PROJECT FINAL REPORT

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Content

1 Final publishable summary report

1.1 Executive summary

Terrorist attacks by bombing or CBR-agents (Chemical, Biological and Radiological) are threats with a low probability but with disastrous consequences. There is strong need to protect people, the societal community and critical infrastructure against being damaged, destroyed or disrupted by deliberate acts of terrorism. Solutions have to be derived to realize sufficient resilience within urban infrastructure for rare occasions with minimum effect on normality. Hitherto, normal regulations and building guidelines do not take into account the CBRE (Chemical, Biological, Radiological and Explosive) threat.

The FP7 project SPIRIT contributes to societal resilience by providing the technology and know-how to minimise the consequences of a terrorist attack in terms of number of casualties/injuries, damage and loss of functionality and services. SPIRIT's contribution comprises

1. Methodologies to quantify the vulnerability of built infrastructure in terms of the number of casualties/injuries, the amount of damage and the loss of functionality and services.
2. A guidance tool for designers and builders to assess the vulnerability of proposed/built infrastructure and select efficient and cost effective countermeasures (ready to use solutions) to achieve a desired protection level against terrorist attacks.
3. Protection portfolios for new and existing buildings. These comprise, inter alia, blast resistant window/facade systems, retrofit system for walls, explosion resistant columns and detection and filtration systems to counter the CBR threat.
4. Recommendations for draft EU regulatory framework to enable safety based engineering and the incorporation of 'CBRE protection' into the commonly used building guidelines and regulations.

The scope of the project concerns the resilience to CBRE terrorist threats of large modern buildings, where significant numbers of people can be present. Based on a preliminary threat assessment, a representative range of potential scenarios (20 chemical, 12 biological, 9 radiological and 14 explosive) has been defined. Together with two concrete buildings based upon typical structures seen in the urban landscape, these scenarios form the basis for the quantitative vulnerability study.

Extensive damage and consequence calculations (including loading predictions, dispersion calculations, injury and lethality predictions and finite element simulations) have been performed to generate a database of results. These extend beyond the initially defined scenarios and buildings, as options to apply the results to further threats and structures have been developed.

With regards to the protective solutions, multiple tests and extensive assessments have been conducted, thus providing quantitative information about the protection level provided by the tested products. Designs of the studied protection products have been improved and optimized and the costs of these products have been explored. Other available protective solutions have been identified through internet searches, consortium members' previous experience and expo visits. All available information is gathered in a portfolio of protection products.

Recommendations for the regulatory framework and a guidance tool have been developed based on the risk assessment methodology, consequence models and data obtained. The guidance tool enables a user to quantitatively estimate the risks and consequences of Chemical Biological Radiological and Explosion (CBRE) attacks on new or existing buildings and to optimize the protective design. There are two versions of the guidance tool, a publically available demo version and the classified full tool.

1.2 Summary description of project context and objectives

Background and context

The existence of terrorist organisations, their ruthless fanaticism and lack of restraint, their growing sophistication, the ability to acquire precursors for (bio)chemicals, and the availability of information for manufacturing explosives, poisonous gases poses a real and permanent threat to our society.

Terrorist attacks by bombing or CBR (Chemical, Biological and Radiological) are threats with a low likelihood but with extremely high impact. Attacks like of the Alfred Murrah Federal building in 1995 and the attack of the Marriot hotel (Islamabad, 2008) illustrate the need to prevent progressive collapse and the implementation of safety based engineering to integrate safety issues at an early stage of the design phase and need of cost effective mitigation products.

Despite the strong need to protect critical infrastructure and utilities against being damaged, destroyed or disrupted by deliberate acts of terrorism and malicious behaviour, the normal regulations and building guidelines do not take into account the CBRE (Chemical, Biological, Radiological and Explosive) threat. The introduction of these regulations or guidelines should realise sufficient resilience within building infrastructure against CBRE incidents.

Project objectives

The overall aim of the SPIRIT project is to provide the technology and know-how for the protection of buildings and people against terrorist threats and to minimize the consequences of a terrorist attack in terms of number of casualties/injuries, building damage and loss of functionality and services. The SPIRIT project achieves this by providing: tools to quantify the vulnerability of built infrastructure;
a portfolio of protective products and; a guidance tool for safety based engineering to realize effective resilience and protection of built infrastructure.

SPIRIT's targeted contributions to built infrastructure protection are:

- Methodologies to quantify the vulnerability of built infrastructure in terms of the number of casualties/injuries, the amount of damage and the loss of functionality and services;
- A guidance tool for designers and builders to assess the vulnerability of proposed/built infrastructure and select efficient and cost effective countermeasures (ready to use solutions) to achieve a desired protection level against terrorist attacks;
- Protection portfolios for new and existing buildings. These comprise, inter alia, blast resistant window/facade systems, retrofit system for walls, explosion resistant columns and detection and filtration systems to counter the CBR threat;
- Recommendations for draft EU regulatory framework to enable safety based engineering and the incorporation of 'CBRE protection' into the commonly used building guidelines and regulations;

The SPIRIT targeted outputs are ready to use solutions (vulnerability assessment tool, protection measures selection tool and suite of protection portfolios) for new and existing buildings that are operationally viable, infrastructure specific and cost-effective.

Focus of the SPIRIT project

SPIRIT addresses terrorist threat of Chemical, Biological, Radiological and Explosive nature targeted at large (public) buildings including the people in these buildings. Of the CBRNE threat framework, Nuclear 'N' is not considered.

The project focuses primarily on physical measures, to a minor extent to organisational measures and not on electronic means.

Within the realm of physical protection, the developing sciences of facility/complex design, zoning, routing/ approaches, vehicle and people barriers as well as wider perimeter structures are not considered.

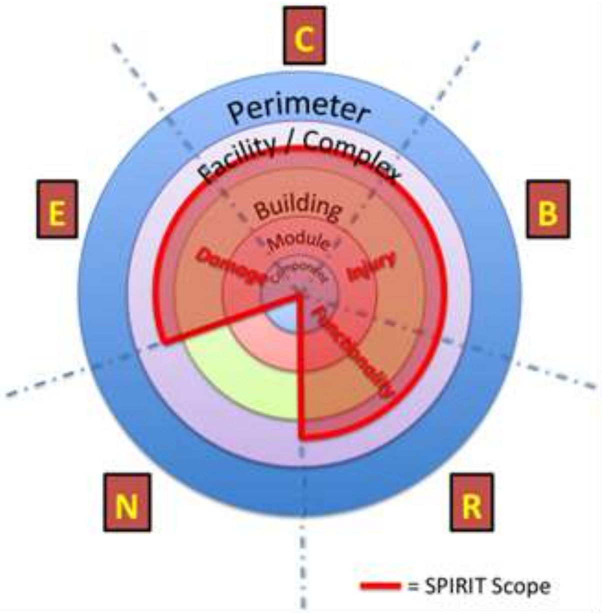


Figure 1 Scope of SPIRIT-project.

SPIRIT uses a construct to look at the physical building of components (e.g. columns), modules (e.g. postroom or parking) and buildings (the whole).

<u>Project structure</u>

Figure 2 shows the structure of the project and the correlations between the different work packages. In addition to these five technical work packages there were also 2 other work packages; work package 6 for dissemination activities and work package 7 for management.

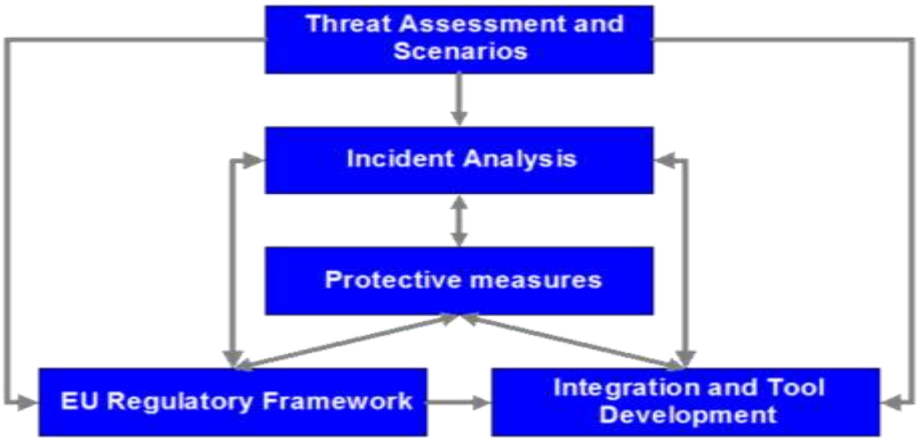


Figure 2 Structure of the SPIRIT-project

Work package 1 (threat assessment and scenarios) forms the basis for the project by defining the threats and by categorizing buildings and installations by structure, use and relative attractiveness to attack. The resulting scenarios, categorizations and structures have been used by all other work packages.

Work package 2 (incident analysis) deals with the quantitative analysis of the incidents. This includes identification of weak parts of built infrastructure facing CBRE terrorist threats, calculations to quantify consequences in terms of damage and injury as well as in disruption of functionality, and development of a consequence database and new calculation methodologies. The challenge within this work package has been finding an appropriate balance between the establishment of a reliable damage level and prediction of damage distribution and ensuring a broad applicability range. There is a strong link with the subsequent work packages. The results of WP2 (i) do show what protective measures are needed (WP3), (ii) have been used as input for the recommendation to the regulatory framework (WP4) and (iii) have been implemented in the guidance tool (WP5) (i.e. the consequence database and models).

Protective measures are the topic of work package 3. This includes an inventory of existing products, development and improvement of products, determination of their effectiveness and cost. This information is collated within a database and guidance tool in order to provide architects and building designers with ready-to-use products and solutions to harden infrastructure against CBRE terrorist threats. Specific products assessed during the project are blast resistant masonry retrofit systems, blast resistant glazing and façades, fibre concrete solutions, detectors and monitors for CWAs (Chemical Warfare Agents) and TICs (Toxic Industrial Compounds), and protection filters for CWAs and TICs. The results are again used as input for the recommendation to the regulatory framework (WP4) and the guidance tool (WP5).

In work package 4 recommendations for new guidelines and standards for the design and retrofit of built infrastructure against terrorist CBRE threats are formulated, based on the results of the other work packages and on specific studies in this work package. The advice is in line with and within common practice, such as European standards, Eurocodes and other guidance documents. The guidelines are considered a useful aid for designers, architects and engineers to deal with specialist protection against CBRE threats. The proposed guidelines are to enable the mitigation of CBRE effects to defined safety levels.

The results of all technical work packages are integrated within a guidance tool as part of work package 5 to make the gained knowledge and developed solutions easily accessible. With this tool a simple incident analysis for CBRE threats can be performed with outputs of the effectiveness of different counter measures and related costs. The tool is considered a useful aid for designers, architects, engineers and building owners to evaluate their building and the potential mitigation measures.

Coordination and management of the dissemination of the project is the task of work package 6. The means for this have included a website of the project (www.infrastructure-protection.eu), project flyers and a project banner, presentations at symposia and exhibitions, and the organization of a workshop.

1.3 Description of main S&T results

1.3.1 Threat categorization and scenario determination

Scenarios have been developed for Chemical, Biological, Radiological and Explosive (CBRE) agents which are specific for attacks on buildings. These scenarios form the basis of the quantitative studies of building vulnerability using numerical models. In total, 20 Chemical, 12 Biological, 9 Radiological and 14 Explosive scenarios have been defined. The attack scenarios are clustered in 3 categories: ‘inside the building’, ‘in the proximity of the building’, and ‘outside the building’.

In order to enable a well-considered choice of the large quantity of available CBR agents, new concepts were introduced. Among these were ‘building interaction vectors’ and a ‘threat space’. Interaction vectors describe how a building interacts with the outside world. Examples of interaction vectors (see Figure 3) include resources, supplies and communication or functional operation such as for example people entering/leaving the building. By considering these interaction vectors, it is possible to develop indications of how a building can be attacked. Also, by inverting safety principles (how can I make things go wrong?), additional attack possibilities are defined.

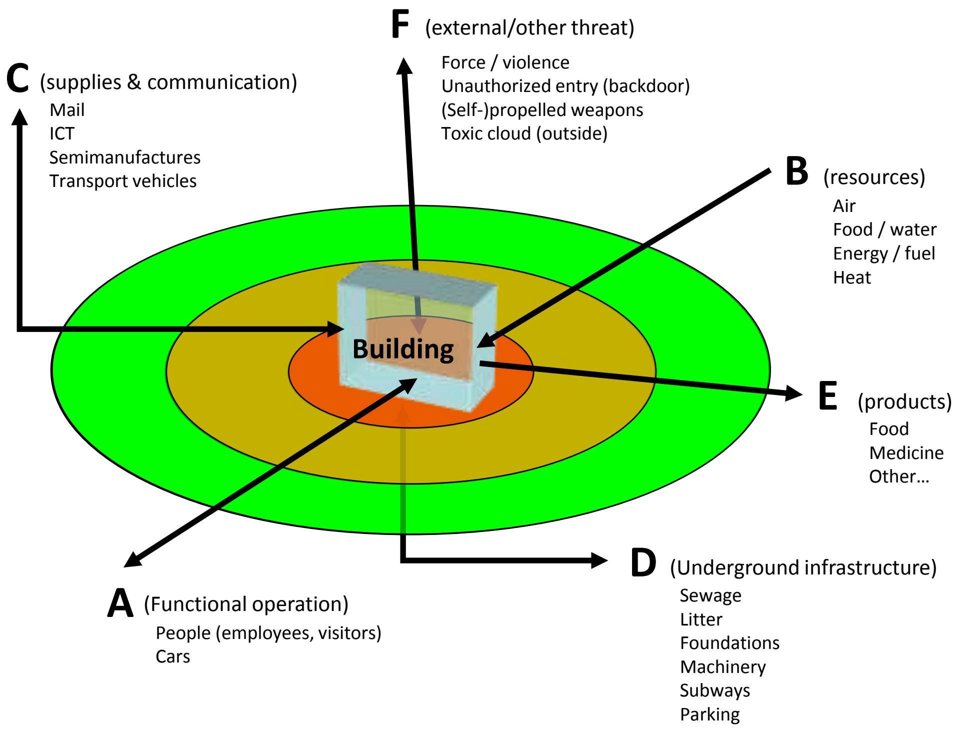


Figure 3 Interaction vectors and carriers of a building with the outside world, that can possibly be exploited as attack vectors

A threat space is a (visual) representation of CBR agents in a multidimensional physical space to prevent bias towards a small number of previous attacks and studies by ensuring that that the threat is evenly distributed through the threat spectrum. Finally a set of 41 attack scenarios were defined to represent the range of credible CBR attacks.

With regards to explosive threats, while a range of explosive materials are known to have been used in actual terrorist attacks, the well established procedure has been adopted of representing credible scenarios by the detonation of representative quantities of high explosive expressed as equivalent weight of TNT.

1.3.2 Categorization and definition of generic structures

SPIRIT generic buildings

Two buildings have been defined within the SPIRIT-project to be used as reference building in the performed analyses. For both buildings reinforced concrete has been chosen as the structural material as this is most common within central Europe. Regarding their structural system and type of use, two different kinds have been designed and documented. For the generic building one a typical residential high-rise building has been designed with mainly apartments. For the second generic building a shopping mall has been chosen with a high degree of pre-fabricated elements. These buildings can be considered as representative and generic for modern buildings in Europe. For both buildings all structural elements have been designed according to the given standards for structural design (Eurocode) and all necessary geometric data, structural properties and properties of the HVAC-system have been given.

Generic Building 1 **Generic Building 2**

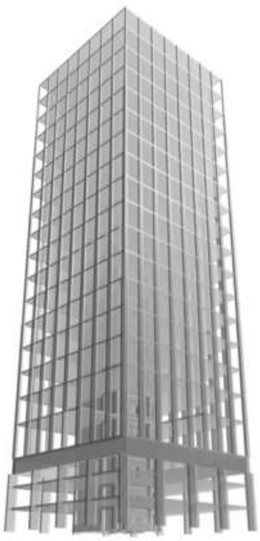
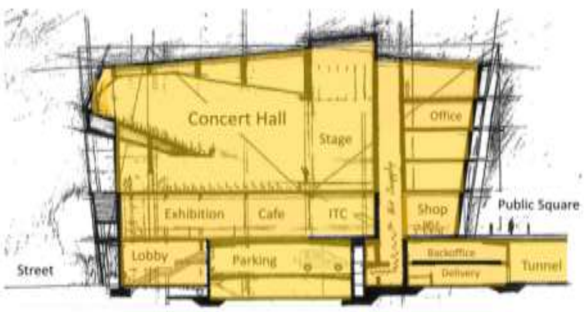


Figure 4 Generic buildings developed for analysis within SPIRIT

Risk analysis on the module level

The definition of a risk is a challenging task for the evaluation of structures against potential threats. Within the project a methodology has been developed, which allows to define the risk of the building on the module level instead of the building level. The approach is therefore able to evaluate the risk more precisely and with a more appropriate level of detail. Herewith critical modules can be identified and depending on their impact on the overall risk be protected against certain threats.

Building Level **Module Level**



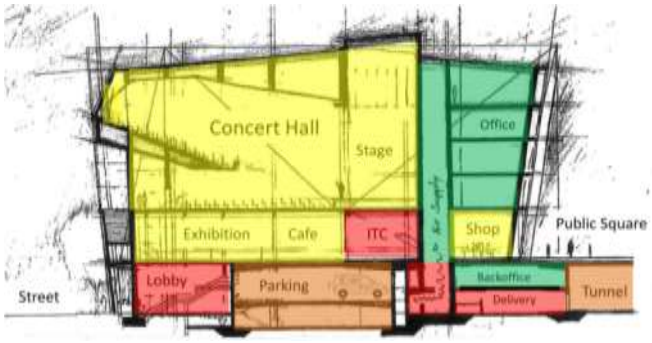


Figure 5 Definition of risk on the building level and module level for a detailed evaluation of an asset.

1.3.3 Protection levels

The consequences of an attack are the direct damage to the buildings and the number of casualties and injuries. In addition, there are longer term consequences due to the loss of functionalities and services that were housed in the building. By categorizing these consequences in a systematic way, the impact of an attack can be determined, or in the inverse form the protection level or effectiveness of countermeasures can be quantified. Protection levels have been defined, in accordance with common practice in the security society.

1.3.4 Explosive threats – loading and consequence analysis

It is a challenge to develop a relatively simple, not too detailed consequence analysis methodology for the SPIRIT guidance tool, that still has the ability to discern between different cases, scenarios and buildings, and that can show the effectiveness of protective measures.

The approach followed is a kind of three dimensional database method, with a bypass, where possible, based on simple quantitative correlations. The three dimensions are threat classes, a categorization of the structures and structural elements, and consequence classes, in terms of structural damage, injuries and/or loss of functionality.

The quantitative breakdown is based on a large number of calculations, both with relatively simple engineering tools, as well as with sophisticated numerical tools. These analyses have been done to understand the more important phenomena that play a role in the consequences and to select the proper parameters to consider in the tool. As a result, several calculation modules have been generated for the SPIRIT-tool.

The overall building response, both due to external and internal explosions, has been studied by simulations of the generic SPIRIT-building. The study concerned several finite element calculations, aiming at finding the different protection categories. A data set and a first step into the categorization has been made. This is however not sufficient for implementation in the generic SPIRIT-tool, as the overall response and the possibility of progressive collapse is building specific.

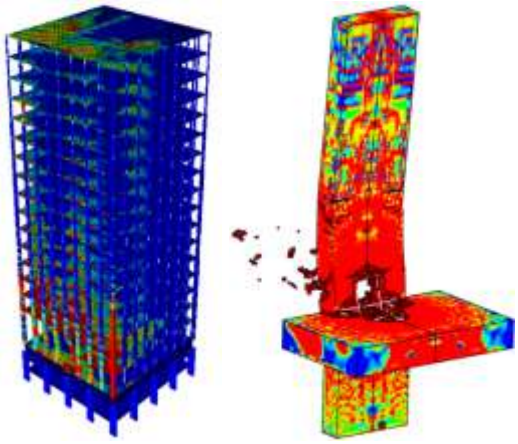


Figure 6 Finite element analysis of (left) global building response, (right) local response.

1.3.5 CBR threats – loading and consequence analysis

When dealing with CBR threats, many difficulties arise. First, it is hard to get reliable information concerning CBR agents because of the sensitiveness of the subject, the large number of CBR agents and the difficulty to determine their effects on health. Secondly, when aiming to evaluate the consequences of a CBR attack inside or outside a building, a large number of parameters have to be considered. In order to build a CBR consequences model, simplifications must be done.
To constrain the scope of the present study but still being representative of all kind of attacks, a thorough analysis of CBR agents has been made to select a reduced number of representative agents. To evaluate the consequences of CBR threats, a simplified (but still covering the dominant mechanisms) model has been implemented in the SPIRIT-tool.

The models also deal with several mitigation measures. The effect of (i) filters, (ii) an emergency air exchange rate for the building (which enables to accelerate, diminish or shut the aeration of the building) and (iii) evacuation can be studied and quantified. In the tool a module for filters and a library with filter characteristics has been implemented.

In conclusion, by careful selection of the simplifications and assumptions the model predictions are satisfying. In particular, it enables to evaluate the effects of many parameters on CBR loading and consequences.

1.3.6 Loss of functionality

Loss of functionality due to explosion effects has been estimated. The functionalities/utilities taken into account are the electrical supply system, the HVAC (Heat Venting and Air Cooling) system and the water supply systems (chilled water, hot and black water). The physical mechanisms that result in a partial or a total disruption of the system are numerous and complex. In practice, detailed analysis of all these mechanisms (pressure effects, impact of debris, failure of the equipment supports, etc.) is not feasible. A simplified approach has been proposed and developed in which the damage to particular equipment is directly related to the pressure level the equipment is exposed to. Pressure level criteria have been derived to estimate the probability of destruction of the different equipment components in the considered system A global analysis using a fault tree has been performed to determine the consequences of the explosion on the entire system. This has been done with the French vulnerability software PLEIADES. Finally the size of the building zone where disruption of the system is expected has been established.

1.3.7 Effectiveness of countermeasures

E-threat at component level

The effectiveness of countermeasures for the E-threat at component level was derived from the different tests conducted. To acquire deeper knowledge about the protection measures an extensive number of test trials have been conducted within SPIRIT. This includes tests in different loading ranges such as:

- Shock tube tests at EMI in Efringen-Kirchen with the new BlastSTAR (Blast Security Test And Research facility), see Figure 7.
- Free field detonation tests at EMI in Efringen-Kirchen and Kandern with relatively small charges.
- Free field detonation tests at GL Spadeadam (UK) with larger loads.
- Internal detonation tests at EMI and GL Spadeadam (UK) for mailroom scenarios, see Figure 8.
- Quasi-static tests at EMI for validation of behaviour of improved Tecdur® BlastWall panel

Figure 7 EMI shock tube facility BlastSTAR.

Figure 8 Test set-up of internal detonation test at EMI (left) and at GL Spadeadam (right).

E-threat at building level

Within the SPIRIT tool the effectiveness of structural countermeasures can be easily studied. The consequences of an E-attack for all affected modules are quantified and thus for the entire building. The effectiveness of the countermeasures is given by the change in the quantified consequences and risk numbers. The effect of an E-attack on structural stability and the vulnerability to progressive collapse is related to column damage. A warning and recommendation for detailed analysis is given when more than two columns lose their bearing capacity.

CBR-threat

The stepwise approach for CBR threats against critical infrastructure developed within SPIRIT project is documented. The scenarios account for the toxicity and availability of threat agents, the physics of agent release and the building HVAC equipment and operation mode. The SPIRIT countermeasure and protection scenarios are based on the availability, installation and operation/maintenance of suitable CBR monitors and suitable CBR filter systems. It can be stated that:

- SPIRIT protective portfolio products can cope with the SPIRIT threat scenarios
- Occupants of e.g. the SPIRIT generic building experience a life-saving protection against CBR threats on proper application of the portfolio products
- The SPIRIT protection system is modular and can be transferred and adapted to a broad range of civil infrastructure buildings

The effectiveness of the CBR protection system is derived from the combined effect of the removal of the toxic threat agent form the air streams and the prevention of mass transfer from the zone of agent release to populated spaces e.g. by means of shutting off the HVAC unit. The overall effectiveness of the system of CBR monitor and CBR filters to threat scenarios to the generic SPIRIT building 1 has been computed. The evaluation shows that in all examined scenarios solutions exist that fulfil those criteria and that therefore building occupants experience the protection needed.

1.3.8 Cost benefit analysis

The purpose of the task has been to evaluate the effectiveness of countermeasures in mitigating the effects of CBRE attacks and comprises two distinct elements. The first is a risk assessment methodology developed from the US Department of Homeland Security Federal Emergency Management Agency (FEMA) Reference Manual to Mitigate Potential Terrorist Attacks Against Buildings (2003). As the SPIRIT project has not sought to quantify all damage, casualties and injuries in monetary value, nor has it considered wider societal costs of terrorist attacks, conventional cost-benefit analysis tools are not appropriate for an assessment of the effectiveness of countermeasures. Therefore, existing methodologies have been improved and adapted during SPIRIT evaluating the initial risk posed by CBRE threats to built infrastructure and the corresponding reduction in risk resulting from the implementation of countermeasures. The method, developed from the FEMA methodology, has been enhanced to allow non-expert users to determine the most effective countermeasures via graphical representations of risk and relative risk reduction. An example from a project is included to demonstrate these techniques.

The second element includes guidance for the implementation of the developed methodology into the SPIRIT tool. It demonstrates how the SPIRIT tool output can be used to generate the appropriate graphical representations of risk reduction versus cost allowing users to determine the most cost effective methodology.

Figure 9 Flowchart demonstrating implementation of cost benefit assessment methodology

1.3.9 Fibre-concrete solutions against detonations

The micro-reinforced high performance concrete DUCON® (DUctile CONcrete), which is exemplarily for fibre-concrete solutions, was analyzed within the SPIRIT project as with regard to protective effectiveness and economical benefit. The conducted tests can be divided into:

a) Blast panel test for facades, spall-plates, wall shields, ceiling shields, floor overlay

The resistance of the ductile concrete against dynamic blast loading was investigated systematically with 7 shock tube tests, varying the geometric parameters and the degree of reinforcement. With additional static four points bending tests, the ultimate tensile limit of the regarded configurations could be determined. Based on the test results Iso-damage curves have been derived in order to be capable to design DUCON-Panels against E-threats.

Figure 10 DUCON after shock tube test.

b) Column wrap test for columns

Altogether, 9 close-in blast tests on RC-columns with different DUCON-confinements as hardening measure have been executed against combined axial and detonation loading with varying confinement thickness and steel content. Depending on the configuration an increased residual capacity between 30 and 150% compared to bare reinforced concrete was determined.

1.3.10 Blast-proof masonry retrofit systems and Glazing and façades

Within SPIRIT numerous tests focusing on different materials, different loading regimes and different protection solutions have been conducted to achieve both broaden the application range and generate basic knowledge about the resistance of existing protection solutions, see Figure 11. Thus, commonly used wall set-ups such as block walls, brick walls, cavity walls and stud walls and glazing types such as windows and glazed façades have been investigated. The tests illustrated that with proper design good protection levels can be obtained.

Figure 11 Excerpt of conducted tests: close-in trials with Tecdur® BlastWall (left), free field test with secondary glazing within Tecdur® BlastWall system (middle), point-fixed glazing (right).

Based on the tests a tool has been developed for calculation of dimensioned and dimensionless iso-damage curves for the retrofitted masonry and the glazing systems.

1.3.11 Detector and Monitor for CWA's and TICs in buildings

State-of-the-art before SPIRIT

Proton-Transfer-Reaction Mass Spectrometry (PTR-MS) was developed in the 1990s at the University of Innsbruck and is a very sensitive trace gas analysis method based on the reaction: $H_3O^+ + A \rightarrow AH^+ + H_2O$ *(A is the trace component)*. IONICON commercialized this technology and provides different quadrupole (Q) and time-of-flight (TOF) mass spectrometry based PTR-MS instruments mainly for the academic market.

Developments and tests within SPIRIT

For SPIRIT we developed a user-friendly, compact and cost-efficient detector and monitor for CWAs and TICs based on IONICON's PTR-QMS 300 model. In order to provide a solution for non-academic users and for standalone (i.e. without the need for an external PC, which is common for PTR-MS instruments) monitoring the SPIRIT PTR-MS instrument is equipped with newly developed detection software installed on an embedded PC. To feed this novel detection software with data, we created a comprehensive CWA/TIC database utilizing a high resolution PTR-TOF 8000. With this TOF based instrument we could investigate the PTR reactions of the different substances in great detail (e.g. fragmentation behavior in dependence on the reduced electric field strength in the drift tube) and develop an algorithm that greatly enhances the selectivity of the low mass resolution PTR-QMS. Parts of these studies were published in peer-reviewed scientific journals (T. Kassebacher, P. Sulzer, et al., CCIs 318 (2012) 438-447. and T. Kassebacher, P. Sulzer, et al., Rapid Commun. Mass Spectrom. 27 (2013) 1-8.). Furthermore, the SPIRIT PTR-MS instrument has two inlet lines that can be switched electronically. This feature is important to evaluate filter efficiencies, i.e. to compare CWA/TIC concentrations before and after the filter.

We tested the PTR-MS detector at first at a tentative test rig in IONICON's laboratories. There we made sure that the instrument as well as the new software worked well and tested the detection algorithm for correct identification and against false positives (cleaning agents, spoiled food, waste, etc.). The final evaluation of the SPIRIT PTR-MS instrument was done at the facilities of artemis.control. For a schematic view and an actual picture of the professional HVAC test rig there see Figure 12. All substances tested in this campaign were detected and identified correctly. Moreover, by switching the inlet lines during the detection tests, we could determine the filter efficiencies.

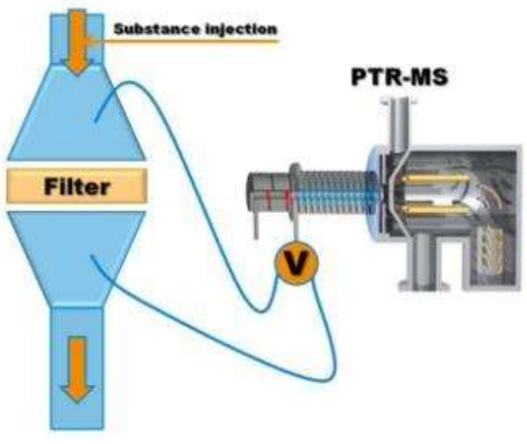


Figure 12 Schematics (left) and picture (right) of the HVAC detection test at artemis.control.

1.3.12 Filter products against airborne toxic compounds

The task was set up to deliver a product series of protective filters for building ready for application. The products need to be capable to protect the occupants of civil infrastructure buildings from life threatening doses of airborne toxic components that could be used within the scope of terrorist attacks. Further requirements for the task have been to design the protective filter products in a way that they can remain permanently installed in the building system for immediate protection and permanent preparedness, that they positively interact with detector & monitoring systems for chemical threats and that their performance and cost contribution can be included in the building protection models and cost effectiveness models developed within the SPIRIT project.

The following inputs have been recognized from other work packages of the SPIRIT project and have been worked upon to consequently perform the necessary work portions:

- The definition of the chemical threat space and the methodology behind it have been considered and supported.
- The derived threat scenarios expressed as concentration-time profiles have been applied to the product design rules and building protection modelling.
- An evaluation of the SPIRIT Generic Building #1 infrastructure with regard to the air handling systems, air distribution and consequences in the attack case has been performed.

The above input has been used to:

- Deduce and specify the design rules for the protective filters with regard to their grid size, the air flow regime in operation and the acceptable pressure drop contribution per unit considering their permanent installation.
- Deduce the requirements for the filtration efficiencies to render the necessary protection considering the threat scenarios and internationally accepted protection levels for toxic agents as AEGL-3 to steer the protective material development in this task.
- Deduce the necessary overall protection performance of the system considering the efficiency and lifetime of the protective filters, the effectiveness of the detectors and the dose effects inside buildings in an attack case.
- Deduce the feasible commercial targets for the protective filters to allow a straightforward assessment of their cost contribution in installation & operation for the planning building engineer.

The work performed in this task rendered the following results that make the protective filter portfolio developed within the project directly applicable to new building projects or retrofit projects:

1. The protective material development work resulted in a series of new protective filter materials and material combinations that fulfil the SPIRIT project criteria of an immediate reduction of threat agent concentrations below a safe threshold limit plus keeping this threshold for a sufficient time period to create on-site safety and enable the roll-out of supportive actions & countermeasures.
2. The component design work rendered a modular system of ANCS-filter casings (left picture of Figure 13) and protective filter insets ready to apply in standard central HVAC units. The system respects the requirements on grid size, pressure drop (< 120 Pa on two serial stages) and protective efficiencies as well as service life under standard environmental conditions to be applicable as a permanently installed protective system. The HVAC product system is further supported by the APFS-outlet system (right picture) for protection at the point of use – at the interface of the HVAC ductwork to the rooms.
3. The examination of the combined system of protective filters and toxic agent monitor both developed in the SPIRIT project proved that the system performance is capable of reducing toxic agents much below dangerous levels and further actuating alerts and safety measures.

4. The delivery of the performance data into the SPIRIT building model provides the basis to design the overall safe scenarios considering building characteristics, stand-off distances and threat scenarios.
5. The evaluation of the installation cost and the operations & service cost for the protective filters & monitors showed that added cost are < 1% on installation with reference to the building cost and below 4-8 €/m2 year on running cost.
6. The evaluation of the cost on attack in its consequence showed that the proposed permanent active protective filter system creates a factor of 30-120 less cost on change of filter panels after an attack compared to decontamination cost and replacement cost for objects in the unprotected building.

Figure 13 Modular system of ANCS-filter casings (left) and protective filter insets (right).

1.3.13 Portfolio

The protection portfolio gives a state-of-the-art overview about CBRE protection systems including both examined systems within SPIRIT and further products available on the market.

Survey on available protection products on the market
A survey of protection measures available on the market was conducted. This includes but goes beyond the products described in the work package. Search sources were security conferences and exhibition editions, internet and direct requests to companies which are active in the security field. To acquire a representative overview of protection products for the portfolio the WP-partners developed survey templates for the different CBRE-protection systems and a cover note that briefly introduces the SPIRIT project and describes the benefit of contributing product information to the portfolio. These documents have been sent out to relevant companies and distributed at expositions. Unfortunately, the general feedback was rather poor. However, an adequate number of readily available protection products are considered for description in this portfolio.

Gather portfolio input
Both the input from the project itself and the filled survey forms were gathered and reviewed. Main editor of the product portfolio was Fraunhofer EMI, working contributions were given by all industry partners.

Consolidated description
A consistent representation of the different protection products was found by taking the form of a document similar to a catalogue, with different chapters for each protection category. The description of the product is such that building designers can comprehend its technical and cost implications.

1.3.14 Recommendations of standard formulations

For explosive as well as chemical, biological and radiological threats, standards are needed to help engineers, investors and authorities to enforce and implement safety and security against E and CBR-threats. Hereto for CBR first recommendations for standards have been formulated and defined which can be taken as a starting point for an application at the moment and should be developed further within the future. In addition possible ways for an implementation of design strategies, methods, constructive rules and a safety concept into the given framework for structural design against common events (Eurocode) for E-threats could be demonstrated.

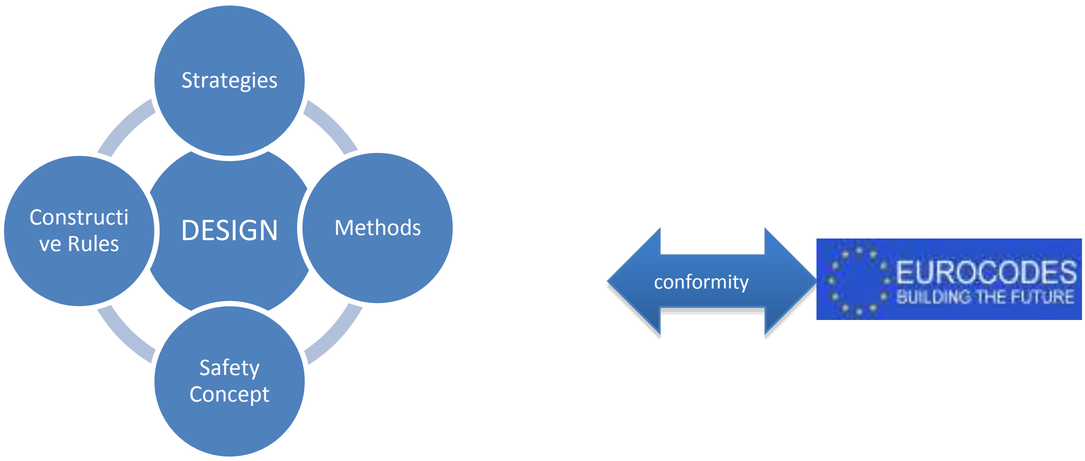


Figure 14 Addressed topics for an implementation of E-Threats into given standards for the structural design of buildings.

1.3.15 Guidance tool

WP5 was defined to integrate the results of the SPIRIT project and make these easily accessible. According the project plan, a guidance tool has been developed that enables the user to estimate quantitatively the risks and consequences of Chemical, Biological, Radiological and Explosion (CBRE) terrorist attacks on a new or existing building. The tool integrates the results of other work packages.

The SPIRIT tool is a guidance to the design of a building against CBR&E terrorist attacks in a cost effective way. It offers the user a large deal of flexibility to define the building. The scenarios can be composed using the SPIRIT threat library, while the output is given in risk numbers for the damage, the casualties and the economic loss. The detailed input data and the consequence output data are stored in output files and are summarized and accessible in windows showing summary tables.

Figure 15 Structure of the SPIRIT tool (left) and the tool features for the user (right).

The building definition:

The user starts with the definition of building dimensions, the lay out of the building modules, the structural properties like the column grid and column dimensions, the properties of internal walls, floor thicknesses, concrete quality etc. All these properties can be altered afterwards to optimize the design of the building and to quantify the effect on the risk numbers for the CBRE scenarios.

The scenarios:
Unique in the SPIRIT tool is that not only explosion but also CBR-scenarios can be analyzed.
The scenarios are defined easily by defining the attack location (internal as well as external), selecting the type of agent, the quantity and the release mechanism from the implemented SPIRIT library. Besides the selection from the predefined masses, the tool offers also the option to analyse scenarios with user-defined masses.

The countermeasures:
Two types of countermeasures can be taken, i.e. 1) measures to reduce the probability of a certain scenario, and 2) measures to reduce the consequences. With the tool the effectiveness of both types of of measures can be analysed.

SPIRIT tool versions
With the SPIRIT tool the consequences of CBRE threats are quantified. The implemented models use classified information. The tool itself has the classification of EU-confidential and distribution is accordingly.
A special unrestricted DEMO version was developed with all the features of the “building” and “scenario-definition” but without the consequence models and risk calculations.

1.4 Potential impact and main dissemination activities and exploitation of results

1.4.1 Impact

The impact of the project will take time to assess both in terms of the commercial and scientific benefit. It will also be difficult to assess. However, one metric will be the interest in the full, classified version of the tool. TNO have developed a plan to allow dissemination of the classified Tool within the security classification restrictions. Feedback will be invited to infirm further development of the Tool. The requirement for building security against these CBRE threats is, sensibly, threat led and the threats are currently low with application of measures expensive.

1.4.2 Main dissemination activities

There has been extensive dissemination throughout the project. One of the 7 work packages and a significant part of the resource was directed towards this activity. In the early stages of the project, these activities were focussed on raising awareness of the project, with results following later. Inevitably much of the dissemination of results and foreground scientific knowledge will continue beyond the end of the project. The main dissemination actions were as follows:

- <u>Project identity</u>. It was deemed necessary that the project establish a strong identity both for the participants and to raise the project profile during dissemination activities. Components of this identity included an impactful project logo for use alongside the EC and FP7 insignia as well as templates for presentations and other stationery. A third party design house was used to develop options and the whole Consortium agreed the final logo. Project partners cooperated well and used the logo in all communications.

- <u>Public Website</u>. A public website was established early and developed as the project progressed. The Web address was carefully selected to articulate the purpose of the project and the domain was purchased to allow the site to remain live for 2 years beyond the end of the project for minimal cost. The final URL selected was www.infrastructure-protection.org with additional domains at .com, .eu and .info purchased too. A dynamic translation tool was added to text heavy pages. The aims of the site were to:

- articulate the Objectives of the project and advertise its EC sponsorship;
- act as contact point for third interested parties in the specific field;
- host of the publications of the project specific research for the general public (flyers, newsletters and technical publications);
- provide links to research activities.
- Provide a dynamic translation for other languages.

All of these aims were achieved. A number of interested parties sent in their details and asked to be kept informed of the project outputs. These parties have all been contacted since. As the project has produced literature, a downloads page was included and electronic versions of all unclassified printed material included. This ultimately included a demonstration version of the SPIRIT Tool. A screen shot from the project website is included at Figure 16.

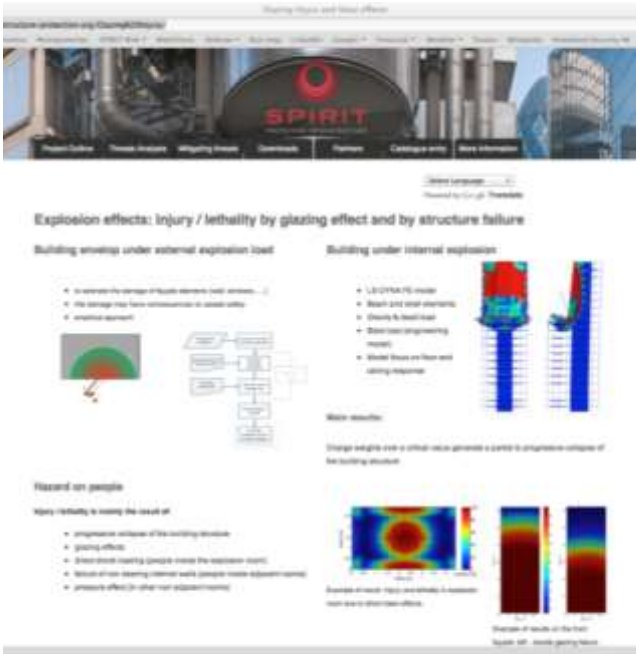


Figure 16 - Project website screenshot

Visits to the site were monitored for interest purposes and advised to the Consortium at meetings. An example of this is the geographical spread of interest, which shows that the website was visited from 72 different countries, presented graphically in Figure 17.

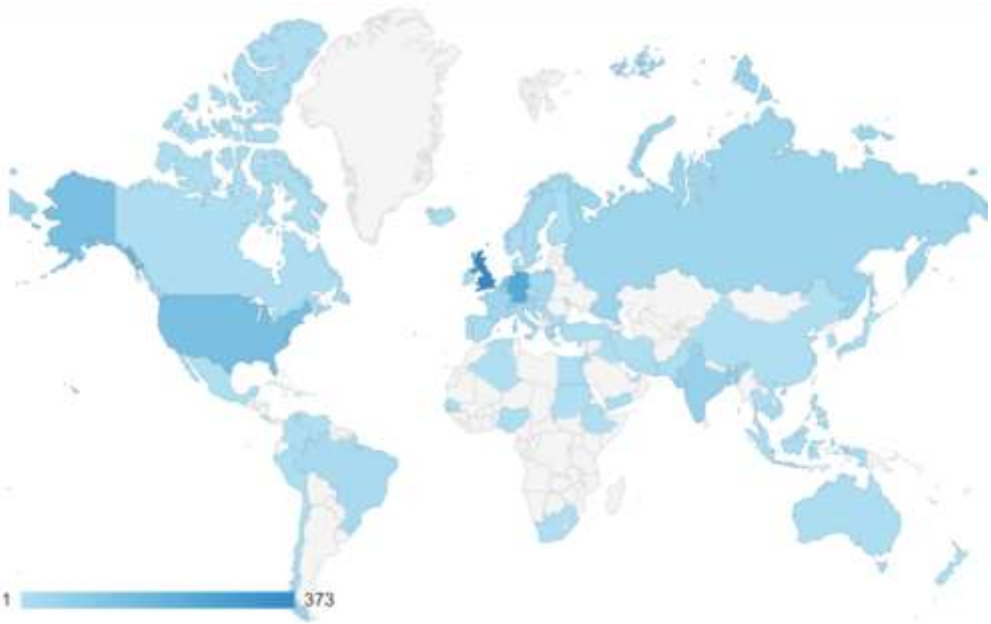


Figure 17 - Geographical spread of website visits

In addition to the original aims of the site, a series of forms were developed for online entry to the project portfolio. In addition, an email address was created to provide a response to those who have made entries.

- <u>Project Flyers</u>. A series of 'flyers' or information leaflets were produced during the project. The initial flyer outlined the project aims and later flyers provided information on the progress of the project. In addition, the third flyer also advertised the project presence at the Counter Terror Expo in April 2013. The leaflets were distributed through the project partners to leave with their contacts in the same way as a business card might. The aim of these leaflets was to spread interest and awareness, as well as to direct interest to the website. Approximately 50% of visits to the website were 'Direct' where the visitor was not directed through a link or search engine, which suggests some success of the flyers. The flyers also advertised the identity of the project partners and the support of the EC. A picture of one of the flyers is shown at Figure 18.

Figure 18 - Project Flyer 4

Instead of newsletters, publications were posted on the website for download. Some were general and provided a more detailed overview of the project.

- <u>Focussed dissemination activities</u>. Project partners placed a high priority on external dissemination including: conference and event presentations; publications; detailed briefs to specialist groups; and distribution results. These activities were intended to promote and debate on the issues and then to accelerate the implementation of the research results. All of these activities emphasised the support of the EC through FP7 using the project templates. The majority of these activities have been recorded on ECAS. Totals at time of writing were of 78 dissemination activities including press releases, presentations, printed materials and conferences. There were 9 recorded publications, many of which have ISBN numbers. The full list is included in section A. Additionally, a number of abstracts for future publications have already been written and more are anticipated. In summary, the project has far exceeded the dissemination targets set in the Description of Work.

- <u>Distribution of key outputs</u>. There were three key outputs form the project: the SPIRIT Tool, a software tool for assessing the vulnerability and cost/benefit for the protection of buildings; the Portfolio of protective products; and the EU Regulatory Framework. Each has necessitated a different dissemination method.

The SPIRIT Tool has unfortunately had to be classified above the level originally intended due to the potential for misuse. In order to promote awareness of the tool, an unclassified demonstration version was created and copied onto 300 Compact Discs for distribution by project partners and directly to those who have expressed interest. In addition, a package of documents and the Demonstration version of the Tool were provided for download on the public website. The full, classified, version will be controlled by TNO and CDs and a cover were printed to allow TNO to copy them as required, to be copy numbered and exported in accordance with security protocols. Images of the Demo CD cover and disc are shown at Figure 19.

Figure 19 - SPIRIT Tool disc and cover (Demo version)

Details of how to get the full version were included on the Demo disc along with an application form for download on the website. A number of applications have already been received.
The Portfolio of Protective Products was included on the Demo disc and on the public website for download. Details of the Portfolio are covered in the relevant deliverable for Work Package 3.
It was necessary to distribute the findings over the EU Regulatory Framework differently. The audience for these recommendations is very small so it has been decided that the project findings should be given direct to the European Commission Subcommittee on building standards and Eurocodes. The Chairman of the subcommittee has been approached but there was not sufficient advance notice (4-6 weeks are required) to present at the June 2013 meeting so a request has been made to submit the findings for review and presentation at the next meeting.

- European Infrastructure Protection Workshop. To formally launch the Project findings and the *SPIRIT Tool* , a restricted access workshop was written into the Description of Work and listed as one of the main milestones for the project. It was envisaged that this would be held as a joint event alongside an existing event and the detailed dissemination plan would identify the venue. A detailed search of suitable events was created and then analysed to find those suitable for the project to find events that were: addressed to an appropriate audience e.g. large, civil infrastructure related and not military/defence focussed; were at a suitable time; would provide both an exhibition and conference. The shortlist was presented to the Consortium and then each event visited in the preceding year. The Consortium then agreed the final selection. Further details are included in the deliverable.

Figure 20 - The European Infrastructure Protection Workshop with 4 of the partners

Figure 21 – SPIRIT Exhibition Stand

1.5 Address of the project public website and contact details

Website: www.infrastructure-protection.org
Contacts:

- Coordinator: Ans van Doormaal, TNO, +31 88 866 1249, ans.vandoormaal@tno.nl
- Regarding tool: Ans van Doormaal (see above) / Jolanda van Deursen (Jolanda.vandeursen@tno.nl), TNO