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TECHNICAL REPORT

Smart Building Volume 6: Guidelines for Program Replication

May 2006

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13. ABSTRACT (Maximum 200 words)

The Defense Threat Reduction Agency conducted a technology demonstration called "Smart Building" Program in support of the 2002 Winter Olympics. It showed that a facility could be protected from chemical and biological warfare agents, and radiological particulates using commercial-off-the-shelf-hardware. The facility selected was the Social Hall Plaza building in Salt Lake City, Utah. The key elements of the Smart Building system were infrastructure protection and consequence management.

The infrastructue protection team developed a comprehensive, automated modular, transportable chemical, biological, radiological protection system and integrated it into Social Hall Plaza. The system provided positive-pressure collective protection, chemical, biological detectors, notification procedures, emergency decontamination provisions, physical security to regulate vehicle and pedestrian traffic, and automated heating, ventilation, airconditioning system response.

The consequence management team provided the capability to assess the potential or actual impact of a threat event through the use of hazard modeling software tools at a Consequence Assessment Center (CAC), using the E-Team TM incident management system. Developing the CAC involved the use of Geo-spatial Information System, population database development, and the linking of the Olympic Coordination Center to first responders and remote sites to the incident management system.

This volume provides planning guidance for infrastructure, with emphasis on the planning approach used for the Smart Building.

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CONVERSION TABLE

Conversion Factors for U.S. Customary to metric (SI) units of measurement.

MULTIPLY ⟶ BY ⟶ TO GET
TO GET ⟵ BY ⟵ DIVIDE

angstrom	1.000 000 x E -10	meters (m)
atmosphere (normal)	1.013 25 x E +2	kilo pascal (kPa)
bar	1.000 000 x E +2	kilo pascal (kPa)
barn	1.000 000 x E -28	meter^2 (m^2)
British thermal unit (thermochemical)	1.054 350 x E +3	joule (J)
calorie (thermochemical)	4.184 000	joule (J)
cal (thermochemical/cm^2)	4.184 000 x E -2	mega joule/m^2 (MJ/m^2)
curie	3.700 000 x E +1	*giga bacquerel (GBq)
degree (angle)	1.745 329 x E -2	radian (rad)
degree Fahrenheit	$t_k = (t^\circ f + 459.67)/1.8$	degree kelvin (K)
electron volt	1.602 19 x E -19	joule (J)
erg	1.000 000 x E -7	joule (J)
erg/second	1.000 000 x E -7	watt (W)
foot	3.048 000 x E -1	meter (m)
foot-pound-force	1.355 818	joule (J)
gallon (U.S. liquid)	3.785 412 x E -3	meter^3 (m^3)
inch	2.540 000 x E -2	meter (m)
jerk	1.000 000 x E +9	joule (J)
joule/kilogram (J/kg) radiation dose absorbed	1.000 000	Gray (Gy)
kilotons	4.183	terajoules
kip (1000 lbf)	4.448 222 x E +3	newton (N)
kip/inch^2 (ksi)	6.894 757 x E +3	kilo pascal (kPa)
ktap	1.000 000 x E +2	newton-second/m^2 (N-s/m^2)
micron	1.000 000 x E -6	meter (m)
mil	2.540 000 x E -5	meter (m)
mile (international)	1.609 344 x E +3	meter (m)
ounce	2.834 952 x E -2	kilogram (kg)
pound-force (lbs avoirdupois)	4.448 222	newton (N)
pound-force inch	1.129 848 x E -1	newton-meter (N-m)
pound-force/inch	1.751 268 x E +2	newton/meter (N/m)
pound-force/foot^2	4.788 026 x E -2	kilo pascal (kPa)
pound-force/inch^2 (psi)	6.894 757	kilo pascal (kPa)
pound-mass (lbm avoirdupois)	4.535 924 x E -1	kilogram (kg)
pound-mass-foot^2 (moment of inertia)	4.214 011 x E -2	kilogram-meter^2 (kg-m^2)
pound-mass/foot^3	1.601 846 x E +1	kilogram-meter^3 (kg/m^3)
rad (radiation dose absorbed)	1.000 000 x E -2	**Gray (Gy)
roentgen	2.579 760 x E -4	coulomb/kilogram (C/kg)
shake	1.000 000 x E -8	second (s)
slug	1.459 390 x E +1	kilogram (kg)
torr (mm Hg, 0^0 C)	1.333 22 x E -1	kilo pascal (kPa)

*The bacquerel (Bq) is the SI unit of radioactivity; 1 Bq = 1 event/s.
**The Gray (GY) is the SI unit of absorbed radiation.

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The authors would like to acknowledge the contributions of Messrs. Robert Kehlet and Richard Lewis, DTRA for their management and technical guidance and support throughout the Smart Building program.

TABLE OF CONTENTS

LIST OF FIGURES

Volume 6 – Guidelines for Program Replication

1.0 Introduction

The Smart Building Program was initiated by the Defense Threat Reduction Agency (DTRA) in 1999. The objective of the program was to develop a "Smart" Building, one capable of automatic protective responses to a Chemical, Biological, Radiological (CBR) threat to protect occupants and other important assets. The Smart Building protection system was designed to be modular, transportable, and easily integrated into most buildings in a relatively short time frame. The Smart Building protection system, identified as "Ancile," included collective protection, detection, decontamination, and physical security systems. DTRA demonstrated this technology at the 2002 Winter Olympic Games. The system was installed on a building known as Social Hall Plaza in downtown Salt Lake City (SLC). Social Hall Plaza had been selected to house the Federal Bureau of Investigation (FBI) Joint Operations Center (JOC) and the Utah Olympic Public Safety Command (UOPSC).

2.0 Purpose

The purpose of this volume is to describe the elements essential to the design of a building protection system comparable to that implemented in the Smart Building.

3.0 Building Protection System Overview

There have always been threats to buildings and infrastructure, from natural disasters such as fire and flood to social actions such as robbery and riots. Recently, the threat of deliberate damage to U.S. buildings and their occupants, particularly by CBR agents, has become a matter of great concern. U.S. government studies have led to the publication of NIOSH guidance for protecting building environments from airborne threats.[1,2] The guidance in this volume complements and is consistent with the NIOSH guidance.

Unlike the military CBR threat, this threat could potentially occur anywhere and with no warning, so uncertainty abounds. We may encounter chemical warfare agents (nerve, blood, or blister agents), biological agents (viruses, bacteria, toxins, toxic industrial chemicals, or radiological agents. The threat may be food-borne, waterborne, or airborne, and the presence of a hazard may be unknown for a matter of days. The nature of the problem is illustrated in Figure 1.

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[1] NIOSH Publication No. 2002–139, *Guidance For Protecting Building Environments From Airborne Chemical, Biological, Or Radiological Attacks*. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health

[2] NIOSH Publication No. 2003-136, *Guidance for Filtration and Air-Cleaning Systems to Protect Building Environments from Airborne Chemical, Biological, or Radiological Attacks.* Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health.

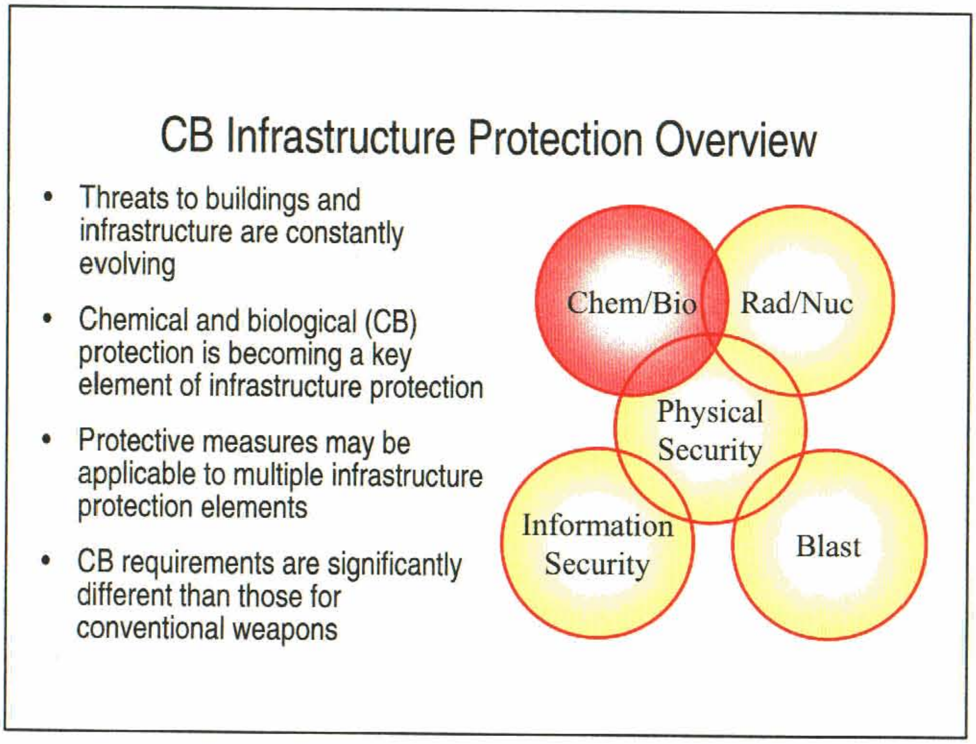

Figure 1. Overview Chart

Most of the CBR protection equipment available was designed for military applications and has not been tested in civilian applications, either in urban and rural environments. Detectors used in non-military environments face different interferents and are required to detect different classes of chemicals. Filters, too, face a new challenge, as military CBR filters are not designed to remove some of the most common toxic industrial chemicals (TICs).

Buildings are particularly vulnerable to CBR attack because:

- CBR agents released into confined spaces can rapidly reach and sustain lethal levels.
- Airborne CBR agents can be rapidly transported throughout a building by mechanical systems.
- Population densities are high in buildings.
- Buildings offer the potential to deliver airborne CBR materials covertly.
- Numerous adsorbing surfaces in buildings make restoration costly and time consuming.

The first step in developing any building protection system is to perform a Threat and Vulnerability Assessment (TVA) to fully characterize the nature of the threat and identify existing vulnerabilities of the protected assets (see paragraph 4.0).

The Smart Building program was specifically intended to address the application of protection to an *existing* building, and the building selection was made beforehand, but ideally, the TVA would begin early enough to influence building selection and design. Then the building could be located, designed, and constructed with protection principles identified in this program and the NIOSH guides integrated into all the decisions.

Based on the TVA, a building protection system should be designed to provide an appropriate level of protection, to meet all applicable building codes, to have no adverse effects on the indoor environment, and to not interfere with the daily operations. Market surveys and evaluations should be conducted to select the best components for the protection system. One key guideline used in the Smart Building program was to incorporate only proven commercial off-the-shelf (COTS) equipment into the system.

The Smart Building protection system included a filtration system, a CBR detection system, a decontamination capability, emergency power system, and a control system. Physical security provisions were added later and managed separately by the FBI. (Details are contained in Volume 2.) Ideally, all aspects of building vulnerability identified in the TVA should be addressed in a single integrated program from the start.

System testing should begin at the same time that design concepts are being selected, as the essential components may not function exactly as described in the marketing literature.

Training for system operators should also begin as early as possible in the program, and ideally some of the same people involved in the design should be present during the training and operation phases.

Operation, maintenance, and troubleshooting of the protective system will likely require technical support and expertise of a level at least as high as that required during design, although with different emphasis.

The protection process is illustrated in Figure 2 and Figure 3.

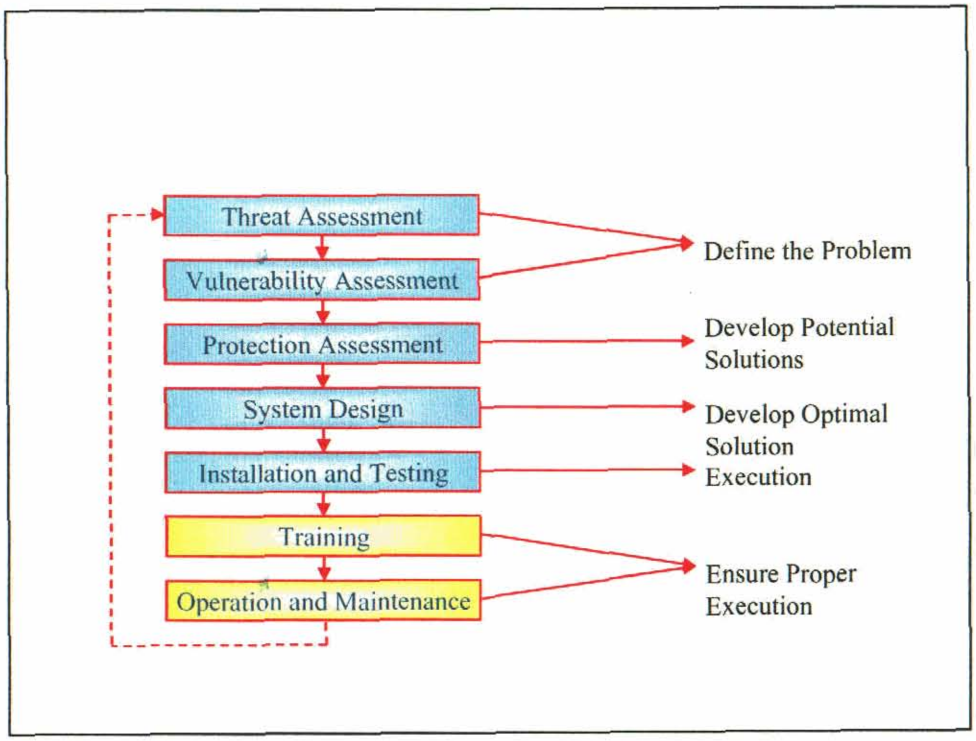

Figure 2. Infrastructure CBR Protection Process

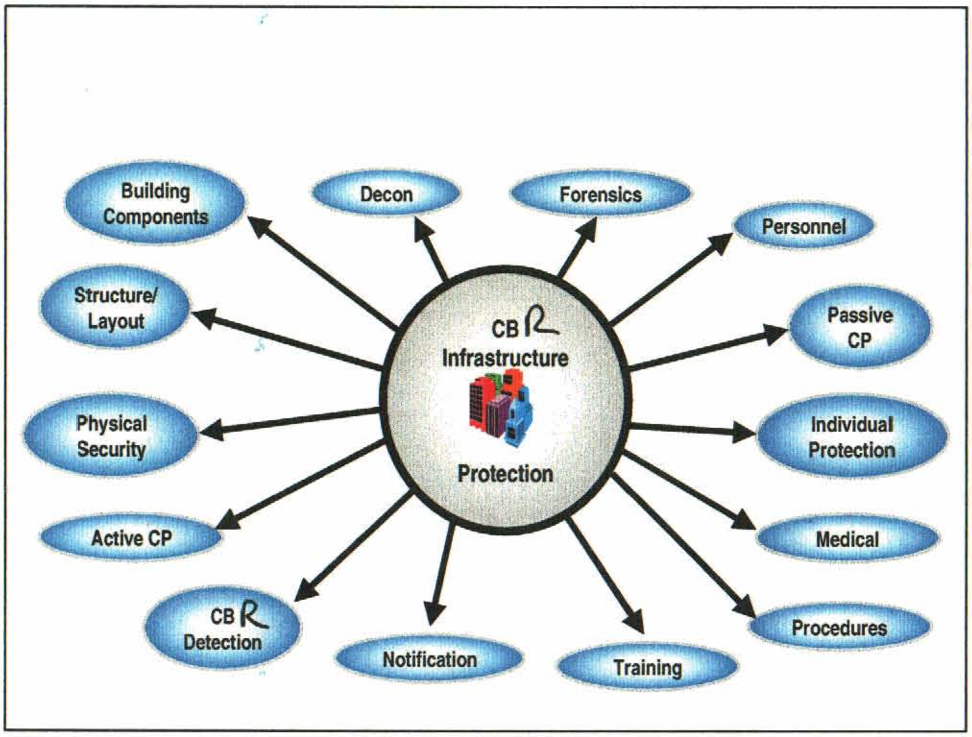

Figure 3. Components of a Building Protection Program

Cost is always a consideration. Generally, cost increases as the level of protection increases – from evacuation to shelter-in-place (SIP), to enhanced SIP, and up to the maximum continuous positive pressure (PP) collective protection (CP). The Smart Building applied the highest level of protection, continuous PP CP. The nature of this relationship is illustrated in Figure 4.

To put costs into perspective, the average cost of military grade positive protection filtration is $10-20/cfm; the average building has a normalized leakage rate of 0.2 to 0.5 cfm/ft^2 at a pressure of about 50 Pa. For an office building with 500,000 square feet of floor space, the cost of the mechanical system alone could be 5 million dollars. Additional provisions would be required to handle threats of internal release and certain TICs.

Technology is improving, but the solutions that are applied in the near future will not likely reduce the costs of high-efficiency protective systems.

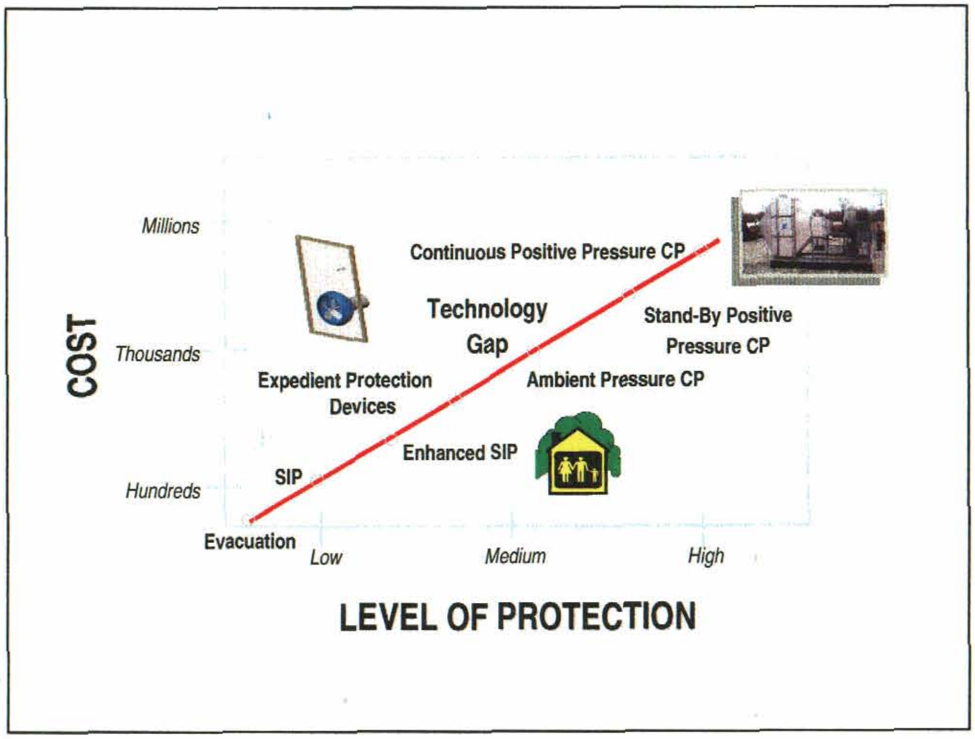

Figure 4. The Incremental Cost of Increasing Building Protection

4.0 Threat and Vulnerability Assessment

A Threat and Vulnerability Assessment (TVA) is needed before beginning any building protection design activity. Such assessments are typically classified documents, so the appropriate security clearances must be obtained well in advance. Because the cost and complexity of protecting against all conceivable threats would certainly be excessive, it is necessary to design a protection system that is focused on the highest priority threats and most significant vulnerabilities.

4.1 Threat Types

The types of threats that might be employed by an adversary against the asset being protected are to be considered. The Federal Emergency Management Agency (FEMA) has defined specific CBR threat events[3], and these may be used as a starting point.

Potential CBR threats must be further considered according to the agent delivery methods associated with them, i.e., external standoff release, external proximate release, internal release, waterborne release, food borne release. The focus of the Smart Building program has been on airborne CBR threats.

[3] Blaylock, Neil W., Williamson, Eric B., Cox, P.A., Engineering Guidance for Mitigating the Effects of and Responding to a Terrorist Attack, Southwest Research Institute Report for the Army Corps of Engineers, March 31, 1998.

The range of potential physical assaults upon the building, from mob violence to terrorist truck bombing, must be considered. Physical security planning should include intrusion detection systems such as closed-circuit television (CCTV) cameras, motion sensors, etc. Before CCTV surveillance is implemented, a master plan should be developed that identifies the critical areas and prescribes the guidelines for each area. Only in this way will the appropriate number and types of cameras be selected, located, emplaced and monitored. It is prudent to employ an expert physical security consultant and refer to published guidance[4] during the both planning and installation phases of a building protection program.

4.2 Vulnerability Assessment

After the potential threats are assessed, the vulnerability of the specific target must be addressed[5]. This assessment has two phases: a broad-area survey and an asset/facility assessment. A broad-area survey evaluates the surrounding area, the external signature of the building, and all entrance/egress routes.

The asset/facility assessment considers the immediate area outside the building and any public access areas inside. It identifies potential avenues of approach that may represent vulnerabilities.

The essence of CBR vulnerability assessment is to identify – from the perspective of a potential attacker -- pathways for the introduction of agent into a building, particularly pathways on which pressures act to produce air exchange. The pathways of concern are unfiltered, unsecured, and under constant inward pressure.

For external attack, the pathways of concern are those through the building shell, and for internal attack, those from room to room or zone to zone. Pressures inducing air exchange are produced by fans, wind, and buoyancy effect. Fans produce near-constant pressures, while wind and buoyancy produce pressures that vary with weather conditions and indoor-outdoor temperature differentials.

The pathways of greatest concern are those that are subject to continuous inward pressure, are accessible and unsecured, involve air that is unfiltered and contaminants that are concentrated, and that pass a high volume of air into large, occupied spaces. Those of lowest rank are those that are inaccessible, subject to intermittent pressure, involve air that is filtered and contaminants that are diffuse, and that pass a small volume of air into small, unoccupied spaces.

Pathways for covert entry or covert introduction of agent are personnel entrances, for hand-carried items; loading docks for supplies and equipment; mailrooms for letters and packages.

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[4] Interim DoD Antiterrorism/Force Protection (AT/FP) Construction Standards, 16 Dec 99 (currently under revision). (available from US Army Corps of Engineers, AATN-CECW-E1, Washington, DC 20314-1000.)

[5] Vulnerability Assessment of Federal Facilities, US Dept of Justice, US Marshals Service, June 28, 1995.

5.0 Filtration Systems

The Smart Building CP system, shown in Figure 5, was mounted on a support platform that was installed on the roof of Social Hall Plaza. The CP system consisted of two Modular Collective Protection Filtration System (MCPFS) units and an auxiliary boiler system. Each MCPFS included a Pre-Filter and Final-Filtration component.

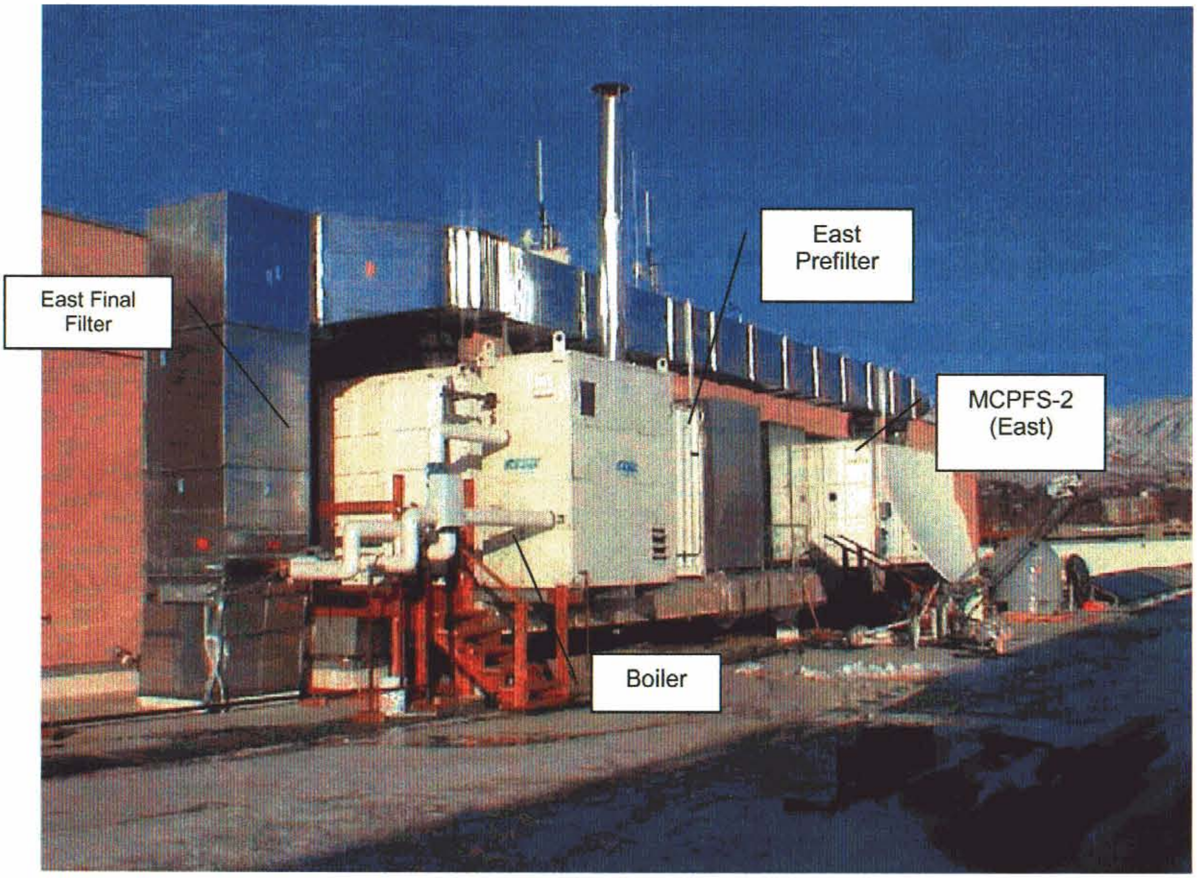

Figure 5. Smart Building Filtration System

Each of the two final-filtration system units utilized a direct drive axial vane fan and a bank of 50 M98 filters (See Figure 6). The M98 filters are the military standard CP units and consist of a HEPA and activated carbon filter. These filters are capable of protecting against all military chemical warfare agents, and biological warfare agents, and many toxic industrial chemicals. They have sufficient capacity for three to four years of continuous operation. The M98 units were installed in parallel to accommodate the volume of airflow needed; all filters would be replaced on the same cycle.

The air-filtration system developed for the Smart Building incorporated multiple cells of radial-flow filters having two-inch deep adsorber cells. The adsorber is the military standard M98 radial-flow 200-cfm Modular Collective Protection Equipment (MCPE) filter, per MIL-PRF-51527A (EA), "Filter Set, Gas-particulate, 200 cfm", Type

II. The cost of one 200-cfm adsorber is approximately $850. This adsorber contains ASZM-TEDA carbon of 12x30 mesh size, the standard military carbon that removes chemical warfare agents listed in Field Manual 3-9 and a substantial number of the toxic industrial chemicals. The specification for the carbon is EA C 1704A, "Carbon, Activated, Impregnated, Copper Silver Zinc Molybdenum Triethylenediamine (ASZM TEDA)", U.S. Army Edgewood Chemical Biological Center (ECBC), Aberdeen Proving Ground, MD. This carbon filter provides efficiency greater than 99.999% throughout its service life. In continuous operation, the estimated service life for this adsorber is about three years. The service life and filter change frequency varies with the air quality of the building in which the filter system operates and the moisture to which the filters are exposed over time.

The HEPA filter of the M98 set employs standard HEPA media having minimum efficiency of 99.97% in capturing 0.3-micron particles. The specification for this filter is MIL-PRF-51526A (EA), "Filter, Particulate, 200 cfm", Type II. These particulate filters can be procured as part of a set with the gas filters (at about $1,100 per 200 cfm set) or separately (NSN 4240 01 066 3266) at about $150 each. For a new filter set, the maximum resistance of the HEPA filter is 0.7 iwg. With continuous operation, HEPA filters may require replacement more frequently than carbon filters, depending upon the environment and the type of pre-filters used.

With the M98 filter set, the adsorbers (35 pounds each) and HEPA filters can be changed by building maintenance personnel. The air-filtration unit should be designed to operate continuously, providing purified air to the protected zones at a rate sufficient to prevent infiltration induced by the wind, stack effect, and exhaust fans that normally operate.

Use of the M98 filter set requires the system to be designed to compensate for a temperature rise of up to 10ºF produced by the filter-blower unit (actual temperature rise to be determined based on the efficiency of the blower selected for the filter unit). The system must allow for periodic replacement of the adsorbers, HEPA filters and pre-filters and provide pressure-drop indications that replacement of the HEPA filter is required.

A regenerable filtration system is being developed to augment the military filters with units that can remove TICs and self-regenerate during operation. A prototype regenerable filter system was not completed in time for application to Social Hall Plaza as planned. However, the technology may be available for future building protection applications.

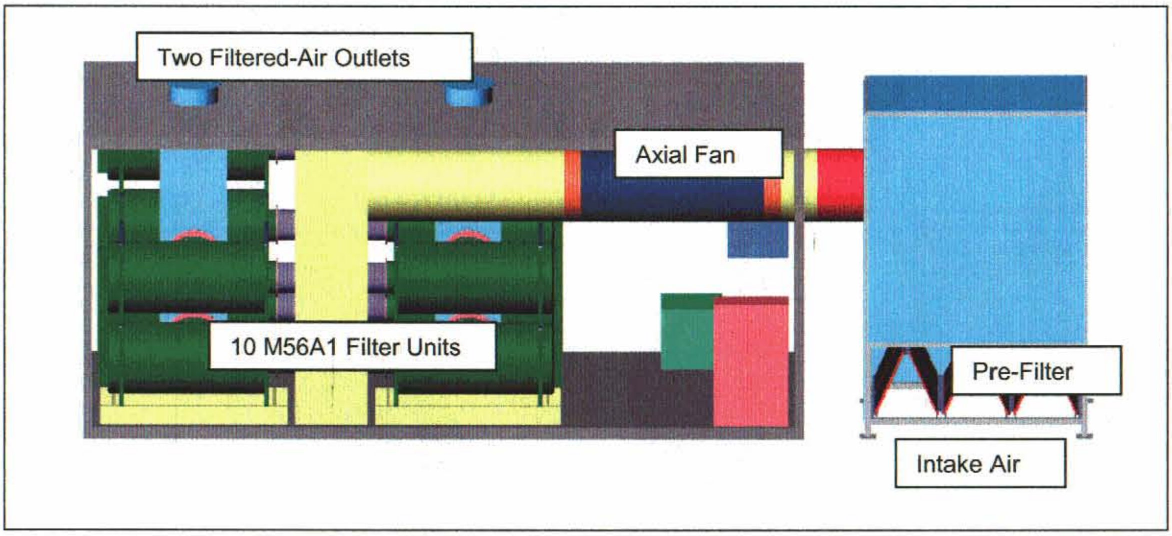

Figure 6. Single 10,000 cfm System Schematic Diagram

Each subsystem should be inspected, operated through its range of performance, and be reinspected. Instrumentation is needed to confirm that the filter subsystems operate at the necessary flow rate as designed without exceeding structural, thermal, or electrical limits.

Filter leak testing should be performed at least twice; first at the factory, then again after final installation of the filtration system. Fan speeds are set to generate full nominal airflow through each filtration unit and the system is leak-tested in accordance with standard filter leak test procedures.

6.0 Detection Systems

The primary objective of the CBR detection system was to provide an early warning of the presence of TICs, chemical/biological warfare agents, and radiological materials in the proximity of the Smart Building. The CBR detection system consisted of sensors located both inside and outside the building. The suggested threats quantified by FEMA for CBR terrorist attack were defined as follows:

- Chemical – 1 to 2 liters of Sarin (GB).
- Biological – 100 grams of anthrax spores in a pressurized can with an aerosol valve.
- Radiological – 600 grams of Plutonium^{238} and 600 grams of Plutonium^{239} in a radiological dispersion device.

Two types of chemical detectors were selected: the CW Sentry Plus from Microsensors, Inc. and the RAID-1 from Bruker Daltonics. The RAID-1 Chemical Detector applies ion mobility spectroscopy (IMS) technology while the CW Sentry Plus is a surface acoustic wave (SAW) device with a second detector employing electrochemical technology.

The Joint Biological Point Detection System (JBPDS) was used as the biological detector, and sodium iodide thallium doped crystal gamma radiation point detectors were used for radiological detection.

Interior detector locations were selected by an engineering evaluation of airflows throughout the building, particularly outside the protective envelope. This evaluation was aided by use of a computerized model developed to predict the concentrations and dosages resulting from a chemical release at any location in the building. Tracer gas tests were used to confirm the predictions for the conditions upon which detector location decisions were made.

The external CBR detection system consisted of sensors in five locations; these were locations identified on buildings adjacent to Social Hall Plaza at a distance great enough to provide sufficient warning time for the building ventilation system time to respond. (Details are given in Volume 2.) Cost considerations affect the total number of exterior locations, so prioritization based on the threat/vulnerability assessment is essential.

A meteorological station was installed at the Smart Building and at the locations of external detectors in order to provide current weather data (i.e., wind speed, wind direction, air temperature, barometric pressure, humidity, rainfall rate and accumulation). The weather data was needed to allow the sixth floor control room operators to determine whether an actual or potential external alarm would affect Social Hall Plaza.

Summa canister systems were installed in the penthouse and programmed to collect background samples. The normal use of summa canisters does not require remotely actuated sampling on demand; appropriate control systems were not available without modification to accomplish the task. The use of systems that collect a positive air sample should be a priority in future CP programs.

7.0 Controls Systems

A control system is required to integrate the components of the Smart Building, to monitor the building management system and to inform control room operators when an automated building response occurs.

The Smart Building control system also incorporated the FBI closed circuit television (CCTV) feeds that were received from cameras located both internal and external to the building. This video was displayed on CCTV monitors in the control room and was stored digitally for later analysis. CCTV is essential to any building protection program, both for physical security and for interpretation of any detector alarms.

The control system was designed to initiate an appropriate automated building response to any alarm from a chemical or radiological detector. The programmed response of the ventilation system should be based on building airflow modeling and a characterization of the airflows in the building. For biological agent attacks, however, there are no real-time detection systems accurate enough to use for a fully automated building response. Therefore, the building response following a positive identification of a biological agent must be implemented manually following notification by JBPDS operators. In the Smart Building Program, therefore, the limitations of existing biological detection technology were overcome by establishing detailed procedures that were followed by highly trained operators, constantly monitoring the detection systems.

All controls system components must be protected by uninterruptible power supplies (UPS) of sufficient capacity to prevent data loss or controls interruption during the interval between a loss of line power and the activation of emergency power.

7.1 Emergency Power System

Emergency power must also be incorporated into the protected building, to prevent loss of protection from any interruption of line power. The specific capacity of the generator and the amount of fuel stored on site should be determined during the TVA for the specific application.

A 1000-kilowatt emergency power generator was selected for the Smart Building. to supply electrical power to the protective envelope and air-filtration system in the event of a power outage. A 2,000-gallon concrete lined fuel tank stored diesel fuel oil sufficient for at least 24 hours of continuous operation.

8.0 Physical Security

Physical security is a key aspect of the TVA for CBR building protection. The Smart Building program emphasized the CBR protection due to the extensive physical security measures already employed within the building. These measures included:

- Urban terrorism barriers and traffic diversions
- Building entrance security checkpoints
- Access badging and automatic access cards
- Access controls added to doors and elevators at selected locations
- Security guards and loading dock restrictions
- Mantraps and receptionists at PE entrances

Building modifications for protection against blast, thermal, and shrapnel from an explosive detonation outside the structure were very limited in this program.

For an explosive threat identified in the TVA, guidance is available in the document, "Interim DoD Antiterrorism/Force Protection (AT/FP) Construction Standards," 16 Dec 99 (currently under revision). This can be obtained from US Army Corps of Engineers, AATN-CECW-E1, Washington, DC 20314-1000.

Physical security barriers to prevent vehicles from approaching the building too closely should be considered as early in the site selection and planning process as possible. Architectural, zoning, and practical considerations may preclude a fully satisfactory solution for some sites. The water-filled barriers used in the Smart Building program were an adequate temporary solution, but they were conspicuous and unattractive.

The building selected for the UOPSC Joint Operations Center was not owned or entirely leased by either DTRA or the FBI. Therefore, access into and out of the building could not be completely controlled.

9.0 Operation and Maintenance

9.1 Control Room Operations

The general mode of operation was to staff the control room with two operators at all times during the special events. A staffing roster was developed that outlined personnel coverage and shift times.

The JBPDS Joint Program Office (JPO) maintained a full-time, 24/7, control center in a nearby bank building for JBPDS operations. Staffing of the JBPDS control center was the responsibility of the JPO.

The control system was designed to bring all of the sensors to a termination point in the sixth floor control room of the Smart Building. The control system was designed to receive and process sensor signals and implement the automated building response.

The control system provided a visual alarm on the control screen whenever any element of the building protection system indicated a potential loss of functionality. The filtration system design, for example, included provisions to notify operators when:

- A differential pressure greater than 5.0 iwg or less than 3.5 iwg was measured across any of the M98 filter banks
- A differential pressure greater than 0.75 iwg was measured across the pre-filters
- MCPFS airflow was less than 75% of the set point.

Pressure sensors were used to monitor the pressurization of the fifth and sixth floors by sensing the following pressure differentials:

- 4th Floor to Fifth Floor Differential Pressure
- Fifth Floor to Sixth Floor Differential Pressure
- Sixth Floor to Atmospheric Pressure Differential
- Mantrap, Airlock, and Decontamination Rooms Differential Pressure

The appropriate protective responses for all possible sequences of detector alarms were pre-planned so that the responses could be initiated automatically by the control system, then be investigated and verified manually by the control room operator with the aid of operations checklists. These alarm response checklists were contained in a binder in the control room..

An event could be initiated by means other than detector alarms. For example, security personnel stationed in the west lobby could call the control room to report suspicious activity or chemical odors. Potential threats could also be received by telephone.

A CCTV recording system was integrated into the control system to record video of specific areas following a CBR alarm. The control system was capable of automatically initiating a recording of the CCTV signals from selected cameras whenever a CBR sensor alarmed. If sensors alarmed, the signals from the cameras in each alarm area would be recorded, up to the maximum capacity of the CCTV recording system. At that point, the control room operator would be given the option to choose which camera signals should be recorded.

Each subsystem was evaluated through extensive testing of subcomponents to insure they were working properly before the subsystem was brought on line and integrated into the overall control system. Once the individual subsystem controls were complete, they were tested for compatibility. Testing and refinement of the control system continued throughout the time the control room was fully operational.

Details of the operations are described in Volume 2, and event responses are described in Volume 4.

9.2 Decontamination Operations

Based on the TVA for the Smart Building, CBR decontamination rooms were built to allow personnel to be processed into and out of the PE following a confirmed CBR challenge on the building. A Decontamination Plan was developed to describe exactly what procedures should be followed during the processing of personnel into and out of the PE. The Decontamination Plan is described in Volume 4.

9.3 Maintenance

The only regular prescribed maintenance for the filtration system was lubrication of the direct drive fan every three months. Fan lubrication was recorded in each Mil Van and in the Control Room logbook.

No regular maintenance of the chemical detectors was scheduled or expected to be required during the course of this program. All settings and consumables were expected to last long enough to span the planned operational period. In practice, however, it was necessary to manually reset the pump relays on the CW Sentry detectors occasionally, and the internal filters on the RAID-1 detectors required significant maintenance efforts.

The biological agent detectors were monitored and maintained by the JBPDS team. At the beginning of each shift, the JBPDS operators inspected each system and confirmed the operational status. If the JBPDS team leader determined a need to collect a background sample, a single sample was collected at this time.

Every 48 to 72 hours each of the two JBPDS units was taken off-line for approximately one hour for scheduled maintenance. Times were staggered such that both units were not off-line at the same time.

The radiological detectors required no regular maintenance. Manufacturer's representatives were present in the control room or on call if technical problems had occurred.

The EPS installation contractor was responsible for emergency maintenance and repair during the operating interval. No regular scheduled maintenance was necessary. As a diagnostic and confidence check, the emergency generator was programmed to automatically start and run for 20 minutes once each week. A remote instrument panel was installed in the control room on the sixth floor to allow the generator status to be monitored from within the PE.

The HVAC system was maintained by Colvin Engineering, Atkinson Electronics and Battelle. The Staefa building management system was operated and maintained by Atkinson Electronics. Several minor problems with the HVAC system were addressed and corrected promptly during the operational period.

The control system was composed of a set of components called "nodes" – the Display, Master, Weather, Filtration and Chemical Nodes. Maintenance for the Control System consisted principally of restarting the nodes after they had been stopped for sensor changes or for any other reason.

10.0 Training

The control-room operators were trained to monitor, diagnose, and correct problems or incidents arising during operations. They established relationships and contracts with technical experts in the fields of HVAC, detection, and the computer controls and communications networks established for the building protection system.

CBR decontamination requires special training and equipment, and its implementation should be tailored to the specific application.

For the Smart Building program, several awareness briefings were prepared for presentation to all those who should be aware of the activities so that they could understand the purpose of the building modifications and the methods being used to protect the building.

11.0 New Construction

Many of the protection principles identified in this program and the NIOSH guides can best be integrated into a facility if they are applied before site selection, design and construction has begun. The following are examples:

- The threat assessment for the facility could be used to select the least vulnerable site.
- The HVAC system could be designed with fast-acting dampers and a separate system for the introduction of filtered make-up air.
- The building could incorporate restrictions on entrances and access routes.
- Building leakage pathways could be minimized.
- Elevators could be designed with protective ventilation systems.
- Safe egress routes and protected assembly points could be provided.
- Separate, well-protected, mail and delivery receiving facilities could be included.

12.0 Future Improvements in CBR Infrastructure Protection

12.1 Filtration and Detection

Numerous market surveys and research efforts are on-going to identify promising technologies for CBR infrastructure protection, to improve performance, and to reduce the costs of chemical detection, biological detection, filtration, and decontamination.

Potential cost saving technologies and methodologies include the following examples:

- Novel filtration media (TICs, regenerable, cleanable, etc.)
- COTS filters
- Leakage reduction methods
- Advanced evaluation tools
- Advanced control and early warning systems

Some novel filtration material/prototypes for CP applications that have been evaluated include the following:

- Regenerable gas filters
- Zeolite filters
- Regenerable HEPA filters
- Cleanable HEPA filters
- Reduced pressure HEPA filters

Testing programs have shown that commercial recirculation filters could enhance the protection afforded by SIP, providing protection factors up to 4 times that of standard SIP in an expedient-sealed room.

Market surveys, laboratory tests, and field tests have been conducted to determine detector effectiveness and applicability to various applications. Research efforts are focused on increasing sensitivity and decreasing false alarm rates, response times, and cost.

The detectors used in the Smart Building program were selected in 2001, and today there are more detectors available with better performance. Nevertheless, current detectors are still limited in their capability to initiate active building-protection strategies.

Research is ongoing to examine air transport in buildings as it relates to CBR protection and the benefits of leakage reduction measures. Leakage factors must be considered when selecting protective envelops and sizing air filtration systems.

Analytical tools are under development to allow efficient assessment of building vulnerabilities and estimate the effectiveness of specific protective equipment and systems. An analytical model should be capable of incorporating various components (ducts, airflow paths, walls, etc.) that characterize the physical configuration of the building. It should have the capability to estimate the amount exposure a building occupant in various locations would sustain in an attack. Steady state or varying weather conditions (temperature, pressure, wind speed, wind direction, ambient contamination) should be factored into the calculations.

12.2 Building Controls and Early Warning Systems

Systems are under development that integrate multiple signals into a single control system with the potential for automatically initiating a building response. Such systems would integrate the following elements:

- .CP systems (filtration system & HV AC system)
- CBR detectors
- .Physical security systems (CCTV, motion sensors)
- Communication systems

Integrated control would be designed to occur with minimal impact on the building occupants. Its potential effectiveness would be limited by the capabilities of the detection technology presently available.

13.0 Summary

Most buildings are vulnerable to an airborne attack with CBR agents, and in their normal operating configuration can provide only negligible protection to occupants. CBR protection systems are currently being applied to a number of key buildings.

There are a variety of CBR building protection options available, ranging from low cost, low protection- factor approaches such as sheltering in place, to high-cost, highly protective systems such as positive-pressure collective protection.

Research is ongoing to provide more cost effective solutions. Solutions may increase the level of protection, but accurate threat assessments are required, because technology cannot provide guaranteed protection against all threats.

LIST OF ACRONYMS AND ABBREVIATIONS USED

Acronym/Abbreviation	Meaning
AT/FP	Antiterrorism/Force Protection
CAC	Consequence Assessment Center
CBR	Chemical, biological, radiological
CCTV	Closed circuit television
cfm/ft^2	Cubic feet per minute per square foot
COTS	Commercial-off-the-shelf
CP	Collective protection
DoD	Department of Defense
DTRA	Defense Threat Reduction Agency
EPS	Emergency power system
FBI	Federal Bureau of Investigation
FEMA	Federal Emergency Management Agency
GB	Sarin
HEPA	High efficiency particulate air
HVAC	Heating, ventilation, air-conditioning
IMS	Ion mobility spectroscopy
iwg	Inches, water gauge
JBPDS	Joint Biological Point Detection System
JPO	Joint Program Office
MCPFS	Modular Collective Protection Filtration System
MET	Meteorological
PE	Protective envelope
PF	Protection factor
PP	Positive pressure
SAW	Surface acoustic wave
SBCCOM	U.S. Army Soldier, Biological, Chemical Command
SIP	Shelter-in-place
SLC	Salt Lake City
TIC	Toxic industrial chemical
TVA	Threat and vulnerability assessment
UOPSC	Utah Olympic Public Safety Command
UPS	Uninterruptible power supply

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