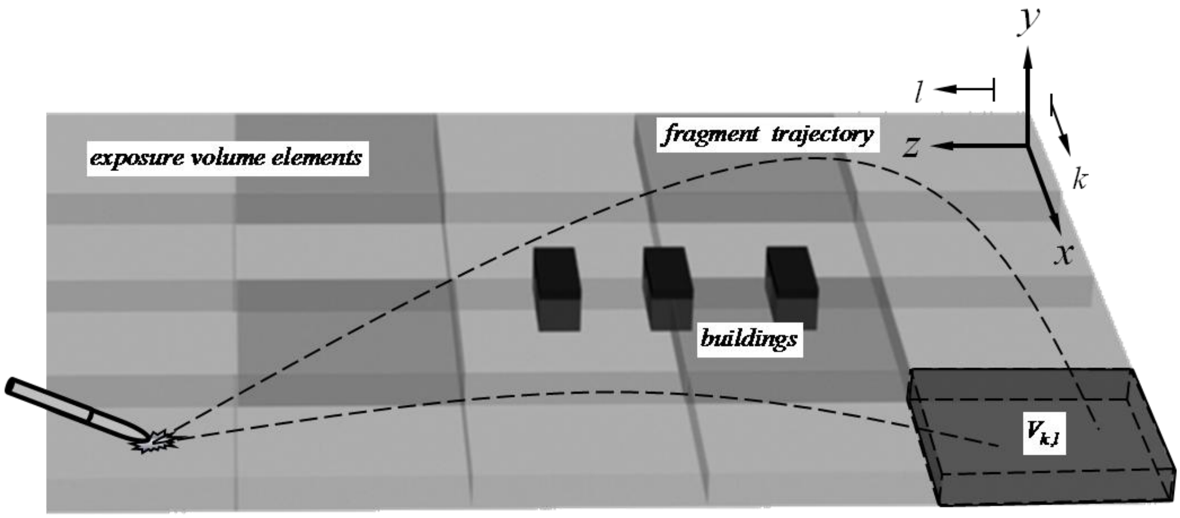

Figure 5: Example scenario with depiction of the outdoor exposure volume elements possibly containing persons.

4.2 Approach

First, possible trajectories of RAM ammunition are calculated leading to a number of representative impact trajectories in the camp as shown in Figure 6.

We consider different types of fuses and impact scenarios. Depending on the fuse type we calculate for each representative impact trajectory the effects of representative initiations in air, at impact or after perforation of structures. The fragment trajectories are calculated. If the shell hits a building, penetration or perforation of the building are computed. This generates threats inside a building due to primary fragments and secondary debris from the building itself.

Knowing the fragment trajectories and specifying areas where people are located possible injuries with different levels of severity can be calculated. To asses injuries for persons we use a three dimensional representation of a human being taking into account individual protection levels and positions (voxel model) [6].

Finally, using event frequency and fractional exposure of persons to different threats, local and global individual and collective risks can be computed.

This information can be applied to identify critical components of the building structures and to minimize resulting risks by employing structural hardening or protective measures, e.g. barriers.

Figure 6 shows two calculated scenarios, where 625 representative initiation points were calculated for the warhead of an unguided 107 mm rocket fired from 4 km away. The upper part of the figure shows an atrium building with massive outer walls and a thick concrete roof. In the lower part the same building is protected on three sides with 2 m high walls. The protective barriers lead to a significant reduction of the injury probability inside the building, as illustrated in the picture. Apparently the applied protective measure is appropriate for a more effective passive protection. All possible single events for a rocket with an impact fuse were considered, i.e. the consideration of more representative impact trajectories leads to the same results close to the building.

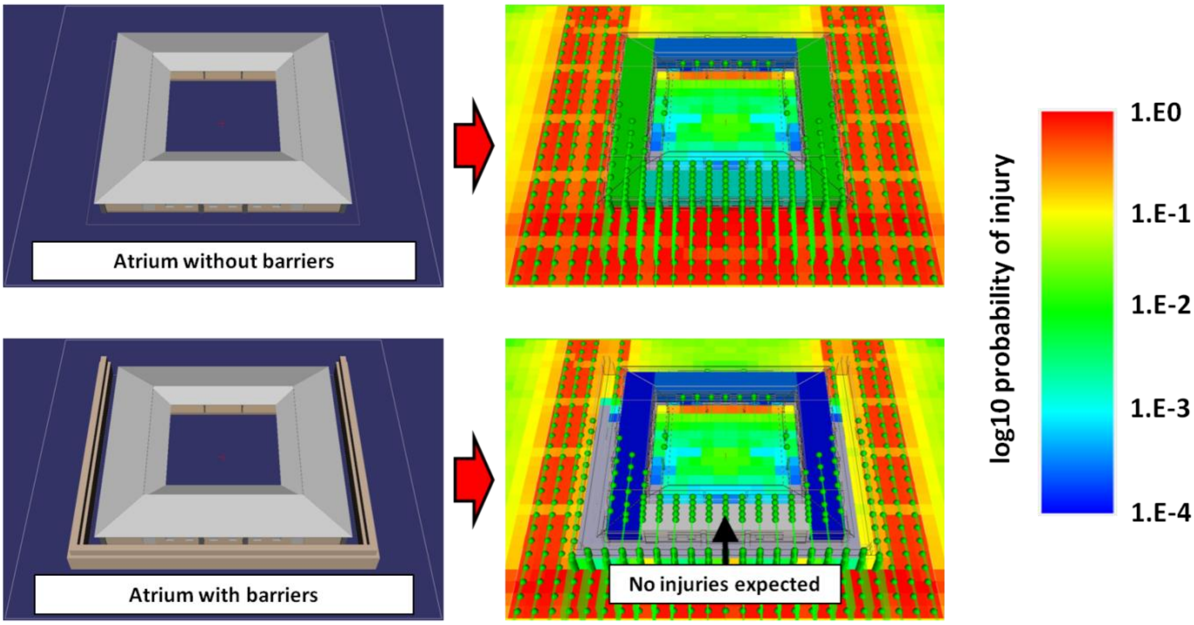

Figure 6: Minimization of consequences inside an atrium building with protective barriers.

5 Industry Foundation Classes as Interface Between Different Models

For users it is of highest importance to connect the different models in an efficient way. Thus an interface for stable data exchange has to be defined. For this purpose we have decided to use the Industry Foundation Classes (IFC) as data exchange format defined in an ISO standard [7]. This ISO-standard is currently introduced to a number of CAD tools. It has the advantage of storing all necessary data including geometrical data and material data in an efficient hierarchical layer like structure as shown in Figure 7. An example might be an ammunition storage house, where in addition to geometrical data material data such as Young's modulus or fracture energy can be assigned to the different objects in the file-format. This will enable us, for example, to compute within models like ESQRA-GE (refer to Section 3) and RAFOB-RAM (refer to Section 4) penetration or perforation of barriers and walls by fragments in an efficient way. At the same time the format contains all the information needed in the planning tool (refer to Section 2) to generate site plans and resource lists.

An important aspect regarding usability of the presented tools is the realistic visualization (refer to Figure 8) of scenarios, and analysis of results using the IFC format.

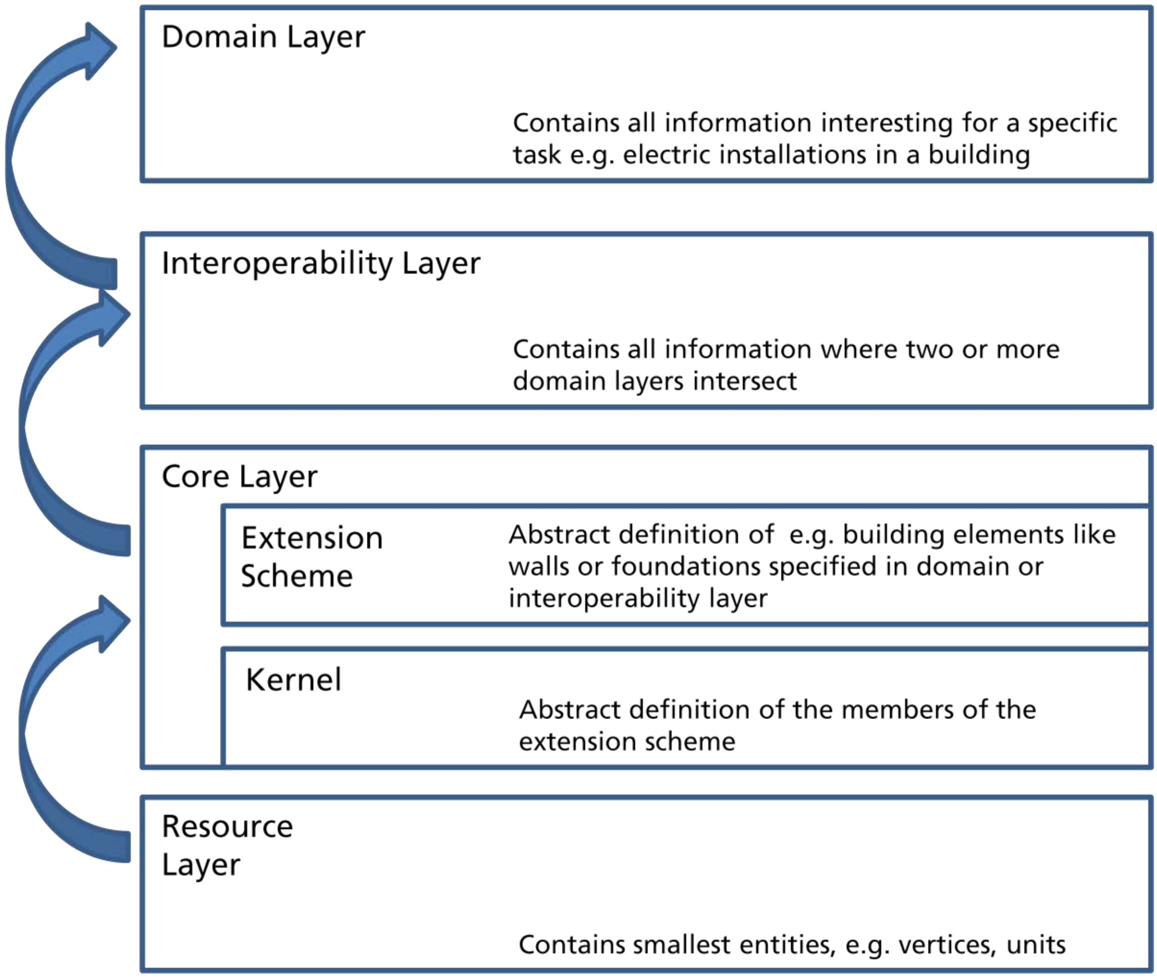

Figure 7: Layer structure of the industrial foundation classes (IFC) [8].

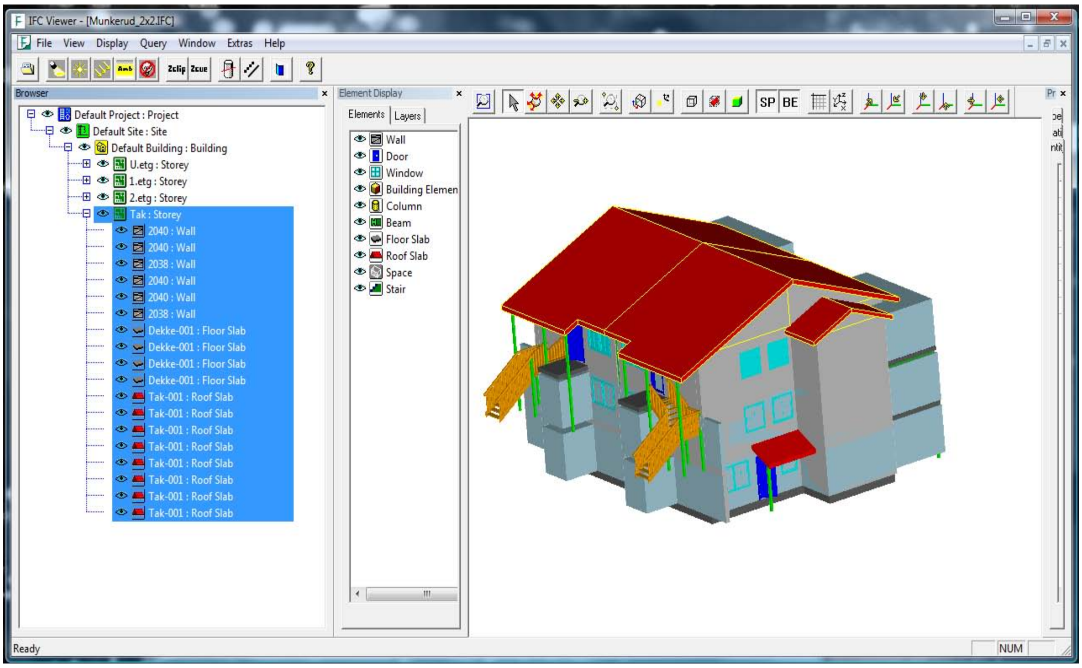

Figure 8: Visualization of a typical building; screenshot taken from IFC Viewer, Forschungszentrum Karlsruhe [9].

6 Conclusions

We have presented the concept of a framework for the planning of ammunition storage field depots, the risk assessment of ammunition storage depots in or close to field camps and the assessment of RAM-threats for field camps including ammunition storage depots. This framework enables us to assess interior and exterior threats, and allows to respond dynamically to changing needs of the German Armed Forces during their out-of-area missions.

7 Acknowledgements

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TOOLBOX FOR 3D PLANNING AND RISK ASSESSMENT OF AMMUNITION FIELD DEPOTS

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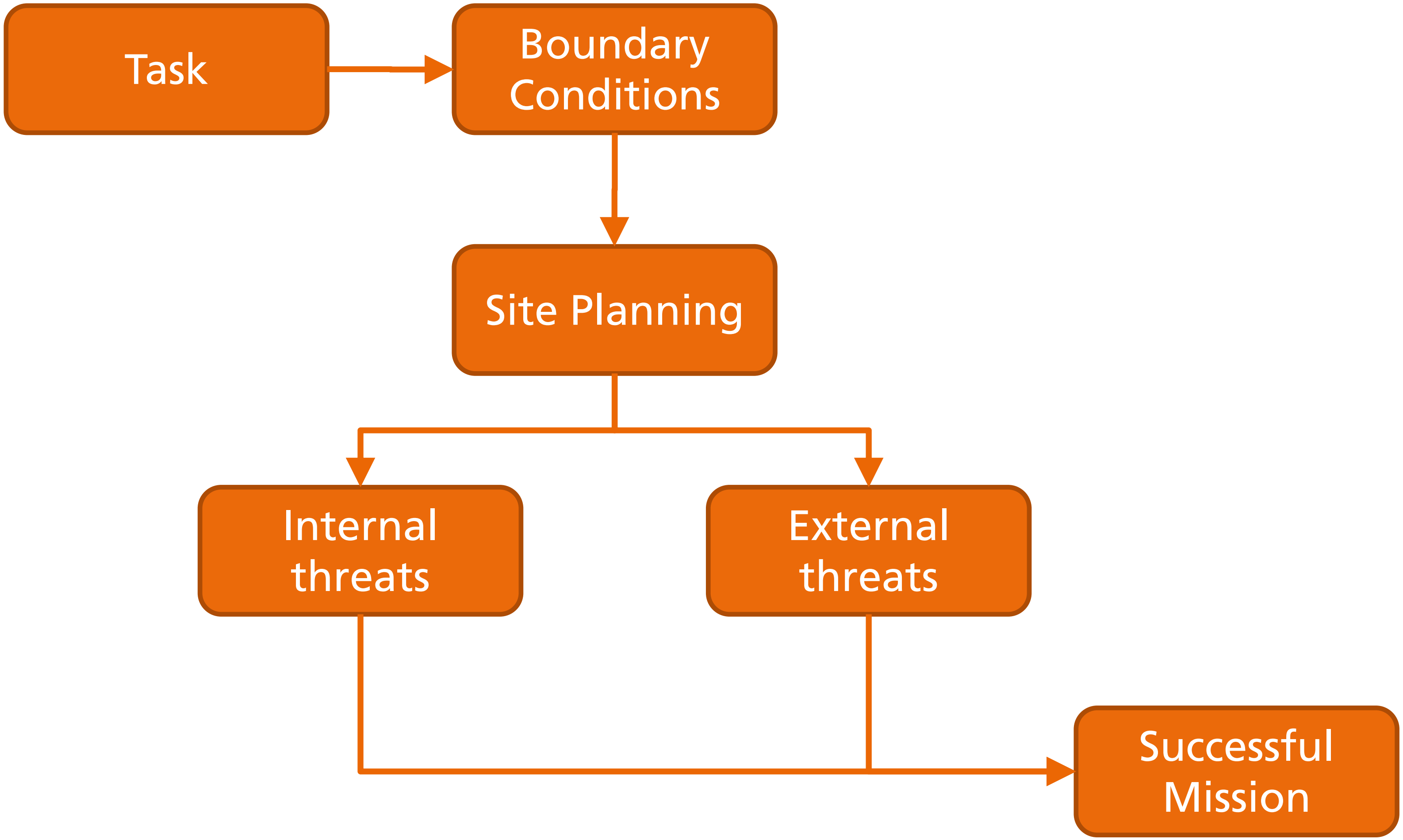
Fraunhofer
EMI

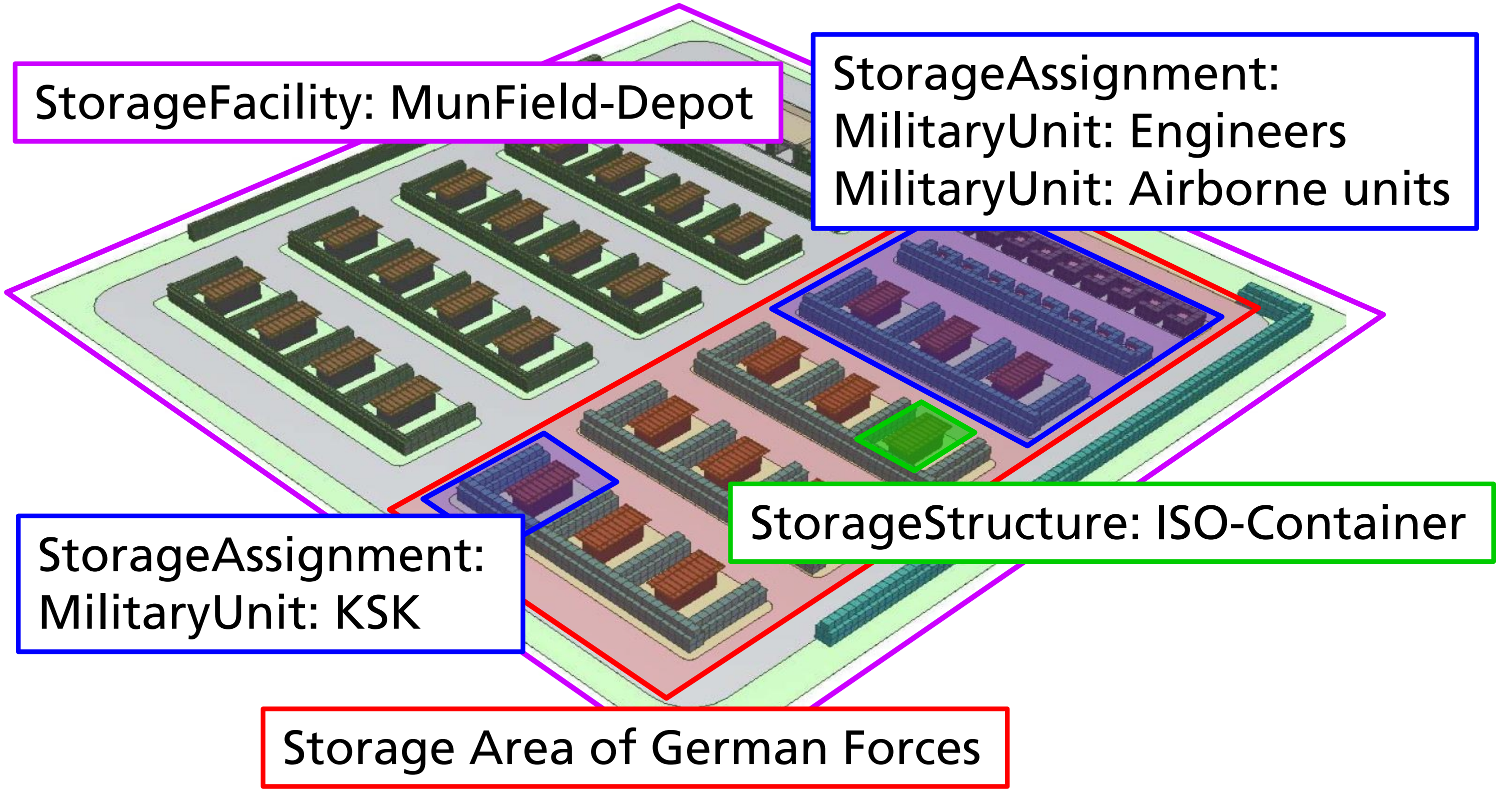
Outline

- Introduction
- Site planning tool
- Risk assessment for ammunition field depots and field camps regarding internal threats
- Risk assessment for ammunition field depots and field camps regarding external threats
- Interface between the different tools
- Conclusions

Framework for Planning and Assessment of Field Camps and Ammunition Field Depots



Site Planning Tool



Picture Source: WTD-52

Program Flow

1.
- Task – Requirements – Boundary Conditions
- Number of Soldiers, Time of Deployment,…

2.
- Type of Ammunition
- Amount of Ammunition

3.
- Choice of appropriate Storage Structures
- Placement of Ammunition

4.
- Site Planning of Ammunition Field Depot
- 3D - CAD-Plans using IFC

5.
- Check Regulations
- Check Requirements

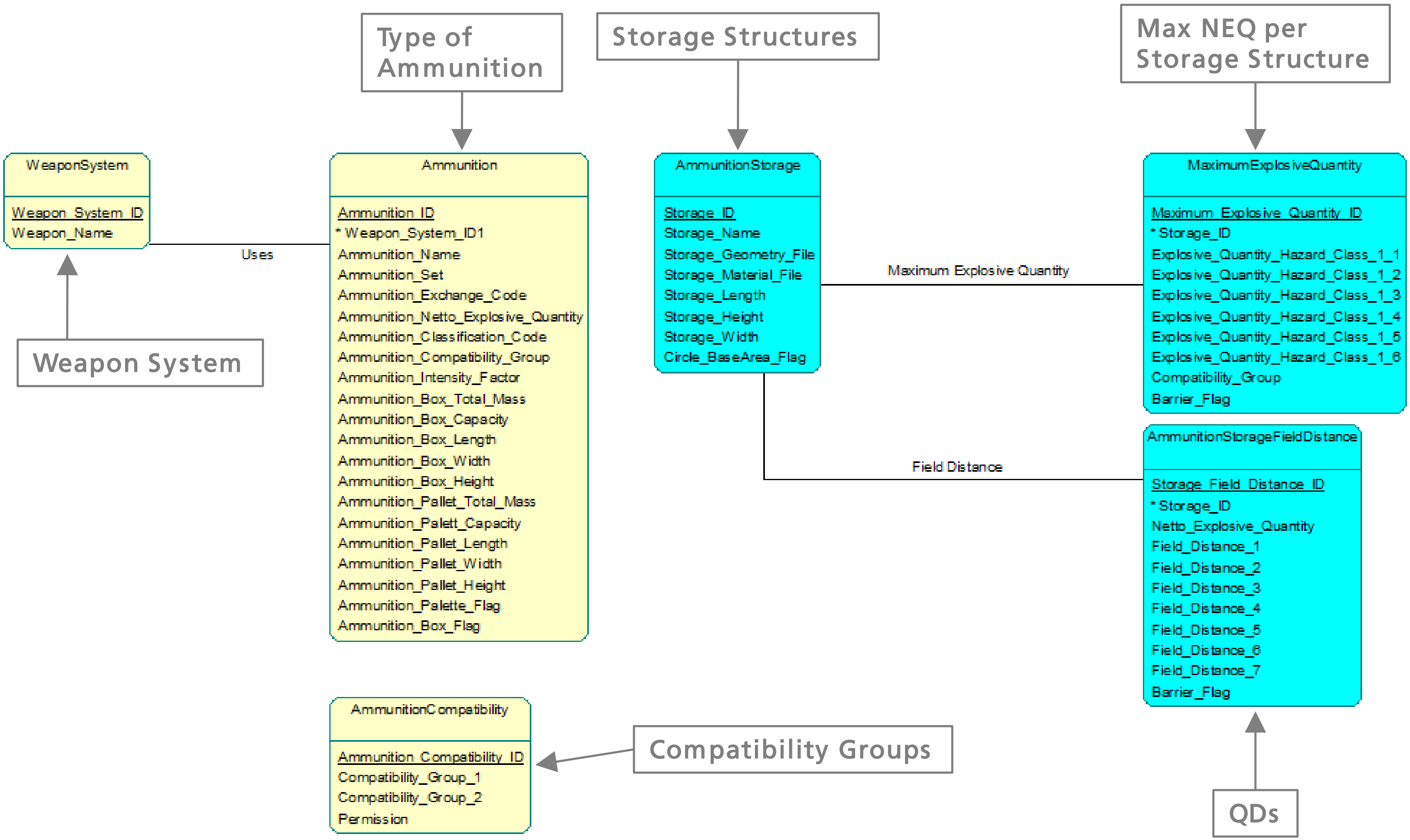
6.
- Adapting Ammunition Field Depot

German Regulations:

➢ Weisung MunTSichBevMunE

➢ Leitfaden Baulicher Schutz

Data Structure of the Site Planning Tool



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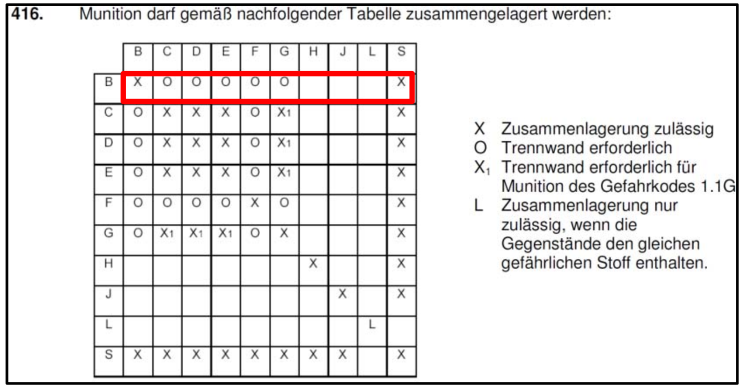
Digitization of Regulations

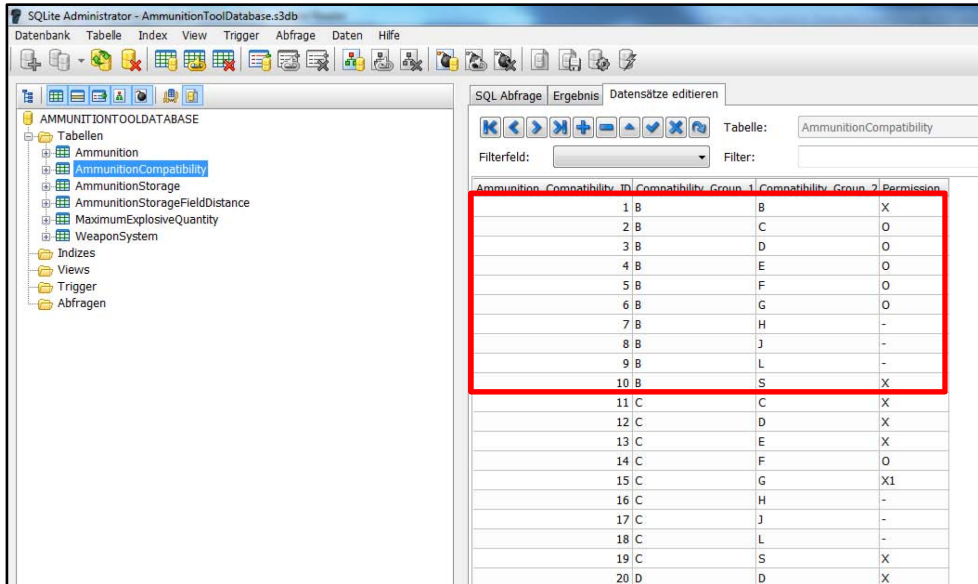
Example: Compatibility Groups



416. Munition darf gemäß nachfolgender Tabelle zusammengelagert werden:

	B	C	D	E	F	G	H	J	L	S
B	X	O	O	O	O	O				X
C	O	X	X	X	O	X_1				X
D	O	X	X	X	O	X_1				X
E	O	X	X	X	O	X_1				X
F	O	O	O	O	X	O				X
G	O	X_1	X_1	X_1	O	X				X
H							X			X
J								X		X
L									L	
S	X	X	X	X	X	X	X	X		X

X Zusammenlagerung zulässig
O Trennwand erforderlich
X_1 Trennwand erforderlich für Munition des Gefahrkodes 1.1G
L Zusammenlagerung nur zulässig, wenn die Gegenstände den gleichen gefährlichen Stoff enthalten.



Ammunition_Compatibility_ID	Compatibility_Group_1	Compatibility_Group_2	Permission
1	B	B	X
2	B	C	O
3	B	D	O
4	B	E	O
5	B	F	O
6	B	G	O
7	B	H	-
8	B	J	-
9	B	L	-
10	B	S	X
11	C	C	X
12	C	D	X
13	C	E	X
14	C	F	O
15	C	G	X1
16	C	H	-
17	C	J	-
18	C	L	-
19	C	S	X
20	D	D	X

Internal and External Threats

RAM

Ammunition Storage

IED / VBIED

Small Arms Fire

Risk assessment for Ammunition Field Depots

- Threat scenario
- Physical hazards
- Damage / Consequences
  - → Hazard and damage analysis
- Exposure
- Event frequency
  - → Probability analysis
- Risk per year, per event, individual, group
- Reference risk
  - → Risk communication
- Protection measures
  - → Risk minimization
- Accept or change scenario

Hazard and damage analysis, Probability analysis, Risk communication → Risk analysis

Threat scenario … Accept or change scenario → Risk management

Internal Threats – ESQRA-GE

RAM

Ammunition Storage

IED / VBIED

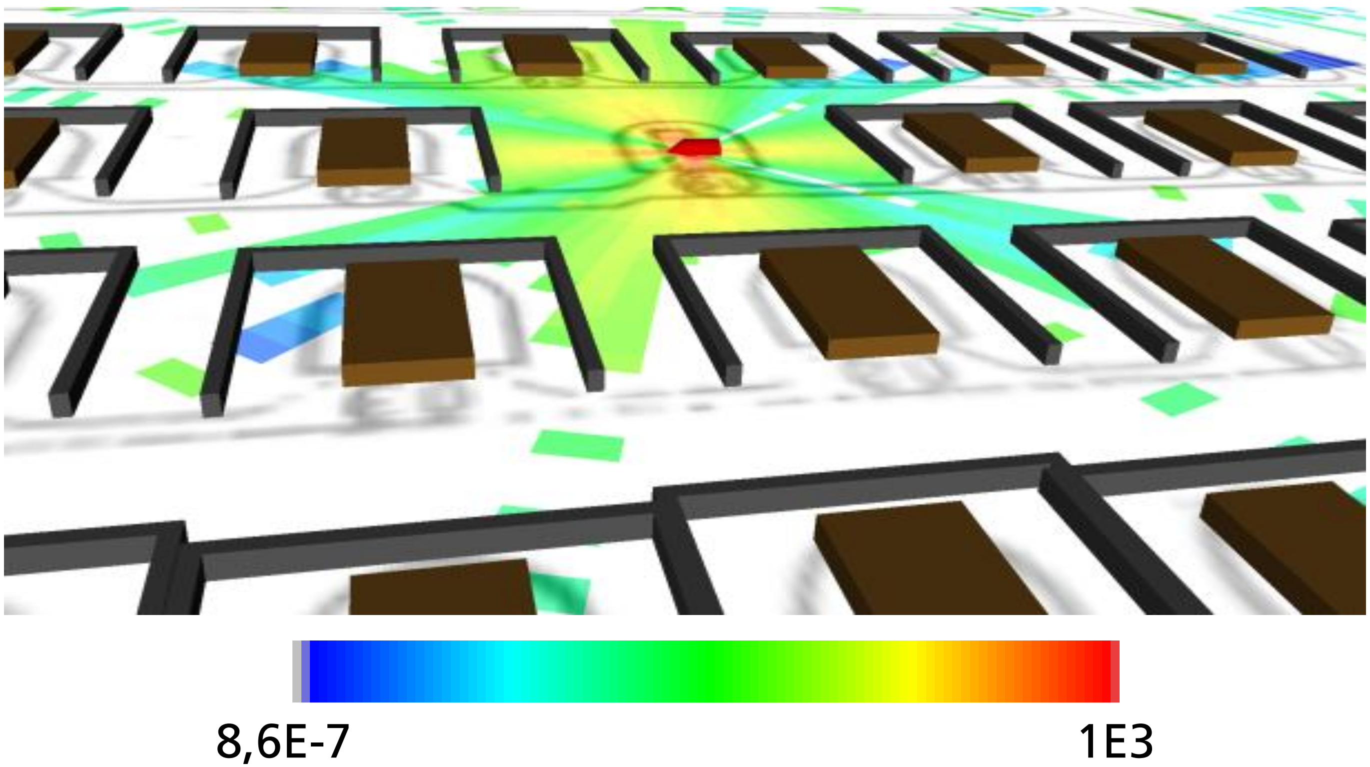
Small Arms Fire

ESQRA-GE: Assessment of an Ammunition Field Depot Regarding Internal Threats

Ammunition Field Depot

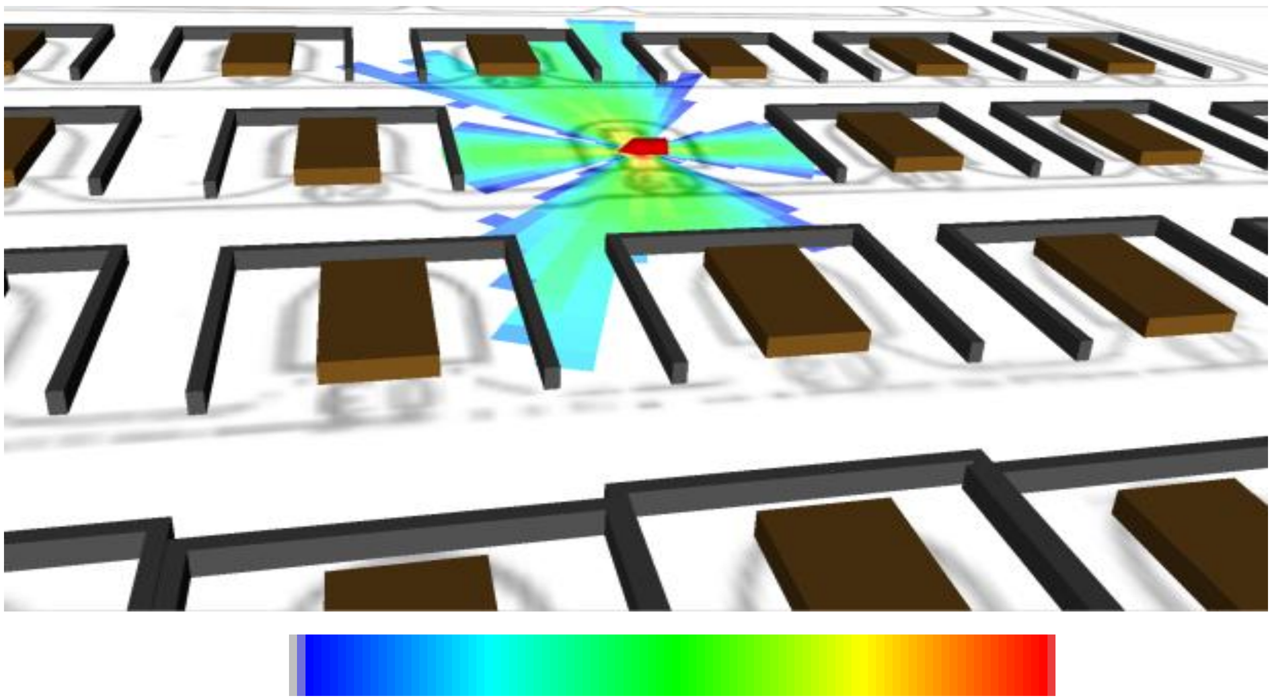
ESQRA-GE: Assessment of an Ammunition Field Depot Regarding Internal Threats

All Fragment Density



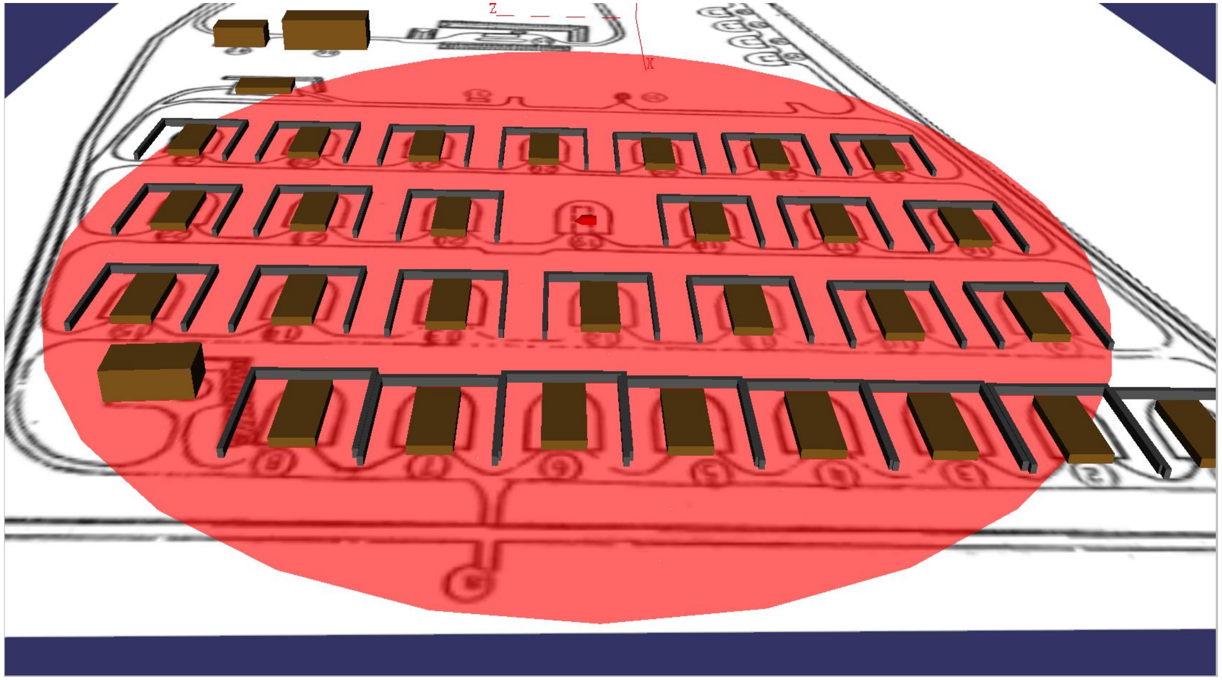
ESQRA-GE: Assessment of an Ammunition Field Depot Regarding Internal Threats

NATO Fragment Density



ESQRA-GE: Assessment of an Ammunition Field Depot Regarding Internal Threats

Damage Zone for Vehicles:
Zone C – slight or no damage



External Threats – ESQRA-GE

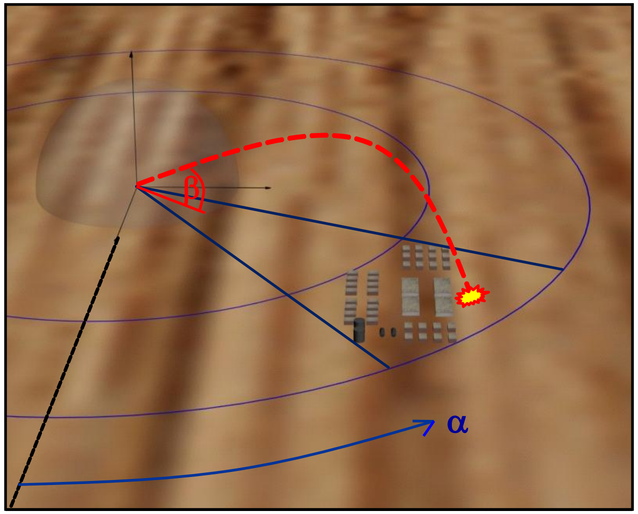
RAM

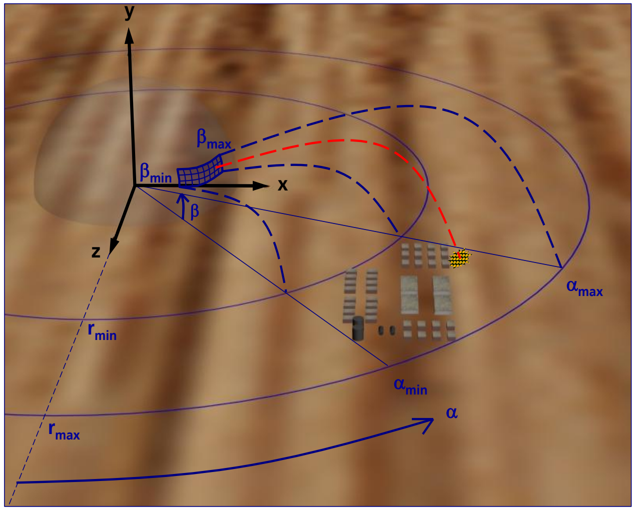
Ammunition Storage

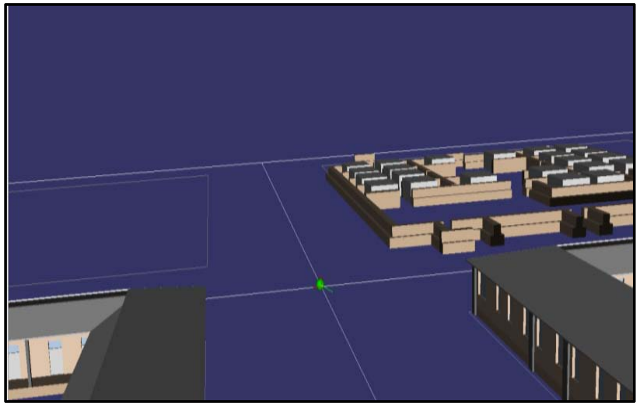
IED / VBIED

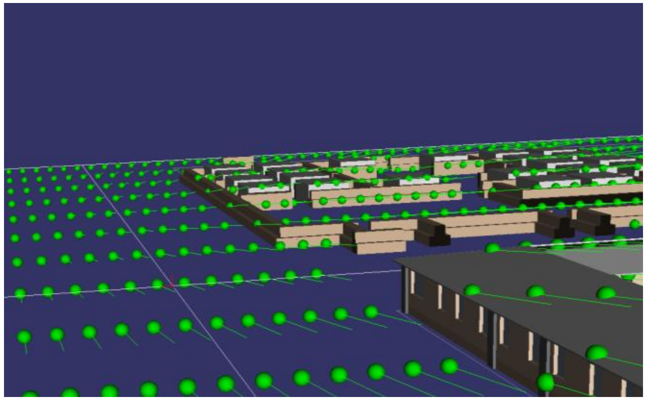
Small Arms Fire

RAFOB-RAM: Assessment of an Ammunition Field Depot Regarding External Threats









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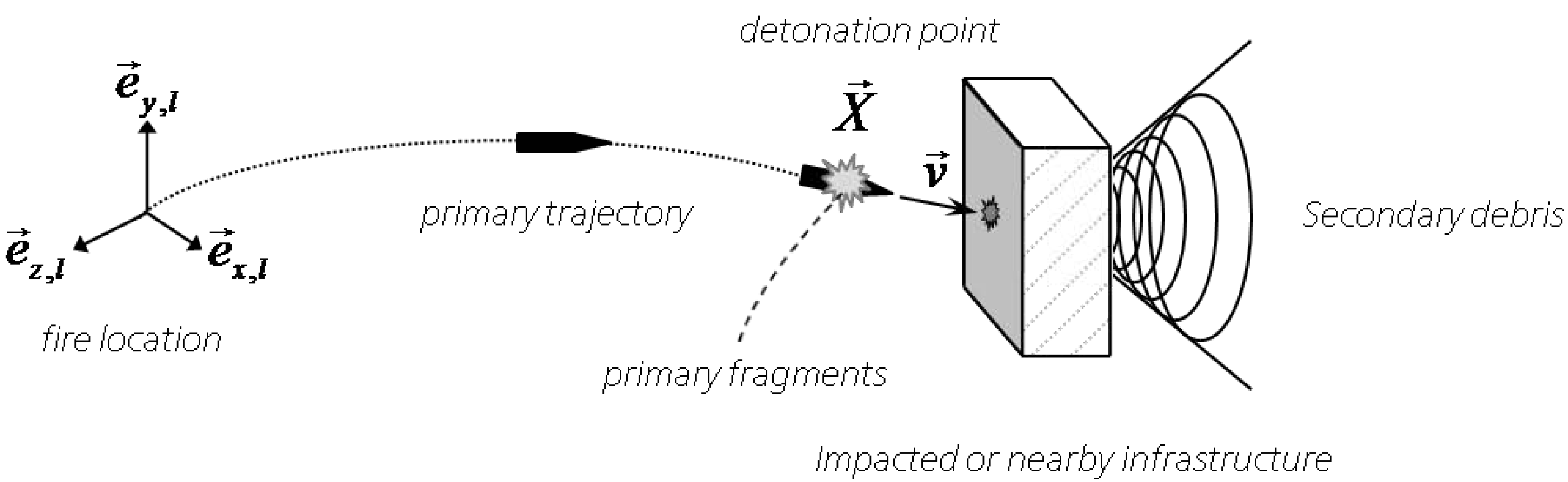
RAFOB-RAM: Assessment of an Ammunition Field Depot Regarding External Threats



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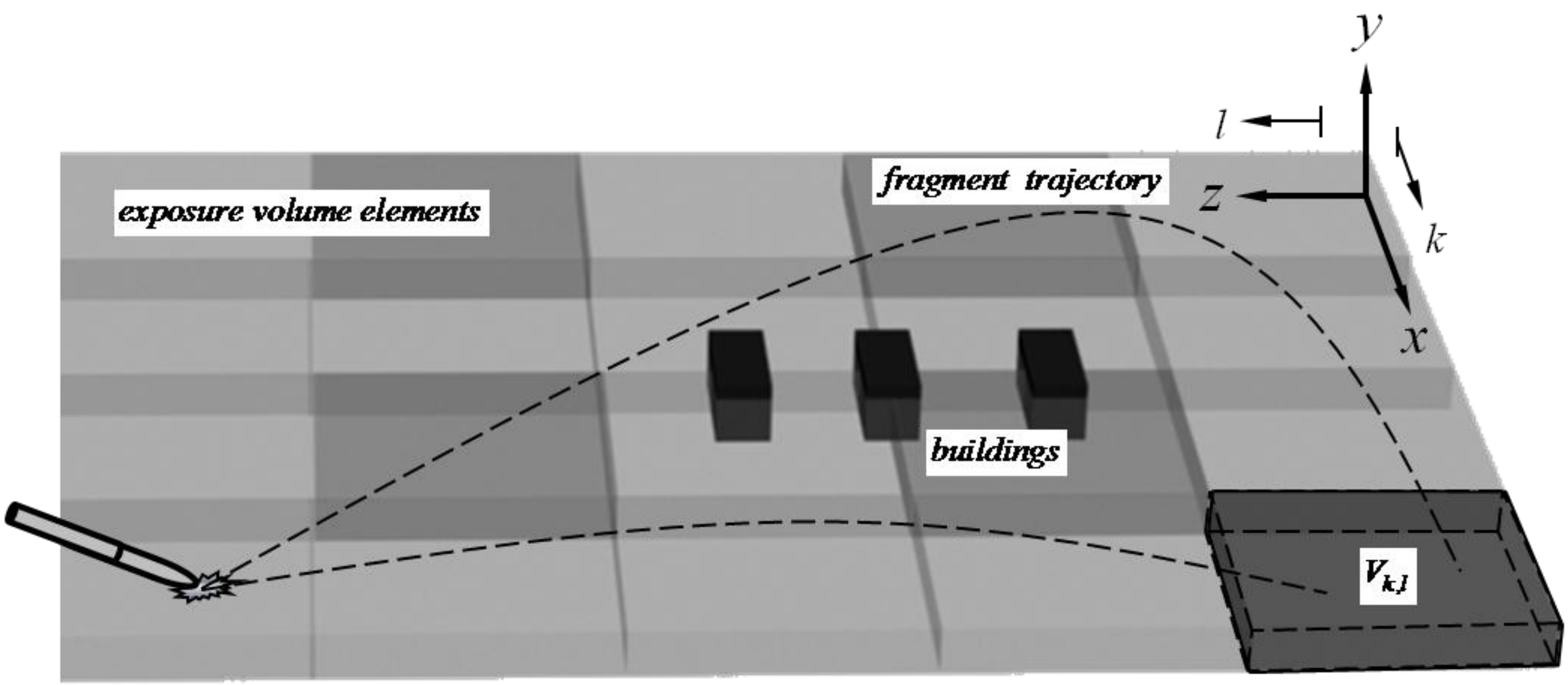
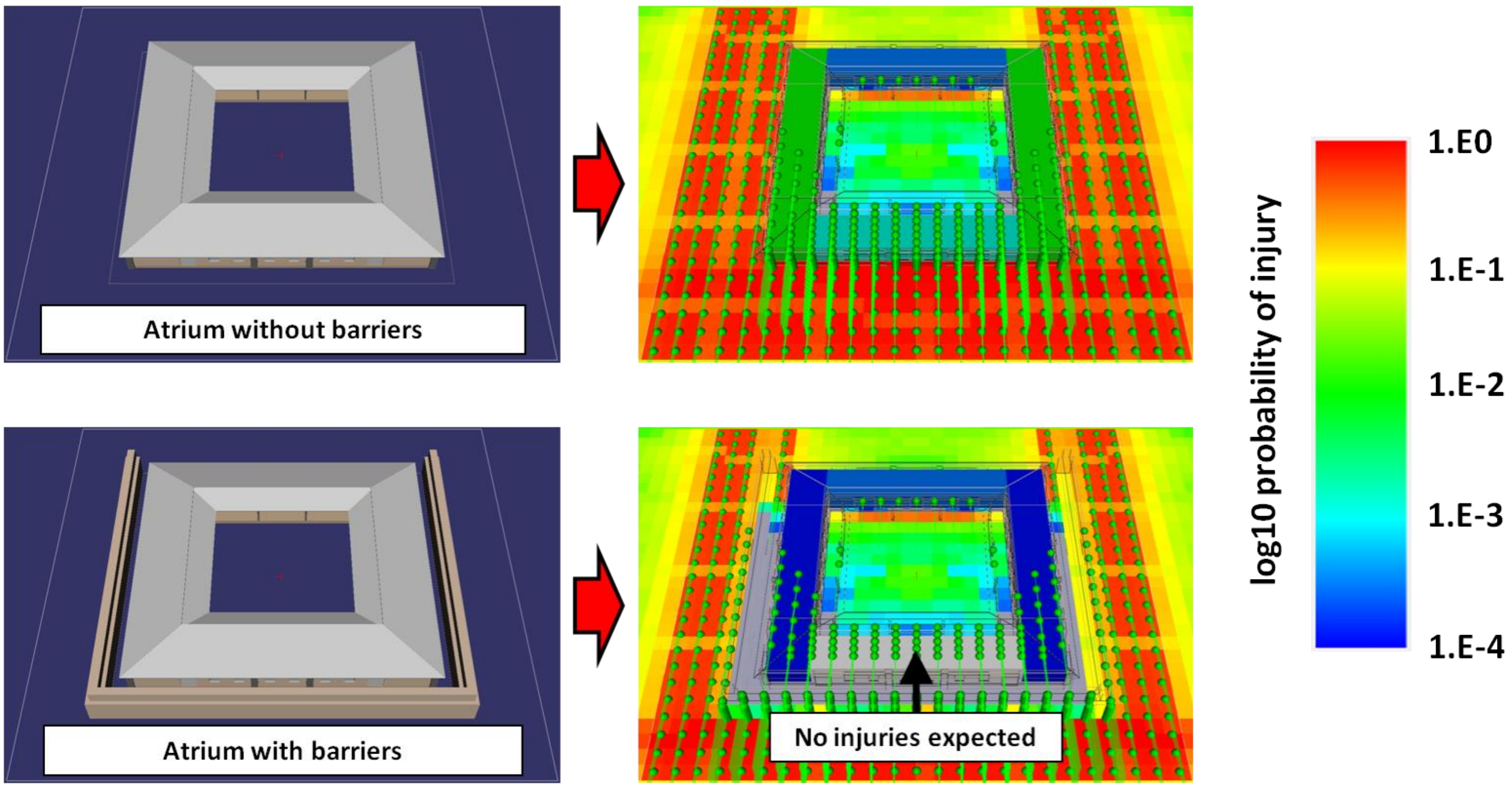
RAFOB-RAM: Assessment of an Ammunition Field Depot Regarding External Threats

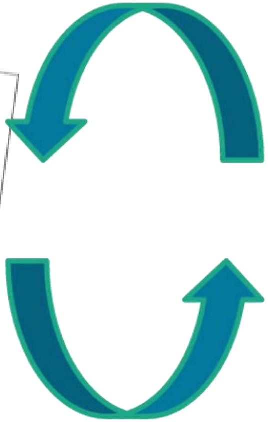


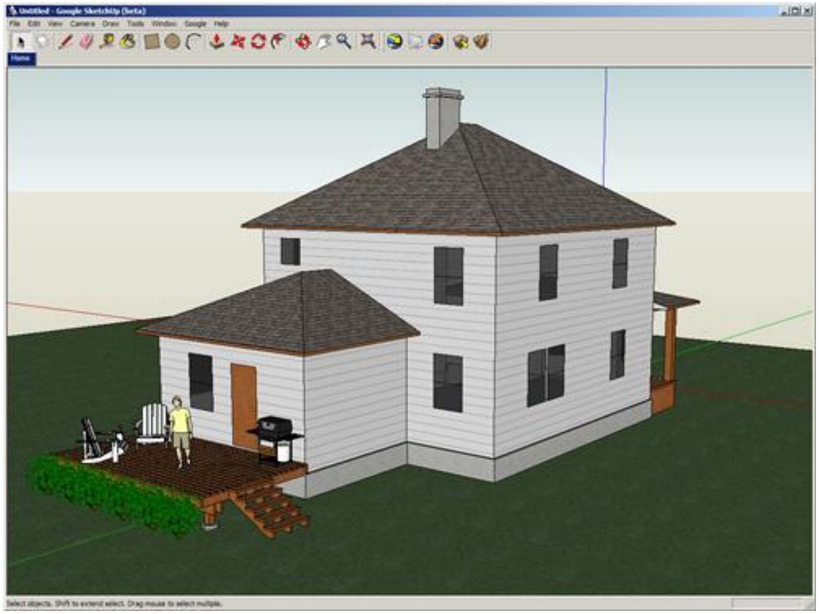
RAFOB-RAM: Assessment of an Ammunition Field Depot Regarding External Threats



IFC – Format: Interface Between the Different Tools

Quelle: www.koramic.de





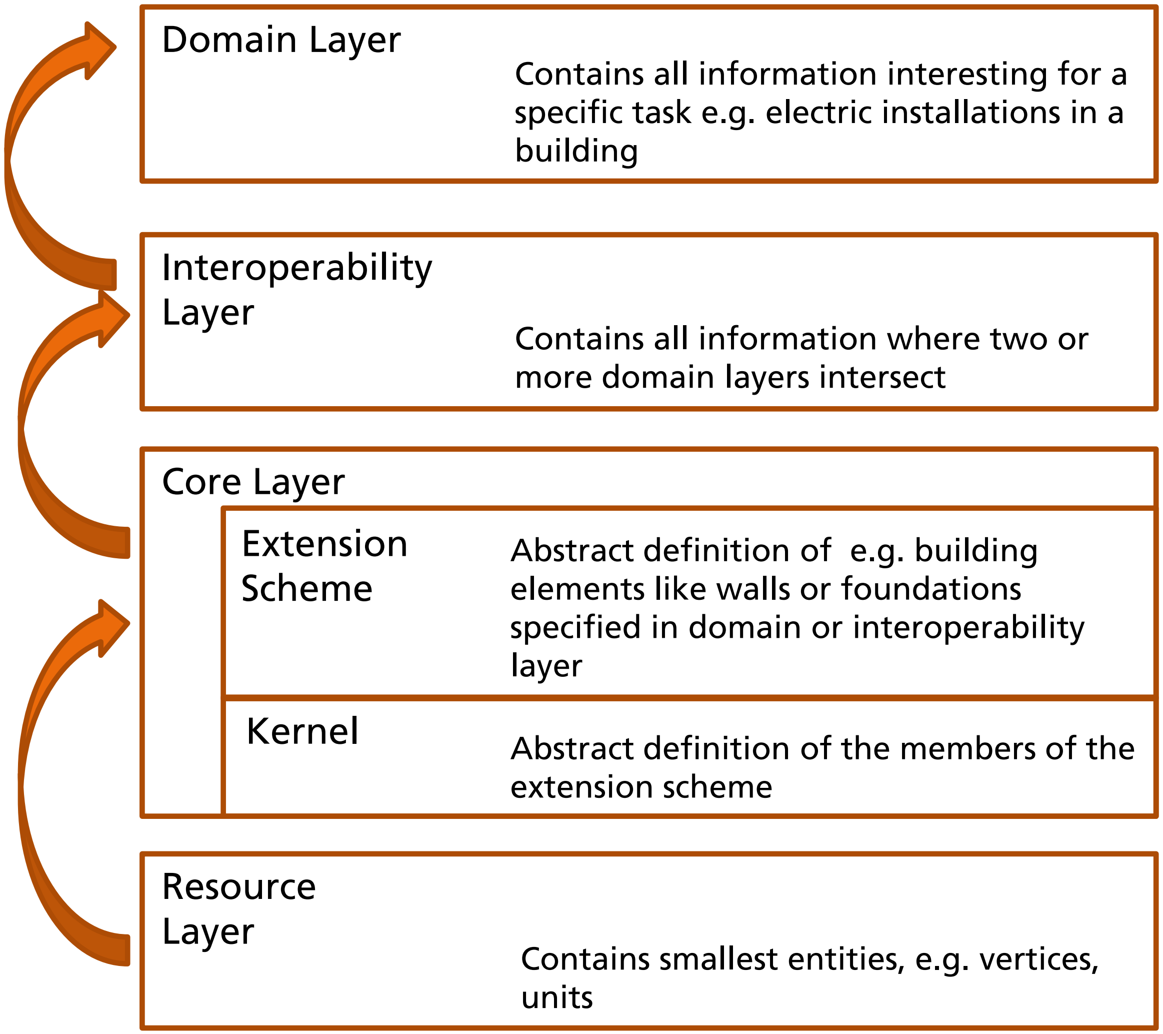
Quelle: Google SketchUp

3D CAD-Data, Material Data, Strength of Material, Amount of Reinforcement, Use

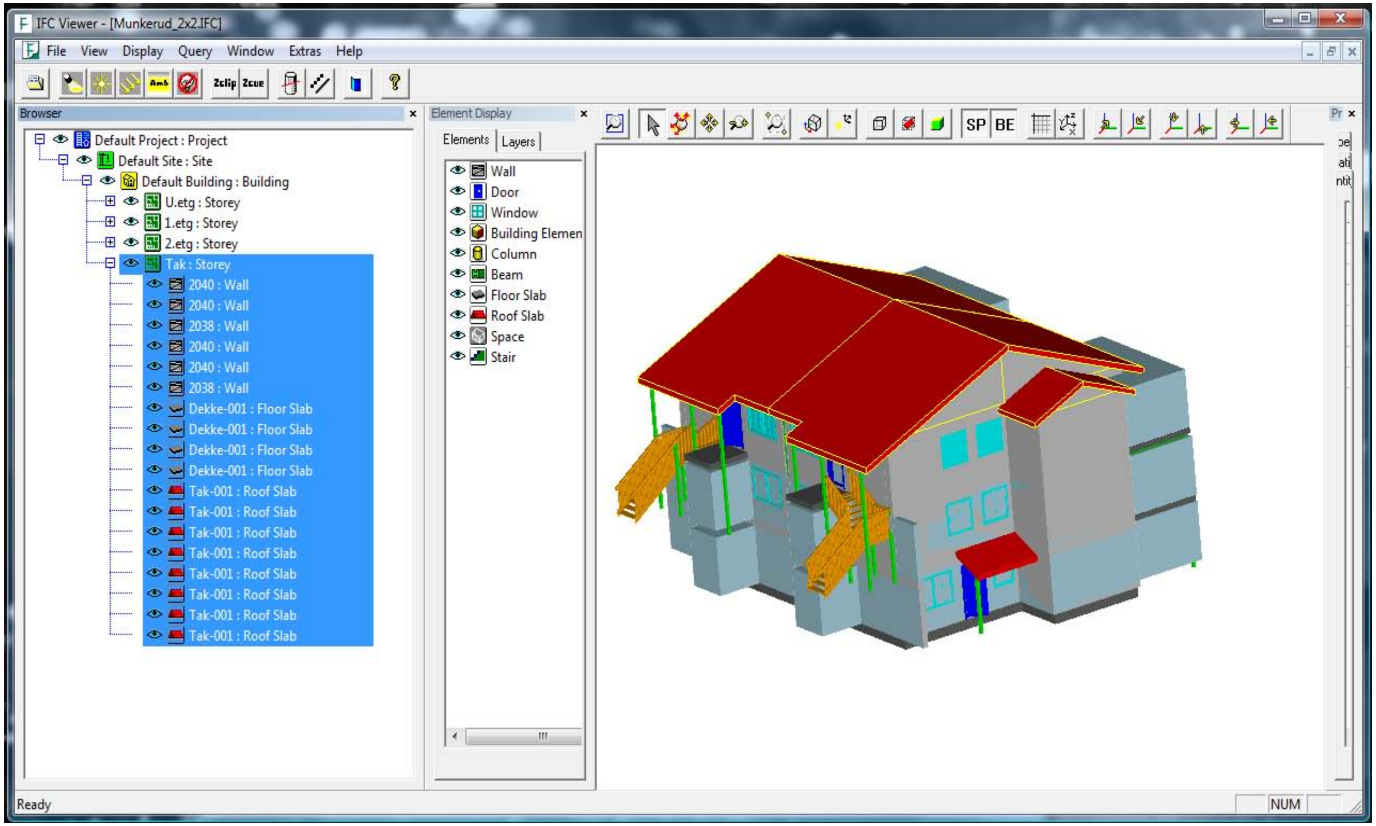
3D Vizualisation using IFC

Fraunhofer EMI

Structure of IFC Data Format



IFC – Format: Interface between the Different Tools



Screenshot taken from IFC Viewer, Forschungszentrum Karlsruhe

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Conclusions