

A Video-Based Surveillance Solution for Protecting the Air-Intakes of Buildings from Chem-Bio Attacks

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ABSTRACT

We propose a layered security concept for the protection of buildings' air-intakes from chemical and biological attacks. The concept is focused on prevention, early warning, and effective evacuation. One of the pillars of our concept is the inclusion of a video-based surveillance subsystem that improves the early warning capability of the protection system. Our video-based surveillance subsystem features a motion detection and tracking module based on DETER – an algorithm that we described previously. We have tested our video surveillance system on various possible attack scenarios with perfect detection results. The current weak point of our solution is that it cannot differentiate between benign and malicious human activities. We are working on incorporating a human activity recognition module, which will endow the video surveillance subsystem with threat assessment capabilities.

1. INTRODUCTION

In the wake of recent global events the threat of a **chemical and biological** (chem-bio) attacks became very real. The community of technology and policy experts has recognized this threat way ahead of its time and a very extensive treatise of the matter can be found at **Error! Reference source not found.** There are various scenarios that the terrorists may follow to stage a chem-bio attack. One such scenario by testimony of one terrorist is to attack through the air-intakes of commercial or Government buildings. In July 2001, the terrorist Ahmed Ressam described in his court testimony how the training he and many others received in Al-Qaeda camps included attacking buildings with chemical agents (**Error! Reference source not found.**). In particular, he detailed how he was trained to use cyanide and sulfuric acid to create deadly fumes and how to inject these fumes into building air-intakes. The targeting of air-intakes meant to

maximize the number of deaths in the building without creating a risk for the attacker.

The possible attack scenarios to air-intakes are low-tech and invariably involve a human. In a typical scenario the terrorist approaches the building air-intakes and unleashes the lethal load in the immediate proximity. Since human motion and activity is involved, it is possible to design a video-based surveillance system to automatically detect and report a possible threat. The threat will be reported on the guard's console. Ideally, if the level of threat is high, the system should also shut down the HVAC air handler to minimize casualties (HVAC stands for Heating, Ventilation, and Air Conditioning system). The staging of a chem-bio attack in a building is anticipated to last at most a few minutes. Therefore, an automated video surveillance system can provide only short notice. Nevertheless, even this short notice may make the difference between life and death if the air-handler of the building is shut down on time and the agent is blocked.

In this paper we define the problem and describe various attack scenarios that an air-intake protection system should be capable of addressing (Section 2). Then, we outline an overall system architecture for the air-intake protection system (Section 3). Finally, in Section 4 we describe the hardware and software components that we have developed so far and their performance.

2. CHEM-BIO ATTACK SCENARIOS FOR BUILDING AIR-INTAKES

We will outline two possible attack scenarios: one chemical and one biological. They both involve a person carrying the lethal material very close to the building air-intakes. The chemical attack scenario may require some short preparation on site. The biological attack scenario typically does not require any on site preparation. For modern western buildings the most deadly attack scenario is the chemical one. In the biological attack scenario the HVAC filtration system is expected to block most of the

agents and minimize immediate casualties even if the building is lightly protected.

One likely chemical attack scenario to building air-intakes has already been spelled out in the testimony of Ahmed Ressam (**Error! Reference source not found.**). The scenario refers to an attacker approaching the air-intakes of a building carrying a backpack and a shallow wide container. Once under the air-intakes, the attacker has to pour a liquid solution in the shallow container. The liquid solution can be kept in a thermos in the attacker's backpack. Finally, the attacker drops dozens of large pills into the liquid, thus forming the chemical agent, and walks away. Wind direction and speed is very critical for the success of the attack. The way this chemical attack is planned points to Potassium Ferrocyanide that exists in pill form. When Potassium Ferrocyanide is mixed with a strong acid such as Sulfuric Acid, it creates the deadly chemical agent Hydrogen Cyanide.

Hydrogen Cyanide is lighter than air and harms or kills in medium concentrations. A lethal dose is 2,500-5,000 mg/min/m³. Therefore, it renders itself as the chemical agent of choice for a "light" chemical attack. A single person can produce very quickly lethal quantities of Hydrogen Cyanide and it is highly dispersible in the atmosphere.

A biological attack scenario may involve the dispersion of a powdery substance near the air-intakes of a building. The powdery substance may have characteristics similar to weapon grade anthrax. One should expect that the natural static charge of the powdery material has been eliminated to make the agent highly dispersible. About 8,000 spores are required to infect a person. Weapon grade anthrax features 15,000 spores per mg and therefore a small amount carried by a single person can have a deadly effect, especially if the filtration system of the building is outdated.

3. ARCHITECTURE OF AN AIR-INTAKE PROTECTION SYSTEM

An effective protection system for a building's air-intakes has to be layered and geared towards prevention, early warning, and effective evacuation. A successful protection design has to take into account the architecture of the building's HVAC system. Figure 1 depicts a typical HVAC architecture of a modern building.

Atmospheric air flows through the air-intakes to the air-handler where it is filtered, tempered, and pumped to the distribution network of the building. From the distribution network the air flows eventually through the ducts to the building's interior living space. The critical flow path starts from the air-intakes and runs all the way to the ducts. In a chem-bio attack the warning from the protection system has to arrive in time for the pump of the air-handler to be stopped and the ducts to be blocked so

that no contaminated air makes it into the building's living space.

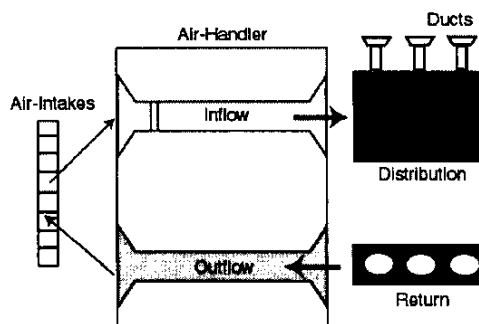


Figure 1: Architecture of a typical HVAC system in a modern building.

We have run two tests with two different air-handlers from typical medium size commercial buildings to draw an idea about the reaction times required. The first test involved an air-handler that draws air from the outside at a speed of $v_n = 500 \text{ fpm}$ (feet per minute). The total travel path of fresh air from the air-intake until the first duct has been measured at $s_r = 110 \text{ ft}$. The latency of this air-handler has been timed at $t_l = 13 \text{ sec}$. During the shut down process we assume that the reduction of air speed is linear and goes from $v_n = 500 \text{ fpm}$ to $v_n = 0 \text{ fpm}$ within $t_l = 13 \text{ sec}$. Therefore, the average shutdown speed is $\bar{v}_n = 250 \text{ fpm}$. This means that during the shutdown process incoming air travels another $s_s = \frac{\bar{v}_n}{t_l} = \frac{250}{13} = 32.5 \text{ ft}$. The worst case scenario has

to assume that contaminated air goes undetected for the first $s_r = s_t - s_s = 110 - 32.5 = 67.5 \text{ ft}$ within the air handling system at the nominal speed ($v_n = 500 \text{ fpm}$). That means that the protection system has to issue the shutdown order to the air-handler within $t_c = \frac{s_r}{v_n} = \frac{67.5}{500} = 13.5 \text{ sec}$ from the time the agent

entered the air-intake or else contaminated air will leak into the living space of the building. A similar reaction time requirement was ascertained for a different air-handler.

It appears that the effective reaction time for an air-intake protection system has to be in the order of a quarter of a minute from the time the agent is released under the building's air-intakes. This is a very challenging detection

requirement for a typical chem-bio sensor. As we have described in Section 2, particularly in the case of a chemical attack the terrorist has to undergo a preparation stage nearby the air-intakes before the agent is released. During this preparation time the terrorist's presence and movements are exposed to visual surveillance. Assuming that the terrorist's activities will last at least several seconds in the vicinity of air-intakes an automated video surveillance system will at least double the advance warning time that any chem-bio sensor can offer. It follows from the previous analysis that video surveillance technology has to be part of an effective security solution.

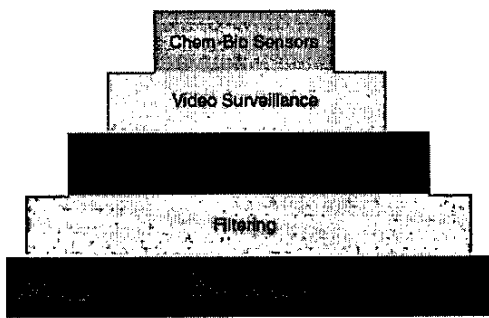


Figure 2: Proposed layered security architecture for the protection of buildings' air-intakes from chem-bio attack. Layers at the bottom of the pyramid represent more basic components that have to be implemented first if the management of the building is working on a step by step approach.

Our overall proposal for a layered security design for the protection of buildings' air-intakes is shown in Figure 2. Specifically:

1. **Chem-Bio Sensors:** We consider the existence of chem-bio sensors of paramount importance. Their role is also dual: a) to cross-validate the existence of a chem-bio attack signaled earlier by the video surveillance system and b) to pinpoint the type of agent released, so that appropriate decontamination measures are effected. The combination of video surveillance with an array of chem-bio sensors constitutes the pillar of the advance warning capability of our proposed protection architecture.
2. **Video Surveillance:** While physical protection of the perimeter will make access to the vicinity of air-intakes more difficult, it will not make it impossible. An advanced video surveillance system is required to detect the presence and movements of the suspect in real-time. The purpose of video surveillance is dual: a) to provide early warning during the preparation stage of the attack and b) to record the suspect's identifiable silhouette and movements for prosecutorial purposes. The video surveillance

system should feature a high degree of automation given the limited span of human attention. At the very minimum it should detect and record automatically object motion in the vicinity of the air-intakes. At the same time it should provide instant warning to the guard about the presence of the suspect. In turn, the guard should assess the situation based on the live video feed and take appropriate actions (e.g. shutdown of the air-handler). We envision a much more sophisticated video surveillance system with threat assessment capabilities. We will describe our work and vision in the next two sections.

3. **Perimeter Protection:** Whenever possible the area around air-intakes has to be physically protected with barbed wire or other fencing measures. This, however, is not always possible because sometimes air-intakes are over public sidewalks. This is typically the case of commercial and Government buildings in downtown areas. In suburban settings, the layout is different and air-intakes typically face an area belonging to the building campus. Fencing is far easier here because the area surrounding the air-intakes is private. The only hindrance is aesthetic. For both urban and suburban settings the most attractive case is when the air-intakes are placed at the roof of the building. Roof air-intakes are more protected by virtue of their location. They can also cater a far greater variety of preventive perimeter measures. In our view, it should be instituted that all new buildings place their air-intakes at the roof and not at their side.
4. **Filtering:** Current high performance bio-filters are extremely efficient in removing bio-particulates. Buildings that are not currently equipped with such filters should consider an immediate upgrade. Although, bio filtering is of very little use in a chemical attack it can provide an effective protection in the case of a biological attack by blocking the agent in the air-handling system for a significant amount of time. Therefore, it is a preventive measure that extends the grace period within which the warning system has to respond.
5. **Evacuation Plan:** The main purpose of all the previous measures that we outlined is to provide enough time for the occupants of the building to evacuate safely. If there is no effective evacuation plan then even an on-time warning can go wasted. The evacuation plan should be hatched in advance and it should be the brainchild of a mixed group of experts encompassing facility management and security

experts. The plan should be communicated to the occupants of the building and rehearsed periodically.

4. VIDEO SURVEILLANCE SYSTEM

We follow our proposed architecture in implementing the security shield for the protection of our building (Honeywell Labs Camden Building in Minneapolis, MN), which serves as our test-bed. So far, we have implemented the two bottom layers as shown in Figure 2: Evacuation Plan and Filtering. We have chosen not to implement the third layer from the bottom (Perimeter Protection) for aesthetic reasons. We are actively working in implementing the Video Surveillance layer. Currently our video surveillance system performs effective motion detection only. It is based on the motion detection and tracking algorithms of DETER that we have developed previously and described in 0. DETER has introduced a new philosophy in the design of video-based surveillance systems. Any development of the surveillance system itself is predated by a rigorous system design. The objective of the system design phase is to pinpoint the optimal number, type, and location of cameras and computational resources. The system design amounts to the solution of an optimization function (see 0). On one hand, the optimization function ensures complete optical coverage of the surveyed area, sufficient resolution for the machine vision algorithms to perform the prescribed tasks, and enough computational power for real-time operation. On the other hand, the optimization function ensures that the technical constraints are satisfied at a minimum expense in terms of hardware units and configuration. Figure 3 shows the resulting optimal camera configuration for the air-intakes layout of our building (Honeywell Labs Camden building in Minneapolis, MN).

We have embedded the DETER motion detection and tracking algorithm within a broader software package called DVM (Digital Video Monitor). DVM is a commercial product of Honeywell. It allows the acquisition and display of multiple video streams as well as their processing by a motion detection algorithm (DETER). Whenever sustainable motion is detected the respective incoming video stream is time-stamped and recorded on a digital storage device (hard drive). At the same time a textual and audible alarm is issued at the central console of the system to alert the operator. The DVM system has demonstrated its capability of detecting suspicious motion under difficult environmental condition in the monitoring of an oil pipeline in Central Asia for the last several months. It's performance in the monitoring of the air-intakes vicinity of our building has been equally flawless. DVM detected all the staged chem-bio attacks in our building (see Figure 4). At the same time, it featured

zero false alarm rate for over a month of continuous operation (24/7).

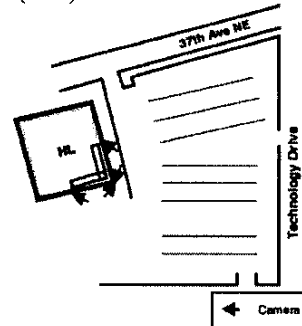


Figure 3: Camera configuration for the protection of the air-intakes of our building. The camera placement is the result of an optimization process. Four cameras provide full coverage in the vicinity of the air-intakes, which are placed on the side of the building and face an area belonging to our campus.

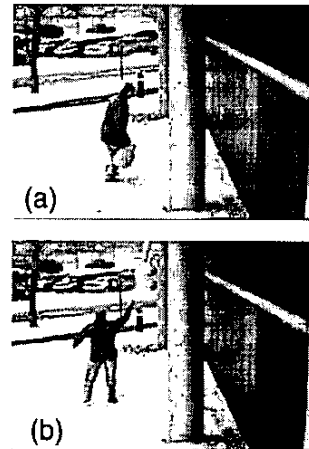


Figure 4: (a) Staged chemical attack. (b) Staged biological attack. Both images were captured automatically by DVM.

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